



Smart Monitoring System For Automatic Anomaly Detection and Problem Diagnosis

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Who am I ?

- **Xianping Qu**

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- **Baidu SRE Team**

- Over 400 Engineers
- Support over 300 products, developed by 20,000 engineers

- **Areas of Interest**

- Monitoring system
- Data Analysis

About Baidu (百度)



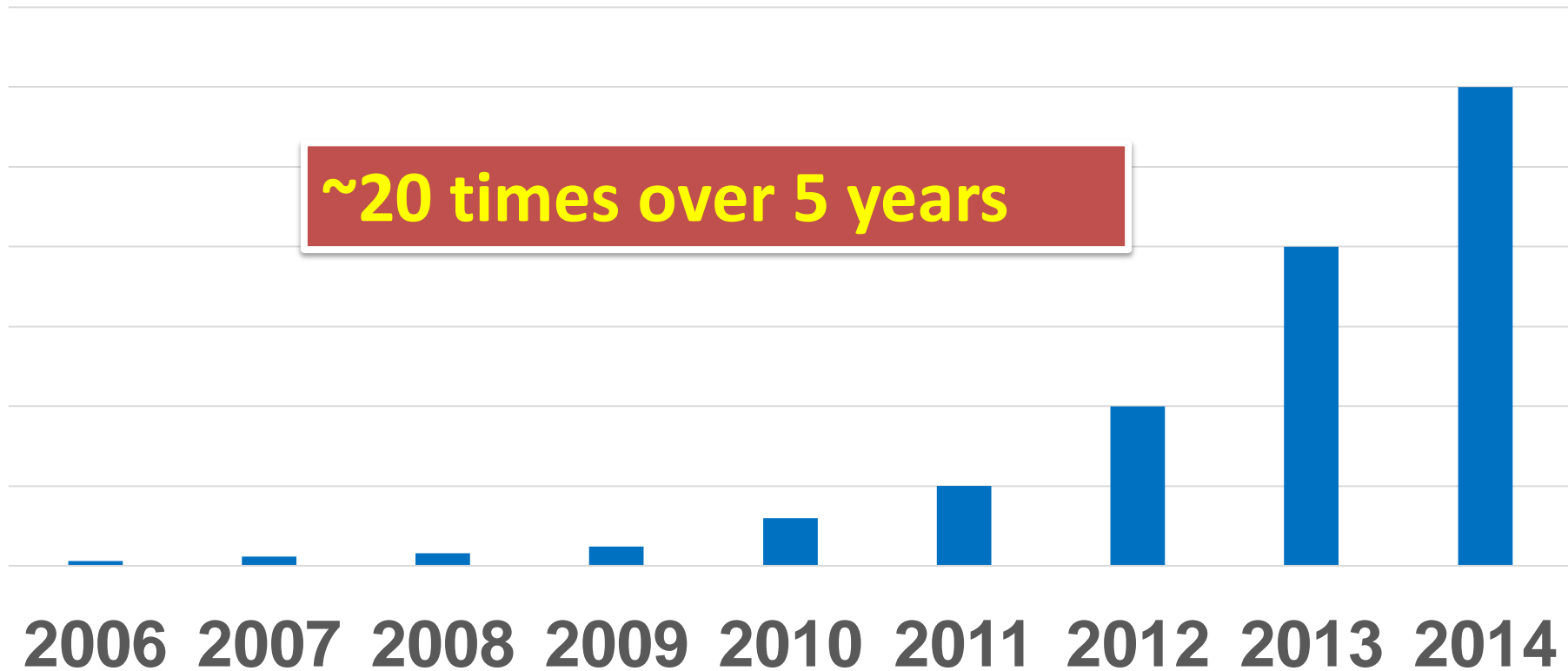
- **Search**
 - Webpage/Image/Video/News/Dictionary/Web Directory/...
- **Social**
 - Forum/Album/...
- **LBS**
 - Maps/Group Buy/...
- **Knowledge**
 - Wiki/Knows/Experience/...
- **Mobile**
 - Search/Mobile phone assistant/...
- **Cloud**
 - Personal Cloud storage/Baidu Cloud/...
- ...

Agenda

- **Background**
- **Smart Monitoring System**
 - Anomaly Detection
 - Alarm Filter
 - Problem Diagnosis
- **Summarize**

Exponentially growing servers

Trend of numbers of servers at Baidu



The scale of the data



Total Data	> 1.5 EB
Webpage count	> 300 billion
Webpage updates	> 1 billion / day
Monitoring data	> 20PB
Monitoring data growth	> 40TB / day

Monitoring and Diagnosis are vital !

Early methods for monitoring and diagnosis

- **Monitoring Items**
 - Machine level: 90 million
 - Service level: 50 million
- **Alarms**
 - Threshold
 - Accuracy
 - Drifting
 - Annoyance vs promptness
- **Diagnosis**
 - Curves, Logs, Trace

Human labor
Human experience



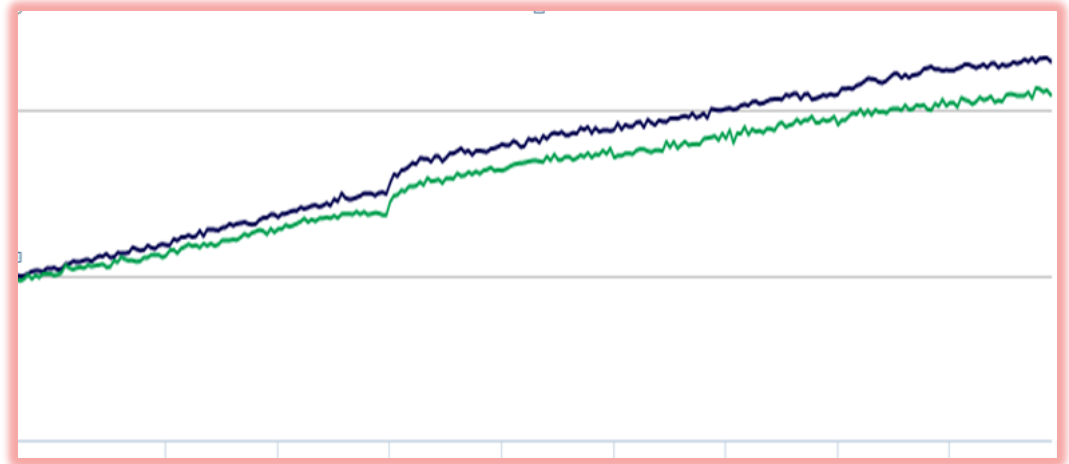
Some Examples In Detail

Diverse thresholds

Threshold against
yesterday's value



Threshold against
accumulated value

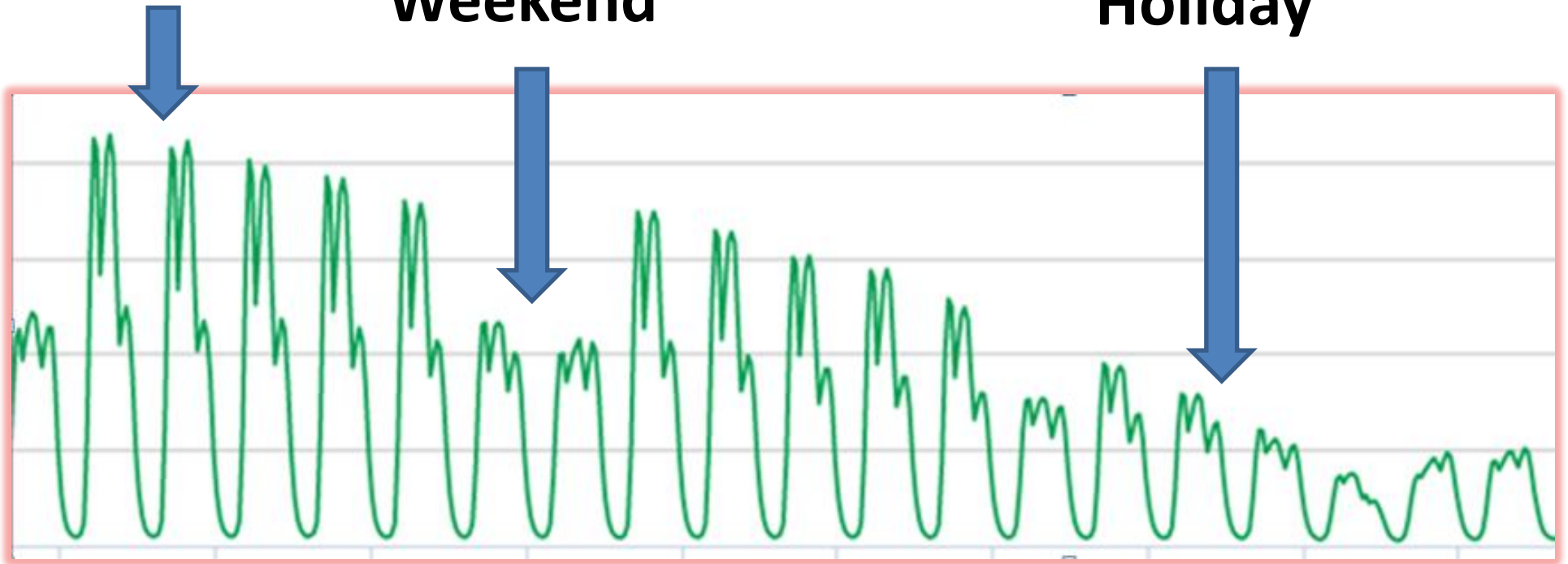


Drifting thresholds

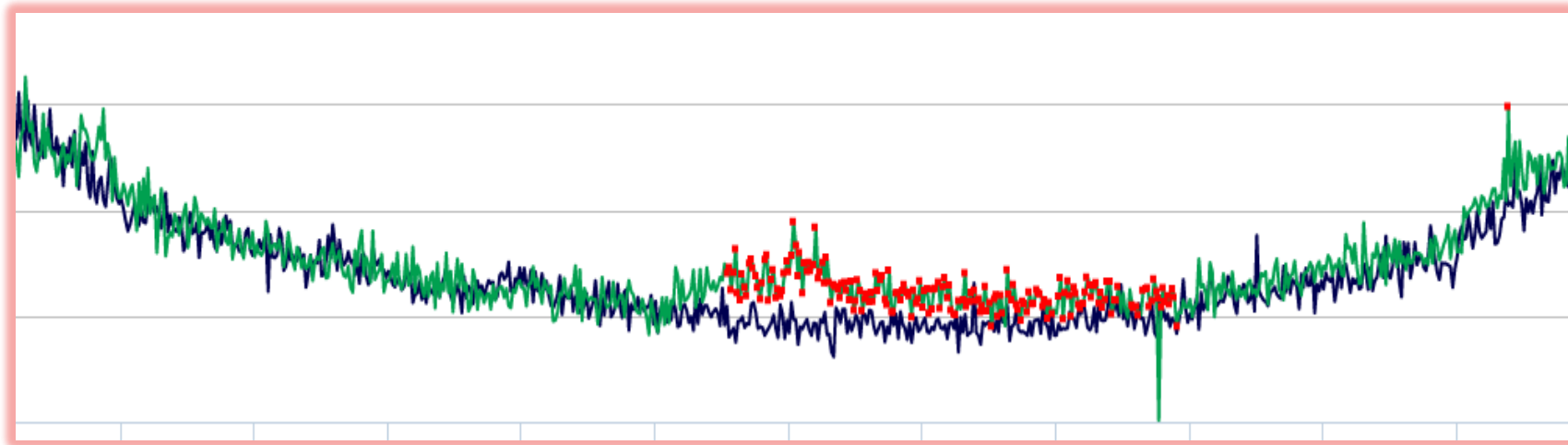
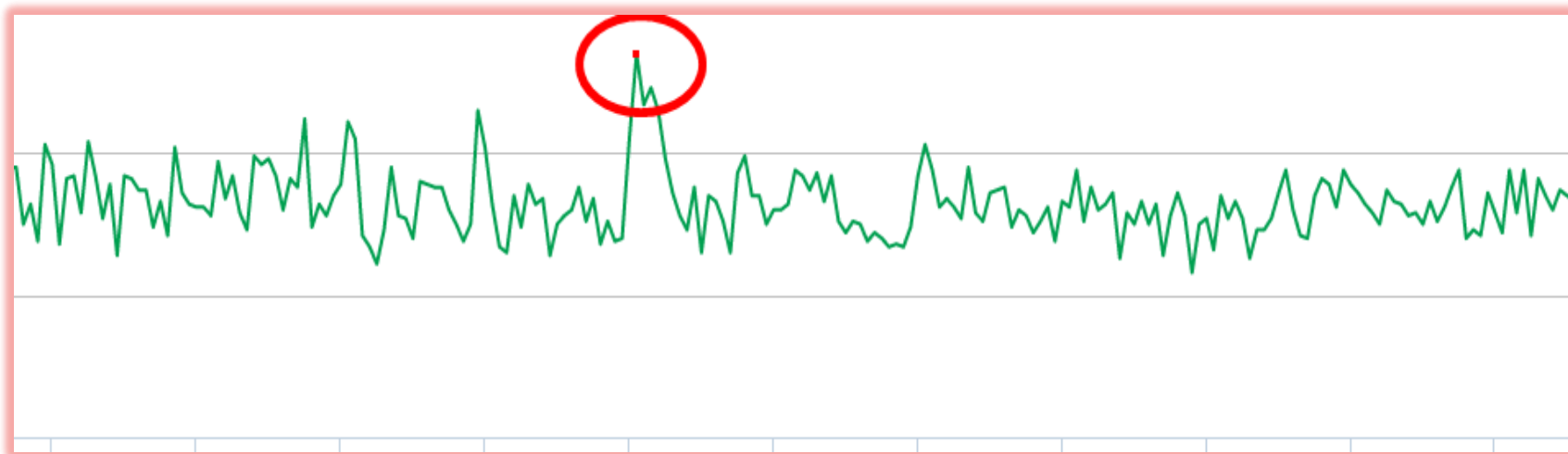
Workday

Weekend

Holiday

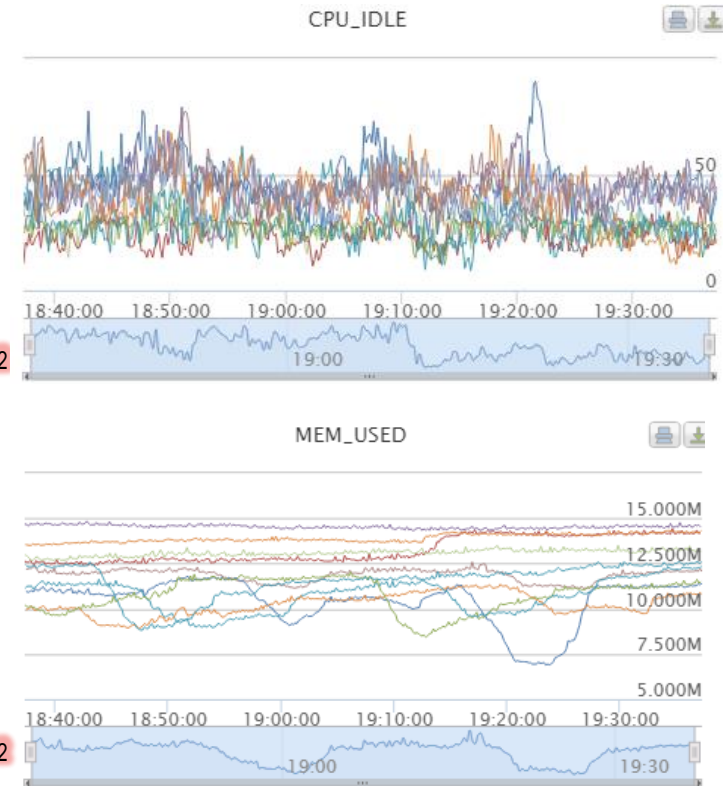
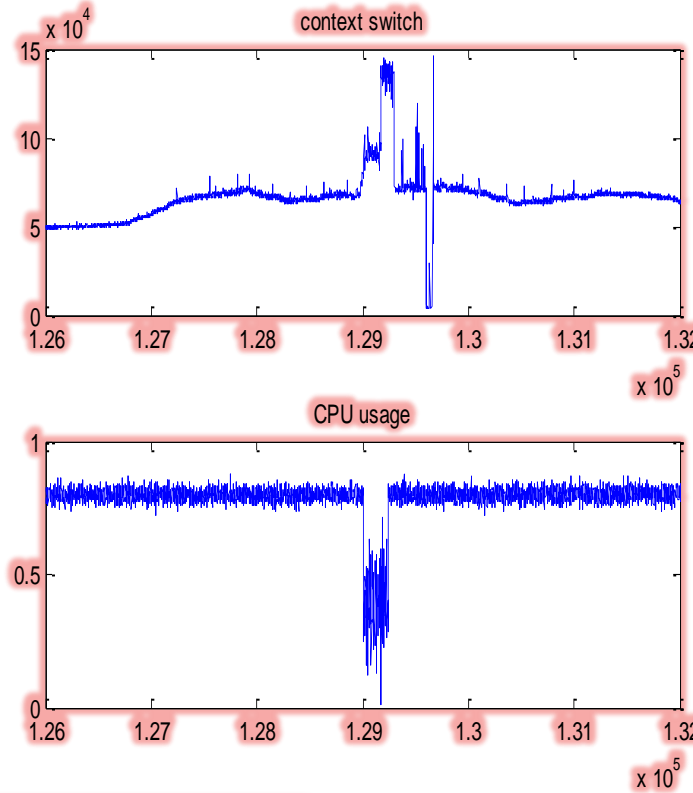


Annoyance vs Promptness of Alarms



Diagnosis

- Monitoring
- Changing Events
- Relationship
- Log
- ...



fcci	hd_vuitemplate-deplo...	vuitemplate		2015-03-10 16:30:51	2015-03-10 16:45:10	SUCCESS	10512 11:00:26 870503 12250 task_manager.cpp:504] insert task to be executed 5.nspis-imbs-999. IM. all 600 10 5 3.5 DAY
downloader	Downloader_http/tbj...			2015-03-10 16:30:42	2015-03-10 16:45:42	DONE	9 12234 detect_task.cpp:890] build threshold success 10.nspis-imbs-999. IM. all:IMBS_FL
fcci	n_vuitemplate_mix...	vuitemplate	I	2015-03-10 16:30:38	2015-03-10 16:42:26	SUCCESS	0 12234 task_manager.cpp:338] abnormal detected: [10.nspis-imbs-999. IM. all:IMBS_FLOW_ expect/upper/lower/977.472/1466.21/293.242
xbox	wise-left-bid-cpmis...			2015-03-10 16:28:05		RUNNING	4 12234 task_manager.cpp:51] execute task success: 10.nspis-imbs-999. IM. all, IMBS_FL
downloader	Downloader_nmg01-fcr...			2015-03-10 16:25:43	2015-03-10 16:40:43	DONE	0 12234 task_manager.cpp:298] create ClientPacket for 10.208.40.22:19050
							0 12234 task_manager.cpp:306] execute query[5.nspis-imbs-999. IM. all:IMBS_FLOW_cnt_avg
							6 12234 task_manager.cpp:338] abnormal detected: [5.nspis-imbs-999. IM. all:IMBS_FLOW_c
							ct/upper/lower/979.234/1468.85/293.77
							3 12234 task_manager.cpp:51] execute task success: 5.nspis-imbs-999. IM. all, IMBS_FLOW
							7 12250 task_manager.cpp:504] insert task to be executed 10.nspis-imbs-999. IM. all
							600 10 5 3.5 DAY
							4 12214 redis_manager.cpp:46] Redis pipeline thread exited

Automatic and smart monitoring and diagnosis

Smart monitoring system: 酷贝

Cool

酷

Bay

贝



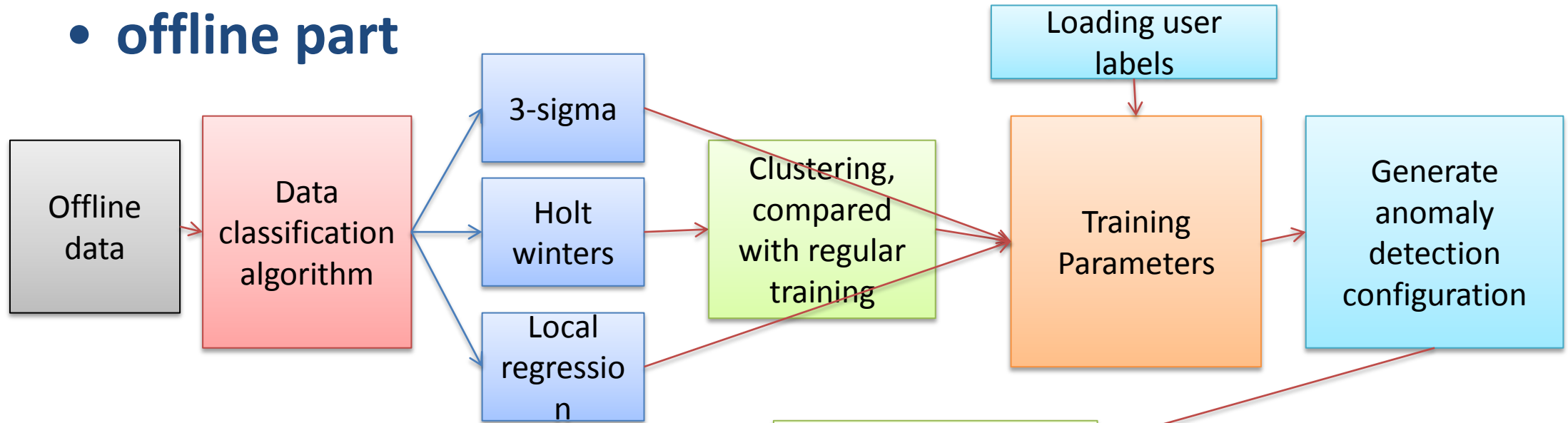
Collection → Detection → Diagnosis

Collection

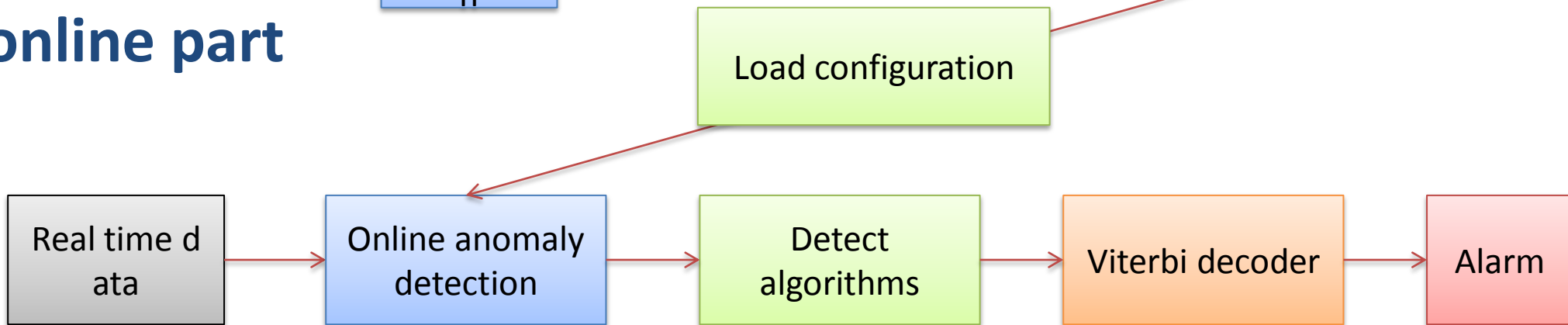
- **Service data**
 - PV, income, flow...
- **Machine & program data**
 - CPU, MEM, DISK, NETWORK...
- **Changing events**
- ...

Anomaly detection system

- offline part



- online part

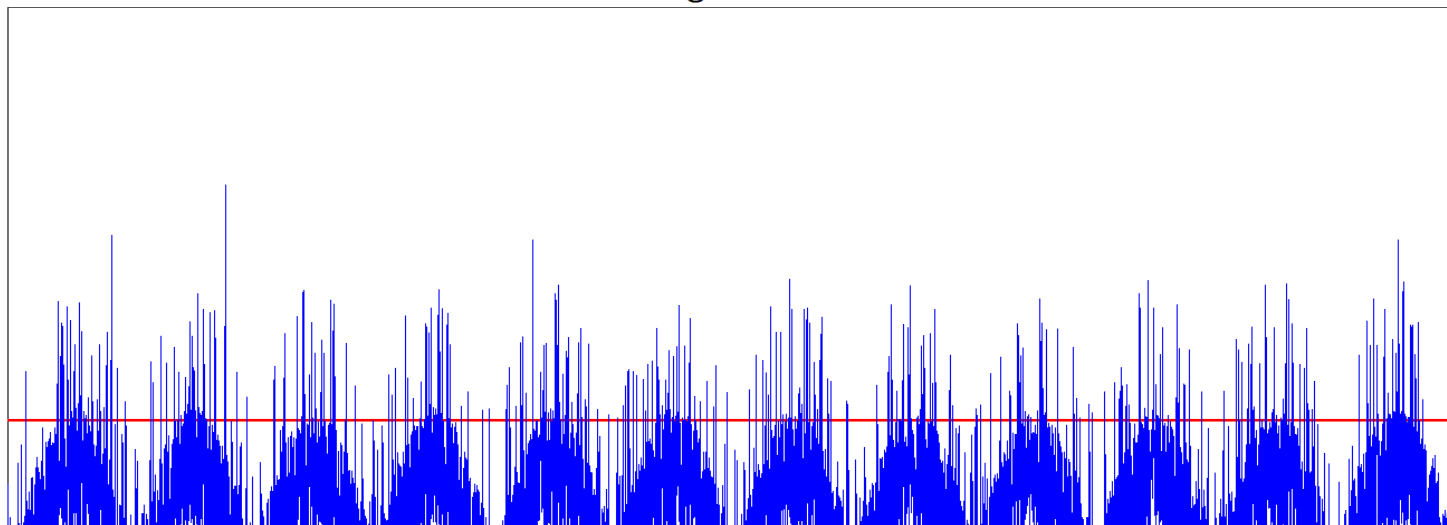


Detection: Strategy 1, 3-sigma rule

- **Determine constant threshold algorithmically**
 - Statistics on past data
 - Assume Gaussian distribution

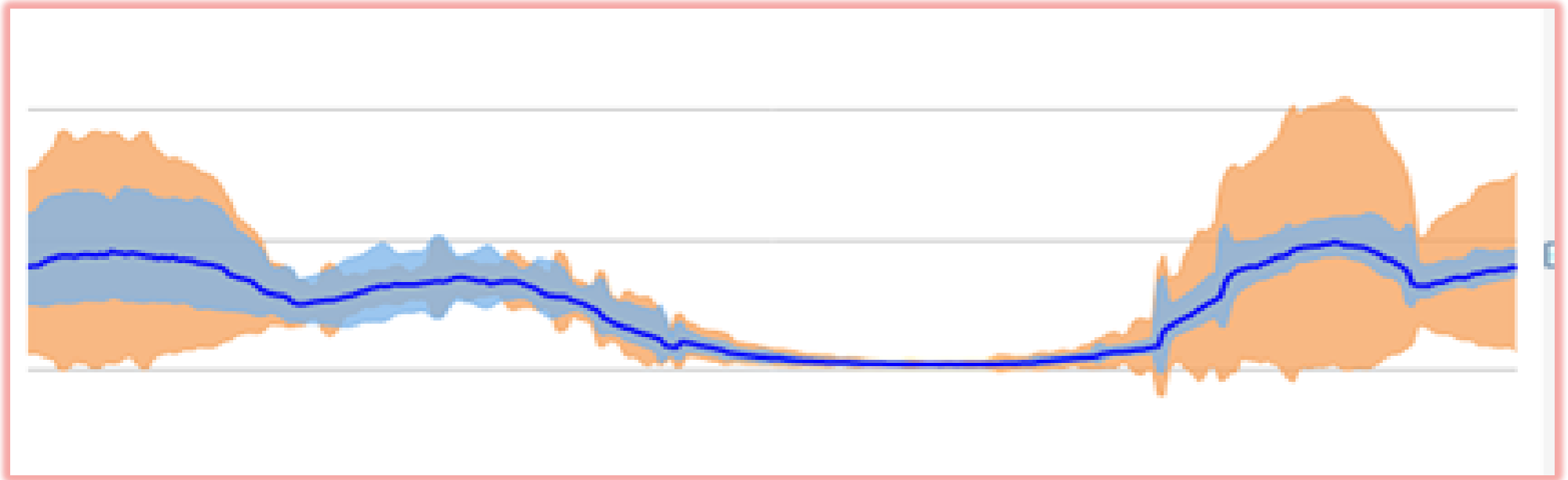
$$\bar{x} \pm 3\sigma$$

3 Sigma Rule

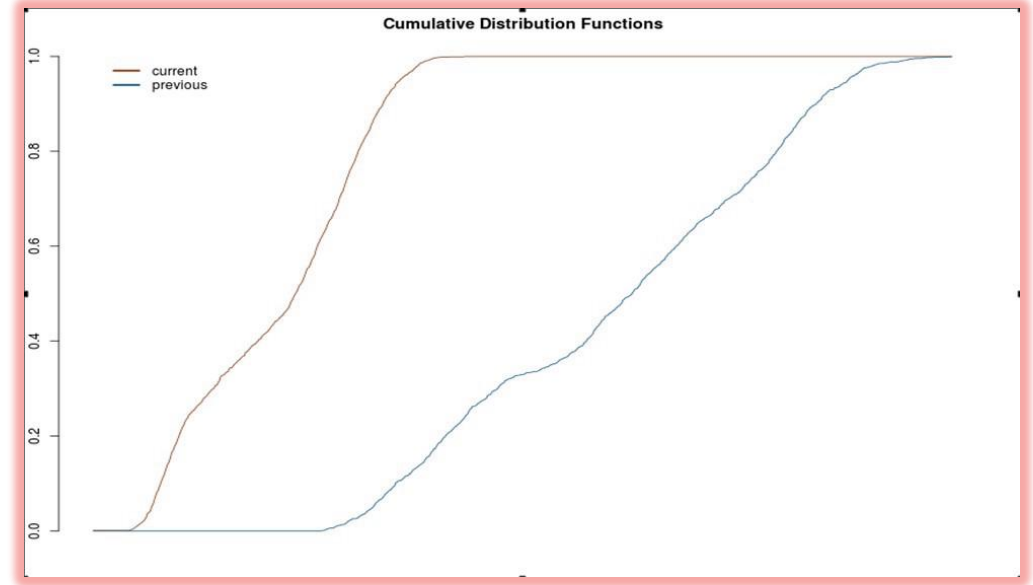
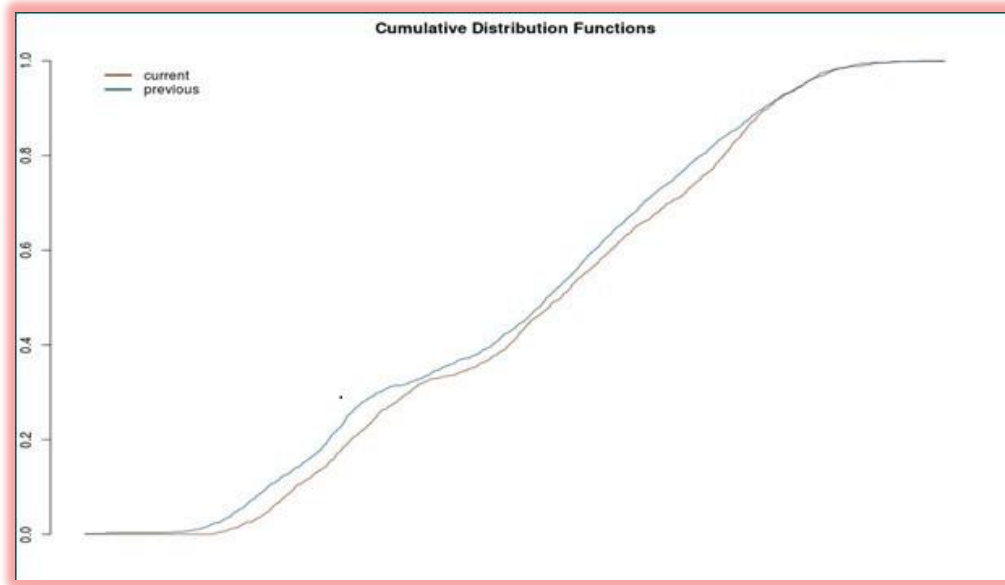


Detection: Strategy 2, the segmented 3-sigma rule

- **Multiple distributions : day vs night**
 - Split data into 15-min segments
 - Day-on-day statistics



Detection: Strategy 3, KS-test



- **Multiple distributions : workdays vs weekends / holidays**
 - Differentiate using KS-test
 - Statistics within Workday/Weekend/Holiday

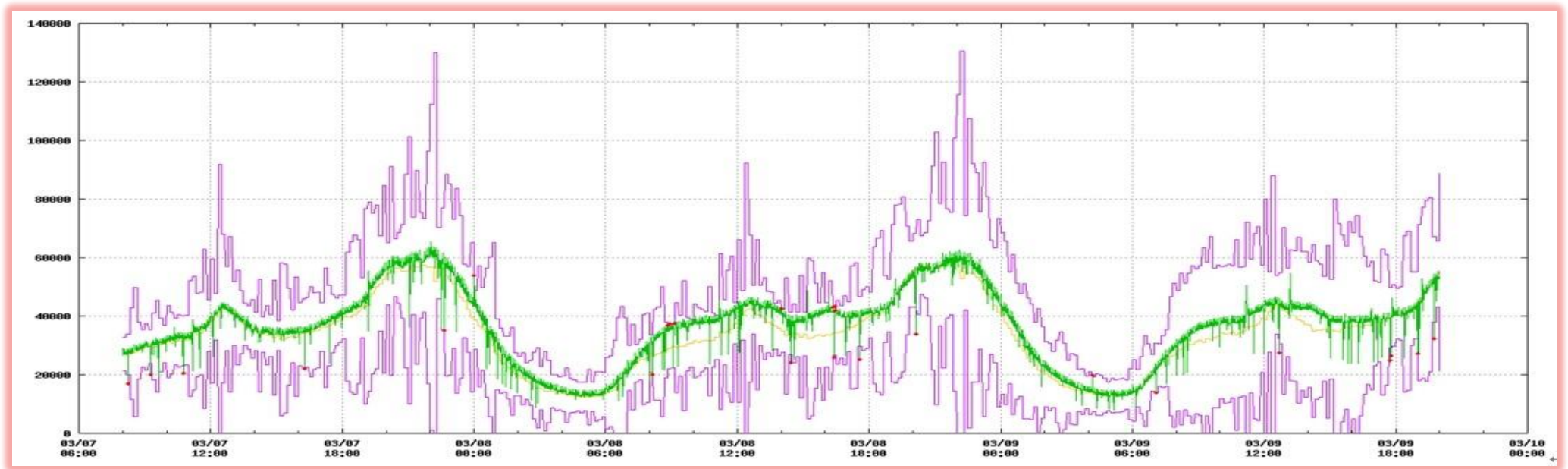
Other factors to consider

- Sometimes, the data is changing
 - e.g. compare the holiday PV with the workday PV



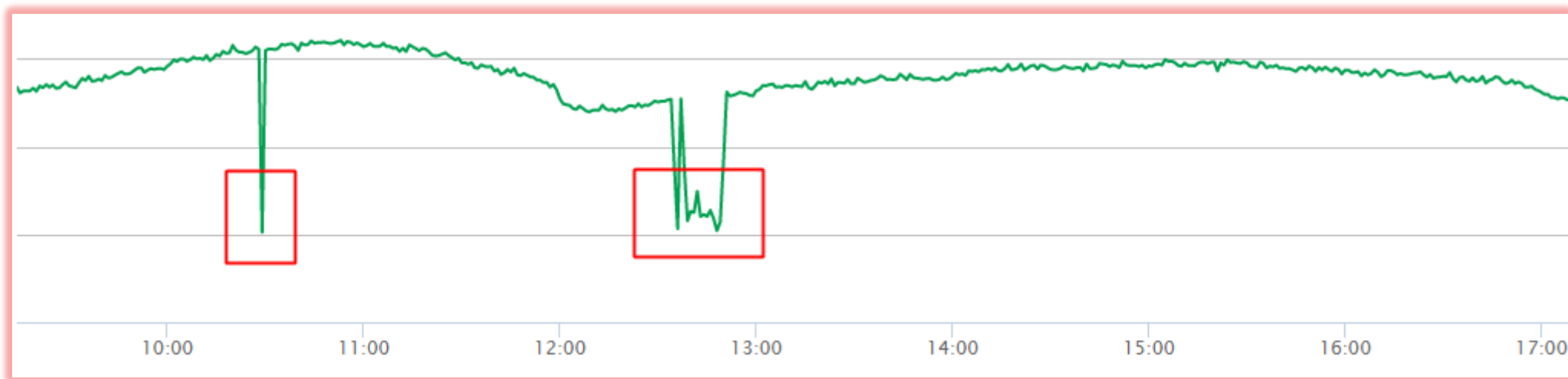
Detection: Strategy 3, holt-winters

- Holt-winters algorithm
- Learn both seasonal and adjacent trend



Detection : Strategy 4, local regression

- The detection of local spurt or sudden drop
 - LOESS algorithm based on local regression



Deal with slow decline in data trend

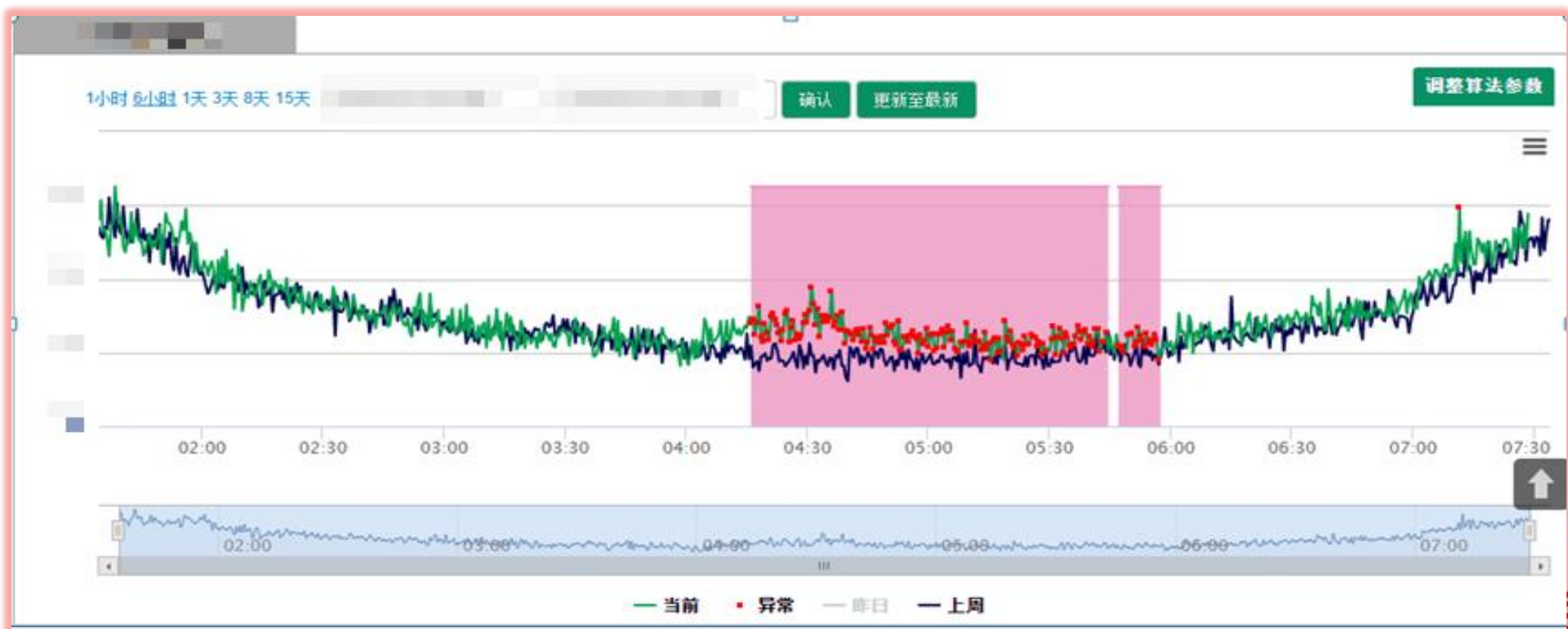
- Smart cumulative method
- The signal cycle of raw data changed
 - 10s, 30s changed to 15mins, 1hour, 24hours
- Then use 3-sigma and holt-winters to detect

Challenge: generated threshold parameters vs. business requirement

- **Incorporate engineers' manual input:**
 - Modify the parameters
 - Mark undetected anomaly
 - Mark false positive alarm
- **Learn adjustment automatically**
 - Alarm label → Adjust parameters + / -

Alarm filter

- Viterbi decoder
- The formation of abnormal events, rather than a single abnormal points



Problem diagnosis

- **Help Diagnose**

- Total-dimensions and sub-dimensions
- Upgrade/operation event and time series data
- Operation and maintenance module relationship

Total dimension and sub-dimension

- Based on the total dimension and sub-dimension
- Example: the total revenue and advertise revenue
- Sort by impact weight

属性	当天值	占比	天同比	天变化量	周同比	周变化量	操作
		0.56%	-11.68%	-465.14	0.97%	33.79	查看
		1.55%	-3.87%	-390.12	19.47%	1,578.63	查看
		0.28%	-12.24%	-240.55	-2.85%	-50.60	查看
		0.50%	-4.39%	-144.71	7.21%	211.84	查看
		0.87%	-1.68%	-92.70	-1.61%	-88.87	查看
		0.23%	-4.82%	-72.90	30.80%	339.08	查看
		0.04%	-20.74%	-69.28	-0.03%	-0.08	查看
		0.04%	-22.99%	-67.92	7.53%	15.93	查看
		0.01%	-52.96%	-57.22	-33.17%	-25.23	查看
		0.79%	-0.83%	-41.00	2.01%	97.13	查看

Heat map

- Sort anomaly numbers by dimension degree
- Slice data by abnormal regional, browser, channel
- Comparison of multi-dimensional anomaly



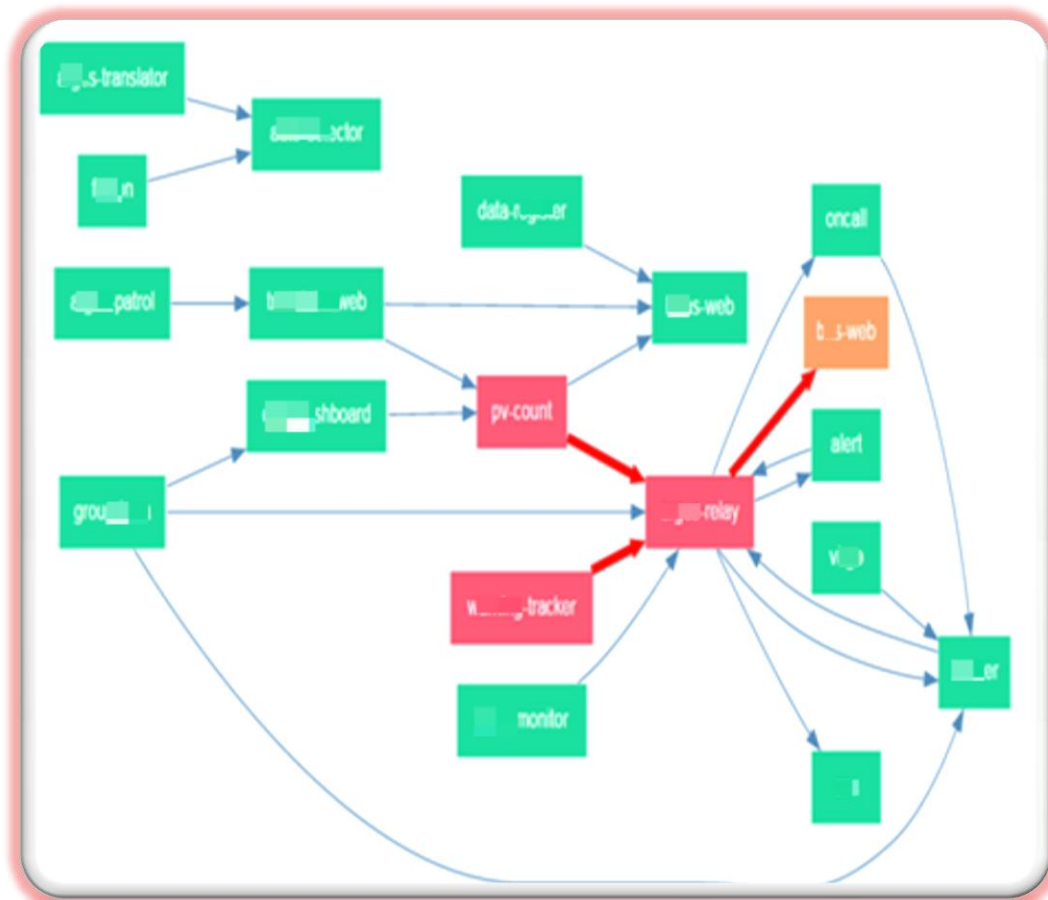
Issues caused by upgrades

- Based on upgrade events and metrics
- Time approximation

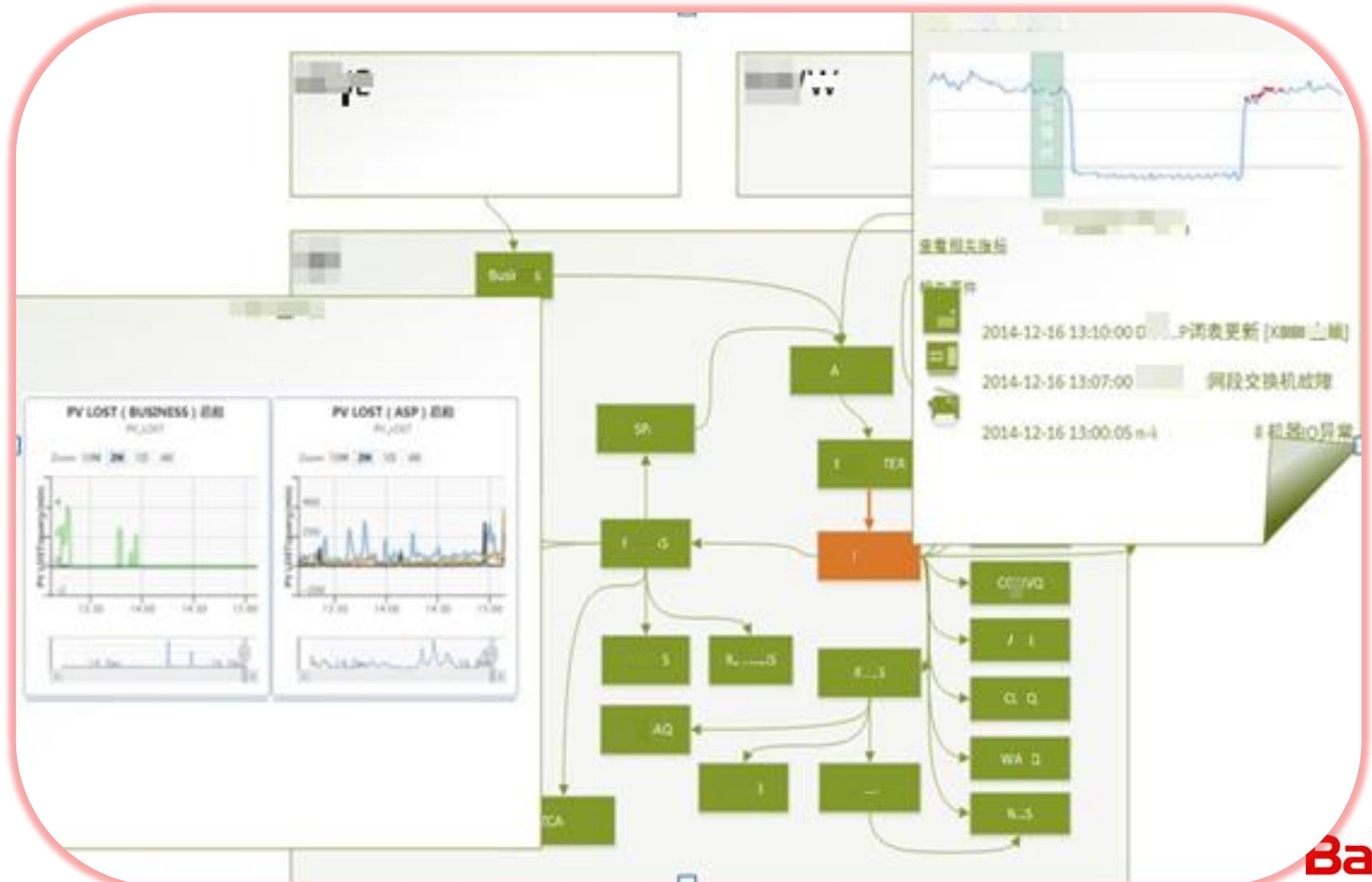


Issues diagnosis from operation and maintenance perspective

- Module calling graph
- Event and module relations



Establish the overall service view



Now, “酷贝” is born!

Summary

- It is difficult to detect anomalies and find the root cause when an anomaly occurs.
- A smart monitoring system for automatic anomaly detection @Baidu is demonstrated.
- Including data model of incidents, proactive anomaly detection algorithms, correlation analysis, and visualization.

Future

- **Characterization of workload spikes**
- **Dynamic resource allocation**
- **Capacity management**
- **Identification of performance problems**
- ...

Thanks

