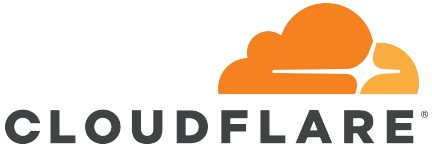


SRECON ASIA AUSTRALIA

Call to ARMs:

adopting an arm64 server into x86 infrastructure

Ignat Korchagin

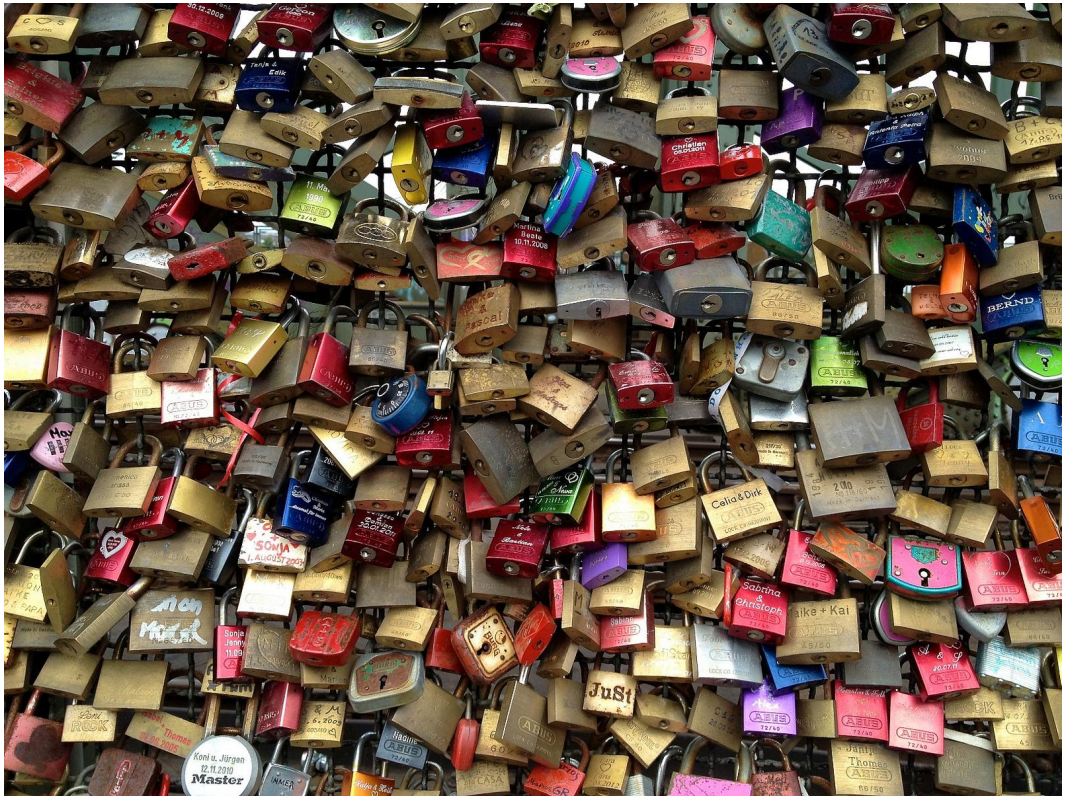
@secumod

$ whoami

- Platform engineer at Cloudflare
- Passionate about security and crypto
- Enjoy low level programming

Why?

Vendor lock-in



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Save the power

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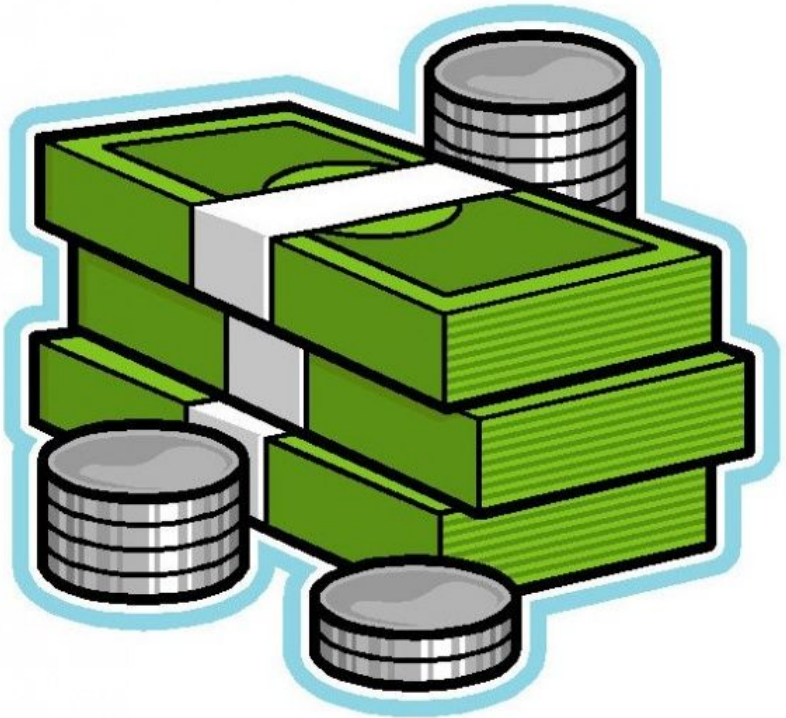
Cut equipment costs



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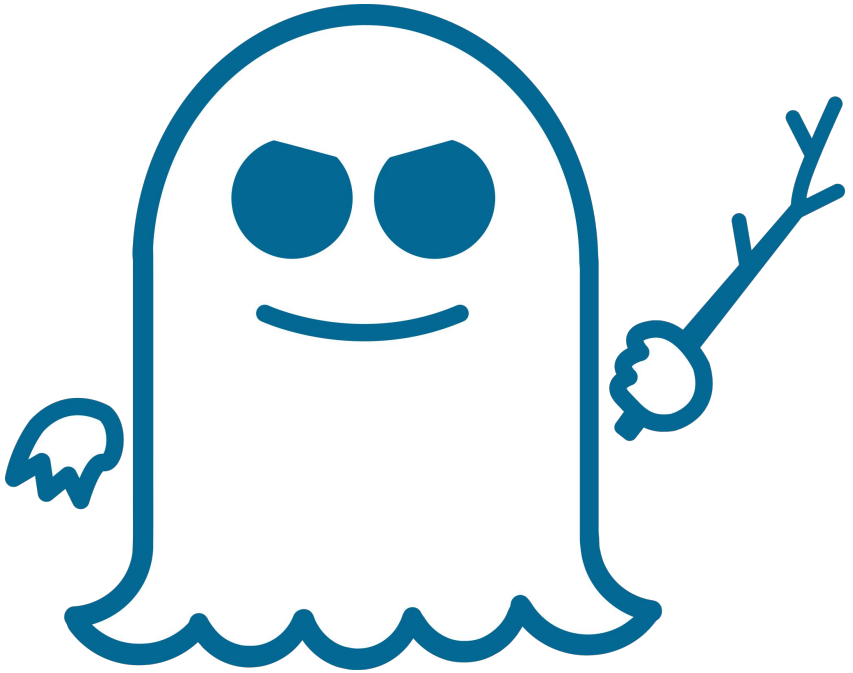
Security



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Why ARM64?

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- performs well in the mobile/IoT space

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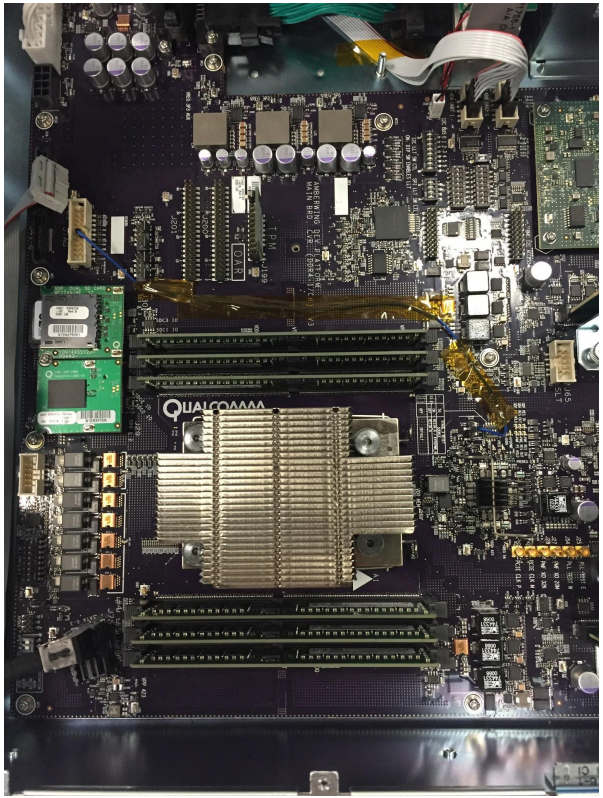
Why ARM64?

- performs well in the mobile/IoT space
- potentially more power-efficient
- huge developer community
- first class support in Linux
- established tools
- > 32 bits
- mitigates the RISC ;)

Initial benchmarks

So you have an ARM64 server

- Falkor core
- 46 cores
- 2.5 GHz
- Thermal design power 120W
  - compared to 170W Skylake



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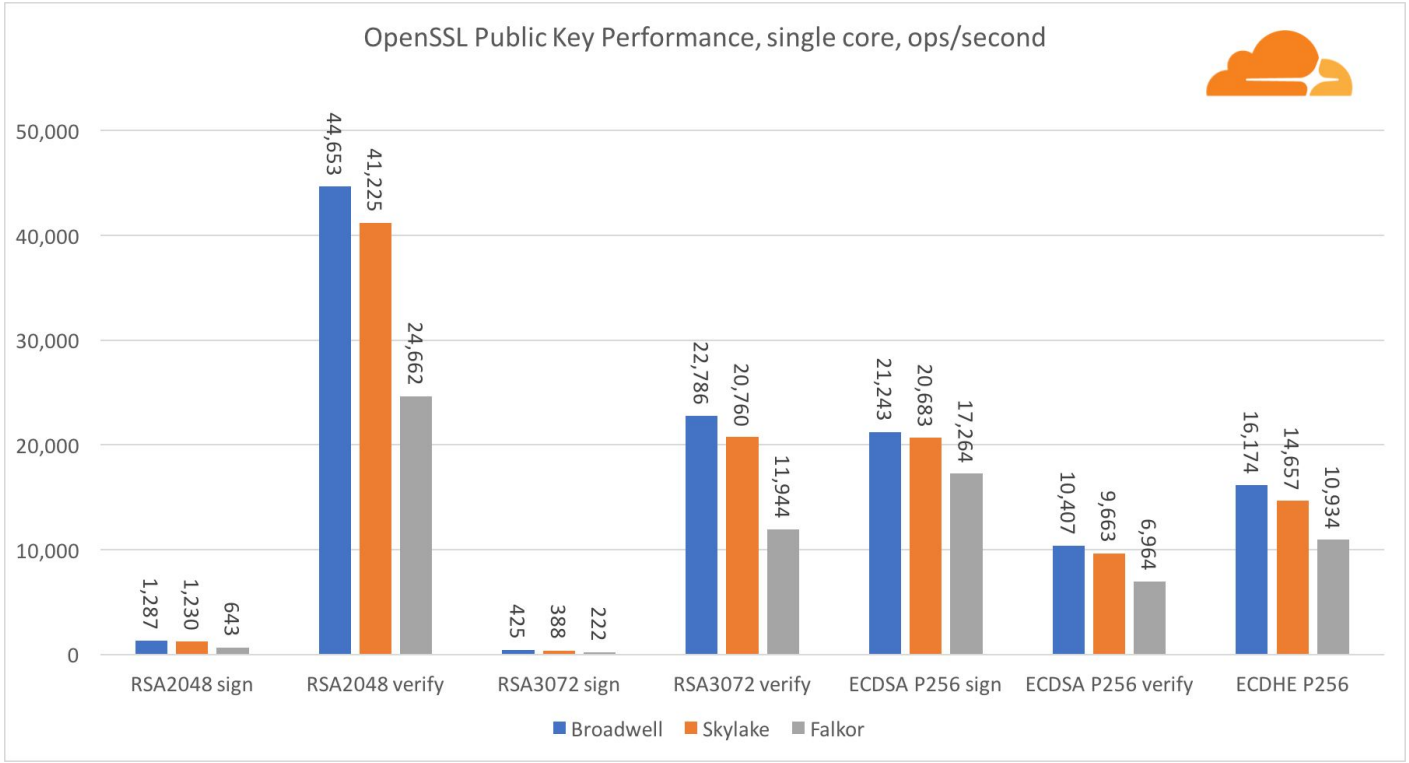
Public key cryptography (single core)



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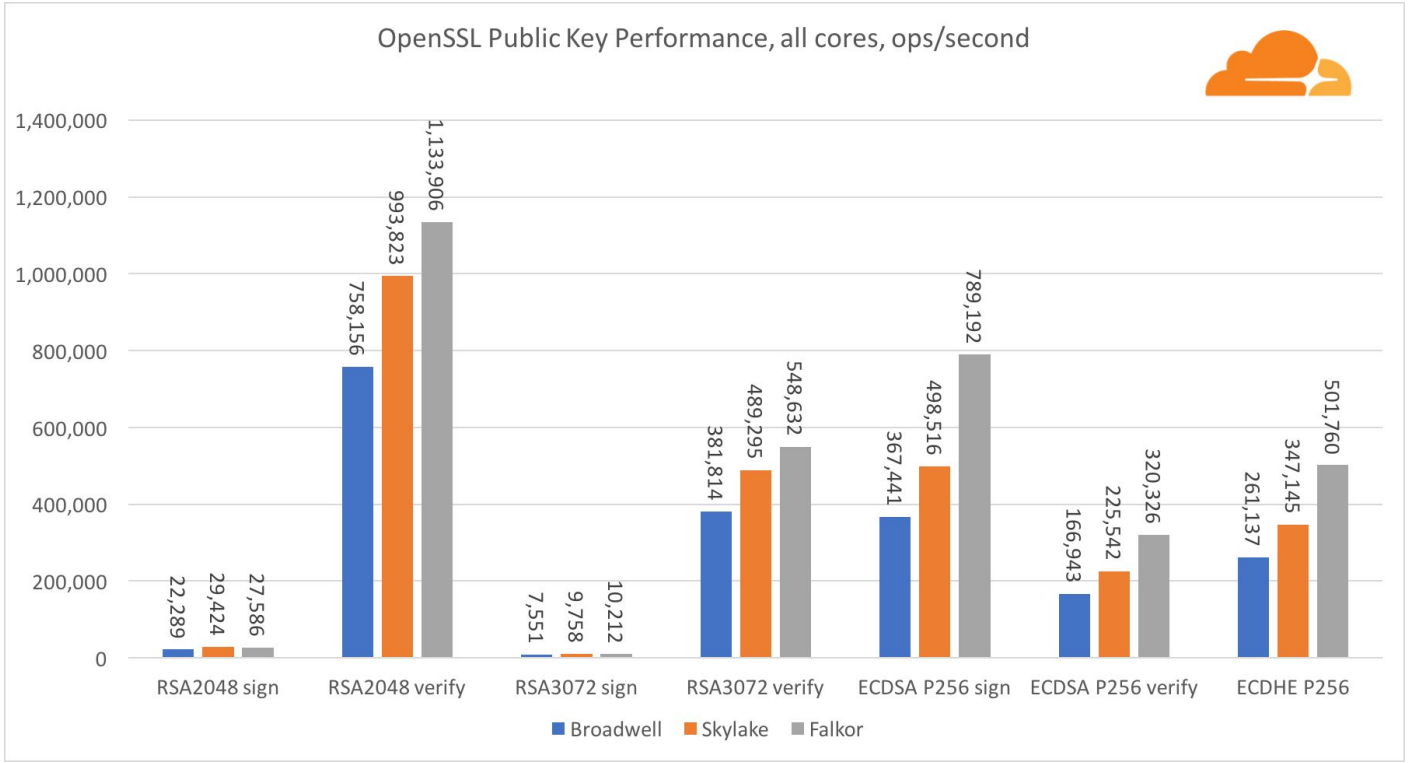
Public key cryptography (all cores)



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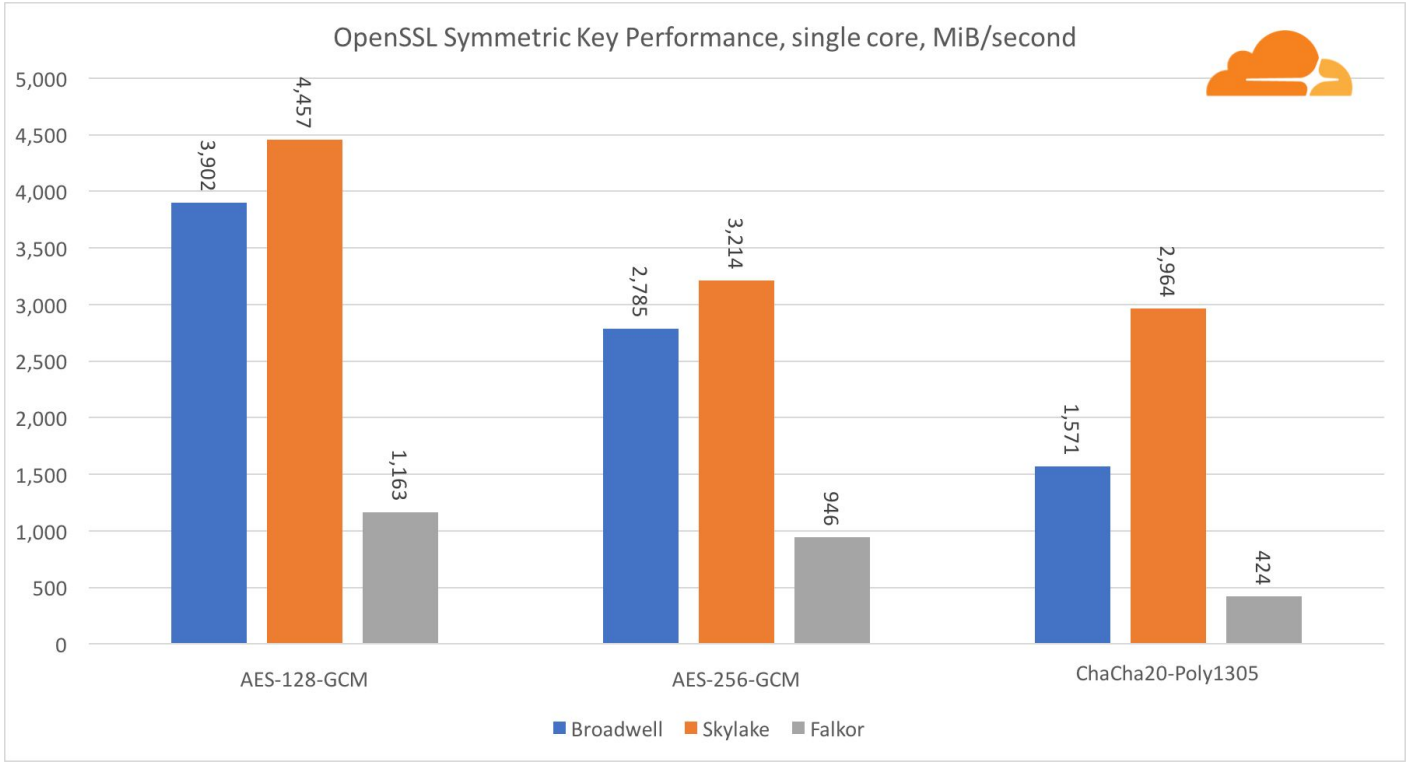
Symmetric cryptography (single core)



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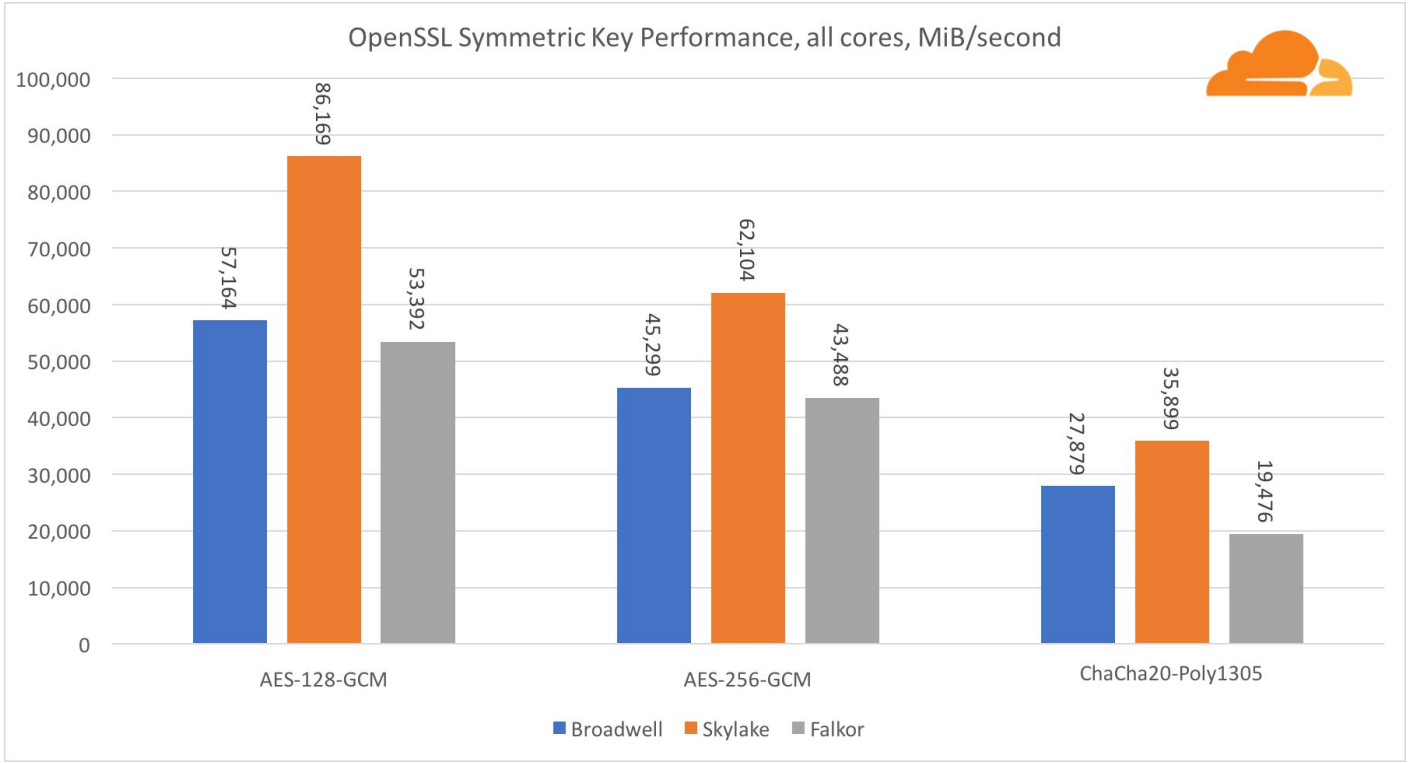

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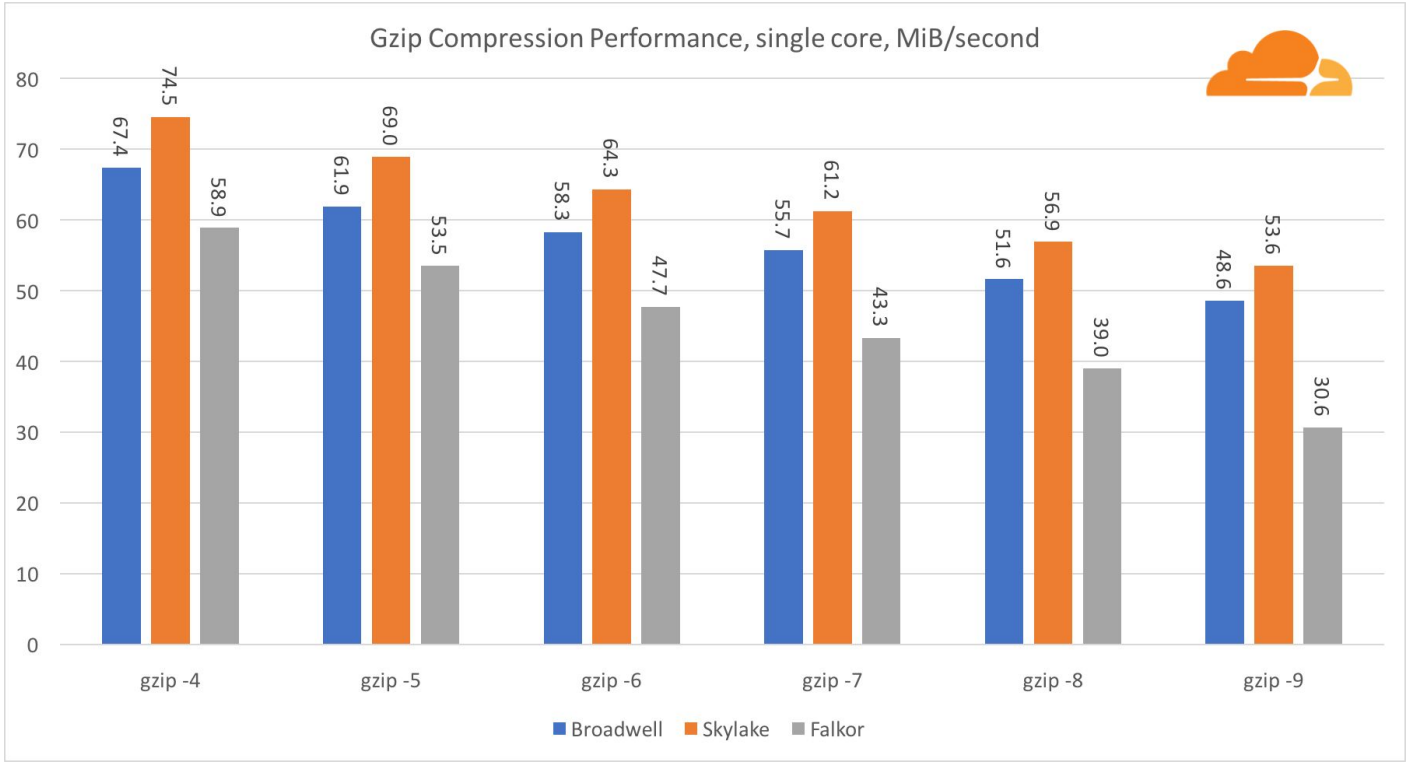
Gzip (single core)



CLOUDFLARE

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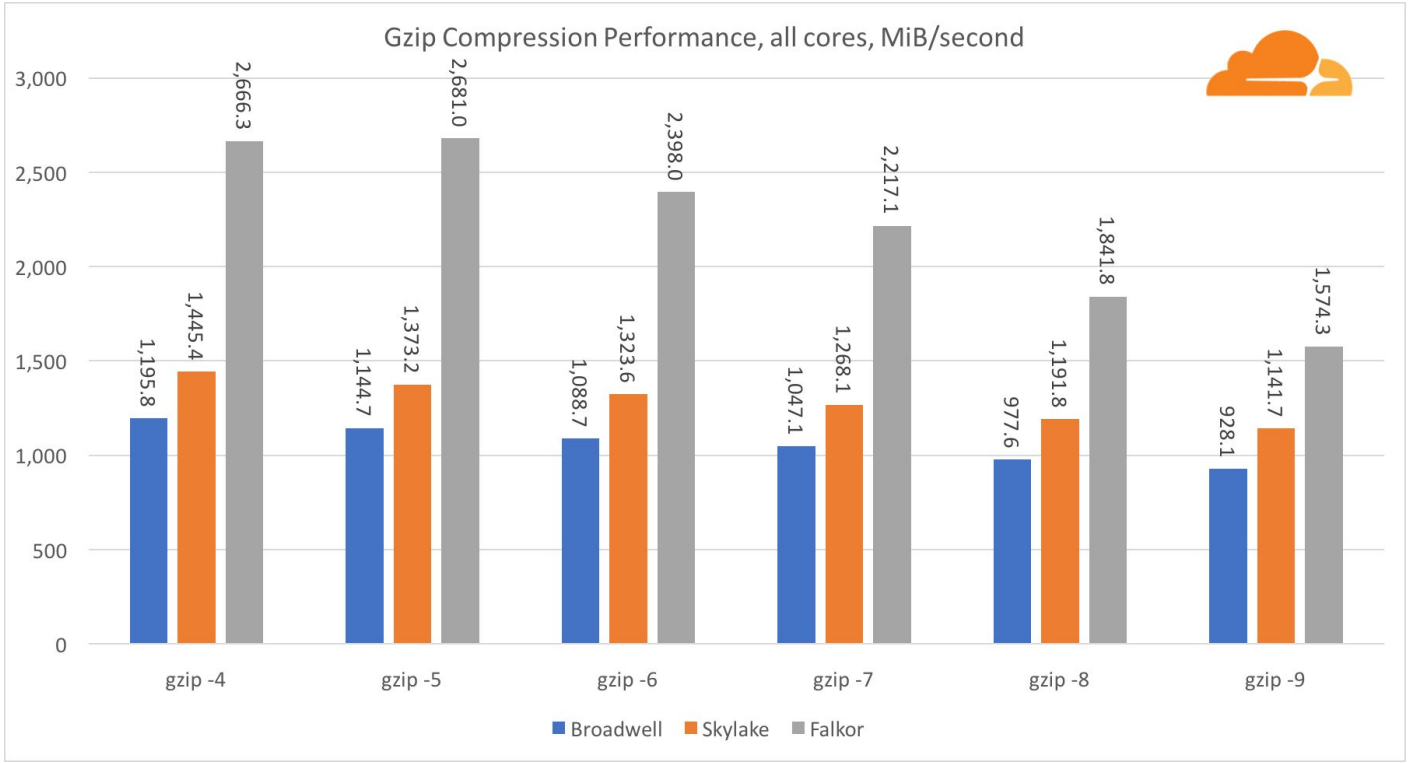
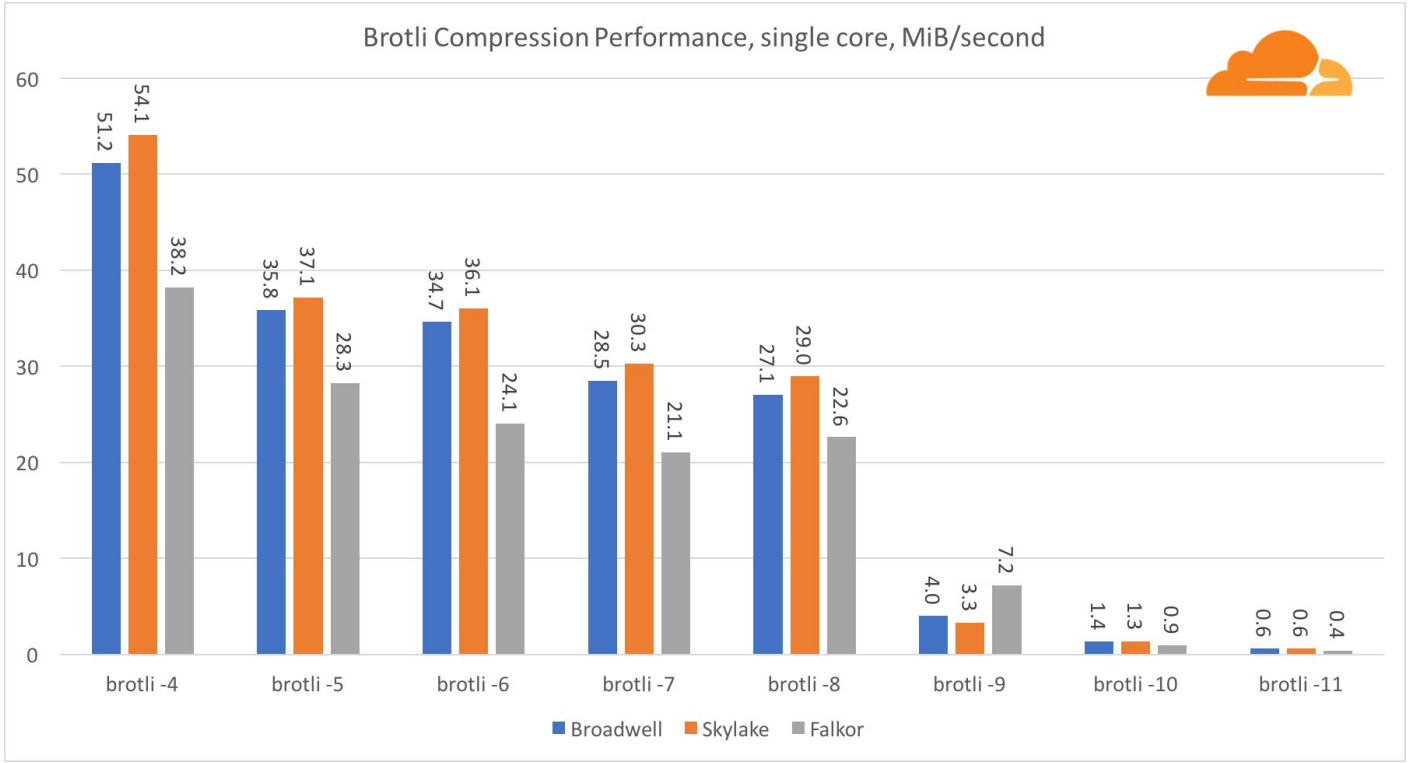


CLOUDFLARE

Brotli (single core)



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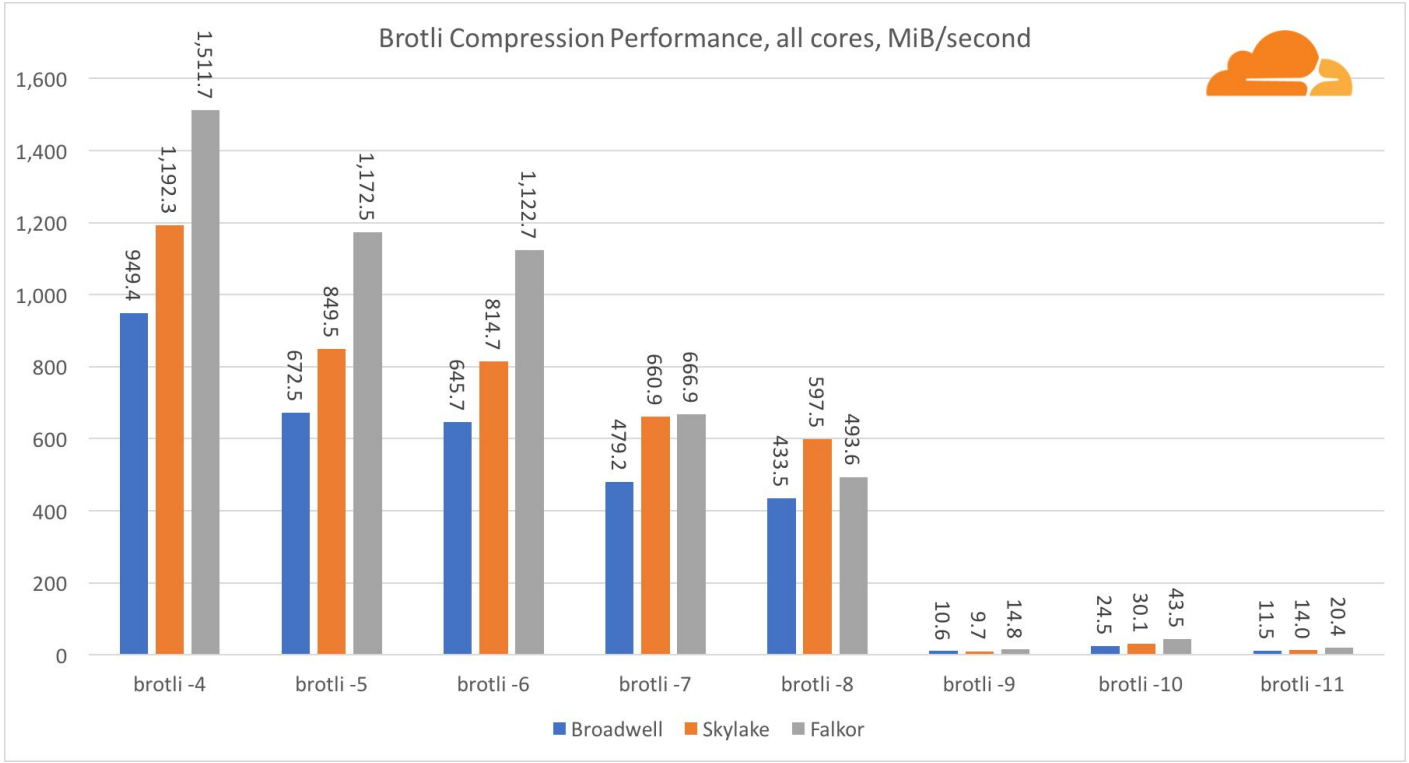

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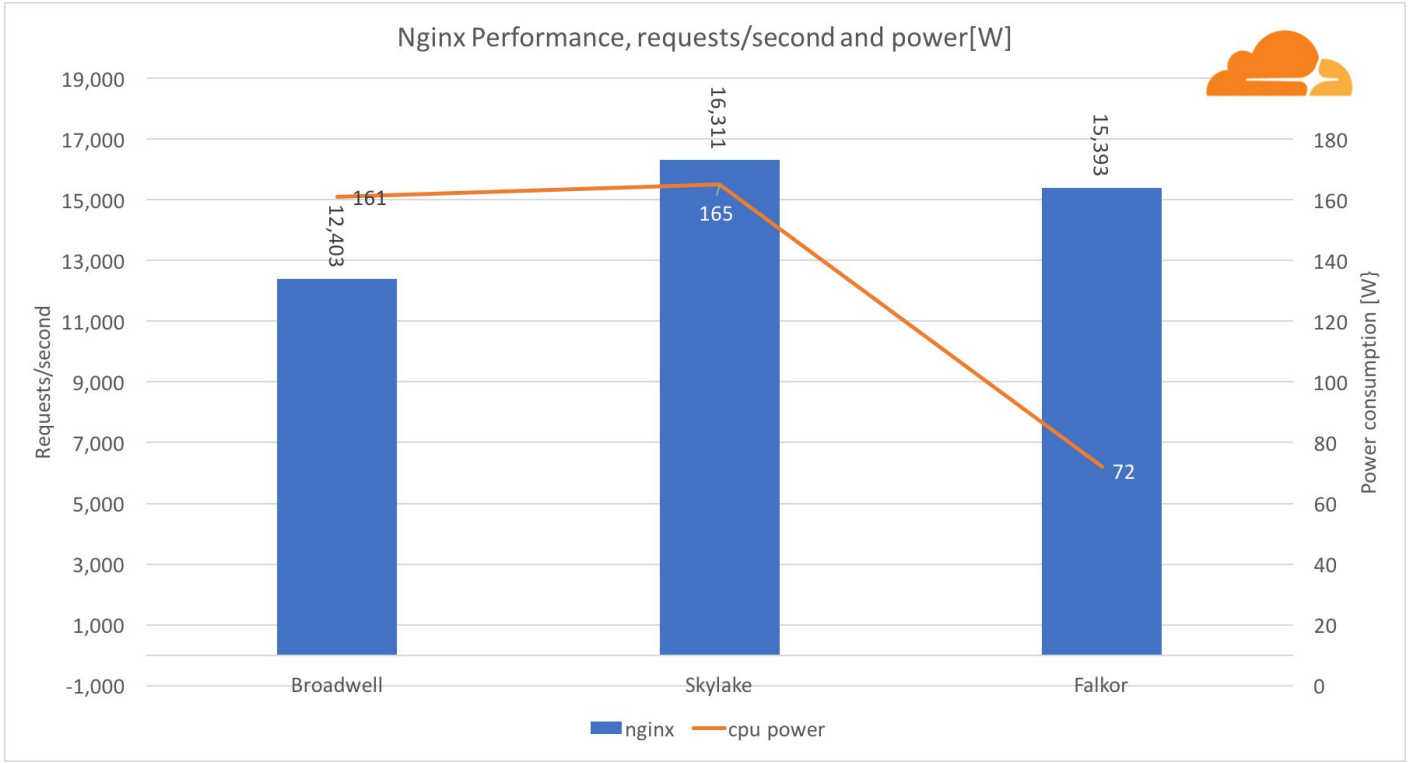
nginx (with power!)



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Putting an ARM64 server in a DC

Initial integration in the DC

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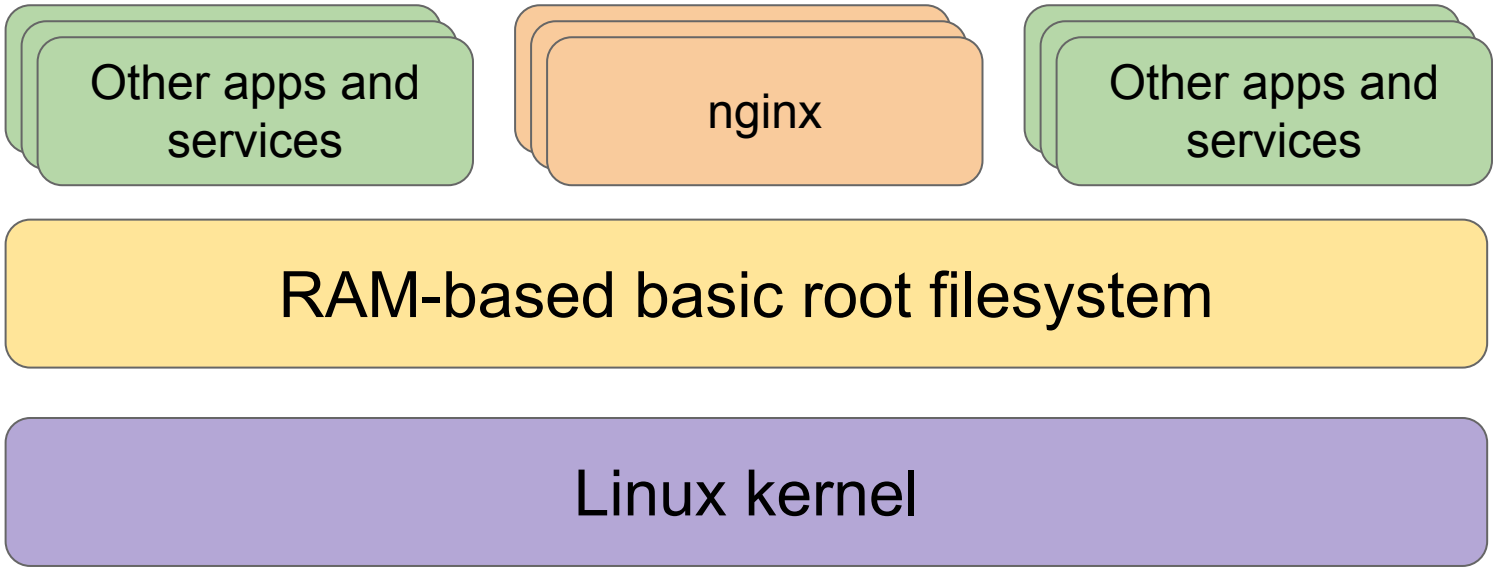
Edge server software stack



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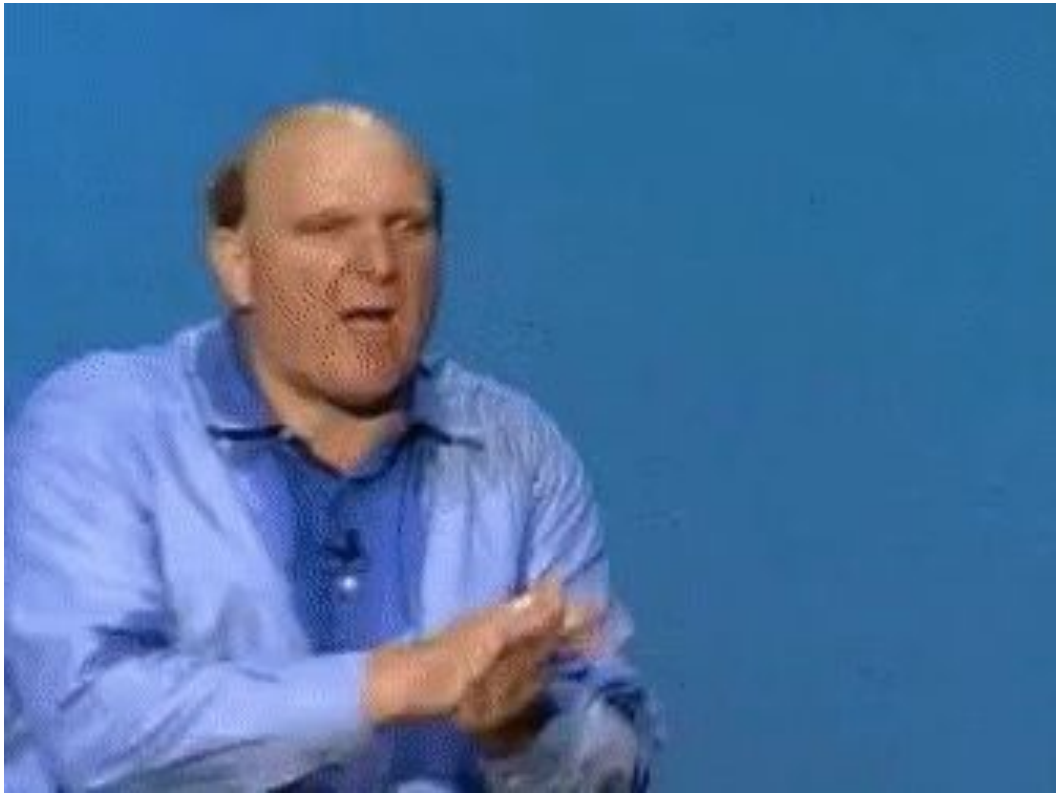
Consider your developers



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Building packages for ARM64

production arch != developer arch

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- need to (cross-)compile packages for a different architecture

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- need to (cross-)compile packages for a different architecture
- cannot run even basic unit tests locally

Building packages for ARM64 options

- cross-compiling
  - relatively easy, but requires many changes
  - potential side-effects (ex. library paths)

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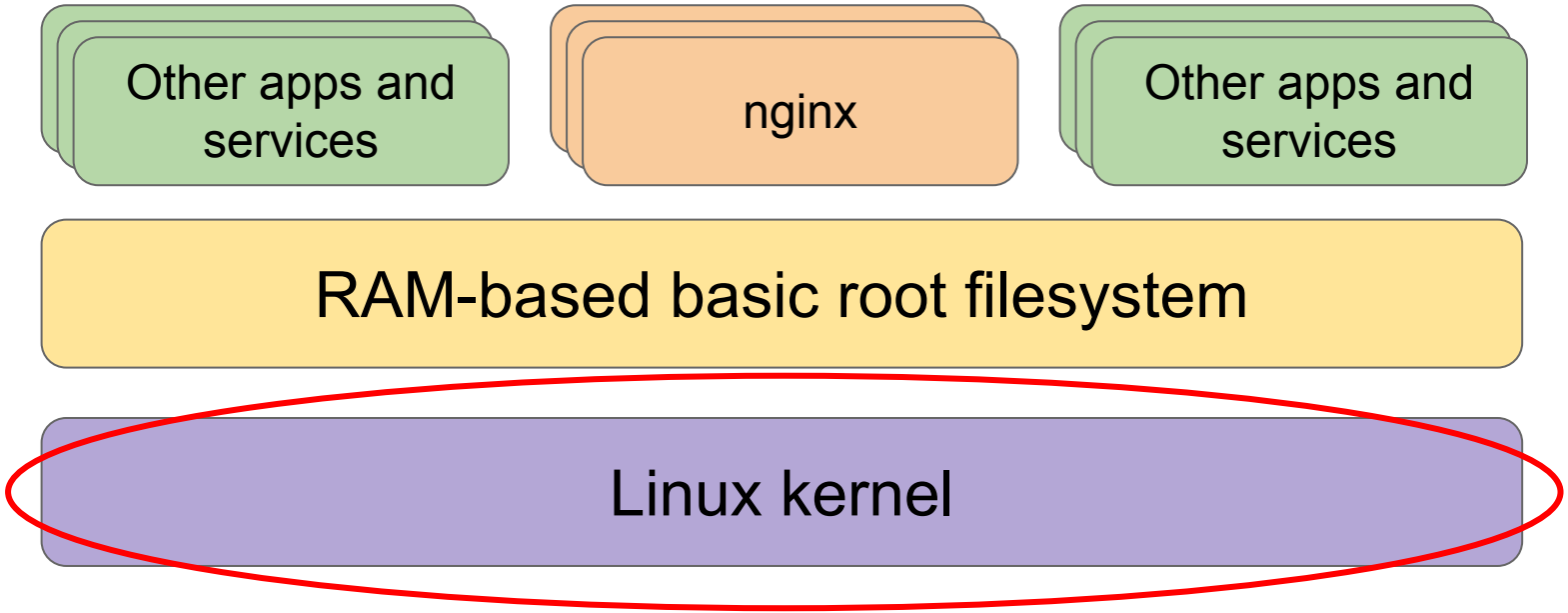

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Cross-compiling Linux kernel

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- need a working kernel configuration file
  - cp config-amd64 .config
  - make ARCH=arm64 CROSS_COMPILE=aarch64-linux-gnu- oldconfig

ARM64 Linux kernel caveats

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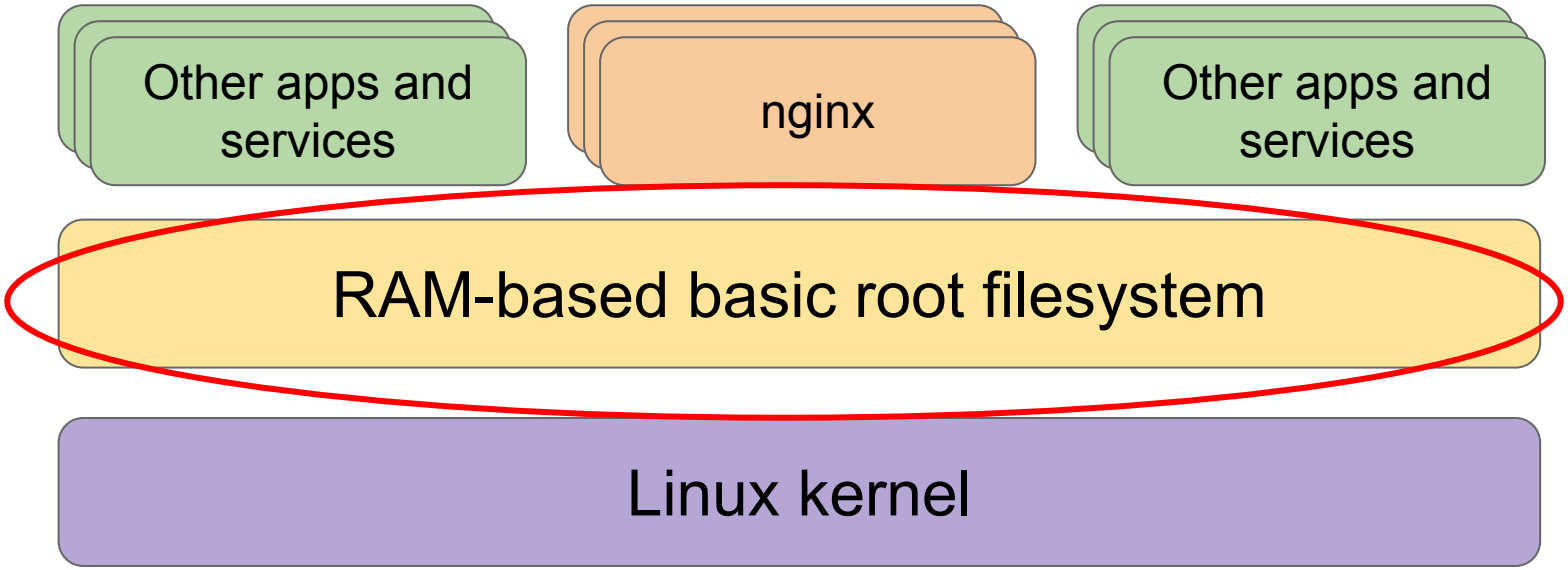
- need to trace down and install many arm64 build dependencies for perf
  - otherwise perf is very limited
- need to trace down and enable required hardware modules
  - our OOB console access did not work until we enabled some non-standard serial driver
- by default your kernel will be configured with 39-bit virtual address space
  - allows to address up to 512GB
  - https://www.kernel.org/doc/Documentation/arm64/memory.txt

Edge server software stack



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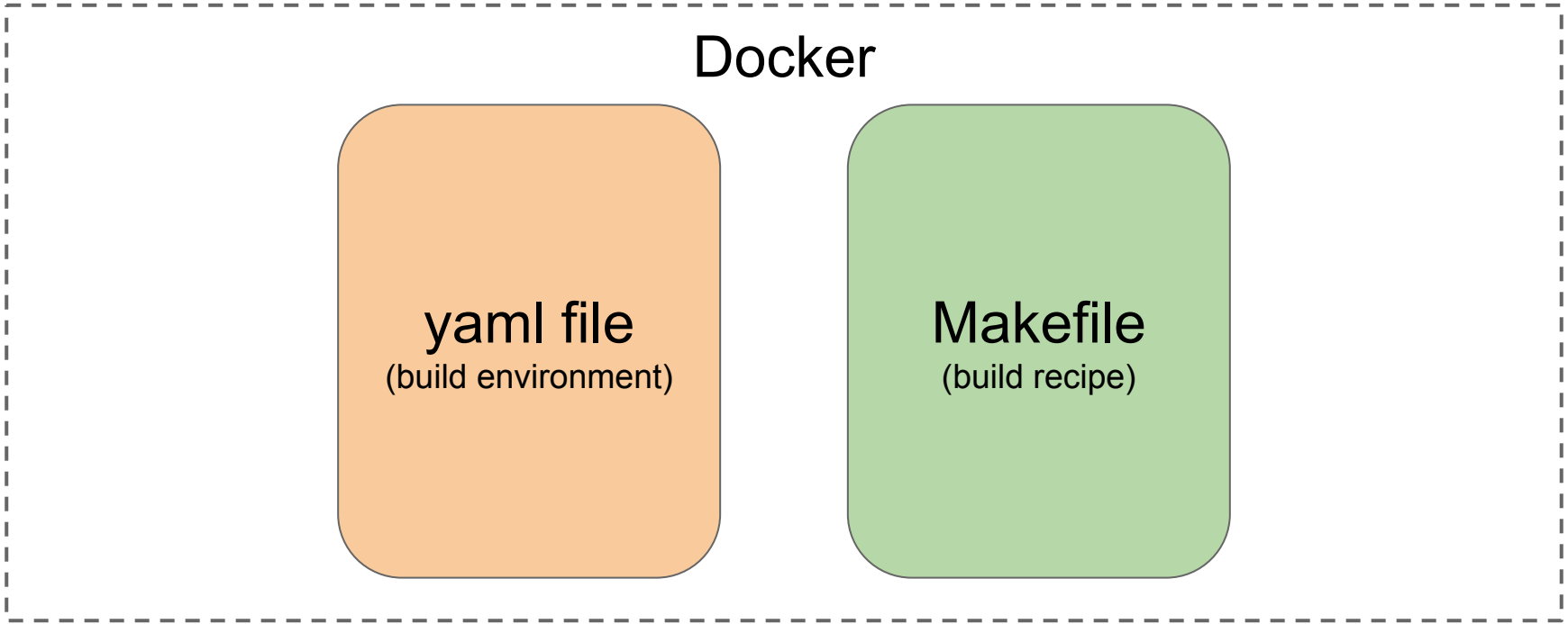
  - https://wiki.debian.org/EmDebian/CrossDebootstrap
- requires many changes and complex logic in both the build system and build environment

Cloudflare build system



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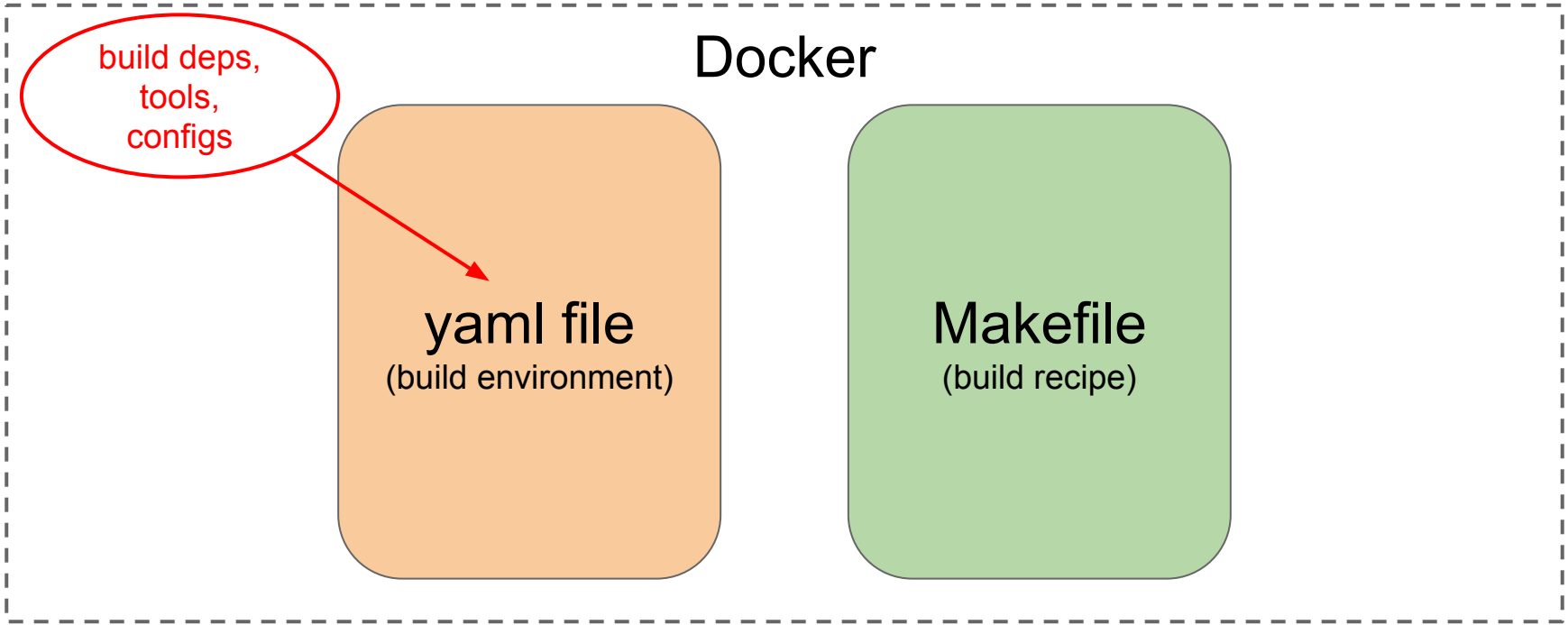
Cloudflare build system



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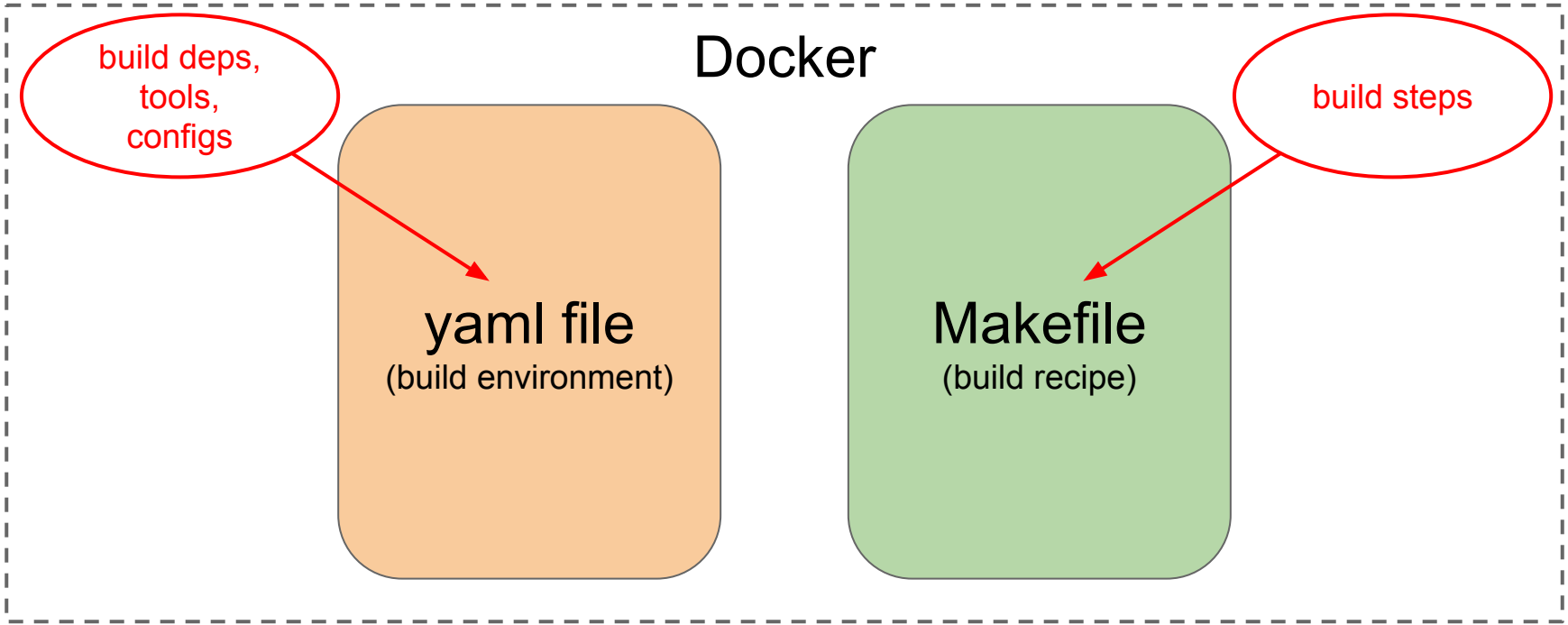

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Cloudflare build system

- Docker-based
  - a Makefile - how to build
  - a yaml file - build dependencies and environment

CLOUDFLARE

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Cloudflare build system

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  - a Makefile - how to build
  - a yaml file - build dependencies and environment
- reproducible in CI

- can we emulate ARM64 environment with Docker?
  - without virtual machines
  - change only the build environment, not the recipe

CLOUDFLARE

QEMU user emulation

- dynamically translates foreign architecture code upon execution
- allows to execute arm64 binary directly on x86

qemu-user in action

```
ignat@dev:~$ gcc -static -o helloarch helloarch.c
ignat@dev:~$ readelf -h helloarch | grep -i machine
  Machine:                           Advanced Micro Devices X86-64
ignat@dev:~$ ./helloarch
Hello, x86_64!
ignat@dev:~$ aarch64-linux-gnu-gcc -static -o helloarch helloarch.c
ignat@dev:~$ readelf -h helloarch | grep -i machine
  Machine:                           AArch64
ignat@dev:~$ ./helloarch
bash: ./helloarch: cannot execute binary file: Exec format error
ignat@dev:~$ sudo apt-get install qemu-user-static
ignat@dev:~$ qemu-aarch64-static ./helloarch
Hello, aarch64!
```

binfmt_misc Linux kernel module

- allows to register custom “interpreters” for specific executables and scripts
- can specify executables by file header or extension

https://www.kernel.org/doc/html/v4.14/admin-guide/binfmt-misc.html

binfmt_misc in action

```
ignat@dev:~$ ./helloarch

-bash: ./helloarch: cannot execute binary file: Exec format error

ignat@dev:~$ echo
":qemu-aarch64:M::\x7fELF\x02\x01\x01\x00\x00\x00\x00\x00\x00\x00\
x00\x00\x02\x00\xb7\x00:\xff\xff\xff\xff\xff\xff\xff\x00\xff\xff\x
ff\xff\xff\xff\xff\xff\xfe\xff\xff\xff:/usr/bin/qemu-aarch64-stati
c:OC" | sudo tee -a /proc/sys/fs/binfmt_misc/register

:qemu-aarch64:M::\x7fELF\x02\x01\x01\x00\x00\x00\x00\x00\x00\x00\x
00\x00\x02\x00\xb7\x00:\xff\xff\xff\xff\xff\xff\xff\x00\xff\xff\xf
f\xff\xff\xff\xff\xff\xfe\xff\xff\xff:/usr/bin/qemu-aarch64-static
:OC

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```
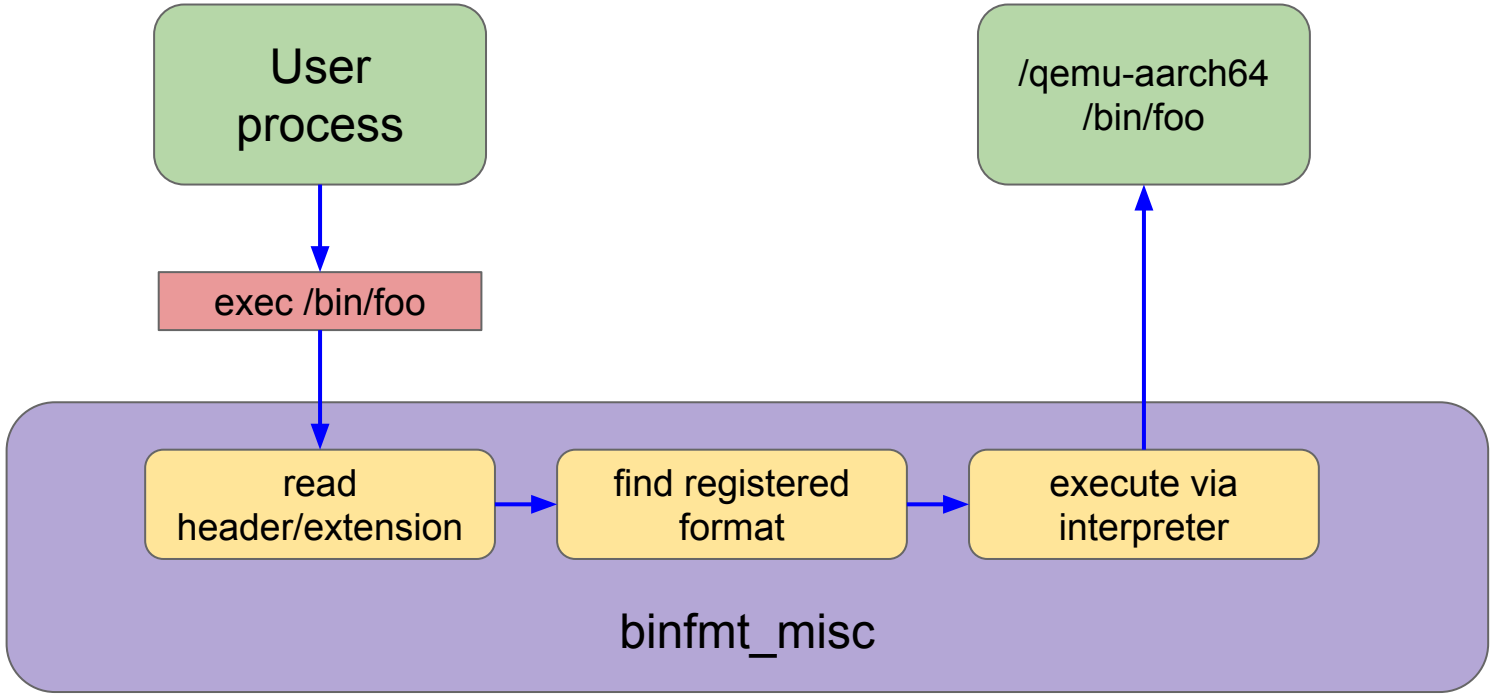

binfmt_misc in action



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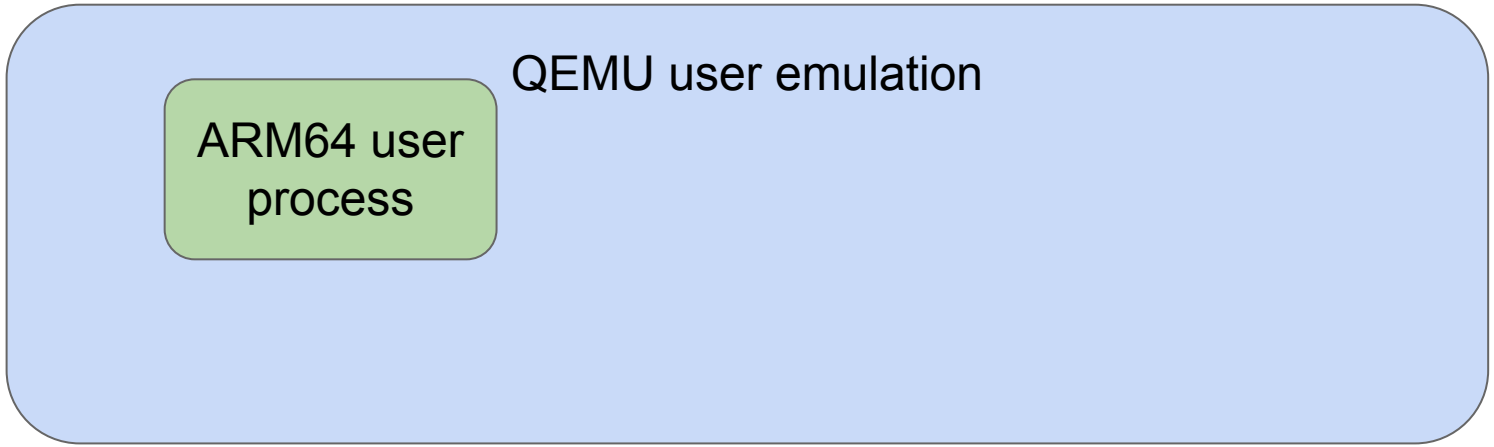
Combining QEMU, binfmt_misc and Docker

```
ignat@dev:~$ cat Dockerfile
FROM arm64v8/debian:stretch
COPY qemu-aarch64-static /usr/bin/qemu-aarch64-static
ignat@dev:~$ docker build -t arm64/stretch .
...
Successfully tagged arm64/stretch:latest
ignat@dev:~$ docker run --rm -it arm64/stretch
root@4e466498353f:/# uname -m
aarch64
```

Foreign arch containers with just qemu

- QEMU translates every system call before passing it on to the kernel

QEMU user emulation



Linux kernel

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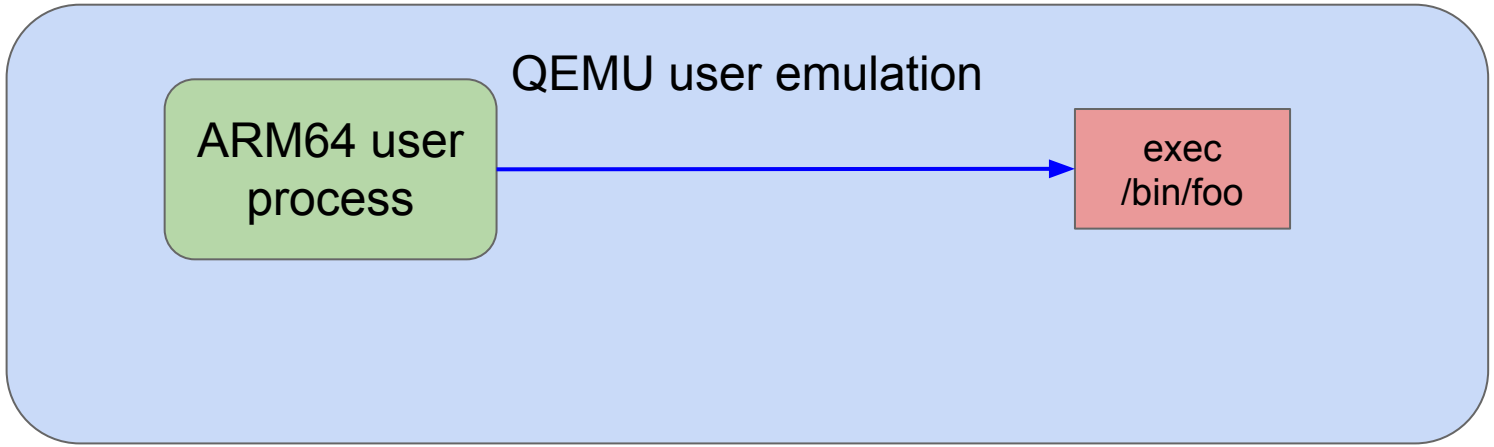

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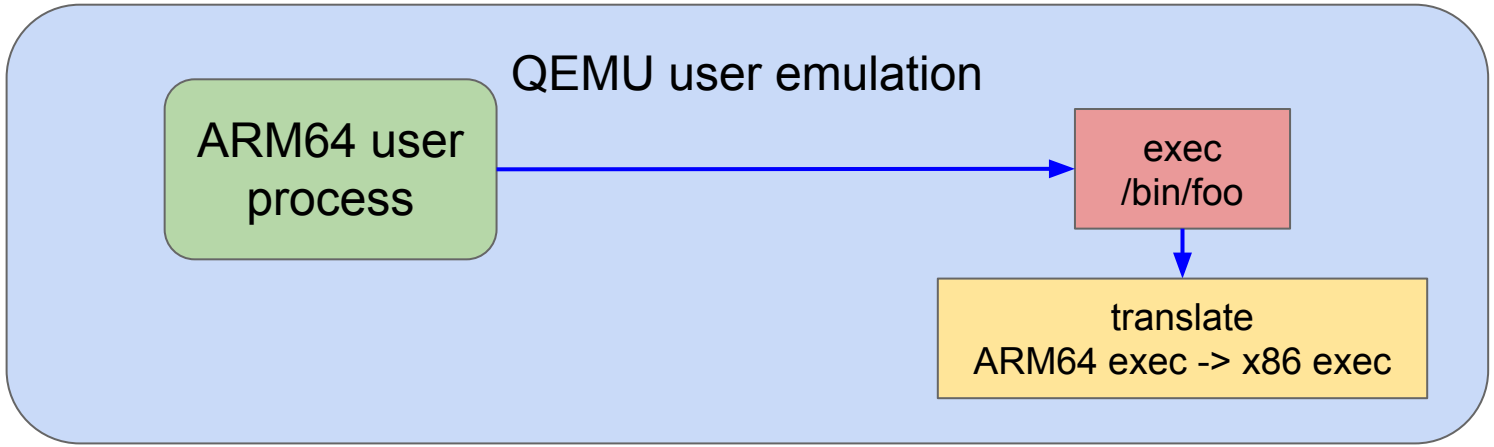

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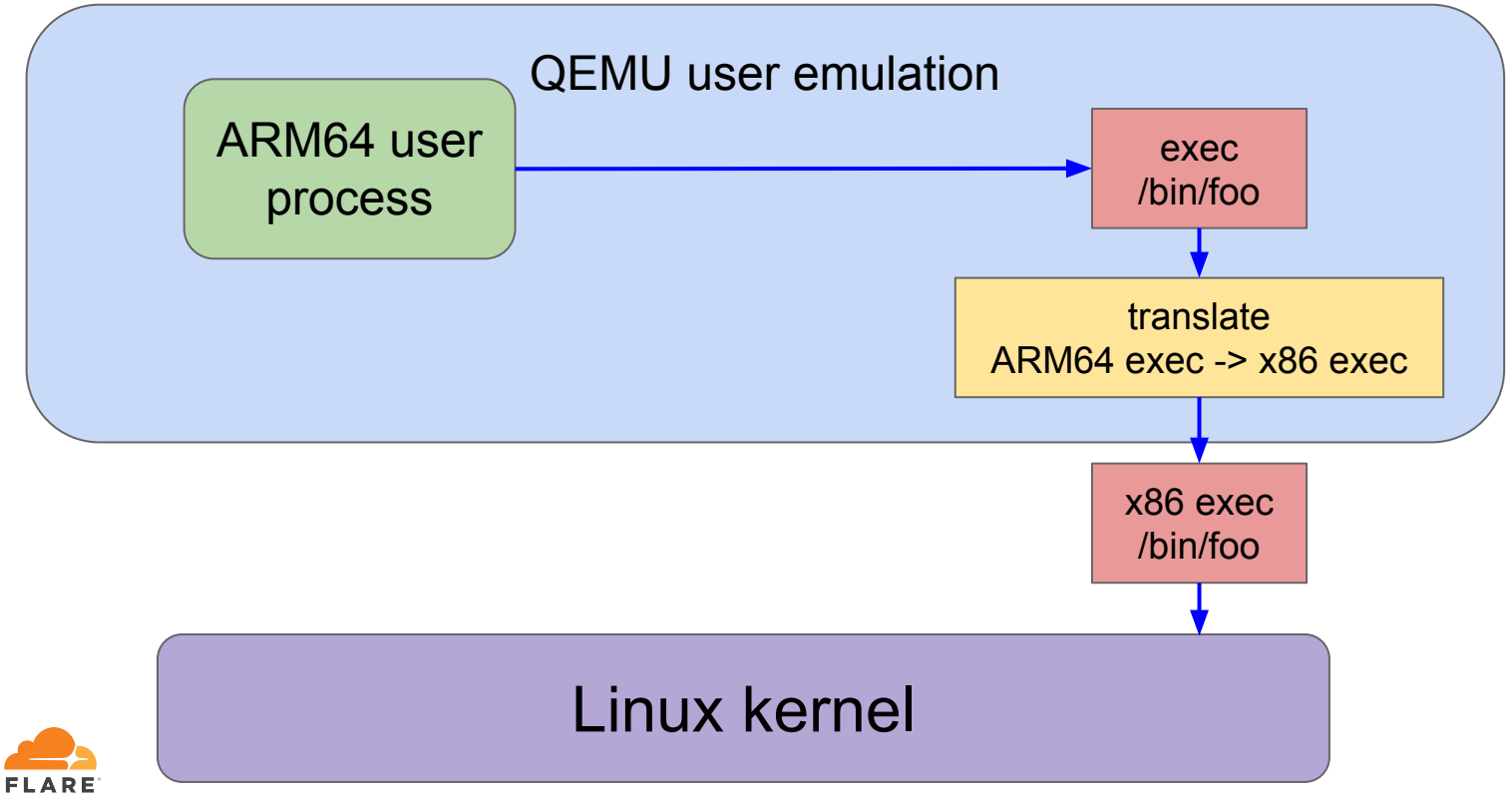

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Foreign arch containers with just qemu

- QEMU translates every system call before passing it on to the kernel
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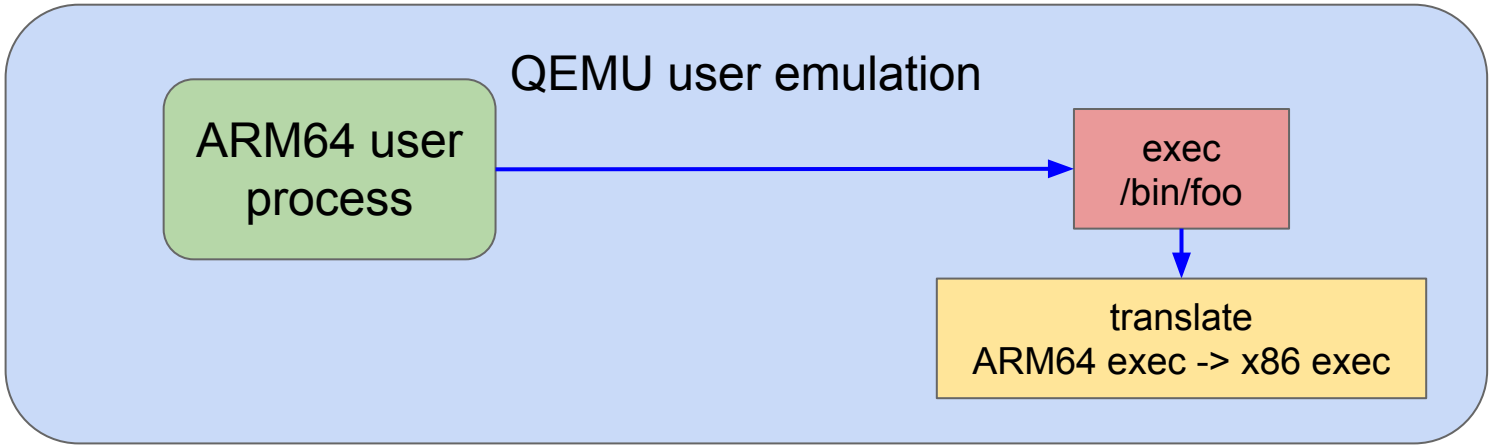
Modified QEMU user emulation



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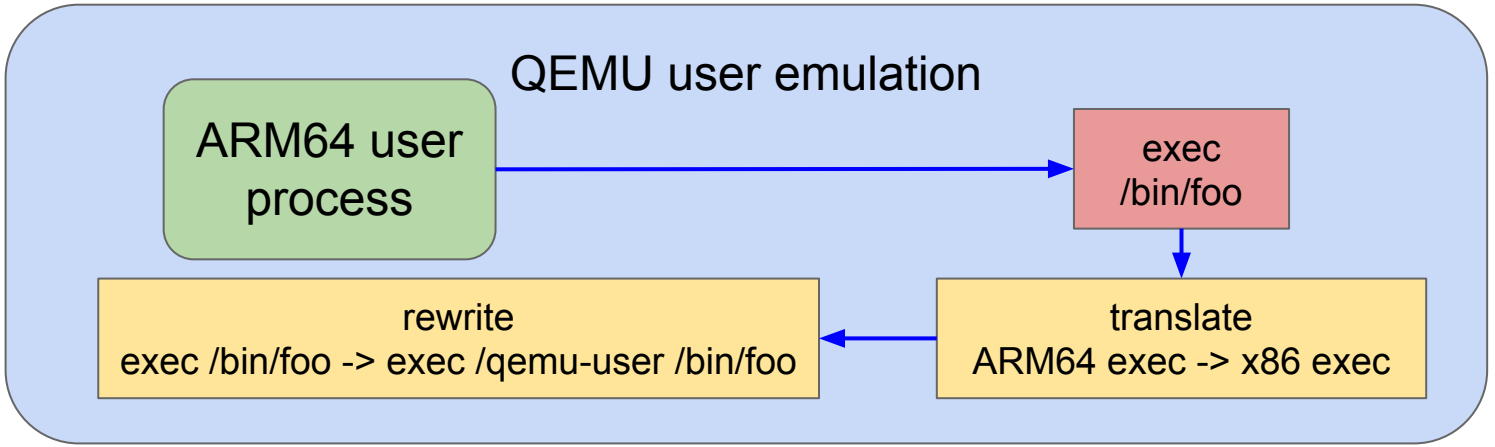

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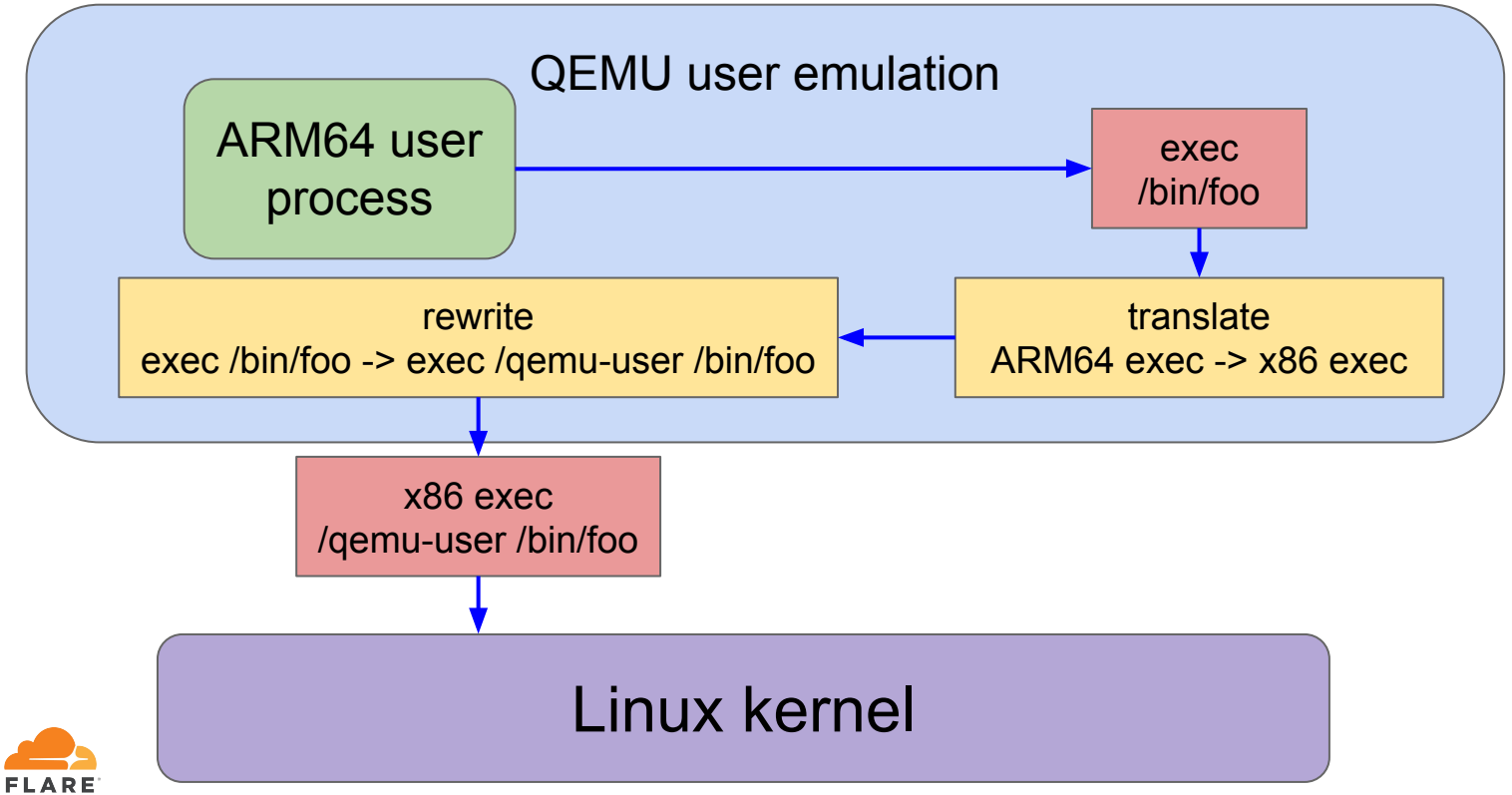

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Foreign arch containers with just qemu

- QEMU translates every system call before passing it on to the kernel
- Why not replicate ***binfmt_misc*** functionality in QEMU itself?
- Don’t need to rely on external ***binfmt_misc*** functionality and can create truly self-contained foreign architecture Docker images

Foreign arch containers with just qemu

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Foreign arch containers with just qemu

https://resin.io/blog/building-arm-containers-on-any-x86-machine-even-dockerhub/

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ARM64 Debian Stretch Dockerfile

```
FROM debian:stretch-slim as builder

RUN apt-get update && apt-get install -y build-essential python
patch libglib2.0-dev libfdt-dev libpixman-1-dev zlib1g-dev wget

RUN wget https://download.qemu.org/qemu-2.12.0.tar.xz && tar xf
qemu-2.12.0.tar.xz

COPY qemu-execve.patch /qemu-execve.patch

RUN patch -d qemu-2.12.0 -p1 < qemu-execve.patch && \
    mkdir qemu-build && cd qemu-build && \
    /qemu-2.12.0/configure --static
--target-list=aarch64-linux-user --disable-system && \
    make
```

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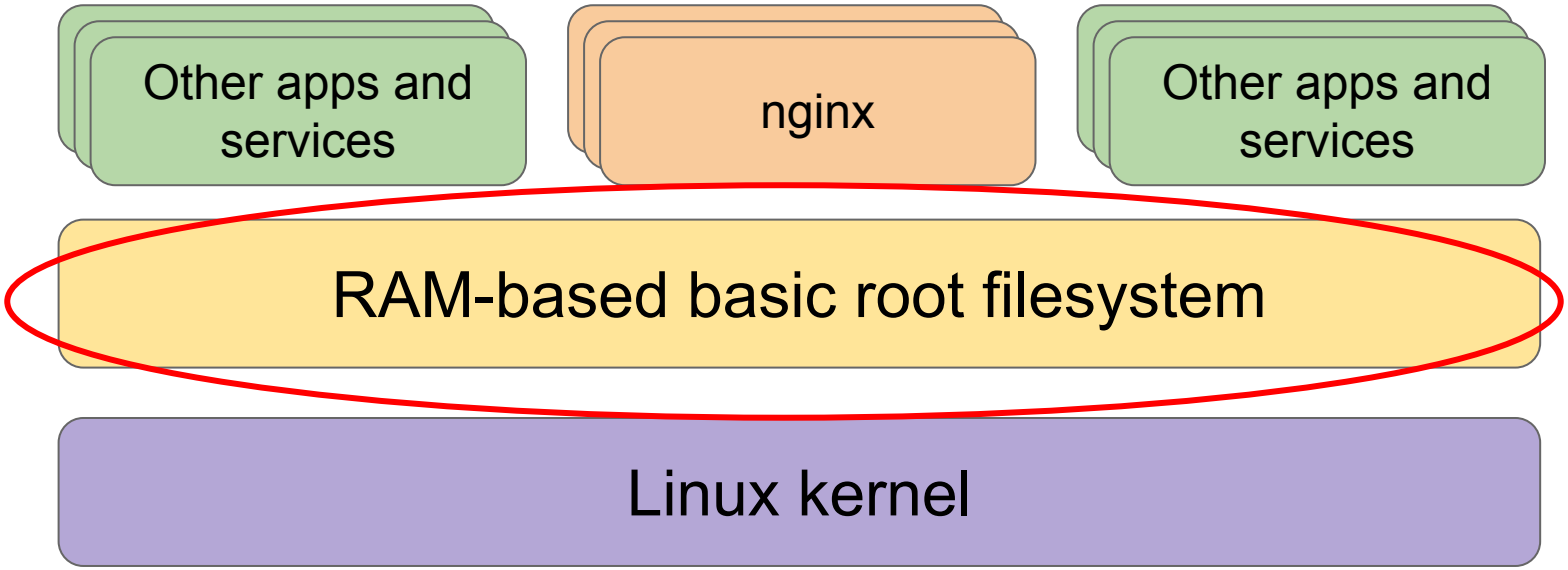
ARM64 Debian Stretch Dockerfile (cont)

```
FROM arm64v8/debian:stretch-slim

COPY --from=builder /qemu-build/aarch64-linux-user/qemu-aarch64
/qemu-aarch64

SHELL ["/qemu-aarch64", "/bin/sh", "-c"]

RUN apt-get update && apt-get install -y --no-install-recommends
libcap2-bin && \
    setcap cap_setuid,cap_setgid+ep /qemu-aarch64 && \
    apt-get remove --purge -y libcap2-bin && apt-get autoremove -y
&& \
    rm -rf /var/lib/apt/lists/*

ENTRYPOINT ["/qemu-aarch64"]

CMD ["/bin/bash"]
```

Edge server software stack



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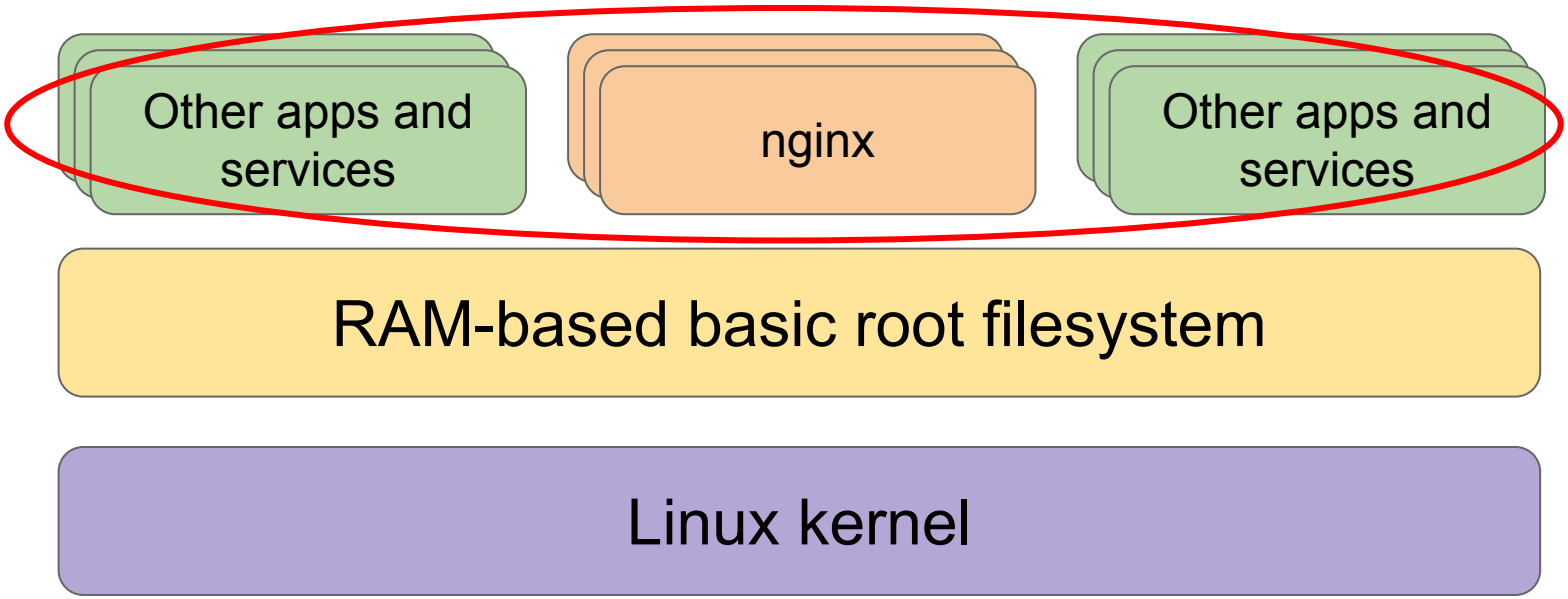
- only a single toggle to use ARM64 Debian Stretch as a base instead of x86 one
- works on x86-based CI out of the box

Edge server software stack



CLOUDFLARE

Porting user-space applications

- reused arm64 Docker based approach
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  - allows devs and CI to run basic tests
- most of the stack was done in ~1 month
- although slower build times due to emulation layer
  - ex. nginx takes 2m instead of usual 10s (~10x slower)

Slower build times - it’s a feature!

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Porting timeline

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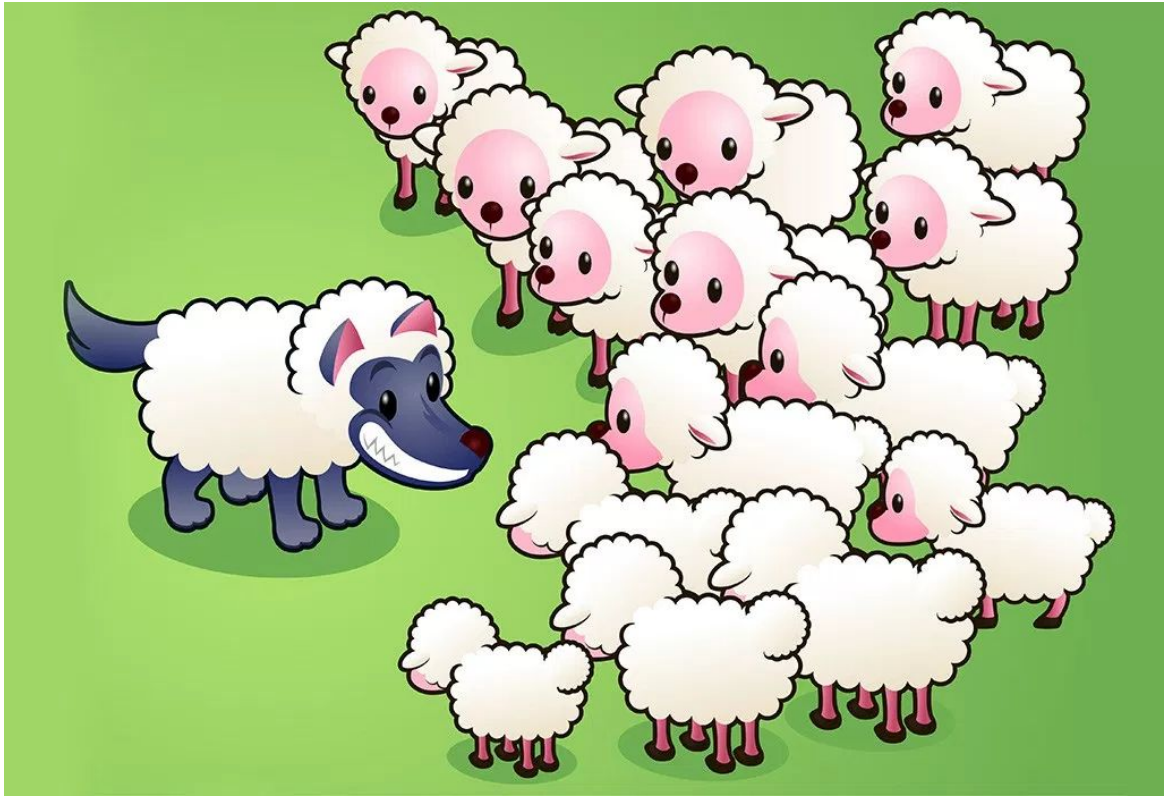
- March 23rd - served first production DNS request

Porting timeline

- started porting applications beginning of March
- March 23rd - served first production DNS request
- April 18th - served first production HTTPS request with cached content

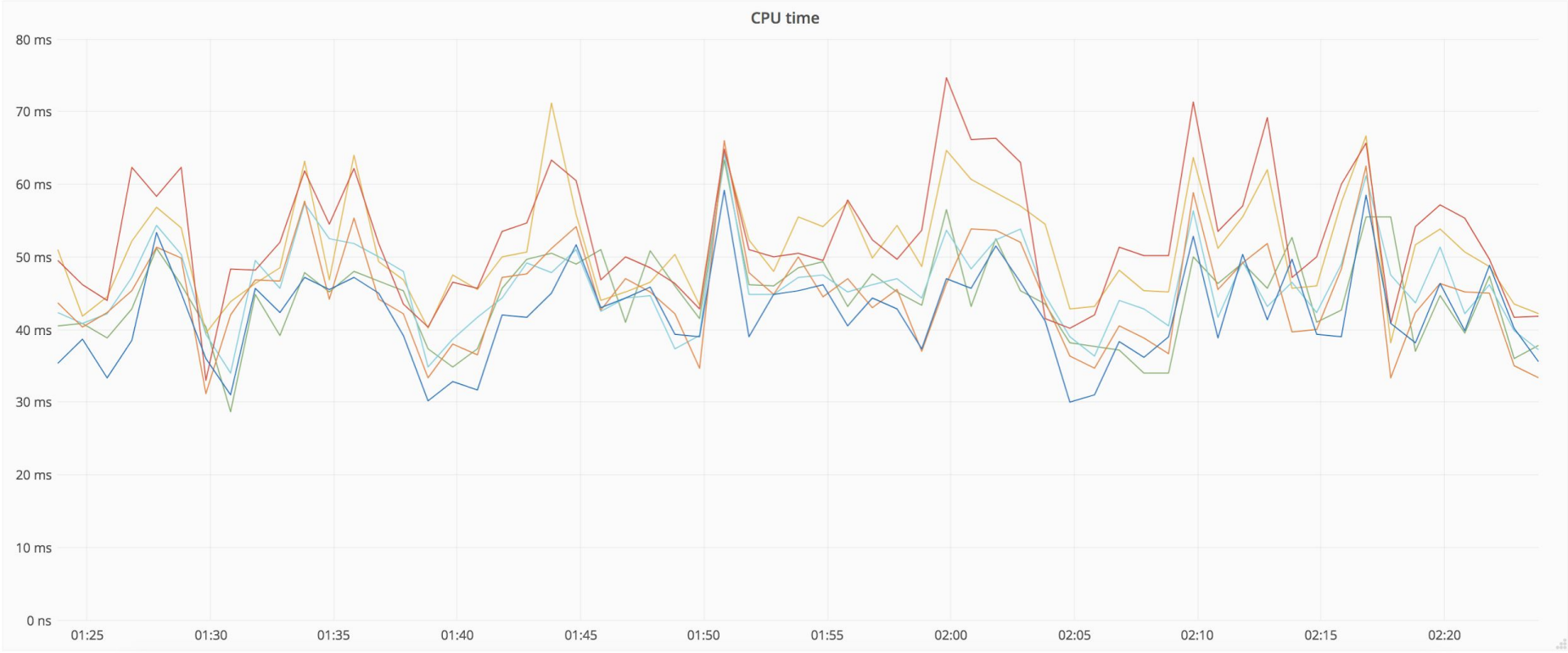
ARM64 in production



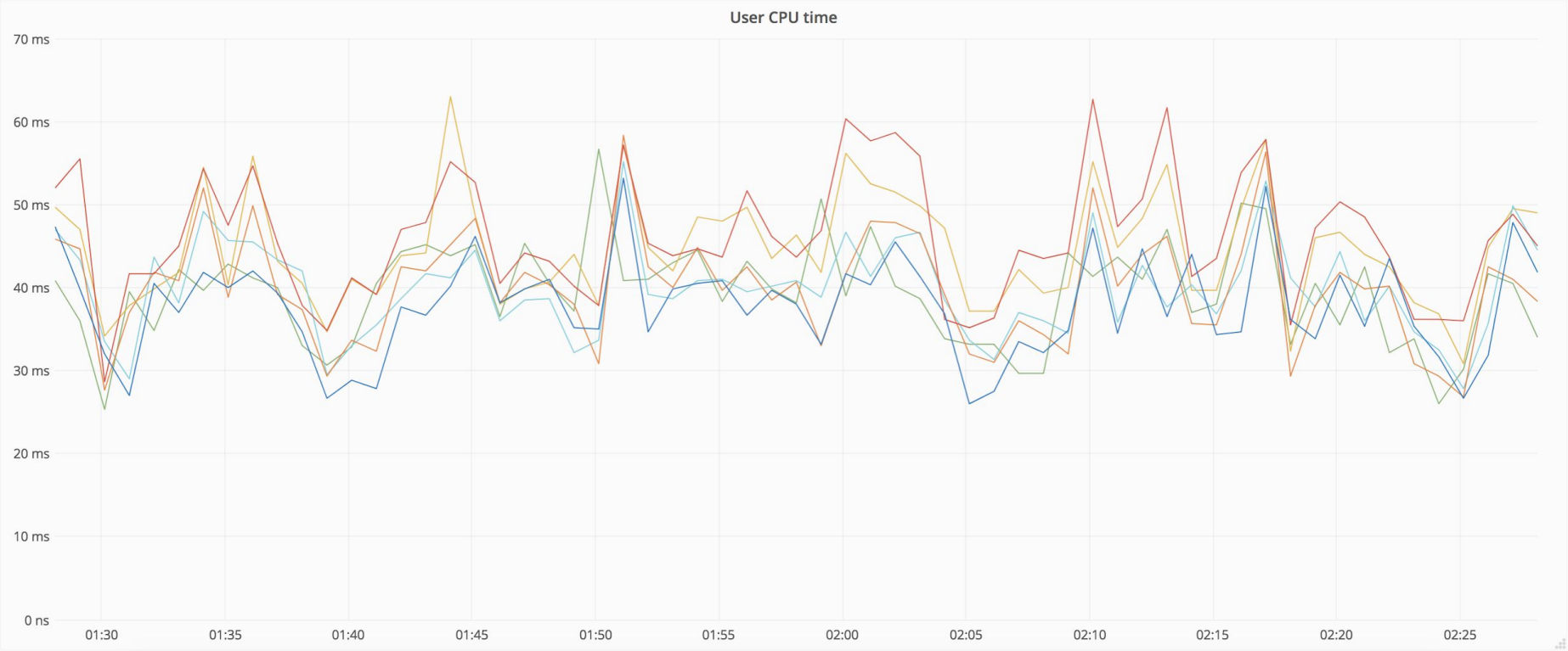
CLOUDFLARE

How is it doing now?

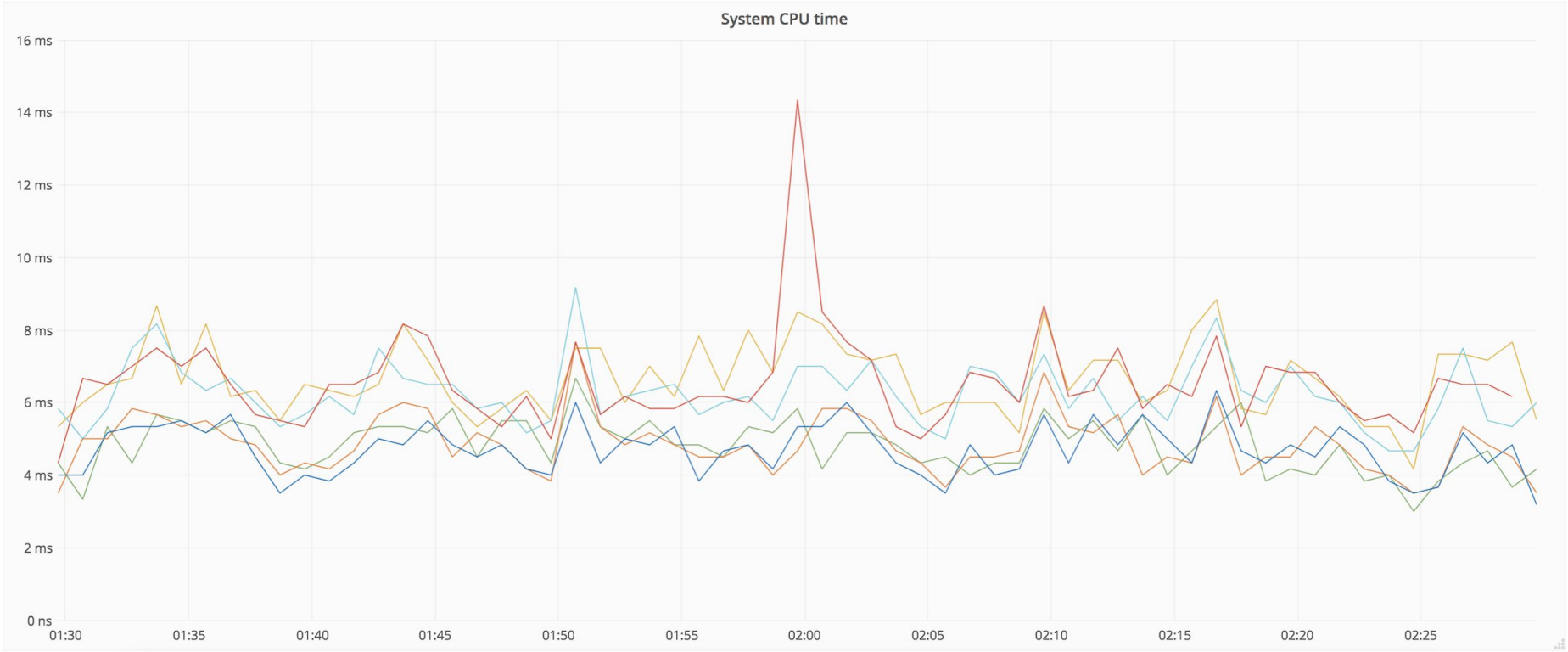
nginx-cache CPU time



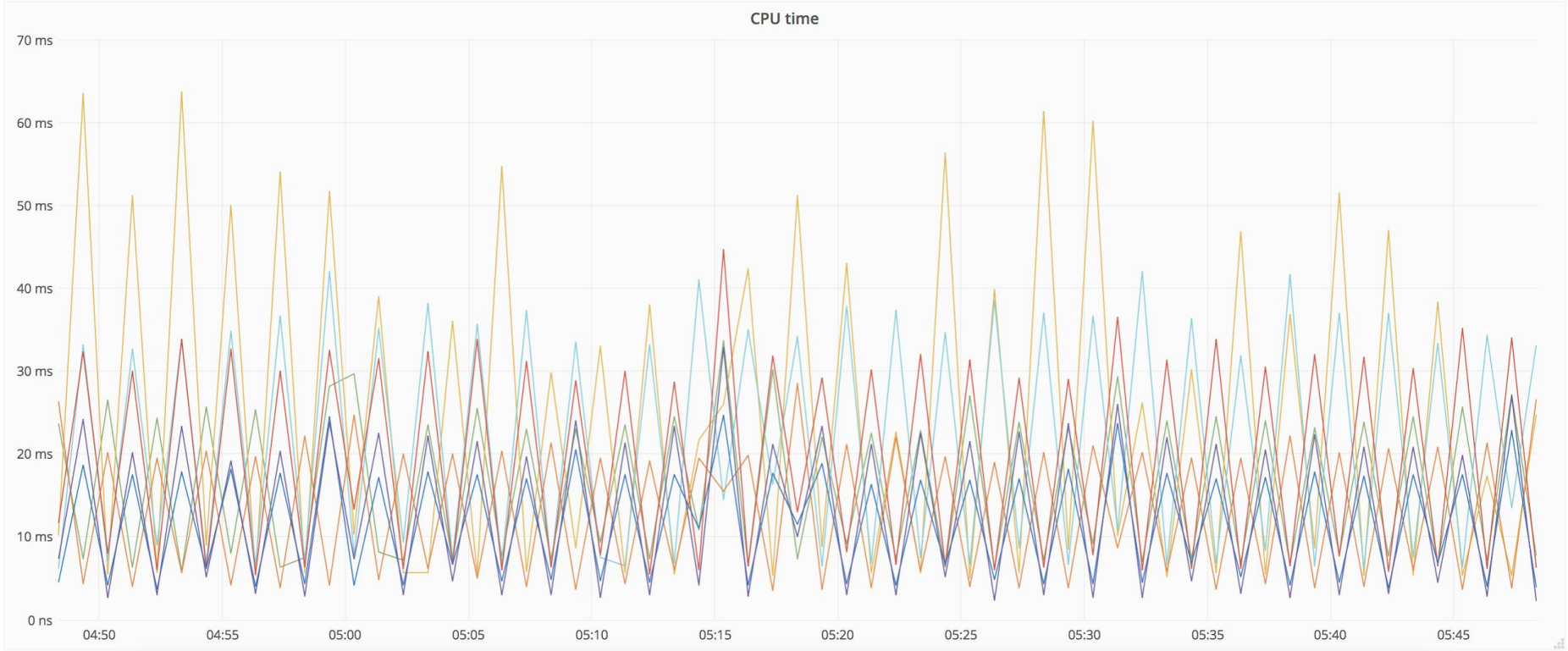
nginx-cache user CPU time



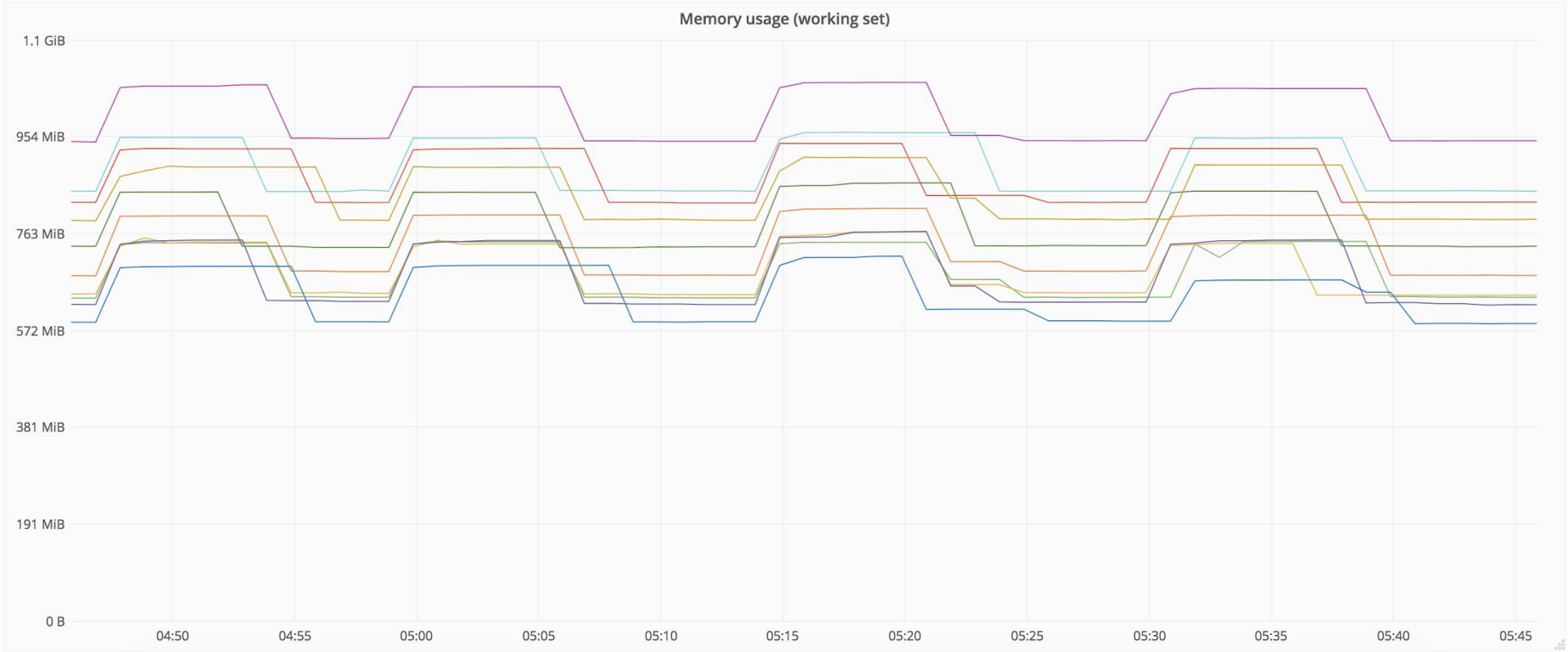
nginx-cache system CPU time



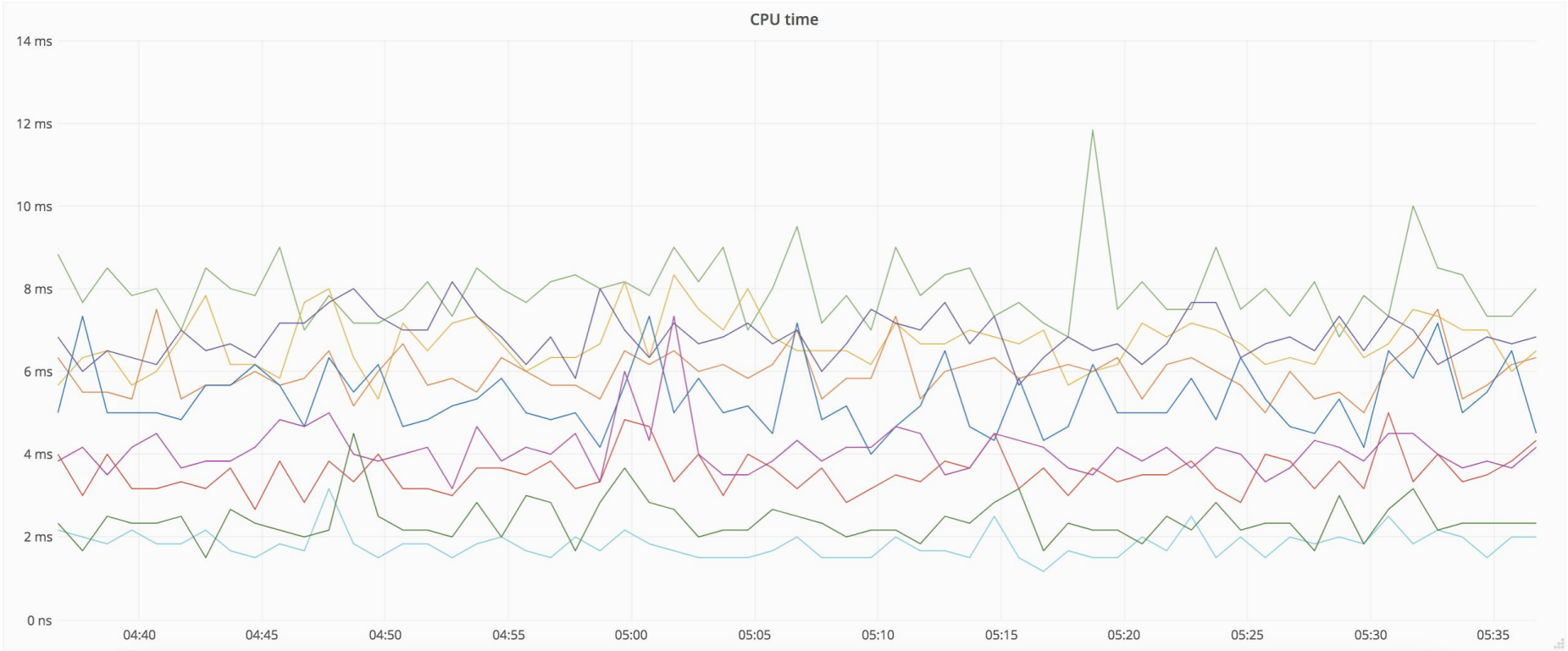
RRDNS CPU time



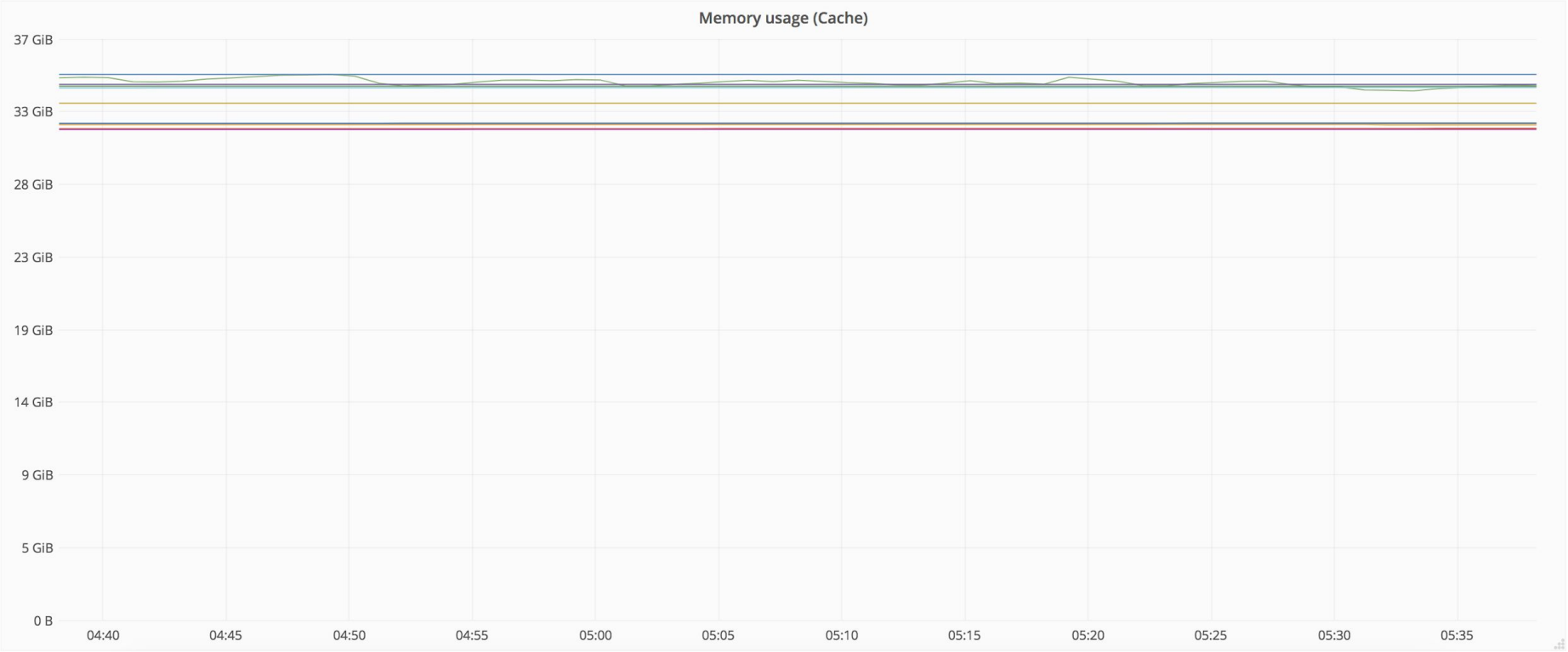
RRDNS memory usage



Quicksilver CPU time



Quicksilver memory cache



Conclusions

- ARM64 is a competitive server architecture
  - most software works OK out of the box
- Migrating to ARM64 is not that hard
  - popular OSes support ARM64 already
- QEMU user emulation + Docker provides a low-cost quick-start solution to port in-house software to ARM64
  - in both hw costs and effort cost
  - minimal disruption to the dev process

Some links

- https://blog.cloudflare.com/arm-takes-wing/
- https://blog.cloudflare.com/neon-is-the-new-black/
- https://blog.cloudflare.com/using-go-as-a-scripting-language-in-linux/
- https://www.kernel.org/doc/html/latest/admin-guide/binfmt-misc.html
- https://resin.io/blog/building-arm-containers-on-any-x86-machine-even-dockerhub/

Thank you!