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Skywriting on CIEL: Programming the Data Center
DEREK G. MURRAY AND STEVEN HAND

Centralized Logging in a Decentralized World
JAMES DONN AND TIM HARTMANN

Backup Strategies for Molecular Dynamics: An Interview with Doug Hughes
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Musings

RIK FARROW

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While preparing this issue of *;login:*, I found myself falling down a rabbit hole, like Alice in Wonderland. And when I hit bottom, all I could do was look around and puzzle about what I discovered there. My adventures started with a casual comment, made by an ex-Cray Research employee, about the design of current supercomputers. He told me that today's supercomputers cannot perform some of the tasks that they are designed for, and used weather forecasting as his example.

I was stunned. Could this be true? Or was I just being dragged down some fictional rabbit hole? I decided to learn more about supercomputer history.

Supercomputers

It is humbling to learn about the early history of computer design. Things we take for granted, such as pipelining instructions and vector processing, were important inventions in the 1970s. The first supercomputers were built from discrete components—that is, transistors soldered to circuit boards—and had clock speeds in the tens of nanoseconds. To put that in real terms, the Control Data Corporation's (CDC) 7600 had a clock cycle of 27.5 ns, or in today's terms, 36.4 MHz. This was CDC's second supercomputer (the 6600 was first), but included instruction pipelining, an invention of Seymour Cray. The CDC 7600 peaked at 36 MFLOPS, but generally got 10 MFLOPS with carefully tuned code.

The other cool thing about the CDC 7600 was that it broke down at least once a day. This was actually a pretty common feature for '70s computers, and something I am old enough to remember.

Seymour Cray wanted to start over with a new design, rather than build on the CDC 7600, and when he was unable to do that at CDC, he started his own company, Cray Research (CR). CR's first design used some integrated circuits, but only very simple ones, like NOR gates and static RAM chips (1024 *bits* at 50 ns). Besides instruction pipelining, the Cray 1 was superscalar; that is, it could complete multiple instructions per clock cycle. Like the CDC 7600, it used a single address space, although the Cray 1 had 16 banks of interleaved memory, allowing four 64-bit words to be read per clock cycle—12.5 ns or 80MHZ. The Cray 1 peaked at 136 MFLOPS, and NCAR continued to use this Cray 1 for weather forecasting until 1986.

To put these levels of performance into perspective, I took a look at the European Centre for Medium-Range Weather Forecasts (ECMWF) supercomputer history Web page [1]. In 1976, it took the CDC 6600 12 days to produce a 10-day forecast, which doesn't sound terribly useful to me. But the ECMWF considered this

hopeful enough to acquire a Cray-1A in 1978. With the Cray-1A, they managed to produce that same 10-day forecast in just five hours.

The ECMWF continued buying and using Crays until 1996. Each new Cray came with more CPUs, more memory, faster clock speeds, and more processing power. But they all shared a critical design element: shared memory. For example, all of the 16 CPUs in the Cray Y-MP shared a total of 16 GB. The Cray T3D was a big departure from this design, as its 128 Alpha processors each had their own 128 MBs of memory. Memory was now distributed among the processors, and the processors were connected together in a torus for fast inter-processor communication.

It was this change, from a shared memory architecture to a distributed memory model, that I believe the Cray guy was concerned with. The ECMWF had to rewrite their software so that it would run well on a distributed memory architecture [1], while all previous forecasting software relied on a shared memory model. The difference is that with shared memory, any data in memory is equally "far" away from any CPU (has similar latency), while in distributed memory, some data requires much longer to fetch, because it "belongs" to another CPU and is also physically separated. The "belonging to" is an important issue, as writes to memory must be coordinated, so that one CPU does not change data while another CPU is using that data—an important issue even with today's multicore desktop CPUs.

The ECMWF and UCAR [2] today use supercomputers based on IBM's POWER5 or POWER6-based clusters. These clusters include CPU nodes (pairs of CPUs) that share memory, but are also connected to other nodes in the same rack over a high speed interconnect, and then are connected to other racks using InfiniBand. So these supercomputers have both shared memory and distributed memory. Having both memory models in the same supercomputer makes programming more difficult, as programmers need to be aware of the differences in latency when fetching "near" data (shared) and "far" (distributed, across a network).

By this time, I was pretty convinced that my acquaintance had misled me into thinking that the supercomputers of old were superior to the supercomputers of today. Instead, what I found is that the programming models had to change, to combine both the techniques designed for the older, shared memory designs and the newer technique for working with distributed memory correctly and efficiently.

Clusters

Today's supercomputers are clusters that combine the shared memory of '70s supercomputers with distributed memory models. Just check out the Top 500 supercomputer list [3] and you will see that the world's fastest computers are clusters that combined shared memory models with fast interconnects to distributed memory. The number two (in November 2010) was a Cray XT5-HE at Oak Ridge National labs, composed of 37,336 six-core 2.6 GHz AMD Opterons (using shared memory) connected together using a proprietary interconnect [4].

You may be wondering why I was even bothering with this wild goose chase. I found the discussions of early supercomputers (just search for "Cray") actually quite interesting and helpful in understanding current supercomputer designs. And as you read this issue of *;login:*, you will notice that clusters, and even supercomputers, have become more common.

MapReduce requires a loosely organized cluster of commodity computers to operate, as does Microsoft's Dryad. When you read the summaries for LISA, you will learn about the trials of the sysadmin in charge of getting a supercomputing cluster interconnect working properly, when the interconnect hardware was limited to a single supplier—one whose key product didn't work very reliably.

There's certainly more that can be written about this topic, and I do have more research to complete before I am willing to write more. Stayed tuned...

The Lineup

Derek Murray and Steven Hand provide us with a crystal clear view of the different ways to program for large clusters. Each method has limitations, with MPI, the most popular library used in scientific programming, requiring a lot of knowledge of the cluster and node architecture. The other big branch in programming for clusters uses distributed execution engines. These range from completely unordered systems, such as SETI@home, to MapReduce, with some ordering, and Dryad, with explicit dependencies. Murray and Hand introduce Skywriting and Ciel, a scripting language and an execution engine that support dynamic dependencies, something none of the other distributed executions can do. Skywriting supports iteration, as well as the simple and explicit ordering of MapReduce and Dryad, providing more freedom to the programmer, without requiring that the programmer understand the architecture of the cluster.

As this issue of *;login:* includes summaries of LISA '10, we have several articles related to LISA. First up, Cory Lueninghoener presents strategies for getting started with configuration management. Learning any software tool takes time and effort, and configuration management incorporates additional obstacles to implementation: homebrew systems and scripts, the coworkers who have built (and probably love) these systems, control issues as configuration management takes over loosely managed systems, as well as the threat of a massive failure during the early implementation phases. Lueninghoener presents advice for dealing with each of these issues, as well as simple strategies for getting up and running smoothly using any of the popular configuration management tools.

Jim Donn and Tim Hartmann share their journey into using Splunk for logging. I found I barely understood Splunk at all before reading their article (and listening to their IT [5]). Donn and Hartmann, like Lueninghoener, provide a roadmap for moving from a barely functioning logging system to one that supports many different user communities. This case study can help you understand Splunk, and may also serve as a warning to you: it seems that Splunk has addictive qualities, which actually speaks very highly of its usability.

Doug Hughes, a Program Committee Co-Chair of LISA '11, tells us why old styles of backups just don't work anymore. In this interview, Hughes explains the systems they use at D. E. Shaw Research, where the focus is on supporting custom supercomputers used for molecular dynamics simulation. This work produces continuous streams of results, all of which must be reliably stored and archived. Hughes describes both a past and the present solution they are using to back up millions of files and tens of terabytes of new data every month.

Ole Tange has another GNU tool to share this time. In the February 2011 issue Tange described Parallel, an improved version of xargs. In this article,Tange explains DBURL, a part of Parallel that unifies access to databases.

David Blank-Edelman decided that his last column, about transferring data, just didn't take us far enough. After all, ftp and rsync are soooo last century. In this column David shows us how to use Perl modules for data transfer, all with his gentle humor and easy style.

Pete Galvin suggests that those who were once interested in Solaris take a look at Solaris Express 11. Solaris Express represents the next release of Solaris, which Oracle has promised for sometime later this year. Solaris Express incorporates Open Solaris features, and Pete covers features he hasn't discussed in previous columns. He also provides analysis on just why you might be interested in a Solaris coming from Oracle.

Dave Josephson waxes eloquent about the reality of clusters and his utter horror at the reality of the hardware. Well, not quite, but close enough. Dave then cuts to the chase with some important advice about monitoring widely distributed clusters, something he must do almost every day (he does take time off, or at least pretends to).

Robert Ferrell takes us for a ride, ranging from a rant about the future (quaternary computing) to civility in the US Congress, then ramping down to poke holes in the belief systems of a certain vendor.

Elizabeth Zwicky has two book reviews, written with her usual flair, followed by three by Sam Stover (one a security book, the other two related to Arduino and Zigbee). Evan Teran took the plunge into a book on kernel exploitation and survived to tell us about it. I review just one book, as the one I really wanted to review still has me wondering just what to say about it. I guess you will just have to wait until the next issue...

We have the conference reports from LISA '10. Do keep in mind that you can watch videos of most of the presentations of LISA's three tracks, and some presentations, such as David Blank-Edelman's closing session, are much better experienced then read about.

References

[1] European Centre for Medium-Range Weather Forecasts (ECMWF), supercomputer history: http://www.ecmwf.int/services/computing/overview/supercomputer_history.html.

[2] UCAR Bluefire supercomputer: http://www2.cisl.ucar.edu/docs/bluefire/system-information-overview.

[3] The Top 500 supercomputers: http://www.top500.org/.

[4] Jaguar supercomputer: https://secure.wikimedia.org/wikipedia/en/wiki/Jaguar_%28computer%29.

[5] LISA 2010 Tech: http://www.usenix.org/events/lisa10/tech/#thurs.

Skywriting on CIEL

Programming the Data Center

DEREK G. MURRAY AND STEVEN HAND

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How do you write a program that runs across hundreds or thousands of computers? As data sources have proliferated, this question has spread beyond the domain of a few large search engines to become a concern for a variety of online services, large corporations, and academic researchers. This article introduces Skywriting and CIEL, which are, respectively, a programming language and a system designed to run a large class of algorithms on a commodity cluster.

Large-scale data processing requires parallelism, and useful parallelism requires *coordination* between processes. In a shared-memory system, coordination might involve updating a shared variable or signaling a condition variable; in a distributed system there is no shared memory, so processes communicate by sending *messages*. However, *explicit message passing* (using network sockets or a library such as MPI) is ill-suited to large commodity clusters, because it requires the programmer to specify the recipient host for every message. In these clusters, machines often go offline due to failure or planned maintenance, or they may be reassigned to another user. In general, cluster membership is far more dynamic than the supercomputers for which explicit message-passing libraries were first developed, and maintaining cluster membership information manually is a challenging distributed consensus problem.

The challenges of programming in a distributed system have led to the rise of *distributed execution engines*. These systems also send messages internally, but they virtualize the cluster resources beneath a high-level programming model. In 2004, Google announced MapReduce, which requires the implementation of just two functions—map() and reduce()—and frees the developer from having to implement parallel algorithms, distributed synchronization, task scheduling, or fault tolerance. Hadoop (an open-source implementation of MapReduce) was released soon afterwards, and has become widely used in many organizations, including Amazon, eBay, Facebook, and Twitter. In 2007, Microsoft published Dryad, which is a generalization of MapReduce that supports a broader class of algorithms, including relational-style queries with joins and multiple stages.

Most distributed execution engines divide computations into *tasks*, which are atomic and deterministic fragments of code that run on a single host. The power of an execution engine comes from its ability to track *dependencies* between tasks, and hence coordinate their execution and data flow. In increasing order of power, these dependency structures include:

1. **Bag of tasks.** In the simplest model, a job is divided into independent tasks, and terminates when all tasks have completed. For example, in SETI@home, the tasks are digitized chunks of radio transmissions, to which the same analyses are applied in parallel.
2. **Fixed dependencies.** There are task dependencies, but they are not controlled by the programmer. For example, in MapReduce, there are only two classes of task: map tasks and reduce tasks. By definition, reduce tasks consume the output of map tasks, so they must run after all map tasks have completed.
3. **Explicit dependencies.** The dependencies between tasks are programmer-controlled, and form an arbitrary directed acyclic graph (DAG). For example, in Dryad, a job is specified as a graph of vertices (representing the behavior of tasks) and channels (representing data flow between vertices).

Each successive model includes the previous one as a special case. Conversely, a more powerful system can be simulated using a *driver program* outside the cluster that submits multiple jobs to a less powerful system. Nevertheless, the advantage of a more powerful system is that the whole job enjoys the benefits of running on an execution engine, especially fault tolerance. The problem is that the most powerful model—explicit dependencies—requires all tasks and dependencies to be declared in advance, which limits the set of algorithms it can represent.

Many algorithms in machine learning, graph theory, and linear algebra are *iterative*, which means that they loop—performing some work in parallel—until they reach a fixed point. This means that the number of tasks cannot be known in advance. To support these algorithms on an execution engine, we introduce *dynamic dependencies*:

4. **Dynamic dependencies.** The dependencies between tasks are programmer-controlled and form an arbitrary DAG. However, each task may choose either to *publish* its outputs or *spawn* child tasks and *delegate* production of its outputs to one or more of its children.

The dynamic dependencies model supports iterative algorithms: one task implements the convergence test and either produces the current result or spawns another iteration. It also trivially supports all of the less powerful models. However, this raises the problem of how to specify a job that includes dynamic dependencies.

The Skywriting Scripting Language

To solve this problem, we created Skywriting, a scripting language for specifying dynamic dependency graphs. The language has three defining features:

- Skywriting is a "full" programming language (i.e., it is Turing-complete).
- A Skywriting script can spawn parallel tasks at any point in its execution.
- Any valid Skywriting script can be transformed into a dynamic dependency graph.

As a result, Skywriting is well suited to specifying jobs that run on CIEL (see the next section). Skywriting is interpreted, dynamically typed, and based on a C-like syntax. The language includes imperative control-flow constructs such as `while` loops and `if` statements, but it also includes first-class functions, which enables a functional style of programming. Figure 1 (next page) shows an implementation of a parallel Fibonacci algorithm, which illustrates the main syntactic features of the language (although the algorithm used is extremely inefficient).

```
function fib (n) {
   if (n <= 1) {
       return n;
   } else {
       x = spawn(fib, [n - 1]);
       y = spawn(fib, [n - 2]);
       return *x + *y;
   }
}

return fib(10);
```

Figure 1: Complete Skywriting script for computing the 10th Fibonacci number

The spawn() function creates a new parallel task. The first argument is a callable object: in the example, it is the name of a function (`fib`), but it could alternatively be an anonymous function or lambda expression. The second argument is a list of arguments that will be passed to the function in the new task. The return value from spawn() is a *future*, which can be passed to other invocations of spawn() in order to build a task dependency graph.

The `return` statement publishes the given expression as a task output. At the top level, a `return` statement publishes the overall job output. In a spawned function, a `return` statement publishes the current task's output. However, as you might expect, a `return` statement within a called function simply returns the value of the given expression to the caller.

Applying the * (dereference) operator to a future causes the current task to block until the producing task has returned the relevant value. In Figure 1, both `x` and `y` are futures, so the expression (`*x + *y`) will block the current task until both values are available. Although a task logically "blocks" when it dereferences a future, the runtime system actually creates a new task, which is called a *continuation task*. The current task delegates its output to the continuation task and adds dependencies on the dereferenced values. Therefore, the *-operator in Skywriting helps the programmer to build jobs with data-dependent control flow, without having to construct the dynamic dependencies manually.

Handling Larger Data

As an interpreted language, Skywriting is well suited to building coarse-grained task graphs, but less ideal for compute- or I/O-intensive work. Therefore the language includes mechanisms for handling large objects and executing external code. Figure 2 shows the implementation of a simple script that invokes external code to count the words in three Web pages.

The ref() function creates a *reference* to the given URL. Like a pointer in C, a reference is a handle to a potentially large object, and references may be exchanged efficiently between tasks. In Figure 2, the references refer to publicly accessible HTTP servers, but it is more common to use the `ciel://` URL scheme to refer to objects stored in the cluster (see the next section).

The exec() function synchronously invokes some external code. (There is also a spawn_exec() function which creates a task to invoke some external code asynchronously and takes the same arguments as exec().) The first argument is the name of an *executor*, which is effectively a loader for the invoked code. In Figure 2, the executor is `stdinout`, which is used to run legacy UNIX utilities that communicate using

standard input and output files. Other executors exist for Java and .NET classes. The second argument is the args dictionary, which contains executor-specific arguments: `inputs` is a list of references that will be concatenated and piped into standard input; `command_line` is the `argv` array for the process to be executed. The third argument controls the number of outputs: exec() returns a list containing one reference for each output. Note that calls to exec() are typically wrapped in a library function (e.g., stdinout(), java()) that sets the arguments appropriately.

```
news_sites = [ref("http://www.bbc.co.uk/news/"),
              ref("http://www.cnn.com/"),
              ref("http://www.foxnews.com/")];

function word_count (doc) {
   result = exec("stdinout",
                 {"inputs" : [doc], "command_line" : ["wc", "-w"]}, 1)[0];
   return *result;
}

total = 0;
for (site in news_sites) {
   total += word_count(site);
}
return total;
```

Figure 2: Complete Skywriting script for invoking `wc` on three Web pages

Since the aim of Skywriting is to support data-dependent control flow, it must be possible for a script to interrogate the output of a call to exec(). Therefore, the * operator can also be applied to a reference, which has the effect of loading the value into the script context. In Figure 2 the * operator is applied to the result of `` `wc -w` ``, which is an ASCII-encoded integer. Skywriting expects that a dereferenced reference is a valid value in JavaScript Object Notation (JSON). JSON resembles the syntax of Skywriting, and JSON parsers and generators exist for most popular languages.

CIEL: A Universal Execution Engine

To run Skywriting scripts on a cluster, we needed an execution engine that can handle dynamic dependencies: therefore we also developed CIEL, which is a *universal* execution engine. CIEL is universal in two senses: informally, because its execution model supports all existing task-parallel execution models, and formally, because the language for specifying the coordination between tasks (i.e., Skywriting) is Turing-complete.

Like many other execution engines, CIEL uses a master-worker architecture (Figure 3, next page). The central *master* schedules tasks for execution: it is similar to the JobTracker in Hadoop or the Job Manager in Dryad. The master stores metadata about the tasks and objects in the system and the (potentially dynamic) dependencies between them. The *scheduler* identifies when tasks become runnable and chooses where to run them, using a policy that reduces the amount of data copied across the network.

A CIEL cluster also includes several *workers*, which execute tasks and store data objects. When a task arrives at a worker, it is dispatched to the relevant executor, which corresponds to the notion of an executor in the Skywriting exec() and spawn_exec() functions. The executor retrieves the task's dependencies and makes them available to the invoked code in an appropriate manner. For example,

the `stdinout` executor forks a process to run a given command-line and writes the dependencies in turn to standard input; the Java executor exposes the dependencies as `InputStream` objects.

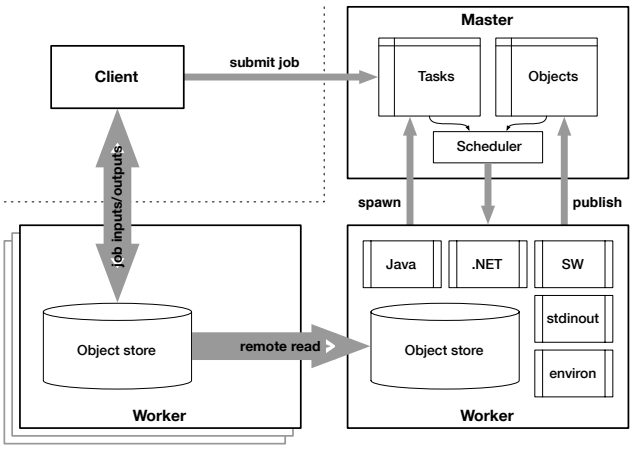

Figure 3: A CIEL cluster has one master and several workers. Arrows indicate communication between components; thicker arrows represent higher-bandwidth transfers.

Each worker also has an *object store*, which is backed by disk storage. CIEL uses objects to represent the input data, intermediate data, and results of each job. An object can contain arbitrary binary data, or it may be more structured (e.g., JSON format). Together, the master and the object stores form a simple distributed file system: every object has a unique name, but identical objects on different machines can share the same name, which enables replication. CIEL includes tools for transferring data into and out of a cluster, with support for replication and partitioning. Once loaded into the cluster, an object may be referenced from a Skywriting script using the ref() function and the `ciel://` URL scheme (Figure 4). A common pattern involves partitioning a file into several objects, then storing an *index object* that contains a list of references to the partitions. This is useful for specifying MapReduce-style jobs over large input data with many partitions.

```
ciel://[<HOSTNAME>:<PORT>]/<OBJECT_ID>
```

Figure 4: Syntax of a `ciel://` URL. If the hostname and port are omitted or become stale, the local master is consulted for up-to-date location information.

The main advantage of supporting dynamic dependency graphs in the execution engine is that CIEL can provide transparent fault tolerance across a whole job, including the data-dependent steps. CIEL provides fault tolerance for the client, workers, and master. Client fault tolerance is trivial, since there is no driver program running on the client, and so it plays no further part once it has submitted a job (except to collect the results). Worker fault tolerance is achieved by re-executing any tasks currently running on a failed worker, and recursively re-executing tasks to recreate any missing intermediate data. CIEL supports master fault tolerance by persistently logging messages from the workers, including spawned tasks and produced outputs: when the master comes back online, it can reconstruct its internal state by replaying the log.

Conclusion

We originally developed CIEL as a successor to systems like MapReduce, Hadoop, and Dryad, which run on large commodity clusters. Our performance evaluation, which is presented in a paper at NSDI '11, demonstrates that CIEL can achieve performance equal to or better than a less expressive system such as Hadoop. Performing control flow within the cluster leads to better performance and fault tolerance, by removing the need for a driver program outside the cluster.

We are now exploring other parts of the design space for dynamic dependency graphs. Skywriting and CIEL are suitable for coarse-grained parallelism on loosely coupled clusters, but other parallel computing platforms are emerging. For example, the performance trade-offs for manycore SMP and non-cache-coherent processors are very different from a cluster, but these platforms can also benefit from a simpler programming model than shared-memory multi-threading or explicit message passing. Therefore we are developing a more lightweight version of CIEL that can support finer-grained parallelism on multicore machines. We are also applying the ideas of Skywriting to other languages, including Python, Java, Scala, and OCaml, with the aim of combining coordination and computation in a single, efficient language. Ultimately, we predict that future clusters will be built from servers containing manycore processors, and the techniques we have described here will be useful for dealing with parallelism at multiple scales.

Acknowledgments and References

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A deeper introduction to CIEL and Skywriting, including implementation details and performance evaluation, can be found in Derek G. Murray, Malte Schwarzkopf, Christopher Smowton, Steven Smith, Anil Madhavapeddy, and Steven Hand, "CIEL: A Universal Execution Engine for Distributed Data-Flow Computing," in *Proceedings of NSDI '11*.

CIEL and Skywriting are available for download from our project Web site, which includes tutorials and example applications: http://www.cl.cam.ac.uk/netos/ciel/.

Getting Started with Configuration Management

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Configuration management tools take time to set up and maintain, but using one is well worth the effort. In this article I will present technical and social problems, solutions, and advice related to getting started with a configuration management tool. Many of the problems I will cover are much easier to fix when tackled early on, while the advice on where to actually get started should help ensure a smooth deployment.

This article has grown out of the Getting Started with Configuration Management BoF that I have led at LISA for the last three years. During that time we've talked about a lot of issues people run into when getting started; too many, in fact, to write about in a single article. Here, I'll just look at the very beginning problems: convincing yourself and your coworkers that you need a configuration management tool, where to get started, and how to plan for the future as you start out.

Why?

A configuration management (CM) tool is a robot that does work for you, keeping track of the files, packages, services, and other pieces of machines in your environment and keeping them up-to-date for you. But why should you use one? Why spend the time up front to deploy the tool and later to keep it up-to-date? In anything beyond a trivial case, a solid configuration management infrastructure will give you faster machine deployment, faster disaster recovery, and greater flexibility than by-hand methods. Everybody has had the experience of bringing up a machine by hand, making a series of "I'll only do this once" changes to it, and then needing to do the exact same thing again two months later. Even with careful notes, it is easy to miss details. By consolidating all of your host configuration to a central repository, bringing up the second (or third, or hundredth) copy of that original machine is a trivial task: just tell your CM tool to build another machine with the same class as the original and make the minimal changes needed for the new hardware. The same is true for disaster recovery: if you lose the disk in one machine, bringing it back can be as simple as popping in a new disk, telling it to boot off the network, and letting the CM tool do the rest. If you've put the effort in up front, that machine can be back doing its job without any further work on your part.

It should be clear that spending the time to deploy a tool and keep it up-to-date will eventually help you out and save you a bunch of time down the road. But there are plenty of other benefits of having a full CM tool deployed that you won't even think of until *after* you've been using it for a while. You'll gain greater flexibility in

your ability to bring up new machines, as you won't need to design each one from scratch every time. Need to bring up an SSL-enabled Web server? Model it after the plain one you already have. Need to bring up a mail server running Ubuntu 11.04 instead of your current 9.10? Start with the configurations you already have and make the minor tweaks needed for the new software. Having all of your configurations in one repository gives you great flexibility to mix-and-match pieces in a way that would be very difficult in an unmanaged environment.

What about documentation? Do you find it hard to make time to write accurate documentation about your current set of machines? Consolidating your infrastructure into one configuration repository does a lot of the work for you: you get a list of machines you run, what jobs they do, and exactly how they are configured all stored in one place. Handing a copy of the repository to new hires gives them a complete view of your network in its current state without them needing to track down every machine owner to find out what exists. Similarly, being able to point auditors at the current state of your network at any time becomes possible; instead of telling them what packages and configurations you think are installed and what machines you think have been retired, you can show them exactly what you have *right now*.

But!

Since deploying a configuration management tool can be a far-reaching project, you will likely run into objections related to time, your environment, and your coworkers. This section may sound negative, but it is a reality you need to be prepared for: addressing roadblocks early on is the best way to ensure a smooth deployment.

Time

The problem of time plagues every project, and your tool deployment is not going to be an exception. The obvious big time sink is the initial one: picking a tool, learning to use it, and deploying it across your infrastructure. Eventually you will also need to worry about the maintenance costs of teaching your coworkers to use the tool and keeping both the repository and the configuration management software itself up-to-date. For this article I'll just focus on the early difficulties, as their solutions map nicely to the later ones.

Picking a tool is mainly a matter of preference. There may be tens to hundreds of tools out there in various stages of completeness, but it is easy to name "the big four" that currently have very active development and large install bases: Cfengine [2], Bcfg2 [1], Puppet [4], and Chef [3]. All of these tools are mature and (perhaps with a little extra coding) can do anything you need to run your environment. If you are strapped for time, rest assured that you can't go wrong with one of these four. Descriptions of each appeared in *;login:* [7], and each of them (as well as many others) were compared in depth for LISA '10 [5]. Check out the language, style, and community of each and pick the one that fits your or your organization's ideals.

Finding time to actually plan and deploy a tool is the next difficulty. Time management itself is completely outside the scope of this article, but the best advice I can give is also shared by experts [6]: "Just start. Once you get started, it won't be as difficult as you thought." At the LISA BoF that inspired this article, I jokingly told people that after ignoring their day-to-day work for one week at the conference they should also ignore it the next week and use that time to get a base configura-

tion management system installed. The point is to make use of the conference momentum to get started on the new task before real life sneaks in again.

My advice to readers of this article is similar: once you finish reading this, decide you aren't going to get anything else done for the rest of the day. Download one of the tools mentioned above, install it on one of your machines, and start playing with it. You won't get your whole environment under configuration management control in one day, but making it over the hurdle of downloading and installing the tool will get you far in the process. After that it is much easier to do incremental work as you move toward complete control. The important thing is to make the time *now* before falling into the trap of routine and never getting started.

Environment

Your next big hurdle is likely to be your environment. Preexisting scripts and already deployed machines are the two biggest problems here. Fortunately, these are also relatively easy to fix with the right mindset.

If you currently manage parts of your infrastructure with homegrown scripts, don't throw them out. All of the major tools have ways to call shell scripts, and in some cases that is the best way to get a task done. In most cases, however, you will want to translate those scripts into your tool's native language or process. Doing so will let you take advantage of the perks of using a consolidated tool: comprehensive reports, sanity checking, abstraction, and predictable behavior are all features to look forward to. But keeping your old scripts around to translate from and check against is very useful in the beginning.

Having a large set of already-deployed machines will make any deployment take longer than starting from a fresh slate, but has its advantages. You'll want to start out by spending some time on a whiteboard categorizing your machines according to their similarity, and then begin by focusing on one machine from each category. As you progress with each, aim to make your configurations as generic as you can. You should find that large parts of your configuration will fit all of the machines, and that the individual machines need relatively little personalization. By focusing on the smaller number of machines and the general configuration first, you will find yourself making great coverage over your environment with much less work.

Coworkers

No matter how well your machines take your tool deployment, you are almost guaranteed to get objections from your coworkers. They have a right to do this: you are deploying something that they see as making changes on their machines without telling them. Especially for people who are intimately familiar with all parts of your infrastructure, this can be a very unwelcome change. Plain old communication is often the best way to defuse this situation: tell your coworkers what you are doing, send them documentation to look through, invite them to "shoulder surf" while you migrate a service into your new tool, and keep them up-to-date as you make progress. Your goal here is not to force your tool on them, but to get them to jump on the bandwagon too. The four big tools (and plenty of the smaller ones) are all great pieces of software. Don't be afraid to help your coworkers see that.

Where to Start

Okay, you're convinced. When you reach the end of this article, you're going to set the article down, download a tool, and install it. But you have 300 machines, each of which has 1500 packages installed, and each of those have their own configuration files, services, directories, and other details to care about. After the tool is installed on a test machine, where do you start with your configuration?

There are three important things to keep in mind when getting started: start simple, start safe, and start with something that others won't argue over. Starting simple is obvious, but easy to forget; it is very tempting to make a big splash with the new tool to prove to yourself or your coworkers what it can do. Instead, remember what they say: "Think globally, act locally." Start simple, getting to know your new tool and planning for the future as you go along. It will save you a lot of refactoring later.

Similarly obvious but easy to forget is the need to start with safe configuration elements. Everybody invariably makes mistakes with their CM tools, and nothing derails a project quite like a spectacular failure early on. Remember, your CM tool is like a new robotic employee that needs to learn your environment. If you wouldn't trust having an intern try something during his or her first week, don't try to make your CM tool do it during its first week either. Start by configuring redundant or seldom-used services, packages, and machines. As you become comfortable with your new tool and prove to those around you that it is safe, move on to the more dangerous (and generally more important) areas of your infrastructure.

Finally, and perhaps most importantly, start with something that won't start an argument. It is perfectly normal for coworkers to be wary of a new tool that will make changes on its own, and it is important to not turn them off to the tool early on. Starting with a set of machines or packages that you "own" and that others won't be upset at you for changing is a great way to prove that your new tool works and that it should be deployed on a larger scale. Keep others informed about your progress (and mistakes) so they see how great the tool is. Eventually you'll need to convert them, and you don't want to make them hate your new tool before you make any progress with it.

So, what configuration items should you start with? If you're really paranoid, start by managing /tmp/foo.conf on all of your machines. This is (hopefully!) not actually used anywhere, so you can put whatever contents you want in it. If you put a current timestamp in it, you can easily update it every morning for a couple of days and monitor how it propagates through your machines. This file fits all of the above requirements too: it is simple, safe, and not likely to be argued over by anybody else.

If you're a little braver, try managing /etc/motd on all of your machines. This is another safe, simple file to manage (in most environments, nothing should break if you mess up the message of the day), but in this case it is something visible to others. This is one of those simple confidence-builders—when you've been managing a file that everybody sees when they log in to a machine with no complaints, you know you're starting out well.

For a more complex task, try managing NTP with your tool. This is a great piece of software to manage, as it includes the three big pieces of configuration: a package, a configuration file, and a service. This gives you a perfect chance to become

familiar with how your tool handles each of these items. But more importantly, NTP doesn't tend to fail catastrophically. If you end up pushing out a bad package install, an unparsable configuration file, or a dead service, the system's on-board clock will generally back you up until you fix the problem.

Finally, try managing your CM tool with itself. Documentation on how to make a management system bootstrap itself, update itself, and ensure that it itself is running is standard for the big tools, making this an especially good task to tackle early on. This task is a little more dangerous than the others, since you have the potential to push a bad configuration out to the tool and cause it to wreak havoc, but if you keep the "simple" and "safe" ideals in mind while preparing the deployment, you shouldn't have any problems.

After completing these tasks you should have enough familiarity with your tool to move on to more complex configuration. Everybody has a different environment, but most configuration elements build on the same basic principles used to get through the above tasks. Focus on those first and you'll gain experience with your tool and make lots of headway with fully managing your infrastructure before you get to the hard parts.

Some Best Practices

The concept of configuration management has been around for many years now, and over that time many best practices have been identified. Although many of them are site-dependent, it is easy to identify a short list of practices that are easy to overlook but are very helpful at the beginning of a configuration management tool deployment:

Don't lose early momentum. After you've made some early progress with your deployment, keep making progress by spending 15 minutes a day making it better. Most configuration elements are not directly related to each other and there are always old files that can be cleaned up, so it should be easy to find small tasks that can be done while waiting for a meeting to start or for other people to get to the office in the morning.

Use version control. Don't use it in lieu of backups, but do keep your entire configuration repository in an SVN, Git, RCS, or any other revision control repository you feel comfortable with. This extra step gives you simple features such as commit comments and simple rollback, as well as complex features such as branching and cloning. Even if you just use the revision control system to keep comments from all committers, you will be a very large step ahead of a non-controlled repository.

Put ticket numbers in commit lines. When you make any change related to a ticket in a ticketing system, include the ticket number in the revision control system's commit comment. This makes it much easier to identify this set of changes in the future, whether to fix problems related to them or to make similar changes for a similar ticket.

Use dry-run modes. Most (perhaps all) of the modern tools have some sort of a dry-run mode, so use it. Before making big changes, make sure what you think will happen is really what will happen. You can use this same mode to generate nightly reports on noncompliance or to double check the work of a coworker. The dry-run mode is a simple but powerful tool.

Generate reports. You should know what your tool is doing (or not doing) in order to make the most effective use of it. Set up an email list, dashboard, Web page, or some other way of keeping tabs on how your system is performing. It will make it much easier to identify when some old unpatched machine is brought back onto the network after a year, as well as when conflicts arise and your tool can't make the changes you requested. It is also a great thing to show to auditors and managers to prove that your network is really in the state you claim it is in.

Simplify! Your environment is not the most unique out there. If you find yourself feeling like you need to rewrite a tool to make it fit your environment, it is likely that you are taking the wrong approach.

Conclusions

Now that you've read this article, the next step is to pick a tool and try it. The big four all have tutorials and examples to get you started, and the tasks listed earlier are great places to start in your own environment. As you progress, keep in mind that there are mailing lists and conferences full of people who have already done the same thing. Use those resources! The configuration management community is a generally friendly one with an abundance of helpful people.

After you've started your deployment, be careful not to lose steam and forget about your tool. It does take time and effort to keep your tool and its repository up-to-date, but you should find that that time and effort are much less than what you would spend doing the work by hand. Don't lose the battle after deployment!

The ideas covered in this article should be enough to get you started with a configuration management tool. Hopefully, you will quickly outgrow the topics covered here and move on to the next step in the processes: helping other people get their configuration under control too.

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Centralized Logging in a Decentralized World

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In 2008, we were both working for the Faculty of Arts and Sciences at Harvard University when it became clear that we needed a better way to manage our syslog environments. We both needed a centralized repository for logs that was easily searchable, scalable, and had the ability to produce graphs and reports. We began experimenting with Splunk, and over time we added more and more log sources. Today, we have a vastly improved log management and reporting system, which was the result of a few phased learning periods, with a couple of surprises along the way.

While we quickly realized the benefits of combining our Network and Systems syslog architectures, sharing a common architecture in this fashion was a first for our groups. We were presented with a few challenges right away:

1. Approval to act on this from our management teams, which historically did not collaborate in this fashion
2. Role-based log separation
3. Tandem administration of a single application

We were given the green light to proceed, and a new era of collaboration began. We chose Splunk shortly after running a quick proof of concept within our environment because we found it to be simple, scalable, and extremely useful.

Splunk runs as a server-side application with two major components. The most resource-intensive portion of the application is indexing, which involves converting raw event data into searchable events and storing them. The other major component is searching. Searches can be scheduled to run at specified intervals and take action when criteria, such as event count, have been reached. The actions that you can take include sending emails, updating RSS feeds, and executing scripts. Searches can be very lightweight, involving a small amount of data, or may take several minutes to complete while searching a month's worth of data. Therefore, your server load from scheduled searches can vary greatly depending on your implementation and the frequency of searches.

A few years into the Splunk implementation and after attending Splunk events and speaking with other Splunkers, we initiated a common phased approach to implementing the application:

Phase 1—"Just get them in!"
Phase 2—More logs and field extractions
Phase 3—Indexes and agents
Phase 4—Building custom applications

We will look more closely at each of these phases and share some of our experiences during each phase.

Phase 1—"Just get them in!"

Our first step when deploying our centralized logging repository was to gather as much data as possible and test the application's ability to process information. Since both Network and Systems teams already had their own independent installations of syslog-NG, this was fairly painless. We simply relayed our logs from the syslog-NG servers to the new Splunk server, using unique relay ports to separate data.

This allowed us to leverage the source of the logs to configure group-based user roles and permissions and to share a diverse log pool with Network Engineering, Systems Administration, Research Computing, Application Development, and Network Operations teams.

This quick "just get them in" strategy worked very well with Splunk, due to the way that the application indexes logs and extracts fields. When logs are first received in Splunk, they are indexed, and only a small number of fields, such as hostname and time, are extracted. All other fields are usually extracted at search time. This allows you to build custom field extractions after you have collected logs, without having to wait for new logs to come in to see the changes. Other applications follow a different philosophy, where all incoming logs must fit predefined templates or require custom templates before you can use the data. Both approaches have their advantages and disadvantages.

The disadvantages to post-processing logs:

- There are no canned reports to start with.
- Becoming familiar with the application and Splunk's native commands involves a learning curve.
- You will be reinvesting time into the application as your customer base grows.

The advantages to post-processing the logs:

- You can get started very quickly.
- It allows for greater flexibility when determining exactly what you want to do with the logs.
- You can change field extractions at any time, without having to worry about your repository.
- You can build very customized reports and alerts.

After getting the logs in, we set up a dozen rules to look for critical logs and forward them as SNMP traps to our event management systems. This ultimately replaced our legacy syslog adapter into the alerting infrastructure, which was much more difficult to configure and maintain.

Use the Splunk API!

One lesson that we learned in this phase is that the storage location of the raw data changed during software upgrades. Since our searches could return results for many devices, we needed to evaluate the results before sending a trap for each, possibly unique, host. These changes forced us to update our notification scripts a few times before we started to use Splunk's RESTful API, which has yet to change.

High-Level Architecture

Initially, our infrastructure consisted of a mirrored set of servers running Red Hat Enterprise Linux on commodity hardware, with an internal YUM repository to maintain software deployment and updates. Keeping our architecture simple allowed us to expand easily and spend more time getting useful information out of the application, rather than wrestling with the nuances of application management.

Licensing

The application license is based on the amount of data that is processed (indexed) each day. To ensure that we purchased enough to allow for growth, we combined the sizes of our daily syslog files and multiplied by 2. This 20 GB/day license would give us enough room to double the size of our initial footprint.

Our Views Changed

Now that we had collected all of our data, we wanted to see if we could get a panorama of events that we might have missed. In some ways our methodology for viewing logs started to shift. In our old-world view, we would run large log files (5+ GB) through a grep pipeline to pull out interesting events and build reports. Often, we would have to request that other teams perform similar searches against their logs, and manually correlate the results. In contrast, using our new workflow we found ourselves viewing larger amounts of combined data, obtaining summary information, and correlating events much more quickly.

Our initial deployment ran very well for over a year before we started to look into other ways that we could significantly improve our use of our logging engine. We already had what we set out to create: a simple and useful, low-maintenance tool.

Phase 2—More Logs and Field Extractions

More Logs!

At this stage, we had an easy-to-use search interface to all of our logs with some automated alerting. It was immediately evident to all of the engineers that worked on multiple devices concurrently that "more was better." We started getting requests to assist in getting more devices into the application, as well as to expand to different types of logs.

One challenge we encountered was adding logs from a proprietary application, which did not log to the system's syslogger. This forced us to look at using Splunk as an agent. Neither one of us liked the idea of agents in general; large-scale agent management and concerns about potential resource constraints drove our opinions. However, we installed a few agents to scrape log files for our edge cases where we could not send them via syslog.

Fortunately, Splunk made agent installation and configuration relatively easy. We manually managed the agents, and they proved to be very well behaved. One of the side effects that we saw from the installation of our initial agents was a dramatic increase in our volume of log data. We were processing approximately 10 GB of syslogs per day from 3,500 network devices and 400 servers. With the addition of three agents, we added an additional 8 GB of data indexed per day. While the data gained from forwarders was excellent, it is an important consideration when

attempting to estimate growth and planning for future license requirements. Since these results were unexpected, we had to increase our license from 20 GB to 50 GB.

Now that our new centralized logging model had become well rooted, we collapsed our syslog-NG servers together. At the same time, we also started to forward logs using TCP rather than UDP. When making this change in syslog-NG, we found that we were no longer able to spoof the sending address. Therefore we had to update Splunk to look into the logs to obtain the proper hostname.

Field Extractions

Next, we set up additional field extractions. After running Splunk hands off for over a year, we started investing time into reconfiguring it. We wanted to enhance our ability to troubleshoot issues, create more meaningful alerts, and build better reports. Custom field extractions allowed us to define portions of the logs, using regular expressions, which became pivot points for searches and reporting. For instance, let's look at a standard Cisco syslog:

```
2011.01.20 11:51:32 switch123.harvard.edu local7 notice 65: Jan
20 11:51:31.540: %LINEPROTO-5-UPDOWN: Line protocol on Interface
GigabitEthernet1/0/14, changed state to up
```

To make sense out of the 500,000+ messages like this that we receive every day, we created the following field extractions:

```
Host:          switch123.harvard.edu
Facility:      local7
Priority:      notice
Message_type:  %LINEPROTO-5-UPDOWN:
Message: Line protocol on Interface GigabitEthernet1/0/14, changed state to
up
```

We can now determine which is the chattiest message type over the past 24 hours with a single click after the search. Visualizing trends in log volume for a specific event has proven to be very useful. For instance, seeing a large spike in failed SSH attempts against a single host is something you might want to set up an alert for.

Phase 3—Indexes and Agents

Indexes

As our Splunk infrastructure expanded to 50 GB per day, we outgrew our single-index solution. We were simply putting too many logs into a single index, which made our searches take longer. While you could search different indexes with any revision of the software, the indexes needed to be explicitly declared at search time. We thought that this was too much overhead for our users. However, the next version released allowed a user to automatically search any index that they had permissions for.

With this new update, we migrated our source-based separation of logs to an index-based separation. Since indexes store data in different folders on disk, we gained security with data separation, as well as speeding up our searches by reducing the number of logs searched.

Agents

After proving that Splunk agents were stable and reliable, we placed one on our syslog-NG servers to scrape all of the syslogs that they collected. Instead of forwarding the logs via TCP, we directed the logs to a file, which gets zeroed out once a day. With a simple configuration to the Splunk agent, we were then sending logs to various indexes. This change also came with a few extra benefits.

If there are any communications issues between the Splunk agent and the indexing servers, the data is held until communications resume. This means that we could now restart our Splunk indexing servers without having to worry about the loss of data while the application was not available. These same logs would have fallen into the bit bucket using any other forwarding strategy.

Agents can also be configured to deliver data that they obtain to the indexers over SSL. As we tuned our implementation, we wanted to encrypt all data as close to the source as possible. Since there are devices that you will never be able to accomplish this on (e.g., network devices), the agent on the syslog-NG server gave us the best results.

Splunk Applications and Agents

Free Splunk applications also came with this software upgrade. These applications are really a series of predefined Splunk searches, charts, and dashboards. When testing them out, we found the UNIX and Windows applications to be extremely useful. They allow you to see details of disks, network interfaces, process tables, etc., at a glance. However, to obtain this information, the agent is required to collect it via "scripted inputs." Scripted inputs log the data that is returned after running a specified command or script, such as "df –h", "netstat", "ps –ef", etc.

As you can imagine, having the historical output from these commands, running every $x seconds, has been an enormous benefit in troubleshooting performance-related issues. Every aspect of a Splunk agent is configurable, including the intervals at which the data is collected and which commands are run. We have a few agents collecting data from Expect scripts run against network devices, which allow us to gather data that SNMP cannot provide.

After using the UNIX and Windows apps to resolve a few problems, we realized that we needed agents on every box to gain this level of visibility on our servers. Although Splunk has a deployment application to manage Splunk agents, it is really a Splunk agent configuration tool. It does not upgrade versions of the Splunk agents or ensure that they are installed on any new servers. To address this issue, we used a combination of Puppet and subversion. Puppet ensures that the agent is installed, running, and configured. In addition, Puppet checks out custom Splunk applications directly from version control in order to manage Splunk indexers and search heads. This combination of tools not only mitigates risk but also allows us to approach Splunk application development in a modular fashion.

Phase 4—Building Custom Applications

Now that a few team members had deep knowledge of the application and search language, they had become the point persons for all issues that required "power searching." This represented most of the problems that were incurred on a daily basis. To ensure that anyone could perform more simplified guided searches, we began building small applications. Not only did this free up more resources, but more people became comfortable using the application to solve problems.

Some of the basic applications include:

- Form search for email transactions
- Dashboards to show which machines currently live on a particular Xen server
- Saturation graphs for particular VLANs

After attending a Splunk developers training, we committed to building many more applications in-house. We have a few applications in development that we are very excited about. We are currently developing a "manager of managers" application to serve as the integration point for all data from various monitoring tools, to perform custom correlations, and to act as an event notification system for all alerts.

Architectural Options

Our original architecture was very simple and met our needs for the 20 GB of data that we planned to process per day. However, organic growth and organizational changes increased our potential daily log indexing towards 200 GB per day. With a log volume of this size, we needed to reevaluate our architectural options.

The new architecture design (see Figure 1) includes four stand-alone indexers and separate search heads per side of a mirrored implementation. The stand-alone indexer pool will receive data, which is automatically distributed across all of the indexers. Splunk then uses MapReduce technology to expedite the searches across the indexes. Use of various search heads allows us to expand our customer base to include groups that use different types of authentication, to reduce the overhead on a single server for scheduling searches, and to develop applications for any Splunk administrative group. For example, our Security team can now provision their own users and develop their own applications, which searches a common dataset in the indexing pool. This modular architecture has allowed us to collaborate with several groups at the University.

This model can be leveraged for horizontal growth, which allows us to scale exponentially. When we see that we are going to need to expand the amount of data that we index, we simply add more indexing servers to the pool of indexers. We can also add more search heads as our customer base grows and we find that scheduled searches are starting to overwhelm the existing servers.

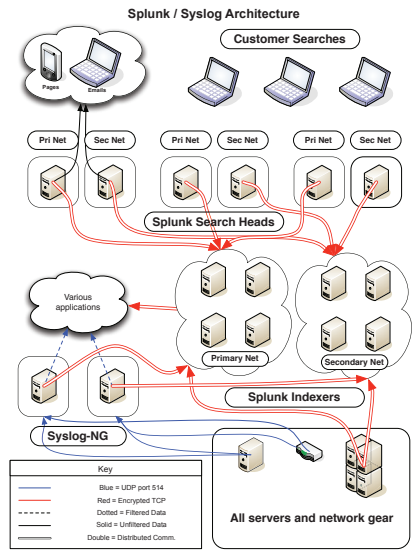

Figure 1: Splunk/Syslog architecture

Figure 1 is a diagram of the architecture that we are currently building out. Our strategies from the bottom up are to:

- Send all data encrypted from the source where possible
- Leverage distributed indexing cloud, using MapReduce technology
- Isolate customer environments from each other to:
  - - Increase security (data and user separation / isolation)
  - - Allow for multiple types of authentication interfaces
  - - Allow independent application development
  - - Increase search performance
- Duplicate vertical environments to ensure the highest degree of availability

Conclusion

We first set out to solve some very simple problems with Splunk. As we learned more about the application and it evolved, we have become much more dependent on it. Splunk has since taken a unique place in our environment. It has become a stable and flexible platform that provides solutions for an extremely broad range of problems. In many places, it has become the glue that fills in the gaps missed by other monitoring applications.

Not only is it a great tool to obtain, parse, and search data with, it is fantastic at providing data visualization, custom applications, and integration with other tools. While it has been referred to as "grep for your logs," it also acts like "awk for your logs," allowing you to pivot reports and searches on any custom field. Splunk also provides a powerful search language to perform analysis with commands, which are very similar to common UNIX tools. Splunk also follows the UNIX model of pipelines, allowing you to pass search or command results into other series of searches, internal commands, external scripts, or other tools.

The open and modular design has allowed us to use Splunk as an engine to power custom tools such as a Puppet dashboard, a MAC address tracker, security tools for forensics and compliance, and a trending tool for network, systems, and applications. While it is an extremely simple tool to start using on day one, it is also an application with great depth. We feel that these are the things that really make Splunk uniquely useful and that drive its continuing growth within our organization.

Backup Strategies for Molecular Dynamics

An Interview with Doug Hughes

RIK FARROW

Doug Hughes is the manager for the infrastructure team at D. E. Shaw Research, LLC in Manhattan. He is a past LOPSA Board member and an upcoming LISA '11 conference Co-Chair. Doug fell into system administration accidentally after acquiring a BE in Computer Engineering, and decided that it suited him.
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Rik: Backup design is important for any organization that values its data. Most sysadmins design backup systems with a focus on efficiency of backup operations as well as swift recovery of lost data. These criteria often mean full backups on the weekends and incremental backups in the evenings, after most work is done, so backups do not cut into operational performance. But what you are doing at D. E. Shaw seems to require different strategies.

Doug: I think a lot of organizations with lots of files and lots of data are struggling with the same issues. When you have 100s of TBs or PBs of data and 100s of millions of files, the traditional strategies break down. No longer can you afford to use dump to scan the file system every time you want to take a backup. Using a traditional find on a traditional file system could take many hours or even days, while the data is changing underneath you. So we've had to investigate, evaluate, and rely on different filesystem features to make this a tractable problem.

In general, I think that because of the geometric explosions of data as the cost of storage has decreased and computing power has advanced with Moore's Law, the task of doing backups has become much more complex. We started out with Linux file servers a few years ago using rdiff-backup. That was good enough for a time. From there we migrated to ZFS for its integrity guarantees and other features. ZFS "knows" what has changed between any two snapshots, and that's a very useful property. Unfortunately, ZFS still has fairly significant bugs and is missing some important features, plus there are various vendor support issues. One only need look at the monthly ZFS patch list to get a little bit nervous. We've experienced many of the bugs firsthand. Luckily, none of them has resulted in any data loss.

The big win about ZFS is that the checksum on every block protects you from mendacious disks and other components (memory, CPU, controllers, etc.). We've actually had ZFS correct data for us. The disk was certifying the data as good and returning it back through the controller, CPU, etc., all the way back to user space where ZFS noticed that the block from that disk didn't match the checksum. We've replaced a couple of disks (out of hundreds over the last couple of years) that have "silently" corrupted data. When you need to know that your data is exactly as you wrote it, this is comforting.

ZFS isn't without its problems, though. First, there are a lot of bugs, though usually with regard to zfs send, zfs recv, and intermittent, vexing performance issues. In the realm of design deficiencies, there's its inability to sanely expand a storage pool once created. Once you define a storage pool, it's very hard to expand that pool. You

can add additional RAID groups to it (RAID5, 6, even 7), but those just get stripped into the rest of the existing pool, so you end up with a bunch of full RAID chunks and an empty one getting written to equally. There are ways you can probably mitigate this by reading and rewriting every block in the file system, but that's heavyweight with 10s of TBs of data. Veritas VxFS and VxVM were awesome in this regard. They still exist but, in my opinion, the product line has not gotten enough emphasis since the purchase of Veritas by Symantec.

So we started looking for a new file system. Safety is one important property, size is another. There are few things as safe as ZFS, but some will at least check that the parity matches on read. That's not as good as block checksums, but better than nothing. Speed is also obviously important, but we're here to talk about backups. The ability to do tiering is yet another important consideration, since our data is continuously rolling, making the fresh data old and the old data ancient in a matter of months.

It's not critical to us that backups follow exactly the same strategies through generational improvements, though consistency is a goal. It was obvious that the ZFS way of doing backups was vastly superior to rsnapshot/rdiff-backup. We could keep ZFS snapshots of user data to near infinity and take differentials between them to send to a backup server. Unfortunately, no other file system is compatible with ZFS snapshots, since it's an intrinsic property. The ability to get a differential file list, which is a minor extension to ZFS snapshots and in the OpenSolaris sources, is really catching on in the filesystem community, and it seems to be making its way into a lot of enterprise file systems.

What we ended up with, for a variety of reasons, was GPFS. It provides a lot of useful features such as failover, data tiering, snapshots, and separation of metadata. It doesn't have differential snapshots yet, but hopefully that will come. We're adaptive, though, and can make use of other features to get to the same ends—not having to run the equivalent of find on 400,000,000 files. The key is separation of metadata coupled with novel arrangements of data sets.

Rik: What's special about your environment?

Doug: As has been publicized in various scientific journals and the mainstream press, we have a custom supercomputer that does molecular dynamics, as well as having several clusters of commodity machines. Actually, we have several of these supercomputers, and each outputs data at a little less than 1 MB/sec. That's not a lot, right? Well, in aggregate, it's about 10 TBs of data every 2–3 weeks, depending upon the chemistry parameters, frame storage rate, and various other things.

We arrange this data into chunks we call lockers. A locker is just an arbitrary chunk/division of the file system into a directory space. When a chemistry job starts, it asks for a locker and then proceeds to dump data frames grouped into trajectories. A frame is a file containing a lot of floating point numbers indicating the current position and velocity vector in three dimensions for every atom in the simulation. We get about 3 million frame and miscellaneous files per day (logs, allocation records, etc.).

Rik: So how do you set up lockers?

Doug: Lockers are managed by a database API which will hand out a directory in a probabilistic manner according to weighting. This has some flexibility, although we tend to only have one active locker at a time, because it means that there's just

a particular directory to scan for files that have changed. In actuality this is not a hard cutover since it would make life difficult for the chemists, so we only scan the most recent set of lockers for changes. This is where GPFS comes in.

There are several key features that make GPFS interesting for this sort of environment, some mentioned above.

- Quotas can be applied to arbitrary groups of files called file sets, in our case 10 TB chunks.
- Snapshots provide capability to recover from mistakes for user data, although I wish there were more. IBM is improving this.
- Storage tiering means that we can keep fast disks for the newly written data and migrate data to slower bulk-storage media for satisfying reads from analysis machines.
- A sophisticated policy engine allows for writing complex SQL-like queries to scan metadata far more efficiently than find, in fact about 20x faster.
- Metadata separation means that we can put all of our metadata on extremely fast storage, like a Texas Memory Systems RamSan620. This takes a full filesystem scan on 20 15K RPM disks from 4.5 hours down to our fastest recorded time of 12 minutes on the flash/memory hybrid device.

To scan 10 TB of a particular locker involves a reduced set of metadata. We can tell the policy engine to just start in this directory and scan those several million objects for any file that has been modified in the last hour, or the last day. This takes about 30 seconds, which is pretty impressive.

Rik: Okay, so by using a cluster file system like GPFS and special hardware for storing metadata, you can now complete your "find new/modified files" in a reasonable time. I am guessing that this allows you to create incremental backups?

Doug: We divide things into hourly sets and daily sets. The hourly sets are files that don't match .log (those may be continuing to update, and we don't need hourly backups of them). The daily sets are every file that has been modified in thepast 24 hours. The frames are the most important bits, and if we did have a disaster, we'd not want to lose too many of them. We get the frames onto the backup media expeditiously, and the rest once a day. Meanwhile, the policy engine is also taking care of other automations to move the data from tier to tier as the data rolls in, including a tier once per week of older files on media that spins down.

Rik: So that raises two questions, although I think I can answer the first. I saw a talk on Anton at a USENIX conference, and a frame represents the position of the atoms in the reaction under study during some time slice, similar to a frame in an animation. But you mentioned a "policy engine." What is this and how does it fit into your backup scheme?

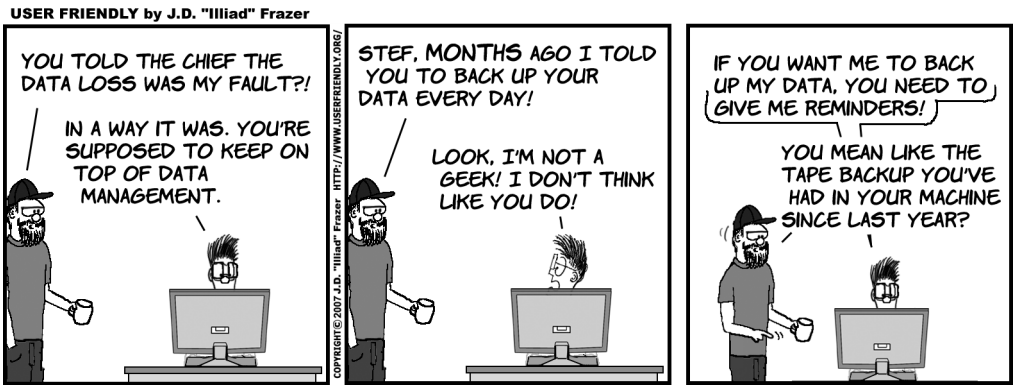
Doug: The policy engine is the part of GPFS that allows you to write queries against metadata that match nearly arbitrary combinations of characteristics. Each one of these little files of quasi-SQL is a policy that is either stored in the file system (i.e., the default write policy) or activated by an administrator applying the policy on demand.

There are several base sets of policy actions one can take. There is the migrate action, which moves data from one pool (tier) to another; there is an external pool action which you can use to migrate data to an external storage pool (such as TSM [Tivoli Storage Manager]); and there are "list" actions which you can use to gener-

ate file lists. We are using this last one to quickly scan the metadata and generate lists of files. These lists are collections of inode, owner, pool, and other metadata along with filename that are passed to a script that you define. This script can do anything you want; you apply an argument to the policy to tell it how many metadata "files" are passed to the script in chunks of lines. We use the script to select only the filename from the metadata, which generates a file of filenames on which to run rsync.

So the backup process works in two parts. We have the policy engine scanning the filesystem metadata directly for things that need to be backed up (via the metadata SQL, which is very fast), which generates a metadata list that is passed to a shell script in batches of 5000 records. The shell script takes the filename and uses the first three components of the pathname to determine where it should go in backups and makes discrete files per destination. In part 2, a backup daemon (written in Perl) scans for these resulting files in a particular directory and uses rsync or Star or whatever (selectable per destination) to send these to offsite backups.

Why two parts? First, because of the way that the policy engine generates its list of metadata with extraneous data, that needs to be filtered, and it's easiest to put this output into a file so that you can later call rsync on it, for example. Second, because we actually in some cases use disk-to-cheaper-disk backup, we have backup servers that eventually get full, so it becomes necessary to have some granularity of control over the destination, which is where the path component comes in. The metadata may arrive in any order; it's just looking for stuff that has changed. This results in often arbitrarily mixed locations for things. The script that processes the metadata is responsible for categorizing these per destination so that rsync doesn't have to worry about it and can just send (using `--files-from=`) to select its source and send it to a single destination as needed.



GNU SQL

A Command Line Tool for Accessing Different Databases Using DBURLs

OLE TANGE

Ole Tange works in bioinformatics in Copenhagen. He is active in the free software community and is best known for his "patented Web shop" that shows the dangers of software patents (http://ole.tange.dk/swpat). He will be happy to go to your conference to give a talk about GNU Parallel and GNU SQL.
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Today there are more ways to access a database from the command line than there are databases. Very few of them unify the access into a single URL and make it possible to give the SQL command to run on the command line.

GNU SQL introduces DBURL and a common way to run queries on databases from the command line.

Background

Around 2003 I was assigned to admin a MySQL database. I found it annoying that I could not use my Web browser for simple browsing of the content of the database. I was thinking that URLs more or less had the same information as was needed for accessing a database: protocol, username, password, host, port, path, and query ought to be enough to do at least simple database manipulation.

In 2007 I became admin of a forest of MySQL, PostGreSQL, and Oracle databases. It was a nuisance to remember the different ways to log into the databases from the command line. In discussions with my colleague Hans Schou, we came up with a common way of addressing the databases as a URL, which we call DBURL. I wrote a wrapper for the different command line tools that uses the same DBURL syntax to access the different databases. This wrapper is today known as GNU SQL.

After developing the first versions of GNU SQL, I realized that others have been thinking along the same lines: Drupal, SQLObject, SQLAlchemy, and Transifex all use some sort of DBURL. I would encourage others to adopt DBURL as a condensed way of writing the information to access a database.

```
sql:mysql://user:password@example.com:3306/my_database?select%20*%20from%20foo;
\_/ \___/   \_____________________________/ \_________/ \_____________________/
 |     |                  |                     |                 |
scheme vendor          authority               path              query
```

Figure 1

DBURL Syntax

A DBURL has the following syntax:

[sql:]vendor://[user[:password]@][host][:port]/[database][?sqlquery]

Only vendor is required. The rest of the elements are optional, with the following defaults:

Element	Default value
sql:	sql:
user	your UNIX user name
password	no password
host	localhost
port	the default port for the vendor
database	your UNIX user name
sqlquery	"" = No query

The DBURL is modeled after the syntax from RFC3986 to resemble a normal URL and is partitioned similarly (see Figure 1). Quoting of special characters is done using %-quoting, thus space=%20 and /=%2F.

Aliases

To avoid having to write the full DBURL all the time aliases has been defined as DBURLs starting with ':'. Aliases are defined in ~/.sql/aliases and are simply the alias followed by the DBURL:

```
:myalias sql:mysql://user:password@example.com:3306/my_database
```

Logging in with GNU SQL

GNU SQL is part of GNU Parallel, which is available for most UNIX distributions. See http://www.gnu.org/s/parallel if it is not obvious how to install it on your system.

You get an interactive prompt by:

```
sql sql:oracle://scott:tiger@oracleserver:1521/xe
```

If the database runs on localhost, the database name is your login name and there is no password. You can simply do:

```
sql postgresql:///
```

When the DBURL is working and you get an interactive prompt, set up an alias in ~/.sql/aliases. Substitute the DBURL with one that works for you.

```
:myalias mysql://user:pass@example.com/my_database
```

Then you can get your interactive prompt by:

```
sql :myalias
```

Executing a Query

GNU SQL lets you execute a query by putting it on the command line:

```
sql :myalias "DELETE FROM users WHERE name LIKE '%tange%';"
```

If you want to run multiple queries you can put them as separate arguments:

```
sql :myoracle "SELECT 1 FROM dual;" "SELECT 2 FROM dual;"
```

or you can pipe the SQL commands into GNU SQL:

```
cat my_query.sql | sql :myalias
```

You can also execute the query by putting it in the DBURL:

```
sql :myalias?select%20*%20from%20foo\;
sql postgresql://user:pass@host/my_database?select%20*%20from%20foo\;
```

Using the Power of GNU Parallel

GNU Parallel is a good companion for GNU SQL. Using GNU Parallel it is easy to empty all tables without dropping them. Here are two ways to do it:

```
sql -n mysql:/// 'show tables' | parallel sql mysql:/// DELETE FROM {}\;
sql -n --list-tables mysql:/// | parallel sql mysql:/// DELETE FROM {}\;
```

But if you want to drop the tables, that is easy, too. Here are two ways to drop all tables in a PostgreSQL database:

```
sql -n pg:/// '\dt' | parallel --colsep '\|' -r sql pg:/// DROP TABLE {2}\;
sql -n --list-tables pg:/// | parallel --col-sep '\|' -r sql pg:/// DROP TABLE {2}\;
```

Run as a Script

When running an SQL script on a database you often end up with two scripts: one that does the connection to the database and one that contains the actual SQL to run. With GNU SQL these can easily be combined using UNIX's shebang (#!). Instead of doing:

```
sql mysql:/// < file.sql
```

you can combine file.sql with the DBURL to make a UNIX script. Create a script called demosql:

```
#!/usr/bin/sql -Y mysql:///
SELECT * FROM users;
```

Then do:

```
chmod +x demosql ; ./demosql
```

When Connections Fail

If the connection to the database is bad or the query is very long, the risk of the connection breaking increases. If the access to the database fails occasionally, retries can help make sure the query succeeds:

```
sql --retries 5 :myalias 'SELECT * FROM really_big_table;'
```

Getting General Info about the Database

Database vendors have not only each chosen their own syntax for logging in, they have also each chosen their own way of getting general information about the database.

GNU SQL contains a wrapper for getting some of the info.

Show how big the database is	sql --db-size :myalias
List the tables	sql --list-tables :myalias
List the size of the tables	sql --table-size :myalias
List the running processes	sql --show-processlist :myalias

See You on the Mailing List

I hope you have thought of situations where GNU SQL can be of benefit to you. If you like GNU SQL, please let others know about it through email lists, forums, blogs, and social networks. If GNU SQL saves you money, please donate (or have your company donate) to the FSF: https://my.fsf.org/donate. If you have questions about GNU SQL, join the mailing list at http://lists.gnu.org/mailman/listinfo/parallel.

Practical Perl Tools

H-T...TP—That's What It Means to Me

DAVID N. BLANK-EDELMAN

David N. Blank-Edelman is the director of technology at the Northeastern University College of Computer and Information Science and the author of the O'Reilly book *Automating System Administration with Perl* (the second edition of the Otter book), available at purveyors of fine dead trees everywhere. He has spent the past 24+ years as a system/network administrator in large multi-platform environments, including Brandeis University, Cambridge Technology Group, and the MIT Media Laboratory. He was the program chair of the LISA '05 conference and one of the LISA '06 Invited Talks co-chairs. David is honored to have been the recipient of the 2009 SAGE Outstanding Achievement Award and to serve on the USENIX Board of Directors beginning in June of 2010.
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Socket to me, socket to me...Okay, sorry, enough with an imitation of Aretha Franklin and Tim Berners-Lee's love-child. Instead, let's continue with a thread we began in last issue's column. In that column, we discussed using various protocols like FTP, rsync, and SSH from Perl to move data from one place to another. The one protocol that we were able to press our nose onto the glass to see but not really touch was HTTP, the Hypertext Transfer Protocol. As promised, here's an entire column on just that subject to help make up for the omission.

Allow me to get some caveats out onto the table before we go much further. First off, I'm probably not going to spend much time describing the internals of the protocol. If I said that the standard request consists of the request itself, some headers that provide some context for the request (such as preferring a response that's compressed or in a specific language) and sometimes a message body, that about covers what you need to know. We'll talk a bit about the different request types ("methods") that communicate using this format, but we're going to stick to only the top three kinds of types. Funky request types like PATCH, defined just last year in RFC5789, won't have even a cameo appearance (unless this sentence counts).

That's the "what we won't be talking about" caveats; here's the "what we will be talking about" set: in the Perl world, there is one group of modules that almost totally dominates the space: Library for WWW in Perl, more commonly known as LWP. Gisle Aas deserves tremendous credit for actively maintaining such a useful set of modules, for over 16 years at this point. It's the first module people turn to for doing lower-level HTTP stuff. There are some others at the periphery that are useful for edge cases, but I'll only mention them in passing. Largely this is going to be "The LWP Show."

Lest you worry there won't be enough material based on just this set of modules, let me point out that there is an excellent book by Sean Burke called *Perl & LWP* (O'Reilly, 2002). I'm just going to skim the surface of the topic here rather than try to rewrite Sean's book. If you'd like to get more advanced in your LWP work, you may want to hunt down a copy. One thing you'll find in that book that is totally absent from this column is the parsing of any data that gets returned via HTTP. We've touched on this subject in other columns, but unfortunately there is not enough room to explore that topic here.

Simple Pleasures Are the Best

I'd like to start out with the simplest way to use LWP. It is entirely possible that this section will cover the vast majority of your day-to-day needs. If that's the case,

you can probably bail at the end of the section and just check out the marvelous proof I give for why it is impossible to separate a cube into two cubes or a fourth power into two fourth powers, or, in general, any power higher than the second into two like powers (assuming it fits in the margin of this column). But if you do bail, you're going to miss a pointer to some of the cooler things that ship with LWP that many people miss.

The key to all of this magic-fairy-simple-dust is the LWP::Simple module. It lets you write code that looks like this:

```
use LWP::Simple;

my $page = get('http://www.usenix.org');
die "Could not retrieve page" unless defined $page;

#... do something with $page
```

That's how hard it is to fetch a Web page. If we wanted to print the information we received instead of storing it in a scalar variable, we could have used getprint() instead of get(). There is a similar function, getstore(), that lets you drop that information into a file instead.

LWP::Simple is mostly useful for HTTP GET operations, but it also can make a HTTP HEAD request (often used to see if a document has changed since the last time you fetched it). The head() function returns a list with the following information:

- Content type
- Document length
- Modified time
- Expiration
- Server

So, for example, when I ran:

```
use LWP::Simple;
use Data::Dumper;

my @results = head('http://www.usenix.org');

print Dumper \@results;
```

the output was:

```
$VAR1 =  [
           'text/html',
           '65735',
           1296087147,
           undef,
           'Apache/1.3.41 (Unix) mod_perl/1.31 mod_ssl/2.8.31 OpenSSL/0.9.8k'
         ];
```

Be the Agent of Your User

If your needs extend beyond those that LWP::Simple can handle—for example, you need to do more than just a generic HTTP GET or HEAD request—then it is time to move up the food chain. The next most commonly used part of LWP is the

LWP::UserAgent module. With this jump, we leave the land of naive function calls behind and enter LWP's object-oriented framework. You won't need to be an OOP ace to make use of the modules we're going to talk about, but I thought it best to mention this switch before I start to use words like "class" and "method" for the first time, in the next paragraph:

The LWP::UserAgent module provides what the LWP tutorial calls the two main classes you have to understand from LWP. They are the eponymous LWP::UserAgent class and the HTTP::Response class. The LWP::UserAgent class lets you write a "Web user agent...to dispatch Web requests" (to use the terms from the documentation). Answers to these requests come back to us in HTTP::Request objects. You don't have to explicitly load the HTTP::Request module to work with these objects, since the LWP::UserAgent module will do that for you. This all probably sounds more complex than it is. Let's look at some code to calm any jitters:

```
use LWP::UserAgent; # or use LWP;
my $ua = LWP::UserAgent->new;
my $resp = $ua->get('http://usenix.org/');
die "Could not retrieve page" unless $resp->is_success;
# do something with $resp->decoded_content;
```

To get us started with LWP::UserAgent, I just rewrote the first LWP::Simple code sample from above. First, we create a LWP::UserAgent object, and then we call the get() method from that object to make our request. It returns a response (HTTP::Response, to be precise) object that gives us methods to test the success of the request and return the contents of the reply. No biggee so far, right?

Now let's do something we couldn't do with LWP::Simple. Let's tune the request a bit. Some Web sites will tailor their responses to a query based on the browser making the request. If we want to pretend to be another browser, we can change some of the default settings, such as the header the browser uses to identify itself, before we actually make the get() request. Let's make your favorite Web designer twitch a little by pretending to be an Internet Explorer 5.0 session on a Solaris box:

```
use LWP::UserAgent;
my $ua = LWP::UserAgent->new;
$ua->agent('Mozilla/4.0 (compatible; MSIE 5.0; SunOS 5.10 sun4u; X11)');
```

Perhaps an even more useful method you might use is credentials(). This lets you authenticate to a Web site that is using basic authentication (ideally, over HTTPS, something we'll mention in just a bit). The documentation shows the parameters it requires:

```
$ua->credentials( $netloc, $realm, $uname, $pass );
```

with this as the example:

```
$ua->credentials("www.example.com:80", "Some Realm", "foo", "secret");
```

This will allow you to authenticate to example.com (i.e., at the point where it requests a username and password for "Some Realm") with that username and password.

If you need to send other headers along with your get() request (e.g., the language you expect a response in or a desire to get the result back in a compressed form), get() takes a set of field/value pairs after the URL. In addition to real headers such

as Accept-Language and Accept-Charset, it also takes "special" fields (e.g., :content_file) which let you redirect the contents of the request to a file. This is quite important in cases where you will be slinging lots of data around. For example:

```
use LWP::UserAgent;

my $ua = LWP::UserAgent->new;

my $resp = $ua->get('http://usenix.org/TerabytesOfFun.html',
                        ':content_file' => 'TerabytesOfFun.html');
```

All GET and No POST Makes Jack a Dull Browser

So far we've only covered writing the kind of HTTP requests that retrieve information, but we've said nary a word about how one can submit information over HTTP. For those requests, we'll have to learn how to submit form elements using both GET and POST requests. Let's take it in that order.

GET request submissions are those that crowd up your browser's URL bar with bunches of parameters sent as part of the URL:

```
http://forecast.weather.gov/MapClick.php?CityName=Boston&state=MA&site=BOX
&textField1=42.3583&textField2=-71.0603&e=0
```

Constructing a huge URL like this programmatically isn't necessarily much harder than just string concatenation, but there are a few catches. These catches are largely centered on what characters are legal for a URL and which need to be escaped before they can be used. There are a few Perl modules that will pay attention to those details so we don't have to. Here's a slightly modified version of an example given in the LWP tutorial:

```
use URI;
use LWP::UserAgent;

# makes an object representing the URL
my $url = URI->new( 'http://us.imdb.com/Tsearch' );

# And here are the form data pairs:
$url->query_form(
    'title'    => 'Blade Runner',
    'restrict' => 'Movies and TV',
);

my $ua = LWP::UserAgent->new;
my $resp = $ua->get($url);

# do something with $resp->decoded_content;
```

It uses the URI module's query_form() method to create the form submission in URL form, so we can perform a get() request just like before. If we were to print $url after it was constructed, it would look like this:

```
http://us.imdb.com/Tsearch?title=Blade+Runner&restrict=Movies+and+TV
```

This isn't particularly complex, but I've seen some monster URLs that you wouldn't want to construct by hand. It is far safer to use query_form() when possible.

Okay, so if that is a GET submission, how would we go about doing a POST? It turns out that simple POSTs are actually easier than the GET request we just saw. LWP::UserAgent has a post() method that directly takes the field/value pairs in an

array right after the submission URL. Here's an example that demonstrates a US Postal code lookup:

```
use LWP::UserAgent;

my $ua = LWP::UserAgent->new;

my $resp = $ua->post('http://zip4.usps.com/zip4/zcl_1_results.jsp',
                     ['city'          =>'Boston',
                      'state'         => 'MA',
                      'pagenumber'  => 0 ] );

# do something with $resp->decoded_content;
```

The hardest part of that code is probably determining the names of the form's fields. For this, you can look at the source code of the page (although I cheated and used the `--forms` option to the mech-dump utility we discussed in this column back in February of 2009). In the interests of full disclosure, the code is so simple because the form is simple. HTML forms can get considerably more complex when you start wanting to do things like file uploads. *Perl & LWP* and the lwpcook (LWP Cookbook) man page are two good resources for handling the more advanced cases.

I do want to offer one hint on the subject of forms before we start to leave our discussion of LWP::UserAgent. I was surprised ,when preparing for this column, just how skewed the balance of GET to POST forms is on the major Web sites. It took me over an hour to find a POST form for the previous example that would take in input and return a page of useful output. The vast majority of sites used GET-based forms on their front pages.

A significant number of the rest that did have POST forms used them in their search boxes, but didn't return a page of results directly. Instead, when you posted a search request, the response would be an HTTP Redirect (302 status code) pointing at some other page on the site. By default, LWP::UserAgent only chases referrals for you on GET requests. If you are dealing with a POST request, you can either:

1. Tell LWP::UserAgent to also chase referrals for POST requests, despite RFC 2616 suggesting that this is a baaaad idea:

   ```
   push @{ $ua->requests_redirectable }, 'POST';
   ```

2. Grab the referral and choose whether to chase it yourself:

   ```
   if ($resp->is_referral) {
     # go chase the value of $resp->header('Location')
   }
   ```

Now that we've seen how to use LWP::UserAgent to POST data, what haven't we covered? A number of things: LWP::UserAgent can handle cookies with just a few lines of initialization. It can deal with proxies. It can use callbacks to give your code more precise control over how it will handle the data that comes in. Please see the LWP::UserAgent documentation, the lwpcook/lwptut manual pages, and *Perl & LWP* for more details.

There is one thing I do have to mention before we leave this section, if only to avoid harshing the mellow of my security-conscious editor. We haven't talked about how LWP::UserAgent handles HTTPS requests. I'm afraid this may be a bit

of a letdown, because the answer is "it just does." As long as you have either the Crypt::SSLeay or IO::Socket::SSL modules installed, any URL that begins with https instead of http just works as you'd expect.

What Else?

We're just about at the end of this column, but it is worthwhile mentioning some of the additional capabilities of the LWP module group and two of their competitors. In LWP itself, you can find LWP::RobotUA, basically a robots.txt-compliant version of LWP::UserAgent, and LWP::ConnCache, available to let you use HTTP/1.1 "Keep-Alive" to improve performance of multiple requests to the same destination.

And here's the tip you've been waiting for ever since the foreshadowing in the LWP::Simple section: LWP comes with a number of really useful command-line scripts that get installed when the module group itself is installed: lwp-download, lwp-dump (only included in later versions of the LWP distribution), lwp-mirror, lwp-request, and lwp-rget. You can also choose to install aliases for lwp-request called GET, HEAD, and POST to make, for example, HTTP HEAD requests from the command-line really easy. If you've never noticed any of these utilities before, be sure to check them out. I just recently used lwp-download on a shared host of an ISP that didn't have wget or curl installed, so I know they can be a great help at times.

Even though LWP is the most widely used framework for doing the sort of stuff we've been looking at in this column, it doesn't work for everyone. For example, the people who enjoyed my October 2010 column on ::Lite modules might also want a replacement for this framework that isn't quite as heavyweight. There is a HTTP::Lite module which attempts to provide that, but judging by the HTTP::Tiny documentation (which claims it is more correct and more complete than HTTP::Lite), HTTP::Tiny may be the module for you.

Take care, and I'll see you next time.

Pete's All Things Sun

Solaris 11 Express

PETER BAER GALVIN

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To some of us, Solaris 11 Express seems like yesterday's news. It bears much resemblance to the OpenSolaris distributions, which stopped when it was released. The first OpenSolaris release was OpenSolaris 2008.05, meaning that some sites have been using at least some of the new features for almost three years. However, many of you sysadmins have not played with either OpenSolaris or the just-released Solaris 11 Express. This column is for you.

This column is also for admins who are familiar with OpenSolaris but not yet with Solaris 11 Express. Here I will discuss what is new in Solaris 11 Express, differences from both Solaris 10 and OpenSolaris. The discussion is mostly technical but also includes details on the legal, support, and production status of both releases. If you are already familiar with Solaris 11 Express and its features, then feel free to move along—nothing to see here.

Solaris 11 Express—Should We Care?

Certainly some sites became less interested in Solaris when Oracle bought Sun. Others became disenchanted with the long delay between Oracle's purchase and any word on the future of Solaris, and others when an internal Oracle memo about the future of Solaris made the rounds (see http://opensolaris.org/jive/thread.jspa?messageID=496203). Is Solaris still open? Or is it closed? And should we care about its state or even about its existence?

For many sites, Solaris is a key operating system and will likely continue to be key. They run production Solaris 10 (S10) or earlier releases and wait for production updates before upgrading their systems. For those sites, Solaris 11 Express (S11E) is good news. The Solaris 10 releases have had decreasing incremental improvements over time as Solaris engineers worked on the next generation of Solaris. Solaris 10 shipped on January 31, 2005, and several major changes, including ZFS, shipped in subsequent releases. However, it is unarguable that there are many nice new features in S11E that are not available in S10. Given the long gestation of OpenSolaris, it is encouraging that the first release (even though an "express" release) of Solaris 11 is available. S11E is available for SPARC and x86, affirming Oracle's plan to support both architectures going forward.

The "openness" of Solaris is likewise of importance to some sites, but not others. Many sites did not change their behavior when Solaris was open sourced, and so should not consider any change in openness to be important. However, some sites

do care about the open state of Solaris, whether for philosophical or practical reasons.

Philosophically, many feel that open source operating systems are fundamentally superior to closed ones. Sometimes this feeling of superiority comes from the benefit of non-employees contributing to the code, improving it faster than just the hired engineers could. Other times it comes from the idea of supporting open source efforts, or a basic belief that software's natural state is open and free.

Practically, some like open source because they can make their own distribution or base appliances or products on the source, whether a commercial or free effort. There are many instances of such efforts around OpenSolaris, and many feel that such an ecosystem is a contributor to the health of an operating system. Even more practically, at sites that simply run the commercial distribution based on an open source operating system, they can read source code for debugging, tuning, and general understanding.

Which brings us to the question of the current openness of Solaris. There has been no official word that OpenSolaris is dead or closed. In fact, even the leaked memo states that the CDDL license will not be removed from any code that was labeled with it, fundamentally leaving the code open. But the memo also states that source code will not be released until after the commercial version of Solaris that is based on it is released. Which leads us to the assumption that, once S11 ships, the source code for most of it will be made available. That would likely go far in terms of calming the fears of open source fans and Solaris fans alike.

We should also care about Solaris 11 and its future because, frankly, it has some very nice features—features that many sites would find useful and would enjoy using in production. I'll discuss those features right after addressing the legalities.

Licensing and Support

An operating system can be feature-rich and still not be used, due to its costs and legal limitations. So, what is the status of S11E? The FAQ that was released by Oracle is a good place to start for all of the business-side details [1]. But, in summary, it seems that anywhere you are allowed to run S10, S11E is allowed. If S10 is licensed on a given server, then S11E can be used there as well. Separate support for S11E is available, just as with S10. Further, S11E is usable with a support contract for evaluation and development purposes under the Oracle Technical Network perpetual license. Fundamentally, S11E is a full, supported next-generation release of Solaris. Then why the "Express" designation? There are many changes from S10 to S11, and ISVs need to have a stable code base with which to port or validate their applications. "Express" is also a bit of a warning that S11 is young and may not be appropriate for production use. S11E is a full commercial release, but it should be used with caution until the first S11 release ships.

Features

Several features of S11E were topics in this column as they came out in OpenSolaris. Therefore, rather than re-covering them, please see the appropriate columns.

- Crossbow, the network quality of service and virtualization feature set was discussed in the February 2010 *;login:*, [2].
- Another major new feature of S11E, and perhaps the biggest difference, is the new package management system. This, along with ZFS as the only allowed root

file system and the new installer and boot environment manager, were discussed in the December 2008 *;login:* [3].

- ZFS de-duplication was covered in the April 2010 *;login:* [4].

Some tried-and-true features of Solaris carry through to S11E, including binary compatibility with previous Solaris releases. Old package management still works in parallel with the new IPS packaging system, but there is no patching for those old packages (and certainly not for the new style), but there are certainly many new and different features.

The installer is new, simpler, and better, due to its support of ZFS as the only root file system. Also gone is the old jumpstart, replaced with an "automated installer" that allows customized hands-off installation of multiple Solaris systems.

Unfortunately, there is no true upgrade path from S10 to S11E. This marks a large change from previous Solaris releases, but is an indicator of just how different S11E is from S10. It is possible that there will be an upgrade path included in a future S11 release, but there is no path available today. There is some help for S10 systems, though, in the form of a new "Solaris 10 Container" feature within S11E. An S10 system can be archived and installed within an S10 container inside S11. Oracle says that all applications that ran on S10 will run within an S10 container on S11E. But note that if the S10 system has containers, it cannot be run inside S11E within an S10 container. In other words, there is no concept of containers-within-containers, so all containers in the S10 system must be removed before attempting to encapsulate that system within an S10 container. And even though there is no patching of S11E, there is still patching with Solaris 10 containers (as well as S9 and S8 containers, of course).

S11E itself will be upgradable to S11 when it ships using the new package management system. Much like Linux, S11 can determine the list of all packages that need to be updated, including kernel packages, and download and install them. A new boot environment is created as necessary, and the system can then be booted into the new or previous environments. There is now a "fast boot" option that skips the hardware diagnostics phase of booting. There is also a new GUI "Update Manager" tool which lets the admin download and install packages that are not yet on the system or update those that are. For example, a simple `% pfexec pkg install gcc-3` brings in the Gnu C compilation environment via the command line. Or within the update manager, typing the search term "emacs" lists both installed and available-to-install packages that match the term. Selecting the ones desired and clicking "install/update" installs or updates the packages as appropriate.

ZFS and the underlying file system structures have new features beyond what is available in S10. ZFS gets deduplication and encryption, both major features. The new ZFS diff feature will show what changed between two snapshots. CIFS is now a fully integrated kernel feature, rather than a set of user-land programs. Also, all of the various SCSI protocol implementations that were within S10 have been merged into a single COMSTAR (Common Multiprotocol SCSI Target) facility. At the user level, the "time slider" GUI tool is quite an improvement. It can automate the creation of ZFS snapshots and can also help users visualize the snapshots by showing which files were available at any given time (between the oldest existing snapshot and the current version of the file system). Erwann Chenede has a complete blog posting, including a video demo, exploring time slider [5].

Interesting new commands include zonestat to display per-zone information, flowstat to show Crossbow networking information, and dlstat to show network link statistics. While on the topic of networking, many sysadmins will be pleased to hear that DTrace has been enhanced to be able to observe much deeper into the networking stack, including to and from Solaris containers. Each container can now have one or more dedicated virtual network ports, rather than a dedicated or shared hardware port as in S10. Also, there is a software layer 3/layer 4 load balancer included in S11E. Many other networking improvements are included, such as improved InfiniBand, link protection, and bridging and tunneling technologies.

Security changes are also numerous, including cryptographic framework improvements, trusted extension enhancements, and in-kernel pfexec implementation.

Oracle has published some "what's new" documents that go into detail on all of these changes and many more [6, 7, 8].

So, is Solaris 11E ready for use? Development and Q/A environments can use it as is, giving sysadmins experience with the new features and getting developers ready for the new package management system. In my uses, it has been rock-solid. The performance, security, and feature enhancements are all impressive, useful, and welcome. And Oracle is placing its trust in S11E where its hardware is—Solaris 11E is an option on the Exadata and Exalogic appliances. Apparently, the improved InfiniBand stack made S11E more appropriate than S10 for those systems, among other reasons.

The Future

Oracle has stated that Solaris 11 (the official production release) will be available in 2011. Even if you choose not to try S11E, its features will be available within a reasonable amount of time in the S11 release. But S11E, whether you choose to use it for production, testing, or just exploration, should be a very practical next step into the use of Solaris in your environments.

Tidbits

Life is good for production and performance-oriented sysadmins, because there is a new release of the Chime performance monitoring tool. Chime has been a bit of a proof-of-concept and science experiment until now, but the new features make it quite useful and more powerful. The DTraceToolkit scripts have been incorporated, making Chime a good first stop for lighting up various aspects of the system to understand their performance characteristics. Chime is available for download from http://hub.opensolaris.org/bin/view/Project+dtrace-chime/.

References and Resources

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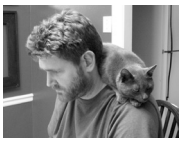

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I attend conferences often enough that they sometimes melt together in my memory. It's for this reason, I think, that I can't be sure where I was first introduced to what's become known as the "Google Commodity Server Model." It was a Google talk at some USENIX conference, I'm sure, and had to have been before the demise of Compaq as a server company, because that was the image it destroyed in my mind. I'd come expecting to be dazzled with a dream-world of orderly, sterile white-space. It would be thoughtfully arranged with row after row of gleaming-white racks housing 8 and 16u beige Compaq behemoths as far as the eye could see. Brainy grad students moonlighting from Stanford or Berkeley would loiter in white lab coats and consult their clipboards while thoughtfully discussing the output from the hundreds of surface-mounted displays in the NASA-like control-center of a NOC.

Perhaps you imagined something similar. I find it comforting to believe I wasn't alone. Maybe you were even in the room with me. There we sat having our expectations smashed by photos of Google's dimly lit cement-floored warehouses. Their doorless black racks literally bulged with sagging desktop motherboards haphazardly shoved into place atop sheets of plexiglass (plexiglass!), their hard drives and RAM shamelessly exposed to the world. Like lumbering, unhappy mules, grungy liberal-arts majors from the nearby community college trudged down the stone passageways in their sweat-stained Creed T-shirts, heaving before them shopping carts (shopping carts!) laden to the brim with replacement hard-drives and DIMMS. We couldn't have been more wrong. Really, what *were* we thinking?

But then, who could blame us? For that time, and for that industry, the model was almost satirical in its absurdity. And like witnessing great satire, we were at first horrified, and then fascinated, and ultimately convinced. One quickly realized that they had a point—either stumbled upon out of necessity, or the proof of a powerfully well-devised hypothesis. Google had at once posited and proven that if you took enough hardware and used it to build a singular, parallel application, then it didn't matter how cheap the hardware was or whether it broke on a regular basis. There are many reasons commodity clusters are triumphing over supercomputers and other large production systems, but this, I think, is one of the most compelling: it's easier (and cheaper) to manage production systems when we can accept as a matter of course that some subset of it is going to be broken, because that is the practical reality, no matter what the scale of infrastructure in question.

Google changed the sysadmin game from large, reliable machines with failover to parallel active clusters of smaller computers and, as a result, never had to worry about system reliability, or vendor lock-in, or the financial viability of one vendor

vs. another, or a 24/7 NOC staff, or uninterruptible power, or a hundred other frustrating nits that we all fought management over in the '90s (although many IT organizations still haven't quite caught on). This is arguably one of the minor ways in which Google has changed the world, I suppose, but it was an important one to the sysadmins among us, and while very few of us have plexiglass in our racks, it's a rare thing, I think, to find a Web site of any size that doesn't have an active parallel cluster of small systems behind it (even if those systems hide their components behind a Dell-branded faceplate).

A few weeks ago I was at lunch with some friends who still work at my last place of employ, and they mentioned one of their sites being down as a result of an IIS update gone wrong. I was actually confused. The Web site was down because a server was down? How does *that* work? At this point there is in my mind no singular, straight line that connects the application to the server hardware, and that is a telling transposition. The application is a bulbous, free-floating organism. Its appendages overlap virtual machines, penetrate network subnets, and transcend physical hardware. For me at least, and I suspect much of the LISA crowd, putting a Web site on a box is a design that no longer computes. It simply isn't how we build infrastructure support for Web applications anymore.

This being a monitoring column, the question begged by my typically wordy preamble is: given that clusters appear to be changing how we build application infrastructure, are they also changing the way we monitor application infrastructure and for that matter, how we monitor the applications themselves? The answer is of course "Yes," and also "duh," but at the risk of telling you what you probably already know, I thought I'd spend this month's column exploring some of the ways clustering is, for me at least, changing systems monitoring.

In the production environments I build and maintain, everything is pretty much a cluster up to and including the routers and firewalls (which are OpenBSD systems), as well as the load balancers (which are fancy Apache boxes). Our monitoring efforts are numerous and wide-ranging, but here I'd like to focus on availability monitoring of clustered applications. In this context I believe there are a few categories that are directly affected by a clustered infrastructure, for better or worse.

The first is the use of an external end-to-end application check. By this I mean a system or set of systems, located outside your network, that monitors the application by using it the same way a normal human would. Given that static content and dynamic content often reside on different systems in different networks, and the myriad, subtle ways application servers tend to fail, it is not a trivial undertaking to define a Web-application outage, much less detect one. The site might be up, for example, but not displaying graphics, or it might be up except running out of threads every so often, and so on. When you add a cluster of application servers to this already complex problem, you're adding all sorts of new failure models. For instance, one server out of the 20 might have an unstable database connection pool, or the application content might not be properly synchronized across all cluster nodes.

If external end-to-end application monitoring wasn't a requirement before clustering, it certainly is the only way to be sure a given application is running well in a clustered world. If your developers follow a formal software development life-cycle, chances are a test plan for the application gets created at some point. I recommend taking that test plan and transforming it into an end-to-end monitoring check. We use an internally developed framework based on curl and run these checks from

a Nagios box hosted in an off-site colo. Sometimes it's sufficient to visit the home page and verify that a few links are present. Other times we execute logins with test accounts and follow several links into the app. Pay particular attention to how the application manages sessions, especially if they are sticky; the monitoring system needs to be able to traverse different paths through the cluster rather than running its check against the same cluster node over and over again.

In our environment we usually find it sufficient to simply dump our cookies in the bit-bucket after every check. Designers of large clusters should put some thought into designing a session-state system that allows the monitoring system to specify its own path through the balancer tier. It may be necessary to use multiple external monitoring nodes for very large clusters (more on this later). In the context of external, end-to-end monitoring, the introduction of clustered systems has complicated things.

Another way in which the concept of commodity clustering has complicated the task of monitoring is by introducing an entirely new category of systems monitoring—that of automated node management. Now that we have 4 or 30 or 800 cluster nodes, we need to automatically fail them out of the cluster when they fail. Depending on the type of cluster involved and what failure means, this can be a serious headache. For routers and load balancers, it's usually sufficient that each node is responding on a common IP. Various multicast MAC approaches such as CARP, HSRP, or VRRP are normally used here. When the cluster nodes are running a more complex application, things get hairier, but whatever the details of the nodes themselves, we can't use a traditional monitoring system like Nagios here.

In the first place, we need to detect failed nodes quickly, at the most within a few seconds of the problem occurring. Secondly, the detection model needs to be peer-to-peer. It's a bad idea to depend on a single point of failure, like a management and monitoring node, to tell us when a cluster node is up or down. Third, this monitoring layer needs to take immediate action to offline the node when a problem occurs. This introduces a slew of new problems such as having a fail-safe mechanism for offlining a node, what constitutes a sane timeout, whether or not to automatically re-enable a node, and capacity planning concerns such as whether the load from the failed node will balance gracefully across the rest of the cluster and whether the rest of the cluster will be able to bear the brunt of losing the node.

We've had to solve these problems several times over in our production environments for different types of clusters, and despite several attempts to bring commercial hardware and software solutions to bear, we always seem to return to assembling our own tools from the same small assortment of open source programs. We've had good experience with CLUSTERIP [1] in the Linux kernel, as well as OpenBSD's CARP [2] and UCARP [3] on Linux. Apache's mod-proxy-balancer [4] does a good job of quickly detecting and disabling app-tier nodes that are not responding on their respective ports, and it has a nicely automatable node management interface. Finally, we've written a fairly complex application-layer node management framework that we refer to internally as "webstated" to detect higher-order application server errors and disable nodes accordingly.

Automated cluster node management is, in my experience, a hairy endeavor with simple applications. It is made nearly impossible (or at least maddeningly frustrating) with cluster nodes that are running unreliable and strangely behaving Web-application frameworks. Our various solutions are stable and I'm quite happy with them, but given the amount of attention we've had to pay to this problem, I'm often

surprised by the simplicity of the commercial offerings in this context. I suspect monitoring for node management is far from being a solved problem in the world of commercial balancers, not to mention that the commercial balancers themselves cannot usually be actively clustered.

Speaking of systems that aren't actively clustered, I've long been fascinated by the idea of having a cooperative cluster of monitoring systems. Monitoring clusters to date have focused on scalability to meet the demands of monitoring large infrastructures, but a small patch to something like the DNX [5] framework could give us a group of monitoring servers that all monitored the same small group of services, such as a series of external Web sites. Instead of increasing the possible checks per second, this could increase the quality of the monitoring result. A cluster of monitoring systems could watch the same service from different networks and cooperate to form an opinion about the state of the service in question. This could rectify all sorts of false alarms, accounting for failures in individual monitoring nodes and DNS and network provider issues.

There are several commercial entities providing this sort of service ([6], [7]) but if your Web site itself consists of several different clusters of hosts—for example, a balancer cluster, an app-tier cluster, and a database cluster—then you're going to need some flexibility in your monitoring cluster, for the reasons I've mentioned. A monitoring cluster does you no good if all the monitoring nodes are hitting the same app-tier node, or if they're all hitting different app-tier nodes but you can't tell which. To be sure, clusters generally complicate our monitoring endeavors.

In one way at least, Google's commodity cluster model has made life easier in a monitoring context. Once we can be sure that the application is in fact functional and that failed nodes can be reliably detected and disabled, we need not care as much about the traditional alerts we associate with systems monitoring. I, for example, no longer receive alerts from Nagios that a given service on a given host is down, or even that the entire host itself is down. Instead, I receive a warning when a given cluster has degraded to 66% capacity, and that's the sort of thing that can wait until morning.

Take it easy.

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/dev/random
(Parenthetically Speaking)

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It's sobering (presuming the only time you think about these things is when you're intoxicated) to contemplate that computers rule virtually every aspect of our modern lives, yet all they really do is add or subtract ones and zeroes. That's it. The most sophisticated massively parallel six jillion-CPU supercomputer is really nothing more than a silicon-based incarnation of Clever Hans the Math Horse. You can dress it up with all the fancy-schmancy terminology and protocols and standards and engineering specs that you want, it's still just an abacus with two beads. One and zero. Up and down. On and off. Plus and minus. Yin and yang.

Imagine, then, if you will, (sorry, my comma key keeps getting in the way) the awesome power of a computer that could use three or even *four* beads. There's no reason to stop with only two, is there? Maybe a quark-based processor or something. Never again will we have to go get a cup of coffee while we wait for our ancient binary-generation PCs laboriously churning out their meager ones and zeroes. With quaternary processors the answer will be available before we finish asking for it.

Take this even one step further now and imagine *quantum* quaternary computers (Q2-puters)! These processors will be so powerful they will come up with the questions *for* you, even before you're *born*. There will be a new family ritual in which mom and dad will take you aside one day when you're old enough to understand and ceremonially present you with the storage device (probably too small to see with the naked eye by then) containing every digital inquiry you will make in your entire life, along with the answers, all thanks to your household Q2-puter (now available in mauve and tangerine).

Once all intellectual inquiry is moot, we as a species can move on to more engaging pastimes. We've already got killing each other down to a fine art, although I have no doubt we will continue to refine that process, but I'm thinking of something a little less extinction-oriented, like a global MMORPG that uses real currency, motion controllers, ultra-broadband video teleconferencing, and touch-sensitive mittens to allow absolutely everyone on the planet to interact in some fantasy world with unicorns and dragons. (A bit like the Olympics, but more inclusive and grounded in reality, with fewer anabolic steroids involved.) Of course, all of the hardware would be miniaturized and wireless, so you could play anytime, anywhere. You could even be sowing your crops or farming your gold at 35,000 feet on the way from Boise to St. Petersburg. A plane full of squirming, swinging, hacking passengers (and, if past experience is any indicator, pilots) in tiny aircraft seats.

Why blur the line between fantasy and reality when you can rub it out altogether? (Definitely a staple practice for talk show hosts.)

What else can we do in a world with no need for Google? Devote even more time and effort to being rude to one another, I suppose. We never seem to run out of energy or innovation in that field of endeavor. Since I'm just full of radical ideas today, here's another one that came to me late last night when I was counting voters...er...sheep.

You know how in some families there's a jar where you have to deposit a certain amount of money whenever you utter a word not approved for use in the household—"cuss words," as my granddad called them? I think we need one of those in both houses of Congress. Every time some Distinguished Senator or Representative poops out a gratuitous crude pejorative aimed at one of his or her colleagues, 10 dollars needs to be dropped in the jar. We could make a substantial dent in the national debt with this income, methinks. It might also encourage the return of witty repartee in politics, a phenomenon that has not graced this hapless nation in many years. In fact, I would go so far as to posit that wit and political acumen (and by that I mean a talent for climbing over the bloated bodies of your butchered opponents to reach the pinnacle of the dung heap) are seen by this past brace of generations as polar opposites. As an example, take this exchange from the British House of Commons:

Bessie Braddock: "Winston, you are drunk!"

Winston Churchill: "Bessie, you're ugly. And tomorrow morning *I* will be sober."

If this had happened in our current House of Representatives, it would have gone something like this:

Rep 1: "Sounds like you've done had too much corn-squeezins' again, conservative know-nothing."

Rep 2: "Yeah, why don't you just tax me into oblivion, liberal elitist tool?"

Except that I can't print the actual epithets here, this being more or less a family publication ('cause we all know that 10-year-olds constitute the lion's share of Linux installs these days).

OK, I'm over it.

Moving on, I'd like to address the infinitely depressing and intensely aggravating policy of a certain well-known IT company (the enlightened rightly refer to it as more of a cult) of charging developers for the privilege of writing application code for their platform. Let's translate this heinous practice into a more sanguine context.

Let's say, hypothetically, that I buy a new truck (I'm a Texan, and that's what we drive here) from the local Ford lot. It comes with the usual accoutrements: cab, bed, engine, four wheels (all the cool kids actually drive dualies, but so far I've resisted the temptation to drop more on a vehicle than I did on my first house). I decide, being the innovative take-charge sort that I am, that I want to add a killer sound system so I can listen to my George Strait mp3s in surround-sound (this being San Antonio, there's like a city ordinance that you have to own at least one George Strait recording). Turns out, though, that I can't make any changes at all to my vehicle unless I pay an additional "modifier's" fee to Ford. That would fly like a

paper airplane folded from an X-ray apron here in the Lone Star State (that means not well at all, for the simile-challenged).

So, to all greedy corporate behemoths who want to charge me for beta-testing their software or increasing their product's popularity and sales by developing applications for it, let me answer you in the colloquial tongue of my people:

That dog won't hunt.

Book Reviews

ELIZABETH ZWICKY, WITH SAM STOVER, EVAN TERAN, AND RIK FARROW

The No Asshole Rule: Building a Civilized Workplace and Surviving One That Isn't

Robert I. Sutton, PhD

Hachette Book Group, 2010. 225 pp.
978-0-446-69820-7

This is a new edition with an extra chapter about the benefits and drawbacks of becoming famous for writing a book with "asshole" in the title. Probably not worth buying a second copy for, but a worthy extra dollop of amusement.

Eyebrow-raising title aside, this is a sweet and useful book. "Sweet" because not only does it argue that letting people be abusive and stupid is bad business, as well as morally wrong, but it does so self-deprecatingly and with great appreciation for the difficult, socially awkward, and technically demanding who may be swept up by people who are aiming for niceness. "Useful" because it gives advice not only on how to set and enforce a "No asshole" rule, but also on how to avoid being one yourself, and how to survive when a plague of assholery sweeps through your work place. (The author argues convincingly that one reason to avoid nasty people is that it's catching.)

Although I fully support the author in distinguishing pure geekery from nastiness, I think he probably gives high technology more of a pass than he should. The most dangerous assholes are the socially competent ones, but hiding in the flock of perfectly nice geeks who don't do social interaction well are some who actually don't care about people.

Surprisingly, this is an uplifting book; if the turkeys are getting you down, it's a good choice to seek out.

Guesstimation: Solving the World's Problems on the Back of a Cocktail Napkin

Lawrence Weinstein and John A. Adam

Princeton University Press, 2010. 293 pp.
978-0-691-12949-5

I expected to love this and didn't, although not through any particular fault on its part. It's an interesting look at how one answers questions like "How many ping-pong balls does it take to go around the world?" and I like a number of the math bits. But I cannot bring myself to care about how many ping-pong balls it might take, even though I know that this is not the point; thinking about things like the size of the world and how big numbers fit together is the point, and I really like those things. But couch them in terms of guesses about ping-pong balls (or piano tuners, or Spider-Man) and my eyes glaze right over. (The appendix of useful numbers I can read quite happily though. Go figure.)

If you find these questions interesting, it is a great introduction to thinking about planetary scales and big numbers, and estimating with honesty. Not to mention it's the most condensed source of information on a certain class of interview questions and how to answer them.

iOS Forensic Analysis: For iPhone, iPad, and iPod Touch

Sean Morrissey

Apress, 12/27/2010
978-1-4302-3342-8

One of the biggest drawbacks for any forensics book is how fast it becomes obsolete. I tried to review an iOS forensics book a while back, but by the time I got my hands on it the content was so outdated, it wasn't worth the time. Luckily, I got to this book right out of the gate, so it's still relevant as well as technical and complete. There are a number of spelling/grammatical errors, and the flow is disjointed at times, but if you want a book that's going to show you how to acquire data from an iDevice, this is it.

Compared to the rest of the book, the first chapter is a little fluffy, as it covers the "History of Apple Mobile Devices." Not terribly relevant, but interesting if you're into that kind of thing (I'm not). After that, though, we jump into the iOS operating and file systems. This is a decent intro to how the iOS system works, partition specifics, SQLite databases that hold all the information, plus some recommendations on tools to use for SQLite analysis. Chapter 3 drops back from the tech-

nical for a bit to discuss the legal issues associated with cell phone seizure, which is quite complicated due to legislation being quite behind the curve when applied to rapidly advancing technology. After a brief discussion of whether or not an iDevice can be seized, the actual seizure process is outlined. This sets the stage for the rest of the book, which shows what data lives where, and not just on the iDevice, but also on syncing computers and MobileMe accounts. A number of tools ranging from free to several thousand dollars are evaluated, and evaluated quite fairly, a pleasant surprise. One big takeaway from the book for me was learning about the Lantern forensic tool. Of the tools discussed, this seemed to have the best bang for the buck, and the authors were also very quick to respond to my demo request, so I actually got to play with it within about 30 minutes of discovering it exists.

As with most forensic books, this one walks you through setting up your own forensic workstation, along with a fairly complete list of tools you'll need to do iDevice analysis. A significant amount of time is spent explaining how to use the different tools, leveraging their strengths to find evidence. A by-product of reading this book is seeing firsthand just how much information really lives on a smartphone. I used my own iPhone while going through the book, and I was pretty amazed at what I found. Certain applications such as Pandora and iDisk, in particular, cache files, which I didn't realize. Pandora had thumbnails for the last 20 or so songs I had listened to, and iDisk had about 15 files locally that I had completely forgotten I had read. Overall, a solid technical book that any geek with an iPhone should get their hands on, if for no other reason than to see what's on it.

—Sam Stover

Arduino Cookbook

Michael Margolis and Nicholas Robert Weldin

O'Reilly Media, Inc. 2011, 500 pp. (rough cut e-version reviewed)

978-0-596-80247-9

Building Wireless Sensor Networks

Robert Faludi

O'Reilly Media, Inc. 2011, 301 pp. (digital version)

978-0-596-80773-3

Although they focus on different technologies, these two books are interrelated and even have a bit of actual overlap. *Arduino Cookbook* (AC) in typical O'Reilly Cookbook fashion provides almost 200 solutions to various Arduino topics. *Building Wireless Sensor Networks* (BWSN) deals with Xbee radios which use the ZigBee communications protocol. Both Arduino and Xbee are very popular and easy-to-use modules which, although independent, are often used in tandem.

The AC version I read was an O'Reilly Rough Cut, so the finished version might differ slightly from what I discuss here, but probably not enough to make a big difference. There are 18 chapters, each dealing with different types of recipes for using Arduino. Chapter 1 walks you through the Arduino hardware, and Chapters 2–4 introduce the software, some basic programming, and connecting your Arduino to your PC. After that it's off to the races as you learn how to receive sensor data into the Arduino and integrating various devices that provide sensory input (touch, sound, light, etc.). There are so many different things you can do with an Arduino, just listing all the chapters would take up more space than I'm allowed, but some of the really cool recipes include controlling motors, remote controllers, and even functioning on IP networks. In particular, Chapter 14 has four solutions for integrating with Xbee, and Chapter 15 starts out with assigning an IP address, requesting data from a Web server, running a Web server, and interacting with Pachube.

BWSN, not being a Cookbook, goes into a lot more detail, describing the history and technologies in the Xbee radios and the Zigbee protocol. That said, by the end of Chapter 2, assuming you have all the requisite hardware, you'll have two chatting Xbee radios. Unlike Arduino, which is really good at receiving data and acting on it, the Xbee radios are designed to build mesh networks quickly and easily. The Xbees do have some limited sensor capabilities, but when coupled with Arduino the possibilities open up tremendously.

In Chapter 3, Xbees and Arduinos are combined to make a simple doorbell. After getting that under your belt, you are ready to learn more about the different communication protocols available to the Xbee, followed by a solid examination of the flexible and powerful Xbee API. As with all O'Reilly books, the explanations are professional grade and easy to follow, even for someone without an EE background (guilty). Another huge plus for me was the painstakingly detailed pictures and descriptions of the circuits that are used in the various projects. For anyone who's never used a breadboard but wants to learn, this is a great guide, and you'll learn about some pretty cool mesh network protocols in the process.

I really can't recommend these two books enough. I found learning about mesh networks to be fun and easy in BWSN, but it's when you add the sensor capabilities of the Arduino that you begin to see all of the possibilities. Even if you don't have an idea in mind, once you start walking through the example I'd bet that the ideas will start flowing. Well written and with some self-deprecating geek humor, BWSN lays a great foundation for the AC to sit on. Once you know how to connect a bunch of Arduinos together, you can, take over the world, or at least your house.

—Sam Stover

A Guide to Kernel Exploitation

Enrico Perla and Massimiliano Oldani

Syngress, 2010. 442 pp.
978-1597494861

This book is not for the faint of heart. Usually topics like the kernel are reserved for the most hardcore of computer users, and for good reason: the kernel is a vast and complicated piece of software which can take a lot of time and effort to truly understand. *A Guide to Kernel Exploitation* is no exception. This book is an excellent read but is probably not going to be of much interest to the average computer geek.

The book begins by doing a great job of explaining the basics. First, it covers what a kernel is and then, more importantly, the differences between "kernel-land" and "user-land" (the common terms for areas of memory reserved for kernel and user code use). Most notable is the fact that user-space programs rely on the kernel to implement protection schemes, utilizing both software and hardware, to prevent misbehaving software from doing harm, while the kernel can only rely on itself. This means that certain techniques work better in kernel space, and others no longer work at all. I think that this intro is necessary to lay the groundwork for the later chapters, but those who will benefit the most from this book will likely consider it nothing more than a review.

In Chapter 2 we finally get into the good stuff. This chapter is an overview of the different types of bugs that can be used to achieve successful exploitation. The usual suspects, such as memory corruption and integer overflow/underflow, are here, plus there are a few that while present in user-land, are typically not exploitable, such as NULL pointer usages.

Chapter 3 focuses on the typical architecture of x86 and x86-64 kernels and how the little details affect the success of typical attacks. This information is absolutely critical to an attacker for creating a working exploit. The book discusses some basic but interesting techniques such as placing the shellcode in a buffer allocated in a user-space program instead of directly in the kernel memory. For a local privilege escalation exploit, this may simplify things a bit, since the program will be able to explicitly shut off many of the memory protections kernel pages may have: for example, the NX (no-execute) bit. It also discusses some concepts which are unique to kernel-space exploits, such as the possibilities of overwriting interrupt table pointers and how to properly leverage a successful overwrite.

Having established the basics, the book spends the next few chapters going into how to apply these core ideas to several of the more popular operating systems such as "the UNIX family," OS X, and Windows. These chapters do a good job of demonstrating the design principles that the various OSes utilize and the different structures and defense measures that an attacker needs to be familiar with when targeting a system.

All in all, this was a good read. The beginning covered a bit of ground that, to be honest, the reader should already know. On the other hand, some of the later chapters delved really deeply into the fine details, almost to the point of being a little overwhelming. But the book is well balanced and often uses good code samples to help demonstrate the concepts being discussed. For anyone who is typically a user-land-only exploit writer or perhaps even an existing kernel hacker who wants to expand their knowledge to new operating systems, this is likely a worthwhile read.

—Evan Teran

Sleights of Mind: What the Neuroscience of Magic Reveals about Our Everyday Deceptions

Stephen Macknik and Susana Martinez-Conde, with Sandra Blakeslee

Henry Holt and Co.: 2010. 297 pp.
978-0805092813

I bought this book to read on my own over the holidays and can say that I thoroughly enjoyed it. That said, you might be wondering why I consider including a review of it in a CS publication. In truth, computers are never mentioned (as far as I can recall, and that's important). But a lot of what the authors have to say has a real bearing on everyday life, and more importantly, on the designers of computer interfaces.

Macknik and Martinez-Conde are neuroscientists who became interested in magicians as a way of exploring how the human brain works. As they got into their project, they learned that the magicians themselves have a working knowledge of various weaknesses in how humans process sensory information. As an example, Apollo, a magician who specializes in picking the pockets of his volunteers, pointed out that if he wants people to focus on his hand as he moves it, he must move it in an arc. If he moves it in a straight line, the watchers simply move their focus to where his hand *will be*, as it is easy for the brain to predict this.

The authors cover different forms of misdirection as well as the quirks of human vision. These topics are important to anyone who is designing an interactive Web page or the front end to an application. An interface can just as easily confuse the mark, er, user, as help the user work with it without becoming frustrated.

If you want a fun read that is also related to your work, I recommend this book. It does include both an index and refer-

ences, as well as URLs for videos of many of the magic tricks that are performed. Oh, I almost forget to mention that they also explain how tricks are done, as it is this that makes it very clear how imperfect we are at perceiving reality.

-Rik Farrow

Some Follow-Up on Previous Reviews

I reviewed *Building the Perfect PC*, by Robert and Barbara Thompson, for the February 2011 issue, and said I would try building their "mainstream system." I bought all the components necessary (well, almost all the components) from Newegg for $650, and spent about four times as long as the authors did in building a similar system. My experience pretty much mirrored theirs, and I can still recommend their book, but with a minor caveat: they assumed that you have extra SATA cables lying around and didn't mention that you will need more than the pair that comes with the Intel motherboard. Fortunately, I did have a couple (as I build a system every year), so instead of waiting a couple of days for cables to appear, I just had to search my office to complete the project.

I also received the second edition of *The Myths of Innovation*. I reviewed this book when it first came out and can still recommend it highly. Scott Berkun offers words of encouragement to anyone who has banged up against a wall of complacency with existing systems, and to those who find themselves wondering why innovation is so hard. I lent this book to an out-of-work tech friend, and she reported back to me that she was inspired by reading it, as well as surprised by what she learned.

—Rik Farrow

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Conference Reports

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LISA '10: 24th Large Installation System Administration Conference

San Jose, CA
November 7–12, 2010

Opening Remarks and Awards

Summarized by Rik Farrow

Rudi Van Drunen opened the 24th LISA conference with the usual round of acknowledgements to the PC and USENIX staff. Van Drunen said that putting LISA together took him a couple of meetings and about +400 emails, with the staff handling setting up the conference. Then he announced the Best Paper awards. Fei Chen et al.'s "First Step Towards Automatic Correction of Firewall Policy Faults" won the Best Student Paper award, and Paul Krizak, of AMD, won the Best Paper award with "Log Analysis and Event Correlation Using Variable Temporal Event Correlator (VTEC)." Andrew Mundy (NIST) won the Best Practice and Experience Paper award with "Internet on the Edge."

Philip Kizer, President of LOPSA, announced the 2010 Chuck Yerkes Award winner, Edward Ned Harvey, for providing significant mentoring and participation in electronic forums.

Keynote Address

The LHC Computing Challenge: Preparation, Reality, and Future Outlook

Tony Cass, CERN

Summarized by Rik Farrow (rik@usenix.org)

Cass began by quipping that CERN had yet to destroy the universe, but if the many-worlds theory is true, perhaps the other 50% of the worlds have been destroyed.

Cass described some of the daunting requirements for operating the LHC. The LHC needs a vacuum with 10 times fewer particles than exist in the moon's level of vacuum. The superconducting coils that create the collider's magnetic steering fields must be kept at 1.9 Kelvin (-271 C). It was a failure in

cooling that forced the shutdown of the LHC last year. Cass showed images of what happens when the two beams of positively charged particles stray: a stripe of fused metal, and a hole through a solid copper plate used as a target. When two streams of particles collide, the energy is comparable to two trains colliding at 350 miles per hour.

The collisions are the whole point, and the LHC has 100 million data collectors. There are four detectors and 40 million collisions per second, producing 100–1000 MB/s, or around 23–25 petabytes per year of data. On site, they need to archive data, as well as reduce the data before it gets passed onto remote Tier 1 sites for further distribution and research. Cass went on to describe some of the challenges they have faced so far:

Capacity provisioning: together with other sites, the LHC is the world's largest-scale computing grid.

Box management: they use PCs with their own software (Quattro and Lemon) for node management.

Data management and distribution: over a gigabyte per second that must all be saved to tape, with enough redundancy for backup to fill three full SL8500 tape robots per year.

Network management: monitoring the flow to Tier 1 sites, as well as all the equipment used—they have 20 Gb/s links from CERN to Tier 1 sites.

LHC uses Oracle RAC (11g) pushed to the limits. Each day they run one million jobs on the grid, about 100,000 computer days per day, with a reliability of about 98%.

Failures are frequent, with about 200 failures a day, mostly disks. Infrastructure failures are a fact of life, but networks and software have proven reliable. They try to get 100% utilization using virtualization, which is fine for CPU-intensive apps, but expensive (10% penalty) for I/O-intensive applications.

In conclusion, Cass said that they had been preparing for these challenges since the late '90s, when solutions like Hadoop didn't exist and networks were very expensive. There were also sociological challenges, but they have been successful, supporting many thousands of people doing research.

Doug Hughes, of D. E. Shaw Research, asked about data integrity issues with so much data generated. Cass replied that they do use checksums and compress data. If data fails to decompress, they immediately know something is wrong. They also re-read tapes checking for errors. Mario Obejas of Raytheon wondered whether, since they were using Siemens SCADA (PVSS in German) software, they were affected by the Stuxnet worm. Cass replied that he didn't know, but that they have networks separated by firewalls. They are more concerned with power plant issues, and thus carefully protect their control networks. Paul Krizak of AMD asked how Tier 1 sites know that data is correct. Cass responded that the experiments themselves provide software to do that. The Tier 1 sites also provide off-site storage for remote backups. Hugh Grant of the University of British Columbia asked about lessons learned. Cass said, "Don't believe what people say about requirements. They will underestimate things and over-complicate them. Use what you know, exploit what you can, make sure you can scale at least an order of magnitude over what they request."

Refereed Papers

Summarized by Fei Chen (feichen@cse.msu.edu)

A Survey of System Configuration Tools

Thomas Delaet, Wouter Joosen, and Bart Vanbrabant, DistriNet, K.U. Leuven

Thomas Delaet first identified gaps in the current state of the art and then presented a comparison framework for system configuration tools, which helps system managers decide which configuration tool should be bought for managing their system. There are a lot of such tools ,with different purposes and characteristics, so it is very difficult to make a wise choice.

This work built a comparison framework including four categories of properties: properties of the input specification, properties of deploying the input specification, process-oriented properties, and tool support properties. In total, the authors defined 19 properties and, based on these, evaluated 11 existing open source and commercial system configuration tools and summarized their findings. The authors use this evaluative framework to provide guidance on choosing a tool and comparing tools.

Someone pointed out that this work requires the predefined workflow on top of the configuration. However, in general, for many configuration tools, there is no such workflow. Delaet responded that they have a scheme to define a language to define such workflow.

High Performance Multi-Node File Copies and Checksums for Clustered File Systems

Paul Z. Kolano and Robert B. Ciotti, NASA Ames Research Center

Paul Z. Kolano presented their design of mcp and msum, as well as detailed performance evaluation for each implemented optimization. The copy operation is one of the most common operations in computer systems. Because of backup, system restore, etc., files are usually being

moved from one place to another. Hence, maximizing the performance of copies as well as checksums for ensuring the integrity of copies is an important problem.

This work leveraged three major techniques to improve the performance of copies: multi-threading, multi-node cooperation, and hash trees. The authors' experiments show that mcp causes a more than 27-fold improvement in cp performance, msum improves md5sum performance by a factor of 19, and the combination of mcp and msum improves verified copies via cp and md5sum by almost 22 times.

Corral wondered about the user application of this work. Kolano replied that they hadn't deployed it for users yet and mainly have been using it to migrate users between file systems. Skaar (from VMware) asked about system overhead. Kolano said they hadn't specifically measured it, but showed an earlier slide where performance was identical to cp, indicating minimal overhead. Can this code be used for any systems? Yes, this is the general code.

Fast and Secure Laptop Backups with Encrypted De-duplication

Paul Anderson and Le Zhang, University of Edinburgh

Paul Anderson presented a fast and secure algorithm for backing up personal data on laptops or home computers. However, conventional backup solutions are not well suited for these scenarios in terms of security. The solution is really ad hoc. For example, people use external hard drive, DVD, or cloud storage to back up their data.

This work prototypes a new backup algorithm to back up personal data for Mac OS X. The algorithm takes advantage of the data that is common between users to increase backup performance and reduce storage requirements. The algorithm also supports two major functionalities. First, it supports per-user encryption, which is necessary for confidential personal data. Second, it allows immediate detection of common subtrees to avoid querying the backup system for every file.

Someone asked if they use the same key for the same file across different laptops. One user may reveal the files of the other users. Anderson said that's right. If a user has a file, it is possible to tell whether someone else has the same file (but not necessarily *who* has that file). Peter asked how file permissions are handled. Anderson answered that file permission attributes are separated from the files themselves. Why not allow the server to do the encryption? The primary requirement is to not allow the server to know the data.

Invited Talks I

IPv6: No Longer Optional

Richard Jimmerson, ARIN

Summarized by Julie Baumler (julie@baumler.com)

Richard Jimmerson started by explaining that he was going to cover IPv4 depletion, including when it would occur, why, and a number of related issues. He explained that his expertise comes from his experience at the American Registry for Internet Numbers (ARIN), one of five regional Internet registries (RIRs). He started with some historical background: in the mid-'90s people realized that IPv4 is not designed for the global commercial Internet. He mentioned that IPv6 addresses have been issued since 1999, and this became a recurring theme in his talk. The primary factor driving IPv6 adoption is the pending full depletion of IPv4 addresses. As of October 18, 2010, there were 12 /8 blocks containing 16 million addresses each. Registries are issued one or two /8s at a time by the Internet Assigned Numbers Authority (IANA), which holds the free pool for all five RIRs. There is currently a large demand in the Asia-Pacific region and large numbers of existing devices which could use IP addresses but aren't. It is very likely that the free pool will fully deplete in the first quarter of 2011. ARIN expects their free pool to deplete within 1 day to 6 months from the IANA free pool depletion date. The top 10 Internet service providers could deplete a /8 in one day with legitimate requests. Additionally, ARIN will set aside a /10 from the last /8 they receive from IANA to be used only for IPv6 transitions (i.e., to allow new organizations to have IPv4 gateways and things like DNS servers), and these will be allocated in /28 to /24 blocks only.

Jimmerson acknowledged that the end of IPv4 addresses has been announced before and did not happen. CIDR and NAT saved us from depletion in the '90s and there were some false "cry wolf" statements early in this century. He emphasized that this depletion is for real.

A common question is how underutilized blocks from the 1980s and 1990s will affect depletion. ARIN is constantly trying to reclaim them. They are still getting class As and Bs back, but that won't extend the depletion date by much, as an /8 only extends the free pool by a few weeks. There is also a new policy that creates a market in IPv4 addresses by allowing specified transfers of IPv4 addresses from organizations that aren't using them to organizations that meet existing requirements for issue of IPv4 addresses. ARIN has created a limited listing service to support this, and there are already listings.

Another important issue to keep in mind is that IPv4 and IPv6 will both be necessary for many years. For instance, all

content is currently on IPv4 and it will need to be made available to users of both IPv4 and IPv6.

There is currently very little visibility of IPv6 deployment. Jimmerson primarily attributed this to very low incentive for people to share what they are doing. People don't want to publicly be the first. Also, in many cases there is a potential for a huge market share win if a company supports IPv6 and their competitors don't. This means that many people are not deploying IPv6 visibly or are not marketing the fact that they have done so.

Jimmerson outlined a number of different issues and ARIN recommended action plans for different sectors of the IP address-using community, such as broadband providers, ISPs that provide services to business customers, content providers, and equipment vendors. Some common threads are the need to be ready and the need to have content and core services such as email available on both stacks. More details on these recommendations are available in the resources recommended below. ARIN has also been involved in raising awareness of the issues in the government arena.

Jimmerson recommended some resources for further information: http://TeamARIN.net includes a free slideshow and other information to use for educational purposes, and http://getipv6.info is a wiki that includes deployment experiences and information on where to get started. He also mentioned the social media links at http://www.arin.net. Jimmerson emphasized that anyone is welcome to participate in ARIN at no cost; further information about this is available at http://www.arin.net/participate.

Several questioners asked how IPv6 would affect security, system administration skills, and compliance. Jimmerson pointed out in each case that although IPv4 and v6 will form logically separate networks in most cases, the tools and issues are the same. He recommended that system administrators shouldn't be afraid of IPv6; they should just get educated and start playing around with it and testing it.

Someone asked whether there is anything that will preclude using NATs forever. Jimmerson acknowledged that you can build NATs on top of NATs and it will happen, but it's going to get messy, and at some point you will find data that people prefer to serve or receive over IPv6. This will be particularly true for latency-sensitive data. Another questioner asked how we get rid of IPv4 altogether so that we don't have to run both protocols forever. Jimmerson said that the most difficult part of this is that there is no flag date. He feels that for IPv4 to disappear, 99.9% of content will need to be available on IPv6 and you will be able to buy all types of IPv6-supported network equipment in stores. There are working groups coming up with suggested dates for this transition.

Invited Talks II

Storage Performance Management at Weta Digital

Matt Provost, Weta Digital

Summarized by Rik Farrow (rik@usenix.org)

Weta Digital is best known for the *Lord of the Rings* trilogy (LOTR) and *Avatar*. The first LOTR movie required 1.5 TB of storage total, while they had that much RAM when making *Avatar*. Provost suggested that people see *Avatar* in theaters, as the image is 298 GB, compared to just 4 GBs on DVD.

Weta Digital has a grid of 4700 servers, what they call a "renderwall." Producing Avatar required 56 million computer hours, or about 11 days of computing per frame. Rendering is the step that takes the work of artists and turns it into finished frames. Artists' work is the most expensive commodity, and providing file storage that performs well is key to creating a movie.

They use Perl scripts based on templates to create new directories for each shot. Shots themselves get spread out over filers to avoid hot spots. While a shot's frames may appear to be in a single directory, they use symbolic links to manage storage behind the scenes. They created a system called DSMS to build the link farm and use a MySQL database to store this info. The file system remains the canonical view, not the database.

Provost mentioned that some people wondered why they don't use Lustre, and he explained that Lustre 2.0 came out in 2002 (LOTR began in 1999) and requires a lot of space for metadata storage. They had 3.2 million files for Avatar, and most of those files are only 64kb, so the system they use has lower metadata overhead.

Running out of space on a filer causes serious slowdowns, so they monitor disk space. They also reserve space on NetApps (used by artists) and use a script to migrate data that is acquiescent (based on atime) when needed, and change the symlinks when this is complete. NetApps FlexCaches were brought in to help with performance during *Avatar*. They did use flash as well.

Performance is monitored on clients by watching /proc/self/mountstats, and they can trace bottlenecks back to filers by using the pathname combined with queries to the link farm. Provost pointed out that what they had was a combination of HPC and HA. Even artists' workstations are used for rendering at night, and they can't afford downtime.

Provost mentioned that while *Avatar* was shot in high definition, better cameras and 3D will mean that frame sizes may grow from 12 MB/frame to 84 MB/frame. Higher frame rates

and 3D also add to storage demand, so one second of a future movie may require 8 GB.

Don Johnson of NetApp thanked Provost for helping send his kids to college and then asked about the difference between BlueArc and NetApp filers. Provost replied that BlueArcs are really good for write performance, which is required to keep up with the renderwall. NetApp filers are the only thing they trust with their human-generated data. Deke Clinger of Qualcomm wondered if they had problems with the Linux versions of NFS and the automounter. Provost said that they are still using version four of the automounter, although they have their own fork. They can get big mount storms when rebooting the renderwall. They always use TCP with NFS. Jim Kavitsky of Brocade Communications asked if they track communications on the network, and Provost said that they do. They also store this in a database, so they have a historical record. Matthew Barr of MarkitServ wondered if they have looked at pNFS, and Provost said they have already solved a lot of the problems pNFS tries to solve, and that pNFS tends to work best with larger files.

Refereed Papers

Summarized by Fei Chen (feichen@cse.msu.edu)

The Margrave Tool for Firewall Analysis

Timothy Nelson, Worcester Polytechnic Institute; Christopher Barratt, Brown University; Daniel J. Dougherty and Kathi Fisler, Worcester Polytechnic Institute; Shriram Krishnamurthi, Brown University

Timothy Nelson presented the Margrave tool for analyzing firewall policies. Configuring and maintaining firewalls is always a challenging and difficult task, due to the complexity of firewall policies. It is very useful to develop a tool that can help sysadmins to configure and maintain firewall policies. This work describes Margrave, a powerful tool for firewall analysis, e.g., change-impact analysis, overlaps and conflicts detection, and security requirement verification.

Margrave embraces both scenario-finding and multi-level policy-reasoning in its model. It divides a policy into small policies and then analyzes each small policy. Therefore it provides more exhaustive analysis for richer policies and queries than other tools. Timothy Nelson presented the evaluation results on both network-forum posts and an in-use enterprise firewall.

Someone asked: Are you looking at analyzing the routing table? Nelson: Yes, we do want to do that. Matt Disney: Can you say more about how you guarantee exhaustiveness? Nelson: Not all Margrave queries result in simple scenarios like the ones we saw; in those cases we may still be able to make guarantees, but if not, the user can provide a size that they want to check up to. Disney: It would be interesting to collect the system logs. Then sysadmins do not need to query the firewall manually. Nelson: This is a very interesting idea. We may look into this idea.

Towards Automatic Update of Access Control Policy

Jinwei Hu, University of Western Sydney and Huazhong University of Science and Technology; Yan Zhang, University of Western Sydney; Ruixuan Li, Huazhong University of Science and Technology

Jinwei Hu, who had to record his presentation on videotape because of a visa issue, presented RoleUpdater, a tool for updating access control policies automatically due to new security requirements. Manually updating access control policies is tedious and time-consuming. Updating is a key component of maintenance in the RBAC life-cycle. RoleUpdater is a very useful tool for sysadmins to manage their access control policies.

The key idea of RoleUpdater leverages model-checking techniques to update the RBAC policies. RoleUpdater first transforms update problems into a model-checking problem. Then a model checker takes a description of a system and a property as inputs and examines the properties of the system.

There was no Q&A, because the authors were not present.

First Step Towards Automatic Correction of Firewall Policy Faults

Fei Chen and Alex X. Liu, Michigan State University; JeeHyun Hwang and Tao Xie, North Carolina State University

▸ *Awarded Best Student Paper!*

Fei Chen presented an approach for automatically correcting firewall policy faults. Wool's studies have shown that most firewalls are poorly configured and contain faults. Manually checking each rule in a firewall policy and further fixing the fault is a difficult problem and impractical because a firewall policy may consists of thousands of rules.

This work first proposed a fault model of firewall policies, which includes five types of faults: wrong order, missing rules, wrong decisions, wrong predicates, and wrong extra rules. For each type of fault, Chen presented a technique to fix it. Then Chen presented a greedy algorithm that utilizes these five techniques to fix the firewall policies faults automatically.

Tom Limoncelli: Is it possible to use some AI system to automatically filter the packets? Chen: To the best of our knowledge, there is no such AI system, due to security requirements. Matt Disney: What further work is planned?

Chen: We are looking at applying our approach to a faulty policy repeatedly and seeing how much we can fix the policy.

Invited Talks I

Storage over Ethernet: What's in It for Me?

Stephen Foskett, Gestalt IT

Summarized by Theresa Arzadon-Labajo (tarzadon@ias.edu)

Stephen Foskett's entertaining talk, sprinkled with anecdotes and jokes, provided a lot of information about storage over Ethernet. Foskett began by saying that convergence is the marketing topic, and another trend is the rise of open systems. Finally, even though IP and Ethernet have been around a long time, they are becoming the "must-haves" of IT.

There are a few reasons why convergence is happening. First, virtualization is the biggest driver of storage. Systems were optimized for sequential I/O, but virtualization throws it in the I/O blender. Storage companies preach the message of virtualization, consolidation, and converged networking because they can sell a lot of SAN gear. Secondly, there is consolidation from a port count perspective. Converged networking allows you to deal with the spaghetti problem. You can allow your servers to breathe; all those cables interfered with air flow. The mobility of virtual machines allows you to move a running system somewhere else and it can still be the same system. You can't do that with conventional cables. Third, performance is driving convergence because of all the applications that need massive I/O.

Stephen showed graphs displaying the trends of Fibre Channel (FCP), Ethernet LAN, iSCSI, Fibre Channel over Ethernet (FCoE), and Ethernet Backplane. Everything seemed to outperform Fibre Channel, which means it will eventually get left behind. In order to make Ethernet handle storage, the Data Center Bridging project created new protocols: Priority Flow Control (PFC 802.1Qbb), Bandwidth Management (ETS 802.1Qaz) and Congestion Management (QCN 802.1Qau). If all these things can be accomplished, Ethernet could be a decent protocol and SCSI traffic could travel over it. Contrary to Ethernet's PAUSE (802.3x), PFC allows the stop message to be applied to only one class of service and lets other traffic keep going. iSCSI doesn't need this, because it has TCP. Enhanced Transmission Selection (ETS) allows you to reallocate channels in a converged network to different applications. Switches weren't built to handle this, so another protocol was needed. Data Center Bridging Exchange (DCBX) allows devices to determine mutual capabilities. Congestion notification is not standardized yet, but it's in the works. Theoretically, it will allow end-to-end traffic management. There will be a pause in the beginning, but once both ends are informed, traffic flows nicely. In the real world, you can double or triple throughput.

Stephen compared the FCP, FCoE and iSCSI protocols. iSCSI works great, is robust, is mature, and every OS is supported on the client side. Also, there is a nice transition from 1-10GbE. All you have to do is plug in a new cable! Pros of iSCSI are its performance, functionality, low cost, and availability. Cons are that you may want 1GbE for performance or else have an FC Estate. Reasons to go with FCoE are that you have a lot of Fibre Channel and you might want to make better use of that. You can incrementally adopt it and go with end-to-end FCoE later. You may want to consolidate on Ethernet and not want to buy iSCSI licenses and arrays. I/O consolidation and virtualization capabilities are focusing on FCoE, and vendors are pushing this hard. Cons of FCoE are the continued bickering over protocols, the fact that we already have 8Gb FC, and end-to-end FCoE is basically nonexistent, unproven, and expensive.

Stephen briefly talked about NFS. NFSv4 pretty much fixes all the issues with NFS. Vendors support it and there are drivers for it, but hardly anyone uses it. The good thing about it is that it is one protocol with a few commands instead of several protocols with thousands of commands. Plus, there's no UDP! pNFS (v4.1) provides file, block, and object storage and is focused on scale-out.

Server, network, and storage managers each get something different out of converged networking. Server managers win because they don't have to care about storage anymore. They have better support for virtual servers and blades. Network managers get all the headaches, because they have to learn a whole new world of protocols and deal with storage, but they get more tools and can segment the network. Storage managers lose, because everything outside the array is taken away from them. But this can make them concentrate on the real problem with storage, which is that once people write data, they never read it and never delete it.

Stephen gave a counterpoint to Ethernet by stating that InfiniBand already exists, is supported, and is faster. Fibre Channel is kind of pricey and insane, so you might as well go with something that is fast and insane. He proposed that we should go with something else entirely, like Fibre Channel over Token Ring (FCoTR). It's already lossless and the packets match up. He concluded that Ethernet will come to dominate. iSCSI is growing, Fibre Channel is continuing, and NFS is still here and it's all over Ethernet.

Someone asked about the availability of dense 10GbE switches. Stephen suggested looking at what Force10 and Arista have going. Someone else asked how to help out with the growth of FCoTR. Stephen said that there's not much you

can do but have fun with it. FCoTR makes as much sense as FCoE. If we're doing one of them, why not do both?

The 10 Commandments of Release Engineering

Dinah McNutt, Google

Summarized by Gerald Fontejon (gerald.fontejon@gmail.com)

Dinah McNutt said that these 10 commandments are from sysadmins to release engineers, and that the commandments are solutions to requirements. She also stated that the title of the presentation should be "Build and Release." The ideals from this presentation are for all types of software, internal and external customers (Web applications and shrink-wrapped products). Dinah also said that the ideals from the presentation are her own, not necessarily her employer's.

Usually the release process is an afterthought, and the process is minimally managed to "get it done." Release processes should be treated as a products in their own right, and the release process should be a bridge between developers and the system administrator who implements the release. The build and release steps are: (1) check out the code from the source code repository; (2) compile the code; (3) package the results; (4) analyze the results / report accordingly; (5) perform post-build tests based on the results of the analysis steps (i.e., smoke tests, unit tests, system tests)

There is a set of required features within the build and release process: the process should be reproducible, have a method of tracking the changes, and have the ability to audit what is in a new version of the product. Within each build, there has to be a mechanism that uniquely identifies (e.g., a build ID) what is contained in a package or product. The build and release process should be implemented as part of a policy and procedure, and if the automated build and release process has been bypassed, there has to be some documented reason why the process was disrupted. Included in the build and release process is the management of upgrades and patch releases.

Dinah laid out her 10 commandments:

I. Thou shalt use a source code control system.

II. Thou shalt use the right tool(s) for the job.

III. Thou shalt write portable and low-maintenance build files.

IV. Thou shalt use a build process that is reproducible.

V. Thou shalt use a unique build ID.

VI. Thou shalt use a package manager.

VII. Thou shalt design an upgrade process before releasing version 1.0.

VIII. Thou shalt provide a detailed log of what thou hath done to my system.

IX. Thou shalt provide a complete install/upgrade/patch/uninstall process.

X. System Admin: Thou shalt apply these laws to thyself.

On her last slide, Dinah showed how the build and release process relates to system administration. She said, "I think a lot of these concepts apply to system administration and other disciplines, not just software engineering—because my thoughts are bits—and release engineering is all about taking those bits and figuring out a reliable way of delivering them where they need to go."

Paul Krizak asked, "What are your thoughts on some of the newer packaging systems? In particular, I'm thinking of rPath, which takes the build process beyond just making binaries, and builds the entire runtime from the operating system all the way to the application, all in one shot. Do you think that is moving in the right direction? Or is that overkill?" Dinah replied that it depends on the environment that you are working in. She added that it could certainly be overkill, but she also believes there are a lot of applications and situations where it could be beneficial.

Someone asked about deploying applications and dependencies in a Web application—what are the recommendations for the server-user-ID to be used for the release process and its associated location? Dinah replied that the less you can do as root, the better. The subject of location goes back to the discussion on relocatable packages. "I could install the software anywhere and it's going to work."

Practice and Experience Reports

Summarized by Rik Farrow (rik@usenix.org)

When Anti-virus Doesn't Cut It: Catching Malware with SIEM

Wyman Stocks, NetApp

Stocks explained that Security Information and Event Management (SIEM) dumps all your logs in and does event correlation, helping to make sense of 50 million events a day. He found that it really helped having SIEM when systems on their network became infected with Conficker.

Someone outside had noticed the worm traffic and informed them. They immediately rolled out patches, thinking that with AV and SIEM they were okay, but the problem per-

sisted. They started by manually notifying users, but after two weeks they had SIEM send out emails with instructions for cleaning up. They were seeing 30–50 machines a day infected at first, down to 4–11 after two weeks of automated alerts. They sent samples of the infections to McAfee, and saw more than just three Conficker variants.

Someone asked about disabling switch ports, and Stocks responded that people get really upset when you just disable their network port. Someone else wondered which Conficker variants they had, and Stocks said mostly B and C, as variant A was mostly caught by AV. The same person asked about the rules they were using with SIEM to discover infections, and Stocks said they had IDS rules for distinguishing command and control traffic over HTTP, and would look for 445/TCP (CIFS) scanning.

Stocks summarized their lessons learned: they needed to synchronize time across the enterprise, so logging timestamps matched; short VPN connections made it difficult to find infected users; when the volume of infections dropped, the false positive rate increased; finally, you will learn things about your network that may not be that useful. In the future they want to add more preventive measures, such as having DNS black holes for C&C servers, new firewall rules, better network visibility, and historical look-backs to determine attribution.

Matt Disney of Oak Ridge National Laboratory asked if SIEM has replaced any currently used security controls. Stocks answered that SIEM gave them capabilities they didn't have before and added that Windows Domain Controllers rotate logs so rapidly they quickly lose information if it isn't collected in SIEM. Disney asked what features to look for when SIEM shopping. Stocks suggested finding products that can parse events (and aren't limited to the same vendor's products) and are easy to use. You want a balance between flexibility and usability.

In-Flight Mechanics: A Software Package Management Conversion Project

Philip J. Hollenback, Yahoo, Inc.

Hollenback is the release manager for Yahoo mail (philiph@yahoo-inc.com) and led a team of six to convert over 7000 distributed servers for Yahoo mail to Igor. The goal was to upgrade server software with no downtime and to do this repeatedly. The user mail servers are grouped in farms, and each user's email lives on one farm, with hundreds of thousands to millions of users on each farm.

Yahoo has developed its own in-house software installation system, yinst, which is both a packaging system, like RPM, and installation software, like yum or apt-get. Upgrades were made by sshing into a system and executing yinst to install packages. Igor is a state-based package management system already successfully used elsewhere within Yahoo. Hollenback said they thought that all they needed to do was to get Igor working with yinst, but as they worked on the project they discovered several problems.

One problem is that packages had been installed additively in the past, with the expectation in some cases that some key software would just be there, like Perl or a Perl library. Another issue was that they want to have a single set of packages, so configuration needed to be separate from packages. Finally, they also discovered that each farm could have unique, or local, configurations, which had to be documented before they could proceed. Hollenback found himself surveying farms looking for these differences.

In hindsight, Hollenback said they needed to have started with good audit tools to uncover the existing configurations. They also needed other tools, such as pogo, a type of parallel ssh that works as a push tool. Moving forward, they are still working to remove configuration from packages, improve yinst settings, and add central configuration servers. They can roll back upgrades, but this needs to be smoother, and removing configuration from packages is making this easier. Summarizing, Hollenback suggested keeping things simple: install the same packages everywhere, don't inherit system state, use configuration servers, and, basically, don't be too clever.

Paul Krizak of AMD asked about the scalability of upgrades, and Hollenback answered that the nice thing about the system is that it is well distributed. They have software distribution machines in every colo and they have reached the point where they can launch 10k machines at once. Krizak asked about the human element, the pushmaster who watches over upgrades. Hollenback said that is a problem, but pogo helps by doing lots of health checks before and after installs. Hugh Brown of UBC asked about not inheriting system states, and Hollenback explained that this means use package and configuration data, not a system's past state. Each machine has particular roles, and the packages and configuration control which roles. Matthew Sacks wondered if it would have been better to have improved auditing tools early on, and Hollenback said that they need to audit existing systems to see how they were configured. Now they have Igor and it provides the exact set of packages and settings.

Experiences with Eucalyptus: Deploying an Open Source Cloud

Rick Bradshaw and Piotr T Zbiegiel, Argonne National Laboratory

Bradshaw, a mathematics specialist, and Zbiegiel, security, co-presented this experience paper, with Bradshaw starting. They had both been involved with the Magellan Project, a medium-sized HPC, and were charged with discovering if clouds could work for HPC workloads. There are many commercial clouds to choose from, but they decided to work with Eucalyptus, as it is open source, compatible with Amazon's EC2 and works with Ubuntu Enterprise Cloud (UEC), and they could run with patches on top of the usual Ubuntu.

Zbiegiel explained a little about how Eucalyptus works: cloud controllers communicate with cluster controllers and storage controllers, which sit above node controllers (each VMM). There is also another tool, Walrus, which works only with storage controllers. They experimented with different cluster sizes and found that 40–80 nodes worked best, since Eucalyptus can get bogged down as it sends out commands serially and got "impatient" if responses to commands were slow. There was a hard limit to the number of VMs, somewhere between 750 and 800.

Zbiegiel explained that they had two security concerns: networking and images. By default, VMs can talk to any IP address and can also masquerade as cluster controllers, so it was difficult to tell who might be doing something bad. They needed to see if outside machines were attacking or their own VMs were scanning or attacking or running suspect services. They used iptables to control where VMs could connect, and monitored all traffic as it passed through cluster controllers.

Any user can upload an image which becomes visible to everyone in the Eucalyptus cloud, and this is the default. Zbiegiel wishes the opposite were the default. Also, sysadmins can install ramdisks and kernels, and this can be a source of problems as well. Every user on Eucalyptus is a sysadmin, no matter what their actual level of experience is.

Bradshaw explained that they had chosen community-based support because they had only one sysadmin to manage the Eucalyptus clusters. This meant wikis, mailing lists, and best-effort documentation. They discovered that there is a big difference between batch users and cloud users, as cloud users need to support the entire OS. The learning curve for users is steep. He concluded by saying that they do have a cloud and also have a small Nimbus (NASA) deployment and are looking at OpenStack (an open source combination of Rackspace and Nimbus software). He suggested that you shouldn't believe the cloud hype, that clouds are useful, but every stack has its qualities and faults.

Someone asked about system monitoring and adding servers. Bradshaw answered that Eucalyptus does no monitoring, except of user-facing front ends. Setting up new servers can be done using any kind of distributed build process, added Zbiegiel. Chris Reisor of Dreamworks asked where images are stored, and Zbiegiel replied that they are stored in Walrus, the Eucalyptus version of Amazon S3. You create a bucket for each image. Reisor then asked how well Eucalyptus does when things go wrong. Zbiegiel said that it depends; sometimes they can recover, but they have seen it fail in many more fantastical ways that require bouncing (rebooting) the entire cluster.

Invited Talks I

Commencing Countdown: DNSSEC On!

Roland van Rijswijk, SURFnet Middleware Services

Summarized by Rudi Van Drunen (rudi-usenix@xlexit.com)

Roland started off with some of the attack vectors used to attack the DNS system, which sparked the development of DNSSEC. DNSSEC provides authenticity to DNS records by adding digital signatures to the records and validation of those signatures in resolvers. We see that the adoption of DNSSEC has been on the rise since the root of the DNS system got signed.

Roland described how most of the resolvers currently in use already support DNSSEC. To get started with a validating resolver, a good tool to use is unbound (http://unbound.net). As DNSSEC uses public key cryptography, it uses more CPU power, but the impact is negligible. Roland continued by discussing how you have to be pretty careful in your setup in order to run a signed zone. Ideally, setting up a DNSSEC signed zone should be as easy as setting up a normal zone. Surfnet has integrated this in their DNS self-service environment. The infrastructure they use is OpenDNSSEC and a hardware crypto box/key store.

There have been a number of quirks in the recent past due to DNSSEC signed zones that were not operated correctly; these have led to serious outages of parts of the DNS system, so sysadmins and operators need to be aware of the additional issues that DNSSEC brings.

Some pointers to additional material: https://dnssec.surfnet.nl; http://dnssec.net; http://www.dnssec-deployment.org; http://www.practicesafedns.org.

Roland concluded with the following key points:

As DNSSEC deployment really is taking off, you are the one who has to act, by seriously considering enabling validation of signatures in your resolver. Then think about signing your

zones. Mistakes can (and might) happen; please learn from them. And, last but not least, if it works, you don't notice it's there.

How do you protect your laptop? Use a validating resolver on your end-user system (e.g., Unbound). How does that work with captive portals or other nasty DNS tricks? It will not work, so switch off your validating resolver and fire up your VPN, routing all traffic through your home office.

Invited Talks II

Postfix: Past, Present, and Future

Wietse Venema, IBM T.J. Watson Research Center

Summarized by Scott Murphy (scott.murphy@arrow-eye.com)

Venema observed that publicity can be both bad and good for a project. He reminded us of his past security research, specifically an unflattering 1995 *San Jose Mercury* article likening SATAN (Security Administrator Tool for Analyzing Networks) to "distributing high-powered rocket launchers throughout the world, free of charge, available at your local library or school." This was in contrast to the release of Secure Mailer (Postfix) in December of 1998, which was accompanied by a *New York Times* article titled "Sharing Software, IBM to Release Mail Program Blueprint." This was the fourth official IBM involvement in open source between June and December of 1998 and is recognized as the one that caused IBM management to realize that there was no existing open source strategy. A mandate to develop one ensued, leading to the 1999 announcement of an IBM open source and Linux strategy.

So why create another UNIX mail system? As a practical exercise for secure programming, this would be an ideal project. Venema displayed an architectural diagram of the Sendmail program and its monolithic model—the two programs Sendmail and mailer. Highlighted was the fact that root privileges are required for the system to perform its tasks. This was followed by a number of slides listing the CERT advisories on Sendmail and the /bin/mail program over a 15-year period. Two major observations are that one mistake can be fatal and result in privilege escalation and that there are no internal barriers to compromise. This leads to a system that is hard to patch and in which it's hard to determine the side effects of a patch. The Postfix model was then shown, showing three major blocks: input, core, and output, similar to an Internet router. The only points at which elevated privileges are required are at local delivery time and to send to an external transport. Major influences on the design included the TIS Firewall, qmail, Apache, Sendmail, and network routers.

After the architectural overview, Venema went on to some of the considerations in the implementation of Postfix. If you know that your error rate is 1 in 1000 lines of code and that Postfix was 20,000 lines of code, you see you are releasing 20 bugs. Postfix is about 120,000 lines of code now, so perhaps 120 bugs. You want to control this, and the distributed architecture reduces the impact, with fewer bugs per component. Optimization is a special case, as Internet-facing servers have the problem of the worst case becoming the normal case and vice versa. Venema was told to "just implement SMTP without screwing up." As there are only a few commands in SMTP, how hard can it be? Well, multi-protocol, broken implementations, concurrent access, complicated addressing syntax, queue management, SPAM and virus control, and anti-spoofing systems quickly turned up the difficulties.

The official strategy was to divide and conquer by implementing a partitioned "least privilege" architecture, use (mostly) safe extension mechanisms, and let third parties provide the external applications. Several examples were then given, along with supporting architectural diagrams. As a final example, the implementation of Sendmail Milter into Postfix was shown, along with the press release from Sendmail Inc. awarding Dr. Venema a Sendmail Innovation Award for his contribution of extending Milter functionality to the Postfix MTA.

Over the years, Postfix has grown in size from its modest beginnings. Urged on by a friendly comment on the size of the Postfix source file, Venema decided to do an analysis of Sendmail, Postfix, and qmail source code. In order to accomplish this, comments were stripped (reducing Postfix by 45%), format conformed to "Kernighan and Ritchie" style (expanding qmail by 25%), and repeating (mostly empty) lines deleted. A graph showed that Postfix steadily grew up until it was considered officially "complete" in late 2006, after which it tapered off to a significantly slower rate. It surpassed Sendmail in combined size in 2005, while qmail has been essentially flat since its initial release. Venema attributes the lack of bloat in Postfix to the partitioned architecture, asserting that small programs are easier to maintain. Minor features can be added through modification of a small program, major features by adding a small program (for interesting values of small). Currently, Postfix consists of 24 daemons and 13 commands, with the SMTP daemon weighing in at almost 10k lines, or approximately half the size of the initial Postfix alpha release.

You can't really talk about success without including market share. This is a rather inexact item, as the number of mail servers in the wild isn't easy to determine, nor does it accurately reflect the actual users. In 2007, O'Reilly did a fingerprinting study of 400,000 company domains to

determine the mail servers in use. At the time, Sendmail was number one at 12.3%, followed by Postfix at 8.6%. Ten systems were on top, accounting for 65% of the results, other systems accounted for 20%, and there were 15% unknown. Using Google to search for mailserver query volume over time, we get a slowly declining graph for four of the open source servers: Sendmail, Postfix, qmail, and exim. What does this actually mean? We don't know, but Postfix queries exceeded Sendmail queries back in 2006. Today, they are all close together near the bottom of the curve. Searching Google trends has illustrated this as well. Tweaking the search terms in order to reduce result pollution has also shown a decrease in queries on MTAs over the years. This leaves only a couple of conclusions—the results are only as good as the queries, and only a declining minority of users are actually interested in mail servers.

Over the years, the essentials of email have changed significantly. Back in 1999, you built an email system on UNIX, so you did not have to worry about Windows viruses. New problem—your UNIX-based email system is now a distribution channel for Windows malware. New solution—outsource the content inspection to external filters. In 2009, you built a mail system that had world-class email delivery performance. New problem—your high-performance email system is spending most of its resources not delivering email. New solution—work smarter. Venema displayed a new chart showing some research from the MessageLabs Intelligence report for August 2010 indicating that 92% of mail is spam, 95% of which is from botnets. Zombie processes keep ports open, resulting in server ports being busy with nothing and not accepting email. RFC 5321 recommends a five-minute server side timeout which Postfix implements. Zombies own your server. If we assume that the zombie problem will get worse before it gets better, we have some options: spend less time per SMTP connection, handle more SMTP connections, or stop spambots upstream. This third option is slated for release in Postfix 2.8 in early 2011.

The new component, called postscreen, is designed to reject clients that "talk too fast" or make other blatant protocol violations and to utilize greylisting. It also uses black-and-white lists as shared intelligence to decide if it's talking to a zombie, as zombies tend to avoid spamming the same site repeatedly. Venema then displayed the workflow diagram for postscreen, going on to describe the initial connection for SMTP and how to detect spambots that speak too early, using the question, "How does a dogcatcher find out if a house has a dog?" Answer: He rings the doorbell and listens for a dog to bark. Postfix does this with zombies. Good clients wait for the full multi-line greeting, whereas many spambots talk immediately after the first line. He then showed charts illustrating the pre-greet events at two European sites, followed up by some charts on spam load and time of day. This varies by receiver and time of day. A few more charts showed this, with the USA and China displaying atypical patterns from the rest of the samples. Pilot results for small sites (up to 200k connections/day) show detection via pre-greeting of up to ~10% of sites not on the DNS blacklist and an additional ~1% that pipeline commands. Additional protocol tests will be developed as botnets evolve.

Venema wrapped up the talk with a conclusion that reiterated some lessons learned: Don't underestimate good PR—it has enormous influence; don't waste time re-inventing—good solutions may already exist; build your application with stable protocols—use established standards; use plug-ins for future proofing—accept change as a given; optimize both the worst case and the common case—these tend to swap positions as you go; and, finally, don't let a C prototype become your final implementation.

He observed that Postfix has matured well, establishing that a system implemented by a series of small programs is extensible by either a small change or adding an additional small program. Extensibility is a lifesaver, as it means not everything needs to be solved initially, but can adapt over time. While Postfix may be considered stable and released, the battle continues. New technologies on the roadmap will assist in the fight to keep zombie loads under control.

Bill Cheswick (AT&T Labs—Research) asked, "What language would you use instead of C?" Venema answered that the original plan was to do something he had done before and implement a safe language in C, and this safe language would be used to configure the system. It was described as a simplified version of a Perl-like configuration language implemented in C. Unfortunately, he had to first understand enough of the problem and build enough to get mail to and from the network and to handle delivery and local submission. Norman Wilson (OCLSC Calico Labs) said that he always believed that the hallmark of a successful programming system is not how easy it is to extend but how easy it is to throw things out. Have you done this in Postfix? Also, do you feel that building out of cooperating pieces makes it easier rather than harder, not technically but culturally? Venema replied that, in principle, you can throw things out, as it's a loosely coupled system. A couple of things have happened. First, LMTP is a protocol similar to SMTP. At some point LMTP was forked from SMTP and evolved separately for several years. Eventually it was just too much trouble to support both, so he forcibly merged them, effectively discarding a protocol. Second, Postfix uses a table look-up interface for everything. If it's simple strings, use Berkeley DB; if it's tricky, use regular expressions, which is not a

great user interface but will do almost anything. He still has notes about an address-rewriting language that would have replaced the trivial rewrite daemon in Postfix, but this will probably never be written. Monolithic vs. several programs is hardly an issue.

Refereed Papers

Summarized by John F. Detke (jdetke@panix.com)

Using TCP/IP Traffic Shaping to Achieve iSCSI Service Predictability

Jarle Bjørgeengen, University of Oslo; H. Haugerud, Oslo University College

Jarle Bjørgeengen presented work applying TCP/IP packet-shaping methods to SAN traffic in an effort to achieve predictable service response.

The problem is that in the common SAN configuration, free competition for resources (disk operations) among service consumers leads to unpredictable performance. A relatively small number of writes had a large impact on read times. Most applications behave better with predictable, if slower, read performance.

The test setup consisted of four blade servers connected to an iSCSI SAN, with ipfiltering providing the ability to control the data flows. The number of random readers and sequential writers could be controlled while capturing and plotting performance data such as average read or write times and throughput.

Various throttling mechanisms were tested and it was found that adding a delay to the ACK packets resulted in a linear increase in read time as the delay was increased. The optimum delay varies with the workload, so setting the delay to a fixed value is not a good option. Manually adjusting the delay is not practical, due to the dynamic nature of real workloads.

Automating the delay throttling with a modified proportional integral derivative (PID) algorithm was investigated. This turns out to be an efficient method for keeping low read response times with an unpredictable and dynamic write load.

A demo was given showing the software running in the lab, graphing performance data in real time while the workload was varied. First, Jarle demonstrated that adding modest write workloads has a large negative impact on read operations. Next he showed how adding the ACK delay improves things. Finally, we saw how using the PID algorithm to automatically adjust delay results in predictable read responses times.

In summary, common packet-shaping techniques using available tools can be used to automate controlling IP-based iSCSI traffic to provide predictable and thus improved behavior in a SAN environment. Packet delay proves to be a better control mechanism than bandwidth limiting at ensuring fair resource sharing with multiple clients. Future work includes moving the control mechanism outside the iSCSI array to create an appliance that could be used on different arrays without needing details about the array itself. Additional throttling algorithms are being investigated to see if even better results are possible.

YAF: Yet Another Flowmeter

Christopher M. Inacio, Carnegie Mellon University; Brian Trammell, ETH Zurich

Christopher M. Inacio started with a short tutorial and history of NetFlow, including the basic data available, its historical roots in billing, and how it can help with security investigations.

Why build Yet Another Flowmeter? The authors wanted a tool that was compliant with IPFIX, could capture both talker and receiver, performed well, could do weird layer 2 decoding such as MPLS encapsulated on Ethernet, and had an open design that allowed for enhancements.

The basic architecture of YAF was described, along with the various methods available for capturing data. These range from high-speed cards to reading previously generated pcap (packet capture) data. A condensed IPFIX primer followed, discussing data structures and how templates are used to conserve bandwidth and storage requirements. YAF fits between traditional header-only NetFlow data and complete packet capture tools. Options allow tuning which data is captured and how much. This lets you balance issues such as privacy concerns and data storage requirements. Entropy analysis of captured data is possible, which is useful in determining if the data is compressed or encrypted.

Various protocols are understood by YAF; X.509 is being worked on. Understanding who is creating encrypted tunnels on the network can help identify malware.

Christopher talked about common YAF deployments and the type of environment it has been used in. Generally, the capture device running YAF is attached via an optical splitter, providing an air gap that limits vulnerability to attack. Carefully crafted packets and payloads may still be a source of vulnerability. The authors' typical installation involves high data rates (monitoring multiple 10Gb links), which requires high-performance databases.

A toolkit is provided to build your own mediators. The goal is to make it easy to capture and store the particular data that interests you. Future work includes adding protocols and improving data storage abilities, thus providing the ability to use back ends such as MySQL, which should be adequate in environments with smaller data capture needs.

YAF is available at http://tools.netsa.cert.org/yaf/index.html. It has been in development for four years, has been deployed to several sites, and has proven to be stable. The authors are interested in hearing how YAF has been used and what improvements are desired.

Comments and questions about YAF and other tools can also be directed to netsa-help@cert.org.

Nfsight: NetFlow-based Network Awareness Tool

Robin Berthier, University of Illinois at Urbana-Champaign; Michel Cukier, University of Maryland, College Park; Matti Hiltunen, Dave Kormann, Gregg Vesonder, and Dan Sheleheda, AT&T Labs—Research

Robin Berthier started his talk by thanking Christopher M. Inacio for explaining NetFlow so well. The authors felt there were no tools available that fit the gap between tools providing a detailed and a high-level view of network flows. Nfsight was designed to fill this gap. It does so by aggregating flows by host and port number and creating a high-level view along with the ability to drill down to see details.

The challenge the authors faced was to identify bi-directional network flows without requiring IPFIX, which was not yet in mainstream use. Heuristics were developed and analyzed as to effectiveness in identifying flow direction. The back end is a set of Perl scripts that processes Nfsen/Nfdump data and stores the result in both flat files and a database. The front end uses PHP and JQuery to visualize the stored data. Automated alerts can be sent by the front end, and you can tag hosts with notes for team members to document network activity.

The back end is composed of two scripts. The first identifies the bi-directional flows and client/server data and stores these in flat files and a database. A Bayesian inference is used to combine several heuristics to identify flow direction. Robin explained some of the heuristics used, such as timestamps, port numbers, and fan in/out relationships.

By using Bayesian inference to combine outputs, Nfsight is able to improve the accuracy of identifying directionality. Heuristics have differing levels of accuracy, some varying depending on the NetFlow behavior, while none were able to reliably determine direction all of the time. By combining the output of several heuristics, they were able to determine direction most of the time.

The second back-end script provides a framework for writing signatures that identify malicious activity in the bi-directional flow data. The current set of signatures include three categories of flows: malformed, one to many (possible scanning), and many to one (possible denial of service attacks). The IDS signatures are evaluated by sending the top alerts to the signature's author along with links to visualize the flows and then mark the alert as a true positive, false positive, or inconclusive. The results of this voting are then used to evaluate the signature as good or bad at identifying actual attacks. Most of the false positives came from heavily used services, so a whitelist capability is being developed to limit false positives stemming from these services.

The front end is used to visualize NetFlow data stored in the files and database. Flow data can be filtered based on criteria such as IP range, port number, time, and type of activity. The filtered data is then displayed showing endpoints, flow metrics, such as number of packets, and a heat map of activity. The color intensity indicates number of flows, and the particular color shows the type of flow (e.g., client or server). Red is used to indicate that the flow could not be matched to identify a bi-directional flow. This often indicates network problems or scans. Clicking on the heat map drills down to a detailed view, and this is where hosts can be tagged with a note that is viewable by others.

A demo of Nfsight was given that showed the high-level views and drilling down to the different detail views. Several use cases were also presented: the first showed an example of a power outage, clearly indicated by gaps in the heat map. Which hosts were, or were not, affected by the outage was easy to spot. By selecting port number, the tool can visualize external scanning of the network and which internal hosts are answering those scans (and thus may need patching).

Visualizing the flows can also be used to identify distributed and synchronized activity. An example was shown of a simultaneous attack on 20 vulnerable SSH servers. Future work includes improving the IDS signatures and creating additional heuristics to identify the type of service. This could be used to find Web servers operating on ports other than 80.

Nfsight will soon be available as open source at: http://nfsight.research.att.com.

If you have questions or wish to be notified when the tool is released, send email to rgb@illinois.edu.

Invited Talks I

Visualizations for Performance Analysis (and More)

Brendan Gregg, Joyent

Summarized by Mark Burgess (mark@cfengine.com)

Brendan Gregg presented an invited talk based upon a recent article in *Journal of the ACM*. Gregg spoke first about performance measurement in general. He emphasized that measuring I/O performance (or "IOPS") could be a misleading pursuit, since it is difficult to know exactly which layer of the software stack is responsible for the results. Better to study latency as a compound effect, since it includes all layers. If performance has a ceiling, for instance, we have to find the weakest link in the stack. He also emphasized the importance of workload analysis in a network, not just on a single host, and recommended a split between measuring load and architecture as soon as possible in a performance analysis in order to understand the effect of communications in the system.

Gregg promoted DTrace as a toolkit, claiming that it is "game changing" for measurement and showing how some of its data could be presented using a form of granular time-series called a heat map. A heat map is a combination of line graph with histogram over a bucket of time. It shows a rolling distribution, something like using error bars for repeated measurements, but using colors and two-dimensional space to represent the data. The heat map shows not only a single sample line but an accumulated distribution of values in a measurement interval that can indicate skew and exceptional behavior. A color-shaded matrix of pixels was used to show latency versus time. By using a false color palette, it is possible to see outliers in the histogram more clearly—the palette can be used to emphasize details, but the colors can become confusing

Gregg proposed that visualization allows us to use the human brain's ability to pattern-match to maximum effect. Writing software to see the same patterns is very hard. He showed a number of examples based on complex systems of disk reads, showing interesting and even beautiful patterns, although he had no explanation for the patterns that resulted. In questions it was suggested that the patterns might be explained by a model of periodic updating. Gregg ended by suggesting that visualization could be used to monitor the cloud for performance and even for system administration—e.g., in measurement of user quotas.

Invited Talks II

Rethinking Passwords

William Cheswick, AT&T Labs—Research

Summarized by Rik Farrow (rik@usenix.org)

Cheswick pointed out that he was 98th on a list of the 100 most influential people in IT. He then moved on to address a problem that really needs fixing: passwords. We need to have passwords that work for both grandma and the technical audience.

Cheswick went through many examples of password rules (calling these "eye of newt" rules), exhibiting conflicting rules and widely varying lengths. He claimed that he at least shares some responsibility for the rules, as he and Steve Bellovin had suggested having rules in their 1994 firewalls book.

Cheswick then used a short animated clip from a Bugs Bunny cartoon, where a rather stupid Middle-Eastern-appearing character keeps guessing until he comes up with the magic phrase to open a door: Open Sesame. Stopping brute force password guessing attacks was the focus of the NSA's Green Book, back in 1985. What gets ignored are attacks where passwords are stolen: keystroke logging, phishing, and theft of databases containing passwords. If brute force attacks can be limited by inserting delays, Cheswick wondered why we continue to have "eye of newt" rules?

Cheswick suggested that we have only one rule as an engineering goal: the don't-be-a-moron rule. This rule prevents the use of your own name, permutations of your name, and dictionary words. At this point he mentioned that his grandmother had written a disk device driver for the Univac 1, so his standard for "grandmas" seems a bit skewed. Cheswick also mentioned the Schecter and Herley paper from HotSec '10, where they suggest allowing any password at all, but only allowing about 100 people to use a particular password. This way, only 100 people could have the same password, although the "don't-be-a-moron rule" still applies.

Cheswick had a list of suggestions to help prevent brute-forcing and to make these preventive mechanisms less painful for users: use less painful locking—the same password attempt twice counts as one attempt; make the password hint about the primary password; allow a trusted party to vouch for the user (a significant other); use exponential backoff for delays instead of locking accounts; remind the user of password rules (eye of newt), as this might jog her memory.

He went on to suggest better solutions, such as getting away from static passwords entirely. He likes hardware tokens and challenge-response, and had looked at RSA softkeys

on smartphones, saying that the software does not include enough information to reveal the PIN.

Cheswick then provided a lesson in password entropy. He used the example of the 1024 (2^^10) most popular English words, and that using two of these words as your password provides 20 bits of entropy. I wondered about this, as this means the brute force space is only 1024 squared, but Cheswick is right (no surprise there). He went on to explain that Facebook's rules require at least 20 bits of entropy, banks in the 30s, and government and .edu rules in the 40s.

Cheswick has a history of experiments with passwords, and he talked about how baseball signals worked, and how this could work using a challenge-response scheme you could do in your head (and certainly so could his grandma). He then described other potential schemes, such as passpoints, passfaces, blurred images, passmaps, passgraphs, even using a point in a Mandelbrot set.

He concluded with advice for users: use three levels of passwords; write down your passwords but vary them according to memorized rules; write down the "eye of newt" rules. He also suggested using PAM tally, a module found in most Linux distros that does account locking. He likes near public authentication services such as OpenID and OpenAuth.

I started the Q&A by pointing out that devices can be left behind: for example, showing up in Australia on Monday and not having your hard token when it is Sunday morning back in the US. Paul Krizak of AMD said that many people had switched to the site key model, but he found it interesting. Cheswick replied that this was a nice defense to phishing, that grandma could do it, and it was actually a good idea. Jay Faulkner of Rackspace pointed out that anyone playing Final Fantasy gets a physical token, and Cheswick said, "Fine." Marc Staveley said he checked his personal password vault and found he had 200 level three passwords secured with a level four password, and Cheswick suggested that perhaps he spends too much time online. Staveley than asked how we get beyond this, to which Cheswick responded that we need to go to OpenID or Google, or various values thereof.

Practice and Experience Reports

Summarized by Rik Farrow (rik@usenix.org)

Implementing IPv6 at ARIN

Matt Ryanczak, ARIN

Matt began by saying that getting IPv6 to work really won't be that hard. IPv6 is about 20 years old (it was called IPng in RFC 1475), and back then, some people expected to have replaced IPv4 before the end of the '90s. He then went on to explain his own experience setting up IPv6 connectivity for ARIN.

In 2003, he got a T1 from Sprint to do IPv6. Sprint was testing IPv6 to their own site, where it then was tunneled. He needed special device driver support in Linux since ip6tables worked poorly; he instead used pf under OpenBSD, which worked really well. He had a totally segregated network, with a dual stacks system set up to reach the IPv4 side of the organization.

In 2004, he got a second link from Worldcom, also not commercial, used a Cisco 2800 and continued using the OpenBSD firewall. ARIN joined an exchange in 2006, Equi6IX, peered with lots of people, and could get away from T1s. They went to a 100 Mb/s link and no longer had IPv6 to IPv4 tunnels getting in the way, which was much closer to the class of service found in v4.

By 2008, he found the first networks designed with IPv6 in mind. He had wanted to find colos, with dual stacked networks and Foundry load balancers (v6 support in beta). The amount of IPv6 traffic was low enough that a single DNS server was more than sufficient—and still is today. ARIN now had 1000 Mb/s to NTT TiNet, Dulles, and San Jose. In 2010, they have two more networks, in Toronto and St Martin, are still using beta firmware, DNS only, and plan on anycast DNS eventually. Matt said the IPv6 only accounts for a small amount of ARIN's network traffic. He broke this down by categories: .12% Whois, .55% DNS, .65% WWW.

Matt went on to cover a lot of the topics he wrote about in his October 2010 *;login:* article: all transits are not equal, check for tunnels, routing is not as reliable (although it has gotten better). Sometimes Europe would "disappear for days," and parts of the Internet still disappear from IPv6 routing. Matt emphasized that you must understand ICMPv6, because of fragmentation issues. In v4, routers can fragment packets, but not in v6. The sender must receive ICMPv6 for path MTU discovery, and the sender must fragment. Dual stacks are a good thing, okay for security. It does make policy more complicated, and you need to maintain parity between firewall policies, for example. DHCPv6 is not well supported. Windows XP barely supported v6. Linux is okay, *BSD better, Solaris and Windows 7 work out of the box. Windows XP cannot do v6 DNS lookups.

There is no ARP on IPv6; it uses multicast instead. This is also great for scanning networks and DoS attacks and can be routed, providing a whole new world for hackers to explore. Read RFC 4942 for v6 transition, how to properly filter v6 to avoid discovery issues. Proxies are good for transition: Apache, squid, and 6tunnel are valuable. Reverse DNS is

painful; macros in BIND do not work in v6 for generating statements, may be broken, and are difficult to do by hand.

Carolyn Rowland asked about working with vendors. Matt said he has received great support working with Arbor Networks in the security area. Carolyn wondered about problems we saw with v4 stacks, like the ping of death (Windows 95). Matt said that there certainly could be more bad code around. Someone asked which versions of DHCP he was using. Matt replied that they were using the "out of the box" DHCP client software in various OSes, and only Windows 7 and Solaris worked well so far.

Internet on the Edge

Andrew Mundy, National Institute of Standards and Technology (NIST)

► *Awarded Best Practice and Experience Report!*

Andrew Mundy is a Windows network admin at NIST headquarters in Gaithersburg, Maryland. He was asked to provide network services for an experiment in autonomous robots—about a half mile away from any building on campus. As this request came from an outside contractor, it had to be a visitor connection. NIST has a visitor wireless infrastructure in place, but now they needed to reach the middle of a field, to locations that actually changed during the project.

He discovered that they can do this using a different type of wireless access point with an external antenna. But they must have a line of sight to the location, as well as access to a fiber link, and the one guy who could tap into the fiber works only on Thursdays.

Mundy's team picked the rooftop of the administration headquarters. This building even had unused steel structures on the roof they could use for mounting the antenna. They then tried a Cisco 1240 AG with a directional antenna, but it can only provide 80 Kb/s. They tried a couple of Aironets and settled on the AIR ANT3338 with a parabolic antenna with a 23 db gain. They ordered two, one for the roof and one to be mounted on the support trailer, where they will provide local wireless secured with WPA2 and wired Ethernet within the trailer. The trailer used a Honda generator, which provides very clean power for computers.

On roof install day, they prepared by tying on their tools so they couldn't drop them off the roof. They also prepared to ground the steel support structure by attaching heavy RG-6 copper cable to a grounding block. As they were about to enter the elevator, some guys exited carrying some steel pipes, parts of the roof structure they planned on using. They were dumbstruck, as getting the paperwork to replace the structure would take six months. Walking back to their building, they found a wooden packing crate. They "borrowed" it, modified it, added a pipe for clamping on the antenna, and bought sand and sandbags to hold it in place.

With the antenna in place and working, the contractors decided on a new site about three miles away. They used Google Maps to compute a new azimuth (direction) and lost line of sight (some trees), but things still worked, as they had enough gain. They did have to make sure that the wireless power output, plus the gain of the antenna, remained within legal limits. (Editor's note: For more on power, see Rudi van Drunen's February 2010 *;login:* article about "Peculiarities of Radio Devices.")

Lessons learned include using a lot more sandbags, rather than worrying about a gust of wind ripping the box off the roof and dropping it on the Director's windshield. They wound up with 500 lbs of sand. Next, remember that temporary solutions aren't always temporary. Finally, be flexible (Semper Gumby). He never would have thought a wooden packing crate and Google Earth would have provided an enterprise network solution.

Jay Faulkner of Rackspace asked if the signal was strong enough to work during rain and Mundy said that they didn't test it during rain. Someone from Cisco asked how much they had to reduce the wireless signal power to prevent exceeding the legal limit. Mundy said 30%, so as not to exceed the 30 db power limit. Carolyn Rowland asked what they would have done differently, to which Mundy replied they could have used bridge mode, which would have gone miles and miles.

Managing Vendor Relations: A Case Study of Two HPC Network Issues

Loren Jan Wilson, Argonne National Laboratory

Wilson began by asking if there were any Myricom users or HPC administrators in the audience. No hands went up. He then went on to describe Intrepid, which was the number three supercomputer in its time. It is built of IBM Blue Gene/P nodes, which are PowerPC CPUs with local RAM but no storage. There are 1024 nodes per rack and they had 40 racks. Each node requires booting when starting another program. Access to remote storage is key to keeping the supercomputer working, both for booting and for storing results.

The Argonne Leadership Computing Facility (ALCF) had perhaps 5 PBs of useful storage, some over NFS, but most via GPFS. The plan was to connect the nodes in a full bisection mesh. Every node link is 10 Gb, and they needed to connect them via 10 Myricom switches, which provided a 100 Gb uplink. Wilson showed a diagram of the Intrepid setup, then a picture showing thousands of cables connected to the nodes and switches.

Myricom, http://www.myri.com, has totally stupid switches, that is, the only management interface is via HTTP. Myrinet itself is a source-routed protocol, which means that every host keeps a map of the network which is used to route each packet. But the Myrinet switches kept breaking, with about 6% of ports affected by a random port death issue. At first Wilson just switched to spare ports, but then he started disassembling switches and noticed that the ports that died were attached to a particular brand of transceiver. They also had 1000 quad fiber connects fail, and these interconnects don't just fail: they also corrupted packets.

ALCF lost 375 days of compute time due to these network issues. Wilson blames a lot of that on his own failure to create good relationships with the vendors involved. He suggested not starting with "OMFG everything is broken," as it will take years to recover your relationship with the vendor. They got a good deal on the Myricom gear but should have paid more for people to help deal with the gear. As it was, the reseller was pretty useless. Also, Myricom got paid before they shipped a single piece of gear.

After a while, they had weekly phone meetings, and once they started to do that, things worked better. Wilson wrote a switch event collector in Perl, which helped. When disassembling switches, he noticed that it was Zarlink that made the bad transceivers, and not only did the Avago transceivers work well, their support was good. Zarlink never even responded to him.

Carolyn Rowland asked if ALCF learned from these lessons. Wilson said that he wrote this paper when he was working there. Since then, he and a lot of others had left, and ALCF had probably not learned their lesson. Hugh Brown of UBC asked if doing acceptance testing should have been part of the lesson. Wilson replied that you should do acceptance testing, and you should not skimp. He suggested that you come to agreement on how things are supposed to work.

Invited Talks I

System Administrators in the Wild: An Outsider's View of Your World and Work

Eben M. Haber, IBM Research—Almaden

Summarized by Tim Nelson (tn@cs.wpi.edu)

Eben Haber began his talk by reminding us that society depends implicitly on IT infrastructure, and that without system administrators it would not be able to sustain itself. Unfortunately, system administration costs are increasing (as a percentage of total cost of ownership) and so there have been attempts to create "autonomic" systems that would be able to self-configure as well as detect and repair issues on their own. This effort has spurred an interest in how exactly sysadmins do their job.

Haber showed a video clip of two sysadmins making changes to a database table. After a week of preparation, a small mistake nearly resulted in disaster. The clip served as an example of how high-risk a sysadmin's job can be, as well as showing tools and practices sysadmins create themselves to handle the risk. There was also a high degree of collaboration, in spite of how outsiders may view the job.

Haber is writing a book detailing an ethnographic study of system administrators at work. After summarizing the book, he showed a longer series of clips taken from the first chapter. We see a junior sysadmin ("George") attempting to solve a configuration problem. We see George struggle with the issue, call technical support, and also work with his colleague ("Thad"). George finally sees the cause of the problem but misinterprets what he sees, leading to a fruitless search until Thad discovers the problem on his own. George resists the fix, and Thad must debug George's misconception. Finally, George realizes his mistake and fixes the error. Between clips, Haber pointed out communication issues, such as the use of instant messaging to discuss Thad's solution when a phone conversation or face-to-face talk would be better, and observes that we need better tools for accurately sharing system state during collaboration.

In closing, Haber summed up what they had learned about the practice of system administration: that the environment is large-scale, complex, and involves significant risk. The ways sysadmins cope with their environment were interesting and included collaboration, tool-building, standardization, automation, specialization, and improvisation. He then considered the future of system administration. He drew comparisons to the (now obsolete) flight engineer position aboard airplanes, noting that as automation outpaced increases in complexity, the pilot and co-pilot were no longer dependent on a dedicated flight engineer. So far, the complexity of IT systems has kept pace with automation technology, which is why the job is not getting any easier.

Jonathan Anderson commented on the trust relationships that develop between sysadmins and wondered about keeping the balance between personal development and just relying on someone you trust. Another audience member then observed that George even began with a "mistrust" relationship with tech support.

Someone commented that it can take weeks or months to decide on a course of action, but sysadmins get a far shorter window to implement changes. Phil Farrell noted that a large organization will have even worse communication bottlenecks than a smaller one. Alva Couch from Tufts commented

that people under pressure feel entrenched and are more resistant to "debugging." Sysadmins are under pressure to balance open-mindedness with snap judgments.

Several audience members brought up the issue of executive meddling. Haber replied that they had not seen major instances of executive meddling, but agreed that social requirements can exert as much pressure on a sysadmin as technical requirements.

Someone pointed out an ethnographic study of technology workers in Silicon Valley (done in the late '90s at San Jose State). Someone from Google wondered if there were videos of senior sysadmins as well; Haber replied yes, but that their videos were not as compelling for a large audience.

Jason Olson asked whether they had looked at high-performing sysadmins and tried to find indicators and counter-indicators of high performance, such as whiteboards. Haber answered that the sample size was too small, but the whiteboard would be a good example.

Someone asked whether the video recording may have influenced the experiment and whether the subjects might have been nervous because of the recording. Haber replied that there was some initial nervousness but they seemed to ignore the recording process eventually.

Invited Talks II

Enterprise-scale Employee Monitoring

Mario Obejas, Raytheon

No report is available for this talk.

Refereed Papers

Summarized by Julie Baumler (julie@baumler.com)

Using Syslog Message Sequences for Predicting Disk Failures

R. Wesley Featherstun and Errin W. Fulp, Wake Forest University

Featherstun started out by talking about how as systems become larger and, particularly, become collections of more parts (processors, disks, etc.), failures of some sort become more common. If we can't avoid failures, can we better manage them? The key to management is accurate event prediction. Featherstun and Fulp looked specifically at predicting disk failures. Since pretty much every device has a system log, they decided to use syslog. Syslog messages represent a change in state. They wanted to use that to predict future events.

They originally used a Support Vector Machine (SVM) with criticality numbers from syslog to determine priority. Later they found that criticality numbers seem to be falling into disuse and, after some experimentation, switched to a vocabulary of about 24 words from the messages themselves. They used a sliding window so that older messages would be ignored.

For testing they worked with almost two years' worth of data from a 1024-node Linux cluster. Using this method, they were able to achieve about 80% predictability of disk failures. Featherstun discussed the various refinements on window size, lead time, and vocabulary to achieve these rates and how different changes affected the results.

Several questions were asked regarding current and future plans for this technology, and Featherstun suggested contacting Dr. Fulp (fulp@wfu.edu) as Featherstun is no longer working on the project.

Log Analysis and Event Correlation Using Variable Temporal Event Correlator (VTEC)

Paul Krizak, Advanced Micro Devices, Inc.

▶ *Awarded Best Paper!*

The original goal of Paul Krizak's project was to create a log analysis solution that was scalable to large quantities of logs, could take advantage of multiple processors, worked in real time, and would allow other developers to write rules. They had previously been using Swatch, but it did not scale or have good event correlation. They looked at Splunk version 1, which could not scale to index all their data, and at SEC. They felt that SEC's rules were too difficult to use to meet their goals.

The system is written in Perl. It keeps track of how often events occur and has timeouts to avoid multiple notifications. Syslog-ng forms a core part of the system, which consists of multiple rule engines, a variable server, and an action server. The variable server keeps common data so that the rule engines do not have to manage state. The rule engines process the filtered logs coming from syslog-ng and notify the servers as necessary. The action server both produces alerts and queues jobs to solve detected problems. Jobs and alerts can be run immediately or held for a later time, such as business hours for alerts or maintenance windows for repairs. Krizak also discussed some of the lessons learned in producing the system, such as using a language that everyone was familiar with for the rules engine. The system is currently in use and mostly in a "fire and forget" state.

Someone asked if the system was publicly available. Krizak replied that it currently belongs to AMD and much of it is

environment-specific. However, he is willing to work with AMD to make it open source if there is sufficient interest and he does not have to become the project manager.

Chukwa: A System for Reliable Large-Scale Log Collection

Ariel Rabkin and Randy Katz, University of California, Berkeley

In Hindu mythology, Chukwa is the turtle that holds up the elephant that holds up the earth. Since Hadoop's symbol is an elephant and originally a key goal was to monitor Hadoop, it seemed appropriate. Chuckwa is optimized for a certain large to mid-sized monitoring need and allows for two different ways of gathering data: either what you can get as quickly as possible or gathering 100% of the data, which could mean waiting for data that is on down servers. It uses Hadoop and MapReduce for storage and processing.

Chukwa was originally a Hadoop project, is now in Apache Accelerator, and will be moving again to be a regular Apache project. The easiest way to find it is to do a search for Chukwa.

Alva Couch asked if this project was just for applications in the cloud. Rabkin replied that most users are not cloud users—in fact, the killer application seems to be processing blogs—but that Chukwa was designed to be cloud-friendly.

Invited Talks I

Flying Instruments-Only: Navigating Legal and Security Issues from the Cloud

Richard Goldberg, Attorney at Law, Washington, DC

No report is available for this talk.

Invited Talks II

The Path to Senior Sysadmin

Adam Moskowitz

Summarized by Theresa Arzadon-Labajo (tarzadon@ias.edu)

Adam Moskowitz laid out the steps he felt were important for one to become a senior system administrator. He pointed out that the talk was going to be career advice to achieve professional and personal growth and would help advance one's career. The talk was aimed at mid-level sysadmins, but could be used as long-range goals for junior sysadmins.

He broke down the steps into three categories: hard skills, squishy skills, and soft skills. Hard skills are the technical ones, the easiest to achieve for system administrators, and are mainly for the generalist system administrator, the ones who do everything. Squishy and soft skills are the difficult ones and are important for everyone. The USENIX Short Topics *Job Descriptions for System Administrators* should be used as a reference.

An important hard skill is to know multiple platforms, because it's a big win for employers. Backups, email, and networking are the minimum things to know. Familiarity with all the commands on the systems is suggested. It is also necessary to understand the boot process. They should specialize in at least one implementation of backups, RAID, volume management, and authentication mechanisms. A sysadmin needs to have programming knowledge, at least for automation purposes. Shell, sed, and awk should be a starting point. Beyond that, one should have knowledge of at least one robust programming language. Adam recommended Perl, since it's what most system administrators use, but one should learn what is most common in a given environment. Sysadmins should be able to read and understand C. As a bonus skill, assembler can be useful, because the deepest parts of the kernel are written in it. As far as software engineering skills go, familiarity with version control is needed, either with a specialized tool or by hand, so you have a way of rolling back. When writing utility scripts, make sure not to hard code anything. Proficiency in a system configuration tool such as Bcfg2, Puppet, Cfengine, or Chef is suggested, as is the experience of having set one up from scratch in a real environment. Basic knowledge of networking protocols such as TCP/IP, UDP, switches, and routers is important. An in-depth knowledge of application protocols such as HTTP, FTP, imap and SSH is recommended, so that simple debugging can be performed. A sysadmin should have a reasonable understanding of firewalls and load balancers and be able to use a protocol analyzer. A triple bonus skill to have is knowing the kernel. It can be helpful when doing performance tuning. Whether they like it or not, someone who wants to be a senior sysadmin needs to know Windows and be familiar with the basic configuration and common Office applications such as Outlook or Lotus.

Squishy skills are technical skills that don't have to do with a specific technology. Some skills face out and deal with procedure and other face in and deal with career growth. One facing-out skill is being able to do analysis, planning, and evaluation. A senior sysadmin has the ability to look at the "big picture" when dealing with a project. They know how all the pieces interact, for example, knowing the requirements for networking, servers, and power when planning a data center. Being able to know how long a project will take and how to schedule it accordingly is significant. They should know how to perform roll-outs, upgrades, and roll-backs if things don't work out. Another facing-out skill is understanding how a process works. There should be rules on how things get

done, whether it be a formal change management procedure or just an email that is sent out 24 hours in advance. Also, knowing how much process is appropriate is vital, because process can get in the way of getting the job done. But, if done well, a rule-based process helps get the job completed and prevents mistakes from happening. Senior sysadmins should know how to deal with business requirements. They should know the prevailing standards for what they are dealing with (e.g., POSIX, IEEE Std 1003.x, Spec 1170). They must possess knowledge of the regulations that they have to work within (e.g., SOX, HIPAA, FERPA, PCI). Then they can work with experts to correctly apply those regulations to their business. Senior administrators are expected to interface with auditors and consultants, so they should be able to talk about the business. Service level agreements (SLAs) should be appropriate for what the business is. Things should only get done if there is a requirement to do it and not just because it's the cool thing to do. Any future growth should be already written in the business plan. Sysadmins should be able to go to their boss and explain why something is needed and be able to tie it into the business requirements. Budgeting is another skill that is needed. Knowing how to build a budget is not required, because that's what your boss does, but knowing what data goes into it is. A sysadmin should also be able to obtain reasonable quotes from vendors.

A facing-out squishy skill, that is, one that pertains to career growth, is that sysadmins need to learn where to find help, since their manager may not be the one who could help. Places to find help are at conferences like LISA, LOPSA and SAGE mailing lists, local sysadmin groups, and Facebook or Twitter. The personal contacts that are made are very valuable, so paying out-of-pocket or taking vacation to go to a conference is worth it. Sysadmins should have their own library and not rely on their employers to buy the books they need. If they change jobs, they should be able to drop the books on their desk and be ready to work and not have to wait several weeks for the books to arrive. Knowing when to ask for help is a very hard skill for sysadmins to learn. But there may come a point in their career when there won't be many people who can help them out. Pair programming can be a very good skill for senior sysadmins, so that they can explain what they are doing to someone else and make sure that they are not going to do anything bad to the system.

Soft skills are the hardest skills for sysadmins to learn. Understanding that their job is about the people and the business, not the technology, is key. If they got into system administration because they didn't want to deal with people, that may be okay if they are a junior sysadmin. But senior sysadmins deal with a lot of people all the time. An important soft skill is having a friendly and helpful attitude. If people don't want to come to you with their problems, then you have failed at your job. On the other hand, if they like you and know you will fix things, then you will have happy customers. A senior sysadmin needs to be comfortable talking to management and explaining things to them with appropriate detail and reasoning. Respecting other people in the company is an extremely important skill. Sysadmins need to understand that it's not the worker's job to know about computers. Another critical skill is being able to get in front of small groups and make presentations. Senior sysadmins will be required to explain new products or procedures to people and meet with managers. Mentors and managers can help sysadmins work on their soft skills. They can point out what needs to be worked on and can track your progress. LOPSA also has a mentorship program that might be worth looking into.

John from UC Berkeley commented that conflict resolution is useful if the reason you are confrontational is because your manager rewards it unknowingly and you get more results than when you are nice and polite, which can point to larger problems in the organization. Jay from Yahoo! commented that sysadmins are held back by their inability to acknowledge they don't know something and are unwilling to use the resources available to them. He pointed out that having a network is really important. Jason from Google asked about strategies for team building. Adam responded that he didn't have much experience with that, but that Tom Limoncelli would be a good person to ask. Robyn Landers from University of Waterloo asked whether Adam felt there was any value to the Myers-Briggs personality test or other categorization exercises. Adam wasn't totally convinced that it is beneficial in a group setting, but it is more of an introspection thing. He felt that it was worth figuring out what the personality differences are, how they affect things, and how they affect you.

Refereed Papers

Summarized by Misha Zynovyev (zynovyev@stud.uni-heidelberg.de)

How to Tame Your VMs: an Automated Control System for Virtualized Services

Akkarit Sangpetch, Andrew Turner, and Hyong Kim, Carnegie Mellon University

Akkarit Sangpetch talked about automated resource management for virtual machines. He emphasized how virtualization simplifies the lives of system administrators. Consolidation of resources was named as one of the key benefits of virtualization. The problem that the paper and the talk were addressing is how current techniques for sharing resources among virtual machines on a single host fail to consider the application-level response time experienced by

users. Akkarit and his co-authors suggested a way to dynamically allocate resources for virtual machines in real time to meet service-level objectives.

The speaker showed an example of how their system works when a user accesses a blogging application run within a Web server and a database virtual machine. He presented a control system of four components implementing a CPU-sharing policy based on analysis of network packets intended for a controlled virtual machine. Akkarit concluded by explaining the graphed results the model had produced.

Paul Krizak from AMD asked on which virtualization platform the model was tested. Akkarit answered that it was KVM, but noted that there is no reason why it shouldn't work with VMware ESX or Xen. Kyung Ryu from IBM research was curious whether I/O operations and I/O contention could be taken into account with the presented approach. Theodore Rodriguez-Bell from Wells Fargo added that the IBM mainframe community was studying the same topic and asked if there was agreement on results.

Empirical Virtual Machine Models for Performance Guarantees

Andrew Turner, Akkarit Sangpetch, and Hyong S. Kim, Carnegie Mellon University

Andrew Turner explained how Akkarit Sangpetch and he started to work on the topic. The difference in their approaches lies in the starting points of their research tracks. Andrew Turner used the performance experienced by the end user as his starting point, while his colleague was looking at network packets in search of dependencies at a low level.

The presented model is multidimensional and covers disk and network performance as well as CPU. The model lets one infer how these resource utilization characteristics are affecting application performance over time. In the end, a system administrator should be able to distil from the model how resources should be allocated between particular virtual machines (VMs) in order to achieve a specified application response time with a specified probability. A control system that dynamically alters virtual machine resource allocations to meet the specified targets was described. Lastly, the speaker guided the audience through the results acquired with TPC-W benchmark and a three-tiered application for dynamic and static resource allocations.

Paul Krizak from AMD asked if the code would be freely available to the public. Andrew said no. Session chair Matthew Sacks asked how workload balancing was done, whether new VM instances were started on demand or workload was shifted to idle VMs. Chuck Yoo from Korea University asked whether any VM scheduler had been changed and was interested in more details on how modeling was done.

RC2—A Living Lab for Cloud Computing

Kyung Dong Ryu, Xiaolan Zhang, Glenn Ammons, Vasanth Bala, Stefan Berger, Dilma M Da Silva, Jim Doran, Frank Franco, Alexei Karve, Herb Lee, James A Lindeman, Ajay Mohindra, Bob Oesterlin, Giovanni Pacifici, Dimitrios Pendarakis, Darrell Reimer, and Mariusz Sabath, IBM T.J. Watson Research

Kyung Dong Ryu gave an overview of the IaaS cloud project at IBM Research, named RC2. He started by introducing IBM's research division and explained that IBM labs are scattered across the globe. All individual labs buy and install their own computing resources, which are often underutilized but which now can be integrated into a single playground for all IBM employees.

One of the key differences from Amazon's EC2 and Rackspace clouds is that RC2 needs to run on AIX and mainframes too. Dr. Ryu showed the cloud's architecture and briefly stopped on each of the components. He himself was mainly involved with development of Cloud Dispatcher, which handles user requests and prevents the overloading of other components. Among components described in detail were Instance Manager and Image Manager. Security Manager provides a trusted virtual domain with a way to control what traffic can come from the Internet and what communication is allowed between virtual domains. Another important issue raised was the pricing model implemented to make users release resources. It was shown how introduction of a charging policy was affecting cloud utilization.

Answering the question about availability of RC2 outside of IBM, Dr. Ryu expressed his doubt about any eventual open sourcing but pointed out that some of the components may have already been released, such as the Mirage image library. On the other hand, RC2 may be offered as an IaaS cloud to selected customers.

Invited Talks I

Panel: Legal and Privacy Issues in Cloud Computing

Richard Goldberg, Attorney at Law, Washington, DC; Bill Mooz, VMware

Summarized by Robyn Landers (rblanders@uwaterloo.ca)

This panel session was a follow-up to Richard Goldberg's invited talk earlier in the day, giving an opportunity for elaborating on the discussion along with Q&A. Session host Mario Obejas asked most of the questions to keep things going.

Goldberg began by reminding us why cloud computing is "dangerous." You give up control. The government could demand a copy of your data. You or the cloud provider could be subjected to subpoena. The implication is that the cloud provider may not handle your data the way you would have, so there may be more there to expose. Think of it as a legal attack vector.

Bill Mooz countered with the observation that clouds could be less dangerous than ordinary outsourcin,g depending on what SLA you can negotiate, or even your own datacenter, depending on your own operational standards. Activities such as payroll and tax returns were among the first to go to the cloud, yet you'd think those are things people would want to keep most private, and there haven't been disaster stories. Goldberg allowed that it's a question of different dangers, and one needs to plan for them.

The discussion touched on service level agreements, who they favor, the extent to which you can negotiate terms and penalties, and the importance of being able to get out. Again, comparisons were drawn between cloud and regular outsourcing based on whether customers are isolated on dedicated equipment. Software licensing cost and compliance are also issues here, as traditional per-CPU licensing may not apply to a cloud scenario.

After some discussion of the merits of a mixed mode in which you keep your most precious data on-site but outsource less critical data, the conversation came back to legal issues such as HIPAA compliance, questions of jurisdiction when outsourcing to companies in other states or countries, and ownership of and access to data in the cloud.

Rik Farrow asked about the ability to ensure data destruction when using cloud services, since the mixing of data in the cloud may expose more to subpoena, for example. Mooz speculated that you probably can't comply with a DoD contract requiring disk destruction if you're using the cloud. Goldberg agreed; even de-duping on-site mixes data (implying the potential exposure of other data in response to court order is as bad or worse in the cloud).

Johan Hofvander asked whether current law addresses the difference between real property (back in the days of livestock and horse carts) and intellectual property (in our modern times of digital music, movies, and personal information), and the duty of care. Mooz said it's likely spelled out in the contract, and you take it or leave it.

Session host Obejas repeated a scenario from an earlier session: imagine a multi-tenant situation in which one tenant does something bad and law enforcement agencies want to shut it down, affecting innocent tenants. Has this ever happened? Goldberg said that although he originally made up that scenario, it subsequently has indeed happened. A fraud case in Texas led to the FBI shutting down a service provider and taking everything. Mooz speculated that although cloud service wouldn't have the same physical separation that regular outsourcing might, there could be virtual separation. Goldberg pointed out that the FBI might not understand that partitioning and might still take everything.

Farrow wondered whether that's a good enough reason to choose the biggest cloud provider you can find. Goldberg agreed that although the FBI would shut down a small provider, they probably wouldn't shut down Amazon.

The session concluded with the suggestion that one must analyze the risks, decide what's important, and take reasonable protective steps.

Afterwards, Lawrence Folland and Robyn Landers, University of Waterloo, brought up the scenario of a Canadian university outsourcing email to an American cloud service, thus exposing itself to the Patriot Act. Imagine there were Iraqi or Iranian students and faculty members whose data the US government might be interested in monitoring. The speakers agreed that this is an interesting predicament. And viewed the other way around, could the American cloud provider get in trouble if, say, a Cuban national was included?

Invited Talks II

Centralized Logging in a Decentralized World

Tim Hartmann and Jim Donn, Harvard University

Summarized by Rik Farrow (rik@usenix.org)

Hartmann and Donn took turns explaining how they went from a somewhat functional logging infrastructure to one, Splunk, that collects a lot more logs and is easier to use. Hartmann explained that Harvard, like most universities, is composed of IT fiefdoms. His group was using syslog-NG, but kept their logs private. Donn's group was initially not collecting logs, and he set up syslog-NG. Each had different but intersecting goals for their logging infrastructure, with Donn's group focusing on centralizing logs and making searching logs simple, while Hartmann's group wanted more privacy via role-based access. Both groups wanted the ability to trend, alert, and report via a Web interface.

They started out by buying two modest servers (Dell 2950s) equipped with more DRAM than Splunk recommended (16 GB) and one TB RAID5 array each. Hartmann said they initially just used syslog-NG to forward logs to the Splunk indexing software from different ports, and used the port separation as a way of indicating sources for search access

roles. In the next phase, they added Splunk agents to collect more data. They were both reluctant to use agents (what Splunk calls "forwarders") because of their concern for performance and maintenance issues, but were gradually won over. Agents allowed them to collect system and network statistics from servers and to collect logs from DHCP and DNS servers that don't use syslog for logging.

By their third phase, they had to purchase a new license from Splunk, enough to cover gathering 100 GB of log messages per day. This growth was partially the result of adding more agents to collect logs, as well as the addition of another group at Harvard. In their fourth phase, they added servers just as search front ends and added more servers for indexing and for searching. They have two of everything (as Splunk charges by logging volume, not by server)—they have a truly redundant system. They also switched to collecting logs using a Splunk agent on the syslog-NG servers, as the agent encrypts logs and transfers chunks of logs using TCP, making the system much more secure and robust. They are also learning how to write their own Splunk agents. In the future, they plan to add more security monitoring, collapsing some of their MRTG monitoring, but not RRDs, into Splunk, and getting rid of Cacti.

Prasanth Sundaram of Wireless Generation in NYC wondered about their archival policy. Hartmann answered that they follow their university's policy for log retention, which does not require keeping logs very long. Donn pointed out that Splunk classifies logs as Hot, Warm, Cold, and Frozen, with Frozen logs not searched by default and good candidates for archiving. Sundaram then asked about issues in searching segmented indexes. Donn answered that Splunk hides segmentation from the user and searches Hot through Cold logs by default. Sundaram wondered how they decided to set up indexers. Donn answered that they chose to index by function: for example, all Linux servers in one, Cisco equipment in another, and so on. Hartmann said that it takes some time to figure out where you want to put stuff and that they should have been more methodical when they started out.

Someone wondered about the motivation for adding access controls for viewing logs. Donn explained that each college has its own bits of IT and they wanted to find a way to keep all that log data in one place. There are some security concerns, for example, in HTTP logs; people could find out students' ID info. Hartmann said that when they first started out splitting out indexes, they discovered that the app team was doing searches much faster, because they were constrained to certain indexes. Donn explained that all users get a default index, as well as a group of indexes.

Matt Ryanczak of ARIN asked about capacity planning. The logging volume he could figure out, but the server sizes? Hartmann said that for the servers, the Splunk Web site has some pointers, and they beefed up the guidelines when they went with that. They did talk to Splunk reps after they had made plans, and they were told their specs would work well. Donn added that they had to buy systems that would give them at least a year's headroom.

The duo ended by showing some more slides of examples of results from querying their Splunk servers, finding a problem with a new version of NTPD, finding a pair of chatty servers (using a top 10 Net speakers search), and finally showed how six MRTG graphs of firewall activity could be collapsed down to one.

Refereed Papers

Summarized by Shawn Smith (shawnpsmith@gmail.com)

PeerMon: A Peer-to-Peer Network Monitoring System

Tia Newhall, Jānis Lībeks, Ross Greenwood, and Jeff Knerr, Swarthmore College

PeerMon is a peer-to-peer performance monitoring tool. It is designed for general-purpose network systems, such as systems that are normally run in small organizations or academic departments, typically running in a single LAN system. Each machine's resources are controlled by the local OS, and each machine primarily controls its own resources. Each node runs a PeerMon process.

Tools built on PeerMon can allow good load balancing and increase performance. For example, one of the tools developed to utilize PeerMon is called SmarterSSH. It uses PeerMon data to pick the best machines to ssh into. More information about PeerMon and the tools that can use it can be found at http://cs.swarthmore.edu/~newhall/peermon/.

They were asked how they bootstrapped the process. It looks like there are lots of configs. In init.d, they have a script to start/stop/restart PeerMon. At startup, the PeerMon daemon starts and runs as a regular user. A cron job periodically runs to check if PeerMon is still running. If not, it runs the script. Did they run into any issues with race conditions? There aren't any issues with race conditions, since they got rid of the old method of writing data to a file and having peers access the file.

Keeping Track of 70,000+ Servers: The Akamai Query System

Jeff Cohen, Thomas Repantis, and Sean McDermott, Akamai Technologies; Scott Smith, formerly of Akamai Technologies; Joel Wein, Akamai Technologies

This paper is about the Akamai Query system, a distributed database where all machines publish data to the database and the data gets collected at several hundred points. The Akamai platform consists of over 70,000 machines that are used for providing various Web infrastructure services. Akamai needs to have the ability to monitor the network so that if a machine goes down, they can find and solve the problem. The monitoring needs to be as close to real time as possible.

A cluster is a set of machines at a single datacenter that shares a back end. Some number of machines are designated in that cluster to provide data. Every machine has one query process and some number of processes that publish into Query. Every two minutes, the Query process takes a snapshot of all the rows of database tables that have been sent to it, puts them together, and sends them to the next level of hierarchy. Cluster proxies collect data for the whole cluster and put data together to be sent to the next level. Top-level aggregators collect data for the whole network. There are also static tables: machines that are up and down may change pretty frequently, but the set of machines that are supposed to be up only changes when they install or change hardware. Static tables describe the configuration of the network. Some machines are SQL parsers, whose job is to collect the queries and compute the answers.

Some purposes of using Query are mission-critical: down machines, misconfigurations, anything else that might go wrong that they might need to fix. They also need the ability to test out new queries, but don't want to issue test queries to the same place as alert queries, because they might take down a machine. Query's uses include: an alert system; graphical monitoring; issuing incident response queries to figure out where the problem is; looking at historical trends in usage.

For alerts, you can set a priority for each alert: 20% disk space is less urgent than 3%, which is less urgent than completely out of disk space; make sure a machine has a problem for a certain length of time before deciding it's an issue; email only notifications, do more proactive monitoring, and get operators in the NOC to directly go into action. Although most alerts are Akamai alerts, some are for customer monitoring. There are a few hundred machines in the query infrastructure and the system handles tens of thousands of queries every minute, tens of gigabytes turning over completely every two minutes.

How do they address the issue of scale from such a large system when making a query without overloading? They prefetch. Are they polling the system periodically or are the requests random in nature? Some of the uses of Query will be automated, but some of them will be people sitting at a desktop. When a query is made, are they able to tell me how fresh/complete the data is? Yes, there is a table that describes how old the data is. How often do people actually check that data? Depends on the application; if it's a person sitting down and querying the number of machines, it probably hasn't changed much in the past several minutes. But if there are alerts they probably care more about the staleness.

Troubleshooting with Human-readable Automated Reasoning

Alva L. Couch, Tufts University; Mark Burgess, Oslo University College and Cfengine AS

Architecture defines connections between entities, and troubleshooting requires understanding those connections. Human-readable automated reasoning provides a way to recall connections relevant to a problem, and to make and explain new connections via a strange sort of logic. An entity is defined as something someone manages, such as a host, a service, or a class of hosts and services. A relationship is a constraint between entities: for example, a causal relationship involves keywords "determines" and "influences," and a dependence relationship involves "provides" and "requires." An example of the notation is "host01|provides|file service".

It is strange because most attempts at computer logic attempt to translate English into logic and then reason from that, whereas this method translates architectural information into simple English and then reasons from that, without translating the English into logic. The main advantage is speed. The two claims of the paper are that the logic is easy to describe and compute and that the results of inference are human-readable and understandable.

Positive aspects of the system include: uses simple sentences; is very fast; produces a very quick answer.

Negative aspects of the system include: doesn't handle complex sentences; doesn't support complex logic; produces a relatively naive answer, the "shortest explanation."

In the future, they plan to work with field testing, coding in MapReduce for at-scale calculations and applying this to other domains, such as documentation. They welcome people trying out the prototype at http://www.cs.tufts.edu/~couch/topics/ and letting them know how it works, how it could be improved, and what it should really do.

There was only one question: Does it connect with graphviz? Yes, very easily.

Invited Talks I

10,000,000,000 Files Available Anywhere: NFS at Dreamworks

Sean Kamath and Mike Cutler, PDI/Dreamworks

Summarized by Rik Farrow (rik@usenix.org)

Kamath explained that this talk came out of questions about why PDI/Dreamworks, an award-winning animation production company, chose to use NFS for file sharing. PDI/Dreamworks has offices in Redwood City and Glendale, California, and a smaller office in India, all linked by WANs. Solutions like FTP, rcp, and rdist don't work for read/write client access, and at the time NFS use was beginning, sshftp and Webdav didn't exist. And they still don't scale. AFS is not used in serious production and doesn't have the same level of support NFS does.

Their implementation makes extensive use of the automounter and LDAP to fill in variables used by the automounter. The same namespace is used throughout the company, but there are local-only file systems. Their two most important applications are supporting artists' desktops and the rendering farm, which impose different types of loads on their NetApp file servers.

Kamath said that they must use caching servers to prevent file servers from "falling over." They may have hundreds of jobs all accessing some group of files, leading to really hot file servers. For example, some sequence of shots may all access related sets of character data, and the only way to get sufficient NFS IOPS needed is through using caches.

Kamath described their California networks as 1200 desktops, split between RHEL and Windows, renderfarms, 100 file servers, 75% primary and 25% caching, and a 10 GigE core network, including some inter-site connectivity. *Megamind*, the most recently completed movie, required 75 TBs of storage. They have petabytes of active storage, and nearly two petabytes of nearline storage. Active storage is all SAS and Fibre Channel, with nearline composed of SATA.

Kamath went into some detail about how crowd scenes have evolved in digital animation. Earlier, crowd scenes were done by animating small groups of characters, cycling the same set of movements, and repeating these groups many times to provide the illusion of a large crowd of individuals. In *Megamind*, they selected random characters in large crowds and added motion to them, vastly increasing the number of files needed to animate crowd scenes: they went from tens of thousands of files with cycling to millions and millions using random-based character selection.

Kamath summed up by saying that having a global namespace is key, so that users understand where to find things. They leverage the automounter and LDAP, and use local and cross-site caching to keep performance acceptable and reduce migration latency. They work with both developers and artists and keep their architecture flexible.

Doug Hughes of D. E. Shaw Research said that they had a similar problem, but not on the same scale. D. E. Shaw has lots of chemists and data, but they use wildcards with the automounter to point to servers via CNAMEs. Kamath responded that that worked really well for departments and groups, but it is hard to manage load that way. Jay Grisart of Yahoo! wondered if they would use filesystem semantics in the future. Kamath said that they will continue to use NFS, but are looking for alternatives for databases. Someone from Cray asked what configuration management software they use, and Kamath said it is currently a homegrown system. Hugh Brown of UBC wondered if desktops have gotten so powerful that they need caching. Kamath explained that desktops have gotten screaming fast (six core Nehalems, 24 GBs RAM, 1 GigE) and they can do rendering on them at night.

Invited Talks II

Data Structures from the Future: Bloom Filters, Distributed Hash Tables, and More!

Thomas A. Limoncelli, Google, Inc.

Summarized by Tim Nelson (tn@cs.wpi.edu)

A future version of Tom Limoncelli traveled back in time to remind us that we can't manage what we don't understand. In this talk, he introduced some technologies that sysadmins may see in the near future. After a quick intro, he reviewed hash functions (which produce a fixed-size summary of large pieces of data) and caches ("using a small, expensive, fast thing to make a big, cheap, slow thing faster"), then began discussing Bloom filters.

Bloom filters store a little bit of data to eliminate unnecessary work. They hash incoming keys and keep a table of which hashes have been seen before, which means that expensive look-ups for nonexistent records can often be avoided. As is usual for hash-based structures, Bloom filters do not produce false negatives, but can give false positives due to hash collisions. Since collisions degrade the benefit of the Bloom filter, it is important to have a sufficiently large hash size. Each bit added is exponentially more useful than the last, but re-sizing the table means re-hashing each exist-

ing key, which is expensive. Bloom filters are most useful when the data is sparse (hashes tend to be quite large—96, 120, or 160-bit hashes are common) and are commonly used to speed up database look-ups and routing.

Distributed hash tables are useful when data is so large that a hash table to store it may span multiple machines. Limoncelli gave several examples of what we might do with an effectively infinite hash table, such as storing copies of every DVD ever made or of the entire Web. A distributed hash table resembles a tree: there is a root host responsible for directing look-ups to the proper host. If a host is too full, it will split and create child hosts. Since the structure adjusts itself dynamically, the sysadmin does not need to tune it, provided enough hosts are available.

Key-value stores are essentially databases designed for Web applications. While a standard relational database provides ACID (atomicity, consistency, isolation, and durability), a Web application doesn't necessarily need each ACID property all the time. Instead, key-value stores provide BASE: they are Basically Available (it's the Web!), Soft-state (changes may have propagation delay), and Eventually consistent. Bigtable is Google's internal key-value store. Bigtable stores petabytes of data and supports queries beyond simple look-ups. It also allows iteration through records by lexicographic order, which helps in distributing work across multiple servers.

Matthew Barr asked about using memcache as a key-value store. Limoncelli answered that yes, memcache is a (simpler) key-value store using only RAM and is very useful if you don't need a huge amount of storage as Google does. Cory Lueninghoener asked how we should expect to see this stuff coming out. Limoncelli replied that sysadmins should expect to see it in open source packages. Much is already available and may be adopted faster than we expect.

Someone asked about key-value stores with valueless keys, and whether the fact that the key exists is useful information. Limoncelli answered yes, these are used in Bigtable queries and are helpful when sharding queries over multiple machines. Rick Bradshaw (Argonne) asked how complex Bigtable's garbage collection was and whether deleting data was possible. Limoncelli replied that as a sysadmin he doesn't think much about garbage collection, but that he does delete data and can explicitly request garbage collection if necessary.

Practice and Experience Reports

Summarized by Robyn Landers (rblanders@uwaterloo.ca)

Configuration Management for Mac OS X: It's Just UNIX, Right?

Janet Bass and David Pullman, National Institute of Standards and Technology (NIST)

David Pullman started with a quick history of configuration management in the NIST lab. This has been a fairly easy task on traditional UNIX variants with the usual tools such as Cfengine, but not so with older versions of Mac OS, which were mostly hand-maintained. The advent of Mac OS X made it seem as though it should be doable, as the title of the talk indicates. Pressure to ensure compliance with security standards was also a driver.

Pullman outlined their progress towards achieving two goals: getting settings to the OS and managing services. This started with simple steps such as one-time scripts, but these were thwarted by lack of persistence across reboots or per-user applicability, for example. This led them to the investigation of plists, the configuration files for OS X. They supplemented meager documentation available with an assortment of tools, including interesting ones such as Fernlightning's fseventer and Apple's own dscl, as well as OS X utilities such as Workgroup Manager and launchd. Such tools enable detection, examination, and modification of the plists involved in configuring a given service or application. Brief comparisons were drawn with Solaris and Linux service managers.

Some difficulties arising from the inconsistency of parameter values in plists were pointed out. Pullman suggested that perhaps the long lead time before OS X Lion's release gives us an opportunity to influence Apple in this regard. Meanwhile, the approach seems to be successful so far for NIST.

Rick Bradshaw from Argonne National Lab asked whether they started with a custom-built OS image or barebones. Pullman said they don't have enough control at purchase time to inject a custom image.

Lex Holt of the London Research Institute described their environment with about 700 Macs. They use the Casper suite from JAMF for building images, supplemented by their own scripting. Unpredictable arrival of new hardware complicates image building. Pullman's group also looked at Casper, but they prefer to "know where the knobs are" themselves, and sometimes need to act more quickly (e.g., for security issues) than image-based method might allow.

Another audience member asked what version of Cfengine NIST used. They used version 2, but they're talking to Mark Burgess about some enhancements for version 3, and would be happy to share this. Robyn Landers, University of Waterloo, mentioned that they are getting started with DeployStudio and JAMF Composer for image and application management on Macs. Pullman's group had not yet looked at DeployStudio, but they are interested.

Anycast as a Load Balancing Feature

Fernanda Weiden and Peter Frost, Google Switzerland GmbH

Fernanda Weiden began the talk by explaining the motivation for using anycast for failover among load-balanced services: availability, automatic failover, scalability. Amusingly, management buy-in occurred after connectivity to a sales building went out. The combination of anycast and load balancing brought benefits such as simpler routing configuration and elimination of manual intervention for failover. Elevation to desirable service standards was achieved by distributing servers and a load balancer to each site, along with centralized management.

Peter Frost described the implementation. An open source software stack runs on Linux. The Linux-HA Heartbeat mechanism manages NICs and management software (helping avoid the "equal cost multi-path" problem), while ldirectord manages services on the back-end servers. The Linux IPVS kernel module helps with load balancing, and Quagga network-routing software was a key piece for managing service availability, ensuring that peering is always in place while secondaries are kept inactive until needed.

Now that the authors have completed this project, their methodology has proven to be readily extensible to other services, thanks in large part to Quagga's features.

An audience member from Cisco asked how long it takes for the routers to reconverge in case of an outage. If the outage arises from a clean shutdown, it takes less than one second, but in the case of a dirty shutdown (e.g., power failure), it takes 30 seconds. Only one side of the load-balanced pair is active at a time, in order to avoid sharing connection tables.

Rick Bradshaw of Argonne National Lab asked about logging for service monitoring. Indeed, it is logged, and the authors contributed an enhancement to ldirectord code on this. They added the ability for ldirectord to capture the underlying information about events and health check failures rather than merely the fact that such events occurred. This is reported in standard syslog format.

David Nolan of Ariba has been making much use of anycast and wondered about monitoring to verify proper route announcements and propagation. NIST has a small monitoring server at each site, in-band (from the user's point of view), to discover hostnames of the servers. If they don't match with what's expected, it issues an alert.

David Lang of Intuit asked whether the authors considered ClusterIP, given their active/passive arrangement. No, they never needed to consider active/active. They had some concern about security, given the unauthenticated connection between load-balanced servers sharing their data.

Session host Æleen Frisch asked the speakers what's next for them, since their work on this project is finished. Thanks to the extensibility of their system, their colleagues have been successfully adding services such as LDAP, HTTP proxy, and logging into their load-balanced methodology.

Nolan asked about BGP filtering: was there difficulty getting cooperation from network administrators regarding advertising routes? What about the risk of taking over other legitimate IP address spaces not belonging to them? Fortunately, the network people at NIST were friendly and cooperative, and their strict management of routing maps helps ensure safety.

Nolan said that his organization has Windows working very well as back-end anycast servers after a difficult initial setup and wondered about Windows at NIST. All NIST's anycasting is on the load-balancer level, not on the back end. There was no need to worry about difficulty with Windows for configuration of the network stack.

The final question touched on deployment. Did they ship preconfigured servers to their other sites and ask those sites to just trust them and plug them in? No; at first they used a commercial appliance, but the ordinary Linux servers they switched to later were easily configured remotely.

iSCSI SANs Don't Have to Suck

Derek J. Balling, Answers.com

iSCSI SANs typically "suck" because SCSI is very sensitive to latency and Ethernet often has bursts of poor performance, leading to latency. Derek Balling presented his site's experience with servers, iSCSI SAN devices, and the network topology that connects them. The initial approach had various drawbacks that they were able to overcome by careful redesign and reimplementation. Balling showed connection diagrams illustrating before and after connectivity, and transition steps. This helped make the situation more understandable. He also gave some practical advice that should help one carry out any non-trivial project more successfully.

Every server has two network interfaces for ordinary data and two more for the SAN. If a link fails, its redundant link

is activated and the network spanning tree protocol (STP) reconverges to use it. The advantage is that moved to every device has multiple paths with automatic failover to what it needs. Ironically, the concomitant disadvantage is that the time required for STP to converge causes the dreaded latency that iSCSI cannot tolerate well. This was especially noticeable when adding new nodes to the network: virtual machines relying on the SAN would die while waiting for STP to reconverge.

They dodged this by using uplink failure detection in the network equipment to avoid triggering STP. However, the problem repeated whenever rebooting switches, and when adding new switches that don't support uplink failure detection and thus required STP to be enabled. A redesign was thus in order.

The redesign called for a flat network connection topology, with a separate network (rather than merely a separate VLAN) for the SAN. The network administrators were leery of this, so Balling's group had to show how it would work acceptably. Another challenge was the desire to carry out the reorganization live, since the environment was already in production. Thanks to thorough planning and rigorous adherence to the plan during execution, they succeeded in making the transition smoothly. Perhaps unfortunately, it went so well that their management now expects this level of success all the time!

Balling concluded his presentation by emphasizing the rigor of the planning. Everything was drawn out on a whiteboard, and the team verified connection paths at every step in the process. Nothing was rushed; time was given for reconsideration and peer review. Execution was equally rigorous. In the heat of the moment when one might forget why the order of certain steps matters or be tempted to try an apparent shortcut, it's essential to stick precisely to the steps laid out in the plan. System administrators, unlike network administrators, might be less accustomed to such rigor.

In response to Balling's talk, David Nolan of Ariba observed that system administrators and network administrators don't always realize what they can do for each other. How can that deficit be overcome? Balling suggested that simply socializing with one another might help.

Invited Talks I

Operations at Twitter: Scaling Beyond 100 Million Users

John Adams, Twitter

Summarized by Shawn Smith (shawnpsmith@gmail.com)

What's happened at Twitter in the last year: a lot of work on specialized services; made Apache work much more efficiently; moved to Unicorn; changed the handling of Rails requests; and added a lot more servers and load balancers.

Everything in new Twitter is over AJAX; you won't see submit tags in the source. They used logs, metrics, and science to find the weakest points in applications, took corrective action using repeatable processes, and moved on.

Adams said, "We graph everything." They used Mathematica curve fitting to see when they would hit the unsigned integer boundary. He then said, "The sooner you start using configuration management, the less work you'll do in the future, and the fewer mistakes you'll make." About two months into Twitter, they started using configuration management with Puppet. A fair number of outages occurred in the first year caused by human errors. Now something is wrong if someone is logging into a machine to make a change.

They also use Loony, which connects to machine db and ties into LDAP, allowing them to do things en masse across the entire system. With it you are able to invoke mass change. They only run Loony if something has gone extremely wrong, or to find every machine in a cluster that is a mail server that happens to be running Red Hat.

They use Murder, as in a murder of crows. They use Bittorrent for deployment and can deploy to thousands of machines in anywhere from 30 to 60 seconds. They have moved away from syslog, as "syslog doesn't work very well at the loads that we're working at." They use Scribe for HTML logs, and Google analytics on the error page. They modified headers in Ganglia so that everyone knows exactly when the last deploy went out. For every feature you want to deploy at Twitter, it has to be wrapped up in a darkmode or decider flag with values from 0 to 10,000, 10k representing 100% deploy. Rails runs the front end of Twitter, and the back end is Scala Peep, which allows you to dump core on a memcache process. They like Thrift because it's simple and cross-language. Gizzard allows them to shard across hundreds of hosts and thousands of tables, distributing data for single and multiple users. Adams recommends mounting with atime disabled, as "mounting a database with atime enabled is a death sentence."

What steps did they take to go from unscalable to where you are now? They looked at data metrics; get metrics on everything. Are Scribe Hadoop patches available? Yes, on github. Do they have good management support to allow them to work on projects like these? The DevOps movement is about getting cultural changes in place for the better and, yes, management has been supportive. What have they done that is an acceptable failure? How many Web servers can they afford

to lose? If they lost *n*% of our servers,they wouldn't want to alert. They need very fast timeouts. Can they comment on Scala? Scala is a Java-like language that runs inside of the JVM, so the scaling constraints are known; there are a number of things inside Scala that are designed for concurrency that our developers wanted to take advantage of. Twitter has a fondness for oddball functional languages; it has some Scala and some Haskell floating around.

Invited Talks II

Er, What? Requirements, Specifications, and Reality: Distilling Truth from Friction

Cat Okita

Summarized by Scott Murphy (scott.murphy@arrow-eye.com)

This was a humorous yet informative overview of why we need requirements and specifications. Cat opened with the rather blunt question, "Why do we bother with these things?" After all, this is all paperwork and paperwork sucks and this is what nontechnical people do and then inflict on us. This set the context for the talk, moving from theory to practice to reality.

Beginning with theory, Cat displayed a neat little slide showing the "Quick'n'Dirty" overview:

Goals—Why are you doing this?

Requirements—What means that you've met the goals?

Specifications—How do you meet the requirements?

Implementation—Perform the task as per the specifications.

Review—Does the work match the requirements/solve the problem/meet the goal?

Completion—You are done.

Cat continued with a more detailed discussion of the above points, starting with goals. The point of defining the goal is to determine why you are doing something, what you are trying to do and/or what problem(s) you are trying to solve. What makes a good goal? Several examples were given, showing that this can be a very nebulous item. Requirements were next: what meets the goal(s), what is success, what are the limitations, who is involved, and how can you tell that you are done? More examples and discussion followed, again showing that this can be a slippery area. Next up were specifications, getting a little more to the part techies prefer. This part defines how we are to meet the requirements and should be detailed, specific, and prescriptive. Implementation follows specifications and covers the "getting it done"—do stuff, build, test, deploy. Then it's review time. Did we hit our goal, did we meet the requirements, did we follow the specifications? If we can answer that in the affirmative, then we have arrived at completion. The visual is a slide showing a sandy beach and a pair of lounge chairs.

Cat then talked about best practices for requirements and specifications, boiling the whole concept down to getting the most bang for your buck. In order to influence goals, requirements, and specifications, you need to participate in the initial planning meetings where these items are discussed. By participating, you get to influence the project. A project goes much more smoothly if everyone is on the same page, so an air of cooperation and communication is necessary. Document everything, preferably a living document that captures choices, decisions, and reasons why things do not meet initial requirements. It is important to have a common set of definitions and understanding of the goal. Using overloaded jargon or unclear requirements will result in nobody knowing what to do or how to do it. The goal should be appropriate (slide of a fish on a bicycle) and it should be kept short. When defining goals, ask people for input, don't tell them, as that removes a potential information vector. Once all of this has taken place, you need to agree on the goals. This will keep surprises to a minimum—ideally, to none. In summary, a goal should be one or two short sentences that anybody can understand.

Once the goals have been identified, some housekeeping is in order. You need to clarify the goals, define your audience, specify conditions for success, and set limits to the scope. Clarifying the goals will bring focus to the project, turning the goals into something useful and describing what will meet the goals. Defining the audience will identify who actually cares (or should), who needs to be involved and who the project is for. Specifying the conditions for success serves a double purpose: first, to let you know that you have met the goal, and, second, to provide conditions for completion, as both are not necessarily the same. Limits are also a very important item to specify. We want to keep a rein on scope creep, people involved, external items, money, and time. Projects tend to expand without bounds if you do not have limits specified up front. A goal should also be realistic, relevant, measurable, and unambiguous. This brings us to "How do we meet goals?" In order to meet goals, we need to meet the requirements, stay within the project limits, and have details to measure. An example of specific requirements would be "Use Apache 2.x with Tomcat to serve dynamic Web content" vs. "Use a Web server." Requirements should be appropriate, such as describing a Web platform to be a standard readily available system vs. a Cray. They need to be sane. Turning a jury-rigged proof-of-concept into your production platform is only asking for trouble (slide of the original Google setup—scary).

Where do requirements come from? The answer is the project initiators, interested parties, and potential customers. Cat illustrated with an example—"Build a Death Star" followed up with the requirement that it be made from pumpkins. Some discussion occurred at this point, but in the end, only pumpkins were available. A follow-up slide showed a jack-o'-lantern carved as a Death Star replica. This was identified as having a missing component, as it would not be visible at night, leading to the requirement for lights. It was then determined that there is no room for lights inside, so it must be hollowed out prior to installing lights. This leads to the specification to use a spoon to hollow it out. The spoon is identified as the wrong tool. A sharpened spoon is specified next and the pumpkin is successfully hollowed out, the lights are installed and we end up with a Death Star made from a pumpkin that can be illuminated. The goal is met.

At this point, Cat introduced reality to the mix. In most projects, you end up with some choices to make—you can build, buy, or borrow to meet goals. You will probably use a combination of all of them and more. In the real world, communication is very important to the success of a project. If you are not communicating, you lose sight of the goals. Scope creep can intrude, resulting in goals not being met, cost overruns, the wrong people getting involved, etc. Documentation is your friend here. If you can't say "No," document the new requirement. Cat mentioned a "Ask Mom/Ask Dad" concept that can happen during a project—ask a group how things are going and, not liking the answer from one person, ask the next person. This can be fought with a single point of contact. Politics comes into play as well. I'm ignoring you is a political game—you didn't format your request properly, I don't have the resources to handle that right now, etc. Sometimes this can be handled with a discussion, sometimes by kicking it upstairs. Projects also suffer from a level of confusion. If fuzzy language is utilized, clarification is necessary. Words mean different things to different people. Context is important and so is culture. Cat referred to this as craft knowledge and craft-specific language. People involved can be out of touch with reality—10ms round trip time between San Francisco and New York as a requirement. Physics may make this difficult. We get hit with solutions looking for a problem and we can experience consternation brought on by bad assumptions, missing limits, and adding more people to a late project. You can also be hit with "death from above," where things will take on a "new direction," and "It will be completed by next Tuesday." All you can do is get clarification, modify requirements, ignore some requirements, and document everything.

Cat presented a couple of additional examples of projects to illustrate the points presented above. We should also be aware of odd requirements in RFPs (requests for proposals). The idea of the RFP is to solicit proposals that meet established criteria. Specifications as to Blue M&Ms or RFC1149/RFC2549 are occasionally added to ensure that the proposal meets established criteria and that the RFP has been read and understood, sort of a checksum for details.

Someone asked how to define goals and requirements for a project. How do you do it? Cat suggested starting with the Why (goal) and someone who cares about the project, the person who will be driving it. This person will have to come up with a couple of things to at least get people talking about the project. Who do I think I need to involve? This is usually straightforward. You take the people and start the discussion (even if it's wrong), and you get, "We can't do this," signifying a limit; "It must," identifying a requirement; "It should," identifying a nice to have. Now we have a requirements list, so go back and forth between people to clarify requirements. Ask them about their part rather than tell them what they have to do. The person who cares has been documenting, right? Once this is finished, it's time to horse trade (budget). What do we give up? How do we balance out resources? You stop when you get to the point where you are quibbling over vi vs. Emacs; the requirement is that we have a text editor.

Another person commented that the people who seem to have the easiest time learning to do this are ex-military, possibly because this is like an operational briefing: Why are we doing this? Why are we going to this place? What are we going to do there? What are we allowed to do when we are there? What equipment do we have? What is our exit plan if things go bad? How do we declare we have had a successful mission?

Steven Levine, of Red Hat, said that he is not a system administrator but a tech writer. In discussing how you know if you have met your goals, people responded with interesting things about how the goals shift. In his work it's more an issue of compromising the goals. Every day he makes one compromise. It's not that goals shift, they get compromised. Does this apply to system administration as well? I would think this would be more black and white. Cat replied that this applies to absolutely everybody. Levine asked, "How do you keep from feeling that each compromise 'eats at your soul'? How can you sleep well at night?" Cat said that one of the things that always bothers her about that is when it's not clear that you have been compromising. When people look at it and say we didn't end up quite where we wanted to and stuff went somewhere. We don't know why and we don't care why vs. we made a clear decision about this. We've said unfortunately the trade-offs are all here. We are going to have to make a trade-off. Let's go back and say, "You know those goals we had or those requirements we had? We have to change them because we have these limits that we have run

into." I may not have been as clear as I meant to be that a lot of this does end up being an iterative process, so you go through your requirements and say, "Hang on a second. With these requirements, there is no way that we can match that goal." Say I have a budget of $100,000, can I build a death star? I can meet some of the requirements. Can I build it in outer space? Probably not. I'm not going to argue that it's not frustrating,

John Detke from PDI Dreamworks said, "As sysadmins, we do a lot of research as we are not really sure what we are going to do so we develop specifications which change as we discover limitations. At what point do you go back and change the specs or the goals? Are there guidelines for how to do that without going crazy?" Cat asked, "How spectacular is your failure? If we can't do this at all, you probably want to go back and ask if the goal is realistic. If this happens at the requirement/specification phase, I like to say this is a requirement I absolutely have to have. If we can't do this, we stop the project until we can figure out how to do it. Being able to say here are my blocking/stopping points makes it easier to identify where we have to stop and consider what we have to do. Typically, it becomes a judgment call as to major or minor problem."

Someone asked what her favorite tool was for capturing/manipulating all this stuff. Cat said that she's a Mac user and likes Omni-Outliner. In a corporate environment, you may be required to use Word, MS Project, Visio, etc. She's even used vi to outline, so it's whatever you are comfortable with. Pick your poison.

Invited Talk

Using Influence to Understand Complex Systems

Adam J. Oliner, Stanford University

No report is available for this talk.

Invited Talk 1

Scalable, Good, Cheap: Get Your Infrastructure Started Right

Avleen Vig, Patrick Carlisle, and Marc Cluet, woome.com

Summarized by Misha Zynovyev (zynovyev@stud.uni-heidelberg.de)

This talk focused on important issues IT start-ups face in infrastructure design in their first 6 to 12 months. Avleen Vig of Etsy started by emphasizing the importance of setting up a workflow process. He argued that a long ticket queue which feels like eternity to process is better than to forget even a single thing. He also explained how much it pays off to put every aspect of operations code into a version control system and automate as much as possible. The importance of hiring the right people and establishing active communication within the team was also mentioned.

The first rule of making your infrastructure scalable, according to Vig, is to separate all systems from each other and layer them. He declared himself a proponent of the DevOps movement and advocated fast and furious release management. MTTR (mean time to recovery) was compared to MTBF (mean time between failures) as time to assemble a Jeep vs. time to assemble a Rolls-Royce. Infrastructure needs to have the shortest possible MTTR. Data-mining of all logs is very important, as well as graphing all dynamic monitoring information. Besides monitoring everything which has broken at least once, one has to monitor all customer-facing services. Vig also said from experience how crucial it was to monitor the fastest database queries in addition to slow ones. A very high frequency of fast queries can have a stronger impact on performance than occasional slow database queries. It was advised not to rely too much on the caching layer in the database architecture. Cache must be disposable and rebuildable. The back-end database has to be ready to withstand the load if the cache is gone. The Northeast Blackout of 2003 was given as an example of a cascading failure.

Marc Cluet of WooMe took the floor to talk about database scaling. One of the first questions sysadmins face is whether to use relational or NoSQL databases. At WooMe both types are used. The stress was put on how dangerous it is to let databases grow organically. After warning about handling many-to-many tables, the speaker admitted that mistakes in database design are inevitable, but one has to be prepared for them. Adding many indexes is not a path to salvation, since one pays in memory for being fast. Although not all data can be partitioned, partitioning becomes necessary with database growth. At WooMe, data is partitioned by date. Disk I/O is, of course, the thing to be avoided. Hardware load balancers are too expensive for start-ups and there are plenty of software solutions for load balancing. But none of them will give some of the advantages of reverse proxies that are particularly useful for more static data. At WooMe they use Nginx.

At the end Marc Cluet explained the benefits of dividing Web clusters, how it adds more flexibility to maintenance, and how problems can be contained to a fraction of resources. He then proceeded to stress the importance of automation, adoption of configuration management tools, and version control systems, just as Avleen Vig had done before him. At WooMe they use Puppet and Mercurial. The talk was finished by mentioning clouds, which are used by WooMe for backups and potentially could be used for further scaling.

Jay Faulkner from Rackspace asked about the size to which WooMe and Etsy have scaled. WooMe's infrastructure scaled from 10 to 100 servers in two years; Etsy has 6 million active users. Doug Hughes of D. E. Shaw Research commented on the SQL vs. NoSQL debate, and that according to experts it is more appropriate to compare transactional and nontransactional databases, leaving the SQL language out of it. For Avleen Vig it matters what tools are the best for the job and how to support what the business requires. Duncan Hutty of Carnegie Mellon University asked how to distinguish premature from timely optimization, since Avleen Vig pointed out at the beginning of the talk that technical debt is not necessarily that bad and can be more appropriate than premature optimization. Vig answered that one has to estimate how long one's work will be in place, if it is going to disappear shortly. If it stays for a longer time it can be beneficial to spend a bit more time for optimization.

Reliability at Massive Scale: Lessons Learned at Facebook

Robert Johnson, Director of Engineering, Facebook, Inc.; Sanjeev Kumar, Engineering Manager, Facebook, Inc.

Summarized by Matthew Sacks (matthew@matthewsacks.com)

On September 23, 2010, the Facebook Web site was down for about 2.5 hours due to an error introduced in an automated feedback mechanism to keep caches and the Facebook databases in sync. Facebook's Robert Johnson and Sanjeev Kumar presented the lessons learned about designing reliable systems at a massive scale. Facebook currently serves about the same amount of Web traffic as Google. Johnson and Kumar decided to present their findings to the technical community at LISA as a learning experience, which was quite commendable for a company of this stature. It turns out that a feedback loop designed to prevent errors between the cache and the database was triggered; however, invalid data was in the database, so the data integrity logic went into an infinite loop, making it impossible to recover on its own. Ultimately, the site had to be taken down in order to correct the data corruption problem.

Most public technical presentations focus on what was done right, rather than lessons learned from what was done wrong. By reviewing what happened, a lot of progress can be made to firm up these systems and ensure that these problems do not happen again. Johnson said, "We focus on learning when things go wrong, not on blaming people." At Facebook, Johnson explained, when the blame is taken away, the engineering team is much more engaged on what can be improved so that these problems do not happen in the future.

Closing Session

Look! Up in the Sky! It's a Bird! It's a Plane! It's a Sysadmin!

David N. Blank-Edelman, Northeastern University CCIS

Summarized by Rudi van Drunen (rudi-usenix@xlexit.com)

David Blank-Edelman compared the modern-day sysadmin with the superheroes who live in comic books. In this very humorous presentation, David started off with a discussion of the superpowers the comic heroes have and how they map to the tool set of the modern-day system administrator. Also, the day-to-day life of a superhero was compared to the day-to-day life of the sysadmin, including the way to nurture the superpowers by means of mentoring. Important things were discussed such as how to use one's superpowers and super tools to do good, with strict ethics, very much as we sysadmins do.

The presentation was filled with snippets from comic books, movies, and soundbites, and concluded with some hard scientific evidence. This presentation was best experienced, and watching the video on the LISA '10 Web site is encouraged.

Workshop Reports

Workshop 1: Government and Military System Administration

Summarized by Andrew Seely (seelya@saic.com)

The Government and Military System Administration Workshop was attended by representatives from the Department of Defense, Department of Energy, NASA, Department of Commerce, Nebraska Army National Guard, Raytheon, the Norwegian government, Science Applications International Corporation, and the USENIX Board. This was the third year the GOV/MIL workshop has been held at LISA.

The GOV/MIL workshop createxs a forum to discuss common challenges, problems, solutions, and information unique to the government sector, where participants may be able to gain and share insight into the broad range of system administration requirements that arise from a government perspective. The GOV/MIL workshop is an opportunity for diverse government, military, and international organizations to come together in a unique forum; it's not common to have highly technical staff from .mil, .gov, .com, and non-US agencies at the same table to candidly discuss everything from large data sets to organizational complexity to staffing and educational challenges. All expected to find similarities and hoped to be exposed to new ideas, and for the third year no one went away disappointed.

The day started with roundtable introductions and a reminder that the environment was not appropriate for classified or sensitive topics. For system administrators outside the government sector this could seem like an unusual caveat, but for people who work in classified environments it is always a safe reminder to state what the appropriate level of discussion is for any new situation. The group agreed that the day would be strictly UNCLASSIFIED and that no For Official Use Only or higher material would be discussed.

The day was loosely divided between technical and organizational topics. Technical topics discussed included configuration management, technical challenges in classified environments, impact of the Sun/Oracle merger, cloud computing, and disaster recovery. Organizational and policy hot topics centered on technology considerations for foreign travel, rapidly changing information assurance policies, VIP users, and unfunded mandates from external agencies.

All attendees presented what types of personnel their respective sites or companies are seeking to hire, including discussions of what types of education and training are currently desired. Several had positions to fill, and almost all of them required security clearances. Hiring information and career Web sites were shared.

Our final effort was to respond to a challenge from the USENIX Board. AlvaCouch said that USENIX is highly motivated to reach out to the GOV/MIL community but that they have found themselves unable to find the right way in. The GOV/MIL workshop conducted a round-robin brainstorm session and produced a list of ten recommendations for Alva to take back to the Board for consideration.

The final topic of discussion was to determine if there would be sufficient interest in this workshop to repeat it at LISA 2011. It was agreed that it was a valuable experience for all attendees and that all would support a follow-on workshop. The LISA GOV/MIL wiki is at http://gov-mil.sonador.com/. Please contact Andy Seely at govmil@sonador.com for more information about the growing USENIX GOV/MIL community of practice and to help shape the agenda for GOV/MIL 2011.

Workshop 6: Advanced Topics

Summarized by Josh Simon (jss@clock.org)

Tuesday's sessions began with the Advanced Topics Workshop; once again, Adam Moskowitz was our host, moderator, and referee. We started with our usual administrative announcements and an overview of the moderation software for the new folks. Then we went around the room and introduced ourselves. In representation, businesses (including consultants) outnumbered universities by about 4 to 1 (up from 2 to 1); over the course of the day, the room included seven LISA program chairs (past, present, and future, up from six last year) and seven past or present members of the USENIX, SAGE, or LOPSA Boards (down from nine last year).

Like last year, our first topic was cloud computing. The consensus seemed to be that there's still no single definition for the topic. Most of the technical people present perceived "cloud" to mean "virtualization" (of servers and services), but for nontechnical or management it seems to mean "somewhere else," as in "not my problem." Regardless of the definition, there are some areas that cloud computing is good for and some it isn't. For example, despite pressure to put everything in the cloud, one company used latency requirements for NFS across the Internet to identify that something couldn't work as a cloud service. They can then escalate up the management stack to re-architect their applications to get away from the "it's always been done that way" mindset.

Some environments are using "cloud" as an excuse to not identify requirements. However, even with environment-specific cloud services, providing self-service access (as in, "I need a machine with this kind of configuration") and not having to wait weeks or months for the IT organization to fulfill that is a big win. IT organizations are often viewed as onerous (or obstructionist), so going to the cloud allows the customers to get around those obstructions. One member noted that the concept of cloud as virtualized servers and services isn't new—look at Amazon and Google for examples—and yet research is saying "it's all new." In academia, the cloud is "good for funding." (Even virtualization isn't new; this was done on mainframes ages ago.)

That segued to a discussion about how to implement this. We need to consider the security aspect: what's the impact of sending your stuff somewhere else, what are the security models and controls, is old data wiped when you build new machines, is the data encrypted across the Net, and so on. There's also the management assumption that services can be moved to the cloud with no expense, no new hardware, no new software, no downtime, and no problems. One tongue-in-cheek suggestion was to relabel and rename your hardware as cloud001, cloud002, and so on. Management needs to be reminded that "something for nothing" isn't true, since you need to pay for infrastructure, bandwidth, staffing, and so on. "Cloud" may save budget on one line item but may increase it on others.

After our morning break, we resumed with a quick poll on smartphone use. Among the 31 people in the room, the break-

down was Android 11, Blackberry 2, dumb 5, iPhone 8, Palm 3, Symbian 1, no phone 1.

Next we did a lightning round of favorite new-to-you tools this past year. The answers this year ranged from hardware (Android, hammers, iPad, and Kindle) to software (certain Firefox add-ons, Ganetti, Hudson, Papers, Puppet, R, Splunk, and WordPress) to file systems (HadoopFS, SANs, sshfs, and ZFS on FreeBSD), to services (EC2), as well as techniques (saving command history from everywhere).

Our next major discussion topic was careers in general: jobs, interviewing, and hiring. One hiring manager noted that they had a lot of trouble finding qualified people for a high-performance computing sysadmin position. Many agreed it's common to get unqualified applicants and to get few women and minorities. Even with qualified applicants (such as senior people for a senior position), it's problematic finding the right fit. Another hiring manager noted they're seeing more qualified applicants now, which is an improvement from 3 to 4 years ago.

This led to a discussion of gender balance in the field, and sexism in general. The "you need a tougher skin" feedback seems common out in the world, but one participant noted that saying that would be grounds for termination at his employer. Another person hires undergrads at his university to train them as sysadmins, but in nine years has had only two female applicants. Part of the problem is the (American) cultural bias that tends to keep women out of science and technology because "girls don't do that."

One question is whether the problem is finding people or recruiting people who later turn out to be a poor fit. The discussion on interviewing had a couple of interesting tips. If a candidate botches an interview, closing the interview instead of continuing is a courtesy. Not everyone treats "assertive behavior" as indicative of "passion," so watching your communication style is important. Over-assertiveness can be addressed by interpersonal training, and supervisor training to be able to pull someone back is a good idea.

We segued into the fact that senior people need to have an option other than "become a bad manager" for promotions. Most of us in the room have either been or are managers. Several of us see the problem as being that the technical track has a finite limit and a ceiling; one company has a "senior architect" position that's the technical equivalent of VP. Some think the two-track, technical or management, model is a fallacy; you tend to deal with more politics as you get more senior, regardless of whether you're technical or management.

Next we discussed automation and DevOps. There's a lot of automation in some environments, both of sysadmin tasks and network tasks, but it's all focused on servers or systems, not on services. Many places have some degree of automation for system builds (desktops if not also servers) and many have some degree of automation for monitoring, with escalations if alerts aren't acknowledged in a timely manner. There's a lot of automated configuration management in general; a quick poll showed that 22 of 30 of us think we've made progress with configuration management in the past five years. At Sunday's Configuration Management Workshop, we seemed to have the technical piece mostly solved but now we're fighting the political value. Many people work in siloed environments which makes automating service creation across teams (such as systems, networks, and databases) difficult.

One participant noted that many sysadmins have a sense of ownership of their own home-grown tool, which can work against adopting open-source tools. With the move towards common tools—at the Configuration Management Workshop, 70% of people had deployed tools that weren't home-grown—you can start generalizing and have more open source than customization. But capacity planning is hard with the sprawling environment; you need to have rules to automate when to look for more servers. It was also pointed out that automation can mean not just "build server" but also "deploy and configure database and application."

We have seen DevOps skyrocket over the past couple of years; finally sysadmin is getting some recognition from developers that these problems are in fact problems. We may be able to steal their tools to help manage it. As sysadmins we need to lose our personal relationships with our servers. We should be writing tools that are glue not the tools themselves. Moving towards a self-service model (as in the cloud discussion above) is an improvement.

Sysadmins often write software but aren't developers; the software may not be portable or may solve a symptom but not the cause, and so on. Also, many good sysadmins can't write a large solution. There's been a long-standing stand-off between sysadmins and application developers. It's coming to the point where the application developers aren't getting their requirements met by the sysadmins, so the sysadmins need to come up with a better way for managing the application space. The existence of DevOps recognizes how the industry has changed. It used to be that developers wrote shrink-wrapped code that sysadmins would install later. Now we're working together.

One person noted that DevOps is almost ITIL-light. We're seeing ITIL all over; it's mostly sensible, though sometimes

it's process for the sake of process. That segues into a big problem of automation—people don't know what they actually do (as a sysadmin, as purchasing, as hardware deployment, software deployment, and sometimes even the end user); arguably that's a social problem, but it needs to be solved. Beyond that, DevOps is another way of fancy configuration management.

It was noted that DevOps is as well-defined as "cloud." Several people distinguish between system administration ("provide a platform") and application administration ("the layer on that platform is working"). We ended with a sanity check; most of us think, in the general case, that a hypothetical tool could exist that could be complete without requiring wetware intervention.

After our lunch break, we had a discussion on file systems and storage. The discussion included a reminder that RAID5 isn't good enough for terabyte-sized disks, since there's a statistical probability that two disks will fail, and the probability of the second disk failing before the first one's finished rebuilding approaches unity. RAID5 is therefore appropriate only in cases of mirrored servers or smaller disks that rebuild quickly, not for large file systems. We also noted that DropBox (among others) is winding up on the machines of Important People (such as vice presidents and deans) without the IT staff knowing: it's ubiquitous, sharing is trivial, and so on. It's good for collaboration across departments or universities, but making the users aware of the risks is about all we can do. Consensus is that it's good for casual sharing; several recommended preemptive policies to ensure that users understand the risks. In writing those policies, consider communications from the source to the target and all places between them, and consider the aspects of discovery (in the legal sense), and whether the data has regulatory requirements for storage and transmission (such as financials, health, student records). Depending on your environment, much of the risk analysis and policy creation may need to be driven by another organization (risk management, compliance, legal, or security), not IT.

Our next discussion was a lightning round about what surprises happened at work this year. Answers included coworkers at a new job being intelligent, knowledgeable, and understanding of best practices; how much the work environment, not the technical aspects, matter; IPv6 deployment and the lack of adoption (only six people use IPv6 at all and only three of them have it near production); moving from Solaris to Linux because the latter is more stable; moving from sysadmin into development; new office uses evaporative cooling and it works; Oracle buying Sun and the death of OpenSolaris; organizational changes; project cancellations; and virtualization allowing security to push services into the DMZ faster than expected.

After the afternoon break, we resumed with a discussion on security. Most think the state of the art in security hasn't changed in the past year. There have been no major incidents, but the release of Firesheep, the Firefox extension to sniff cookies and sidejack connections, is likely to change that. (This ignores the "Why are you using Facebook during the workday or in my classroom" question.) Cross-site scripting is still a problem. Only one person is using NoScript, and only a few people are using some kind of proxies (e.g., SOCKS). Most people use Facebook, but nobody present uses Facebook Applications; however, the workshop attendees are self-selected security-savvy people. We also noted that parents of young kids have other security problems, and some people don't want to remember One More Password.

Our next topic was on the profession of system administration. We have some well-known voices in the industry represented at the ATW and we asked what they think about the profession. The threats to sysadmins tend to fall into three categories: health, since we've got mostly sedentary jobs and many of us are out of shape; the industry, where there's enough of a knowledge deficit that the government has to step in; and the profession, as sysadmins don't seem to have a lot of credibility. Sysadmins don't have a PR department or someone from whom the *New York Times* can get a quote. Outsourcing was identified as a problem, since they tend to have an overreliance on recipes, playbooks, and scripted responses; this is the best way to head towards mediocrity. It removes critical thinking from the picture and leads to "cargo cult" computing at the institutional level. Junior administrators aren't moving up to the next level. Sysadmin as a profession is past the profitable cool initial phase and into a commodity job: it's not new and exciting; and being bored is one of the key aspects. Furthermore, it's not just about the technology, but also about the people (soft) skills: communication and collaboration are tricky and messy but still essential.

It was noted that as a profession we've tried to move away from the sysadmin-as-hero model. Our services are taken for granted and we're only noticed when things go wrong. This seems to be something of a compliment: train engineers used to be badasses because they were what sat between passengers and death, and computing around the year 2000 was like that. That's no longer true; where are the engineers now? ("Rebooting the train" was one wag's response.) Some believe that as individuals we have more power now, but he believes the reason is because what we do can affect so much more of the business than it used to: IT is more fundamental to the business. Siloing is a characteristic of big organizations.

To get very big you have to shove people into pigeonholes. Others believe that, in part because of siloing and regulatory requirements, we have less power as individuals, since the power is distributed across multiple groups and never the twain shall meet.

Technology is constantly changing, so the challenges we face today are different from those we faced five years ago. As a result we recommend hiring for critical thinking skills. Sysadmins used to be the gatekeepers to technology, but so much is self-service at the end users', that's no longer true. We provide a service that our users consume.

We ended the workshop with a quick poll about what's new on our plates in the coming year. Answers included automating production server builds; dealing with the latest buzzwords; diagnosing cloud bits; handling new corporate overlords; improving both people and project management skills; insourcing previously outsourced services such as email, networking, printing, and telecommunications; managing attrition (a 35% retirement rate in one group alone); moving away from local accounts and allowing the central organization to manage them; outsourcing level-1 help desks; simplifying and unifying the environment; training coworkers; and writing software to manage tens to thousands of applications.

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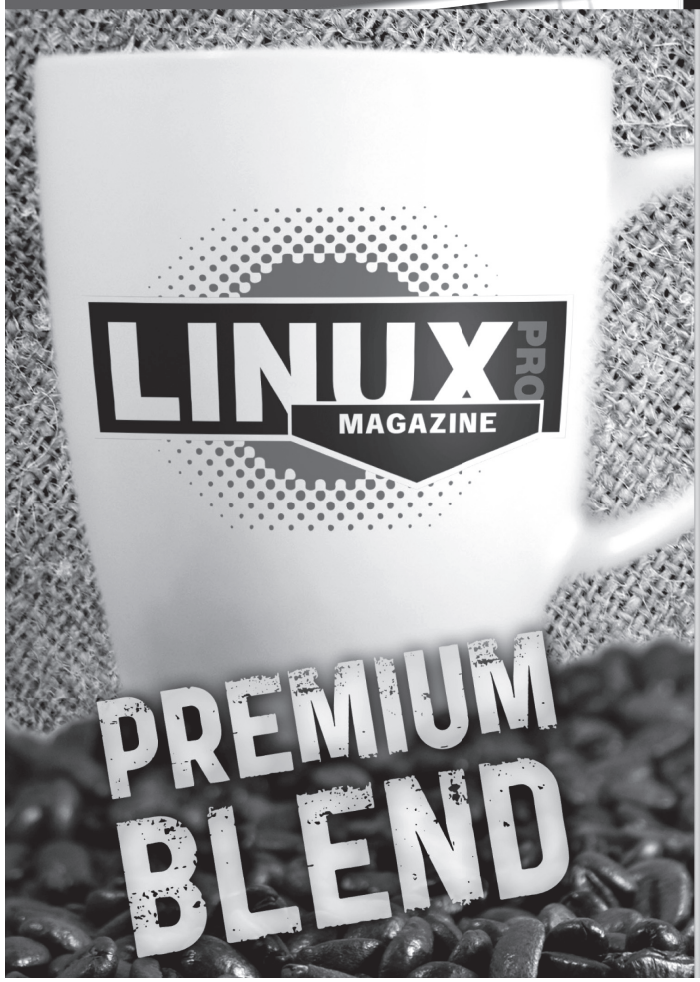

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