AUTOMATIC ROOT CAUSE ANALYSIS IN MOBILE NETWORKS

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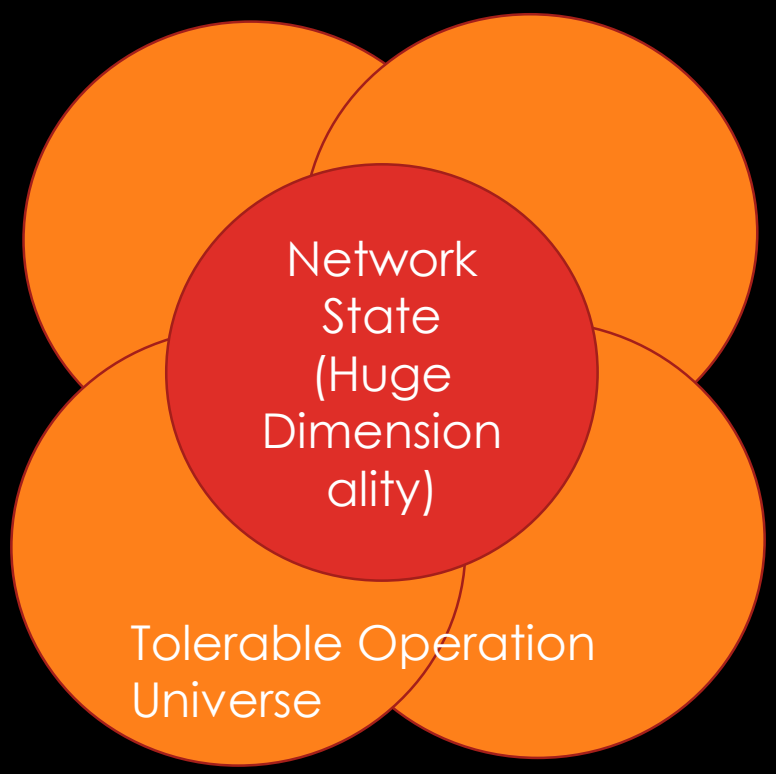
OUTLINE

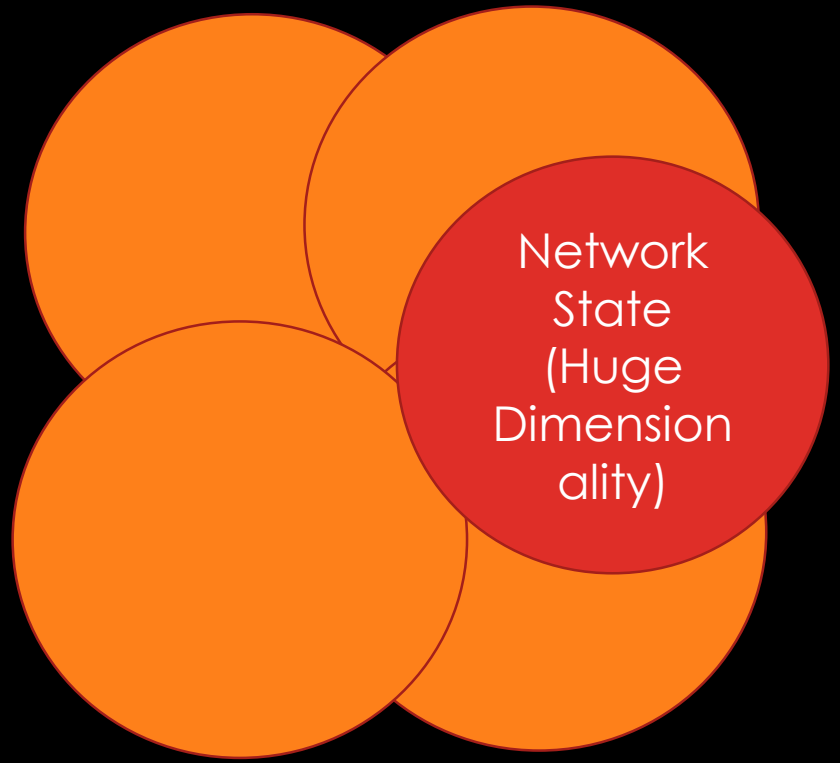
- The Problem
- The State
- The Analysis
- The Conclusion

THE PROBLEM

- Today's mobile networks should ideally
  - **Be fully reliable and accessible** (ideally 100% of the time)
  - Be usable for a wide variety of services (e.g. CS Voice, SMS, PS, VoLTE)
  - Serve subscribers and machines through different technologies (2G/3G/4G) and devices
  - Provide perfect communications for person-to-person, person-to-server (e.g. OTT services), M2M and IoT
- A network is a very complex system and consequently problems arisen are often difficult to diagnose and correct
  - All of us know the WAR-ROOM to WAR-ROOM game
- Problems in the network have a **huge direct financial impact** (revenue loss and the resources associated to operate and troubleshoot the network) as well as **indirect** (loss of credibility and impact on the brand)

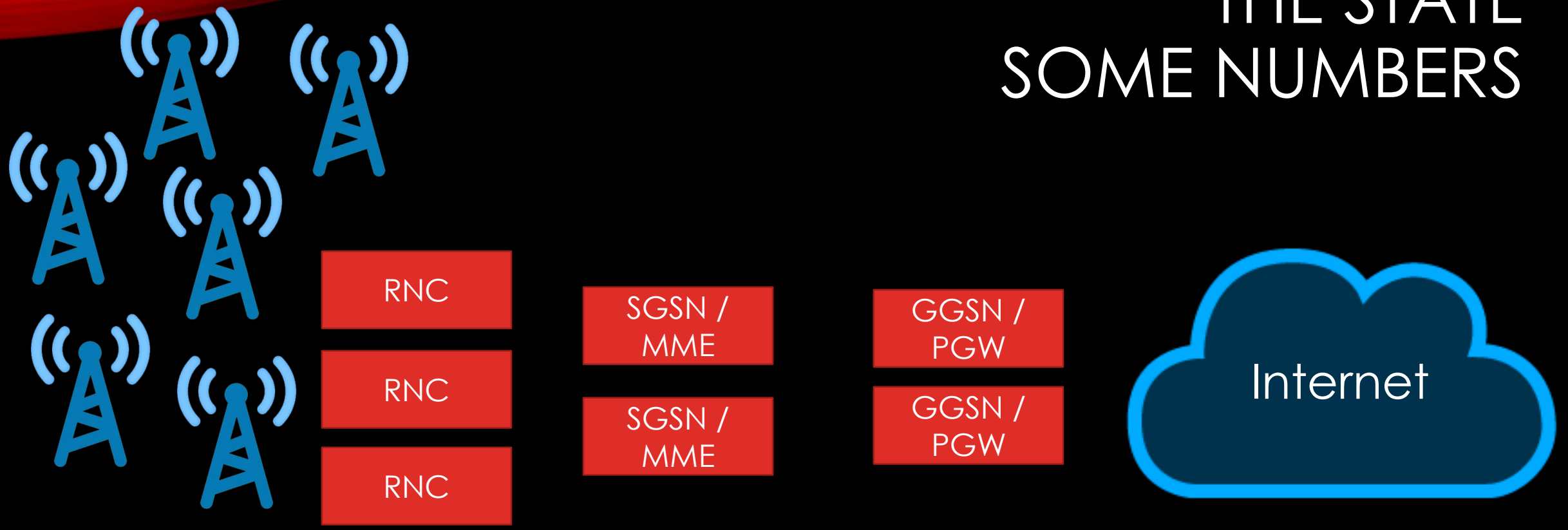
THE STATE





Problematic Operation Universe → Root Cause Analysis and Fixing

THE STATE SOME NUMBERS



50000 e/nodeB x 100 RNC x 20 SGSN/MME x 10 GGSN/PGW = 1000 Million Service Paths

10 State Variables x 1000 Million = 10000 Million Options to Explore

THE STATE ADD MORE ITEMS…

Network Related

- Technology Type (2G/3G/4G)
- Policy servers
- OCS Systems
- DPI Nodes
- Optimizers
- …

Device & OTTs

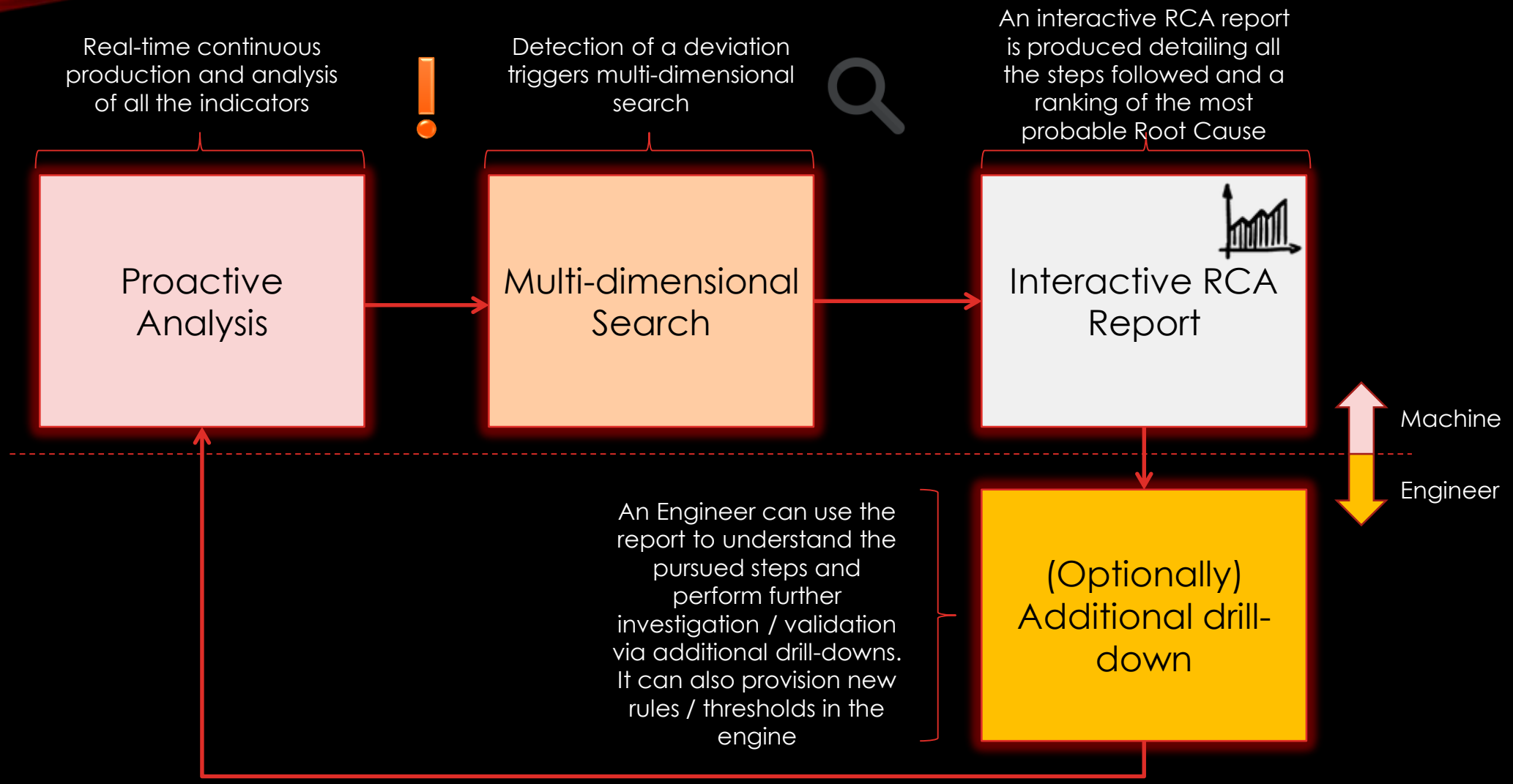
- Device types & models (typically a small network has around 10000 active models)
- Internet servers providing fancy services (e.g. Google, Facebook, YouTube, Periscope, Twitter)
- OTT Apps (e.g. WhatsApp, SnapChat)

Keep on multiplying… The number of combinations to explore in quest of failures is unmanageable

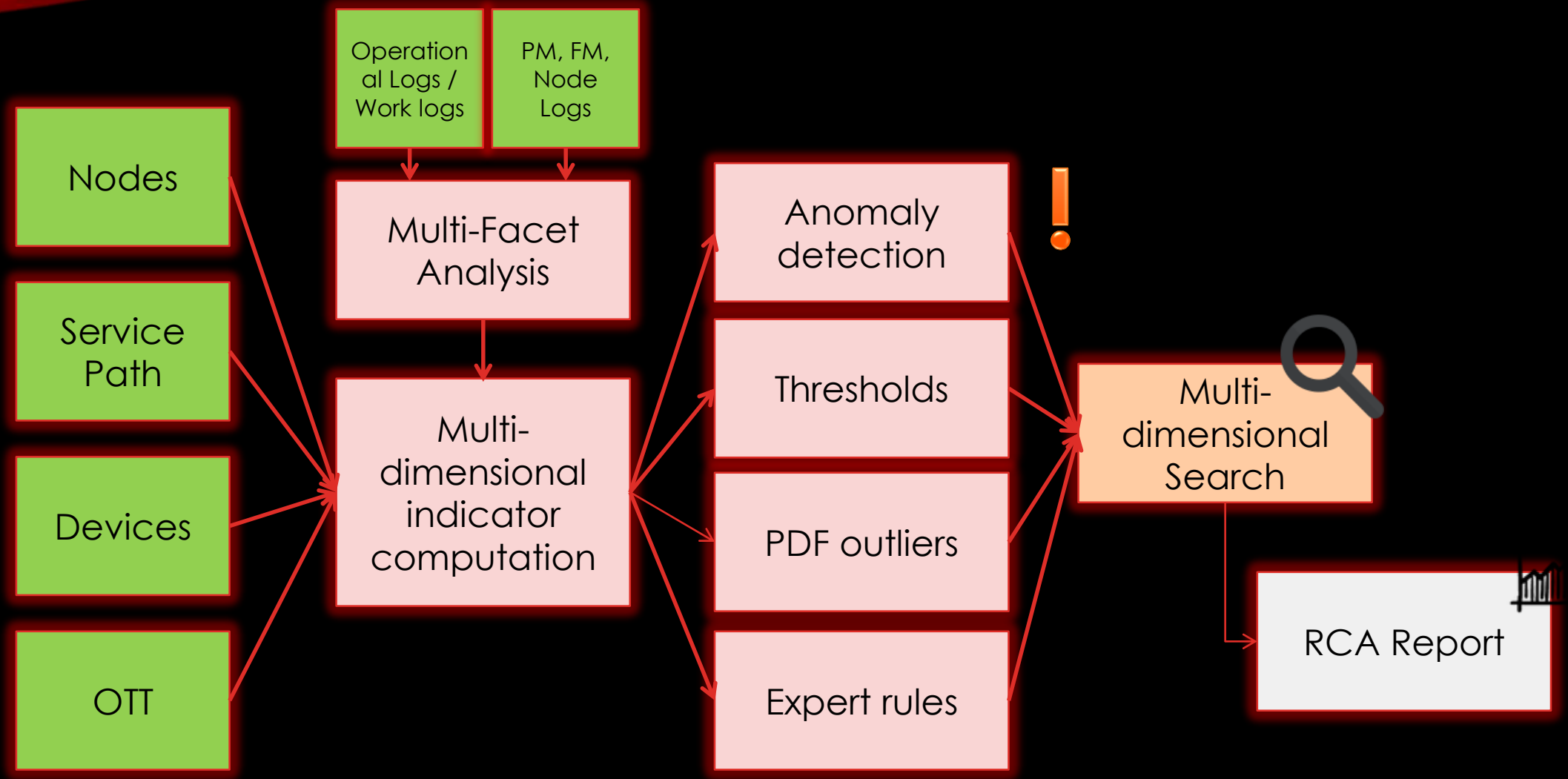
THE STATE
WHAT'S NORMAL

- Given the state, we need to identify the boundaries of the Tolerable Operation Universe
- Typically, this **Tolerable Operation Universe** is delimited by a
  - **Baseline for certain KQIs/KPIs** (dimensionality reduction) – Typical KQIs include accessibility, retainability, speed, etc.
  - + Confidence Interval
- The **Confidence Interval** may be
  - **Hard** – SLAs (typically, human-defined)
  - **Soft** – Automatic Baseline Computation
- Deviations from the baseline + confidence interval are usually due to problems (deviations from normal behavior)

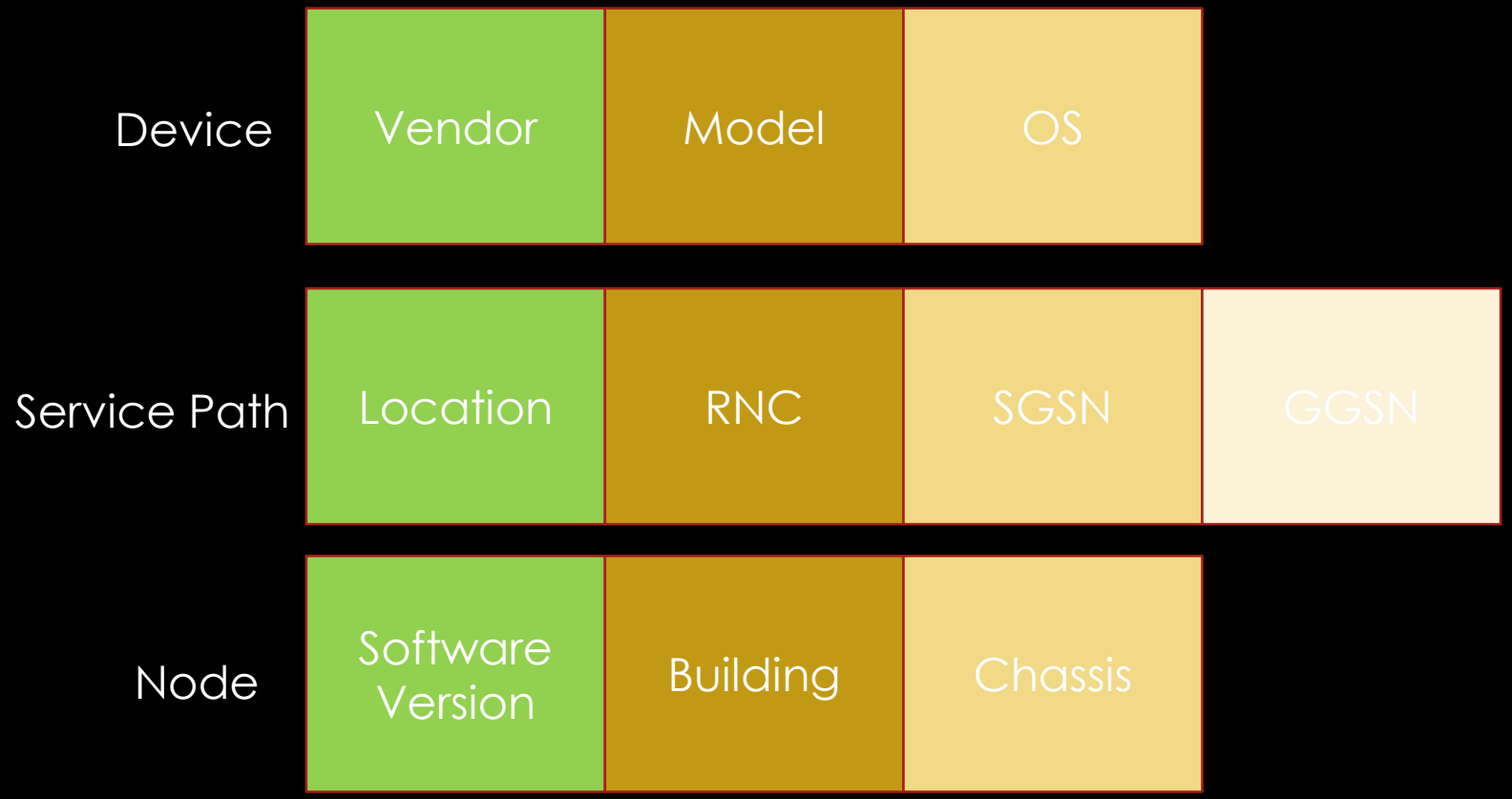
ROOT CAUSE ANALYSIS THE FLOW



AUTOMATIC RCA: INTERNALS

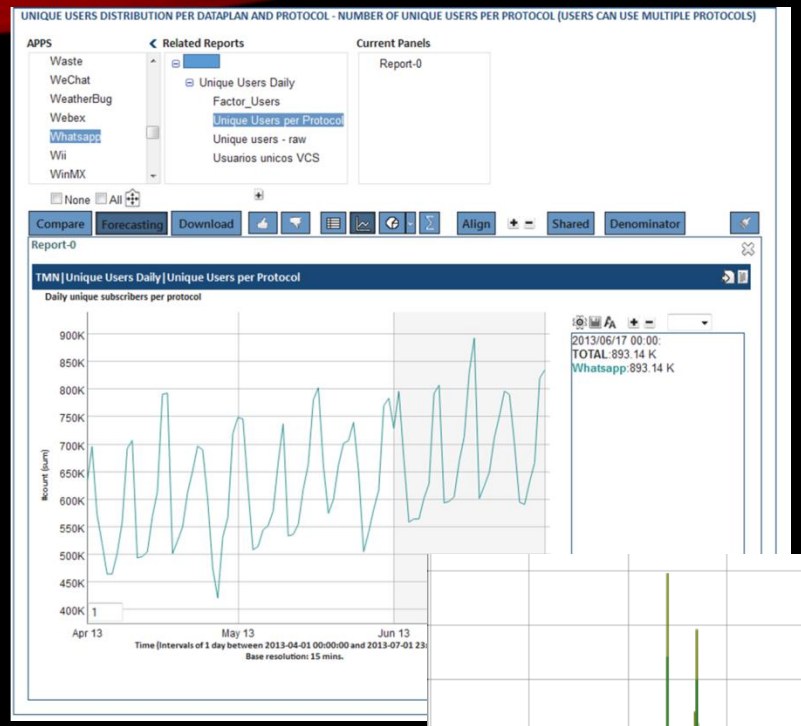


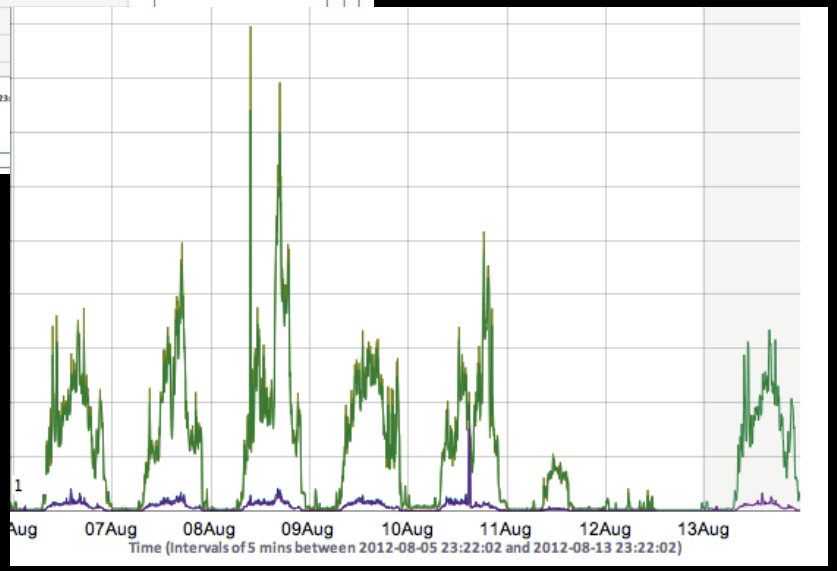
ROOT CAUSE ANALYSIS 10
MULTI-DIMENSIONAL SEARCH: SOME EXAMPLES



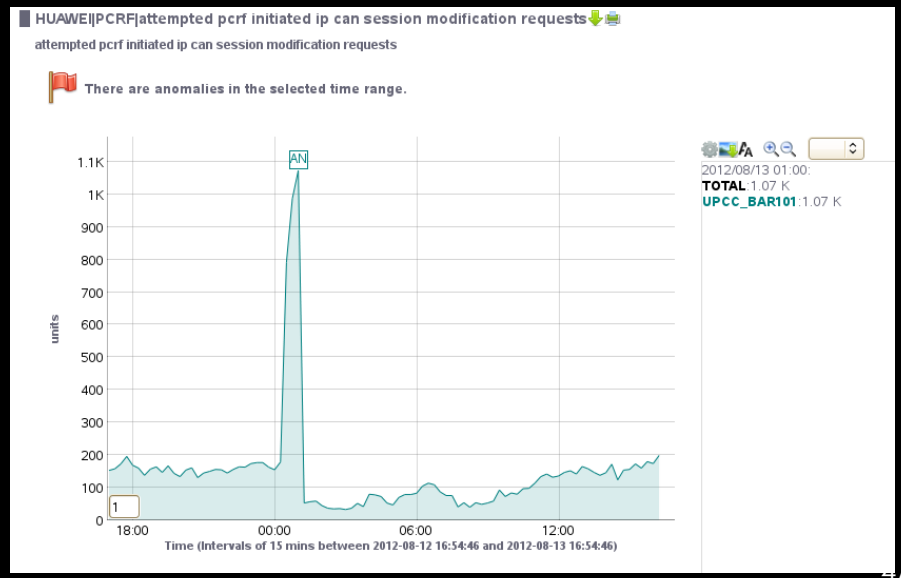
- Indicators are produced for all the dimensions
- A search of the values at the different dimensions allows to isolate origin of the deviations

AUTOMATIC RCA: ANOMALY DETECTION[11]



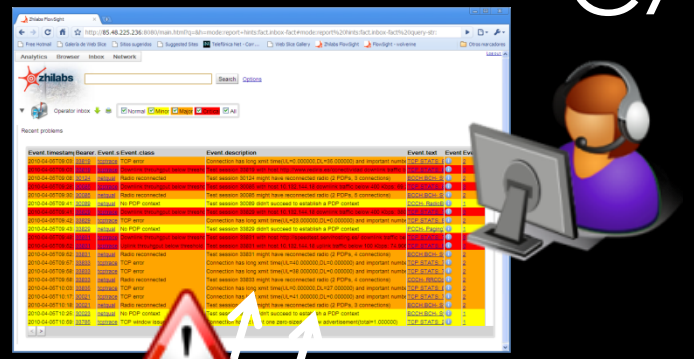


- The same algorithms available in FlowSight are used by the engine under the covers:
  - Forecasting: ARIMA
  - Anomalies: cyclostationary analysis, AR



FORECASTING AND ANOMALY DETECTION AUTOMATIC THRESHOLDS - BASELINE CALCULATION

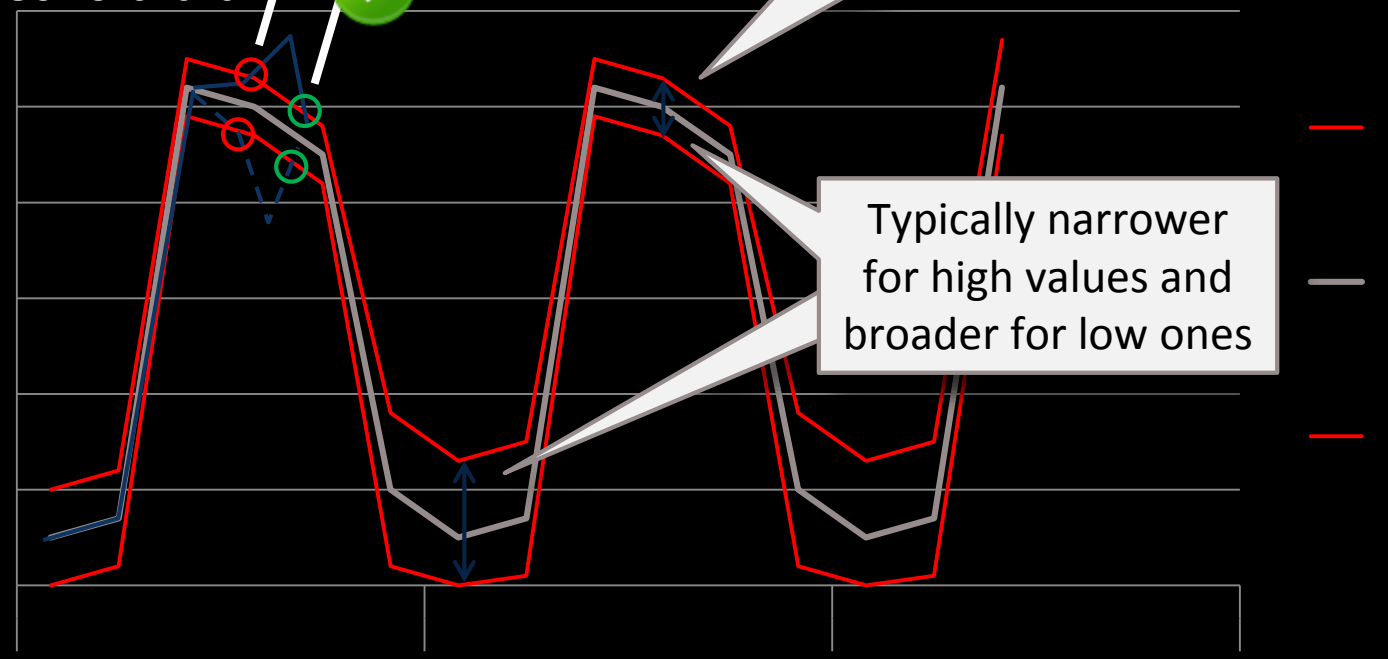
- AR models are good at detecting anomalies
- ARIMA Methods take into consideration seasons and trends



Upper & lower thresholds are automatically calculated, based on the typical deviation around the baseline

Threshold alarm

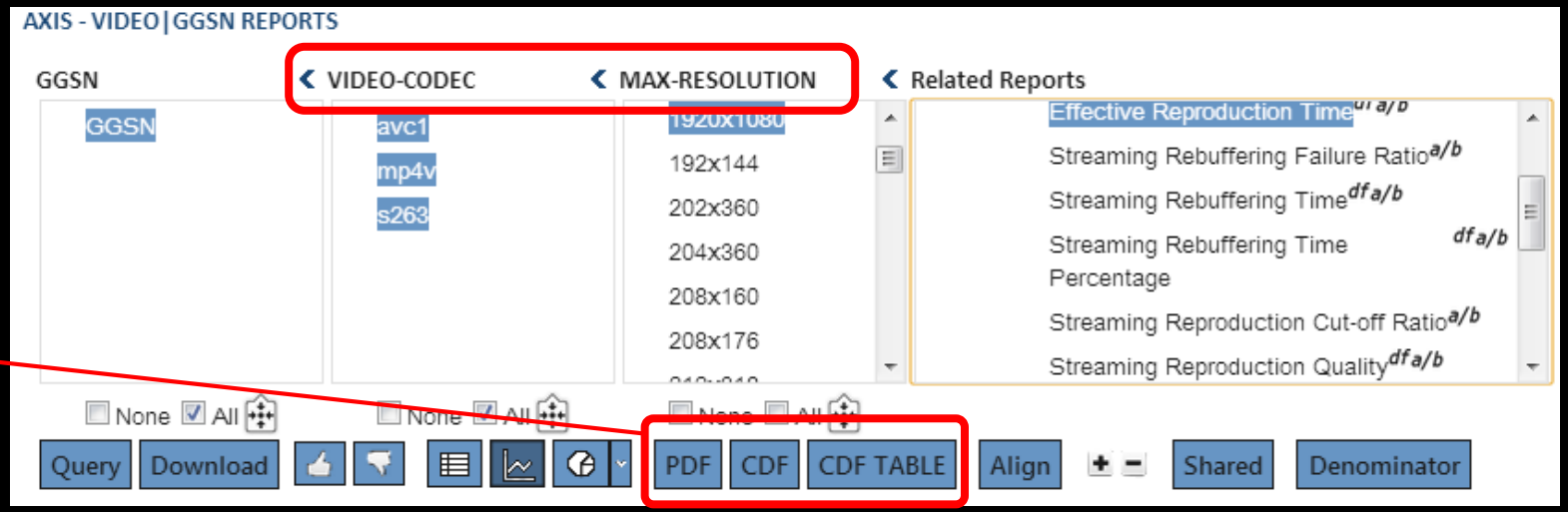
Alarm clear



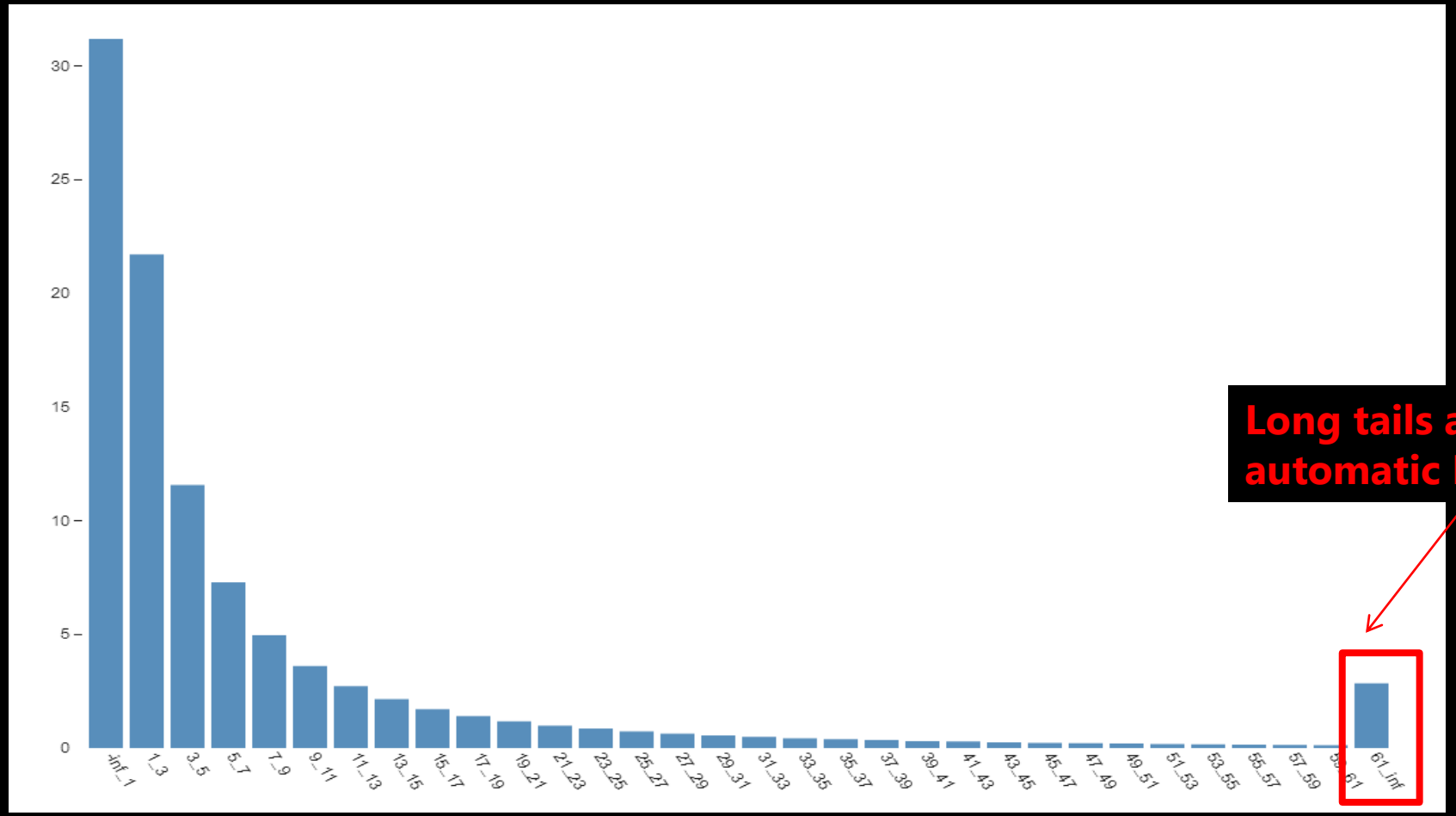
Typically narrower for high values and broader for low ones

MULTI-DIMENSIONAL ANALYSIS AND PDFS

The system computes automatically **Distribution Functions** (**PDF and CDF**).

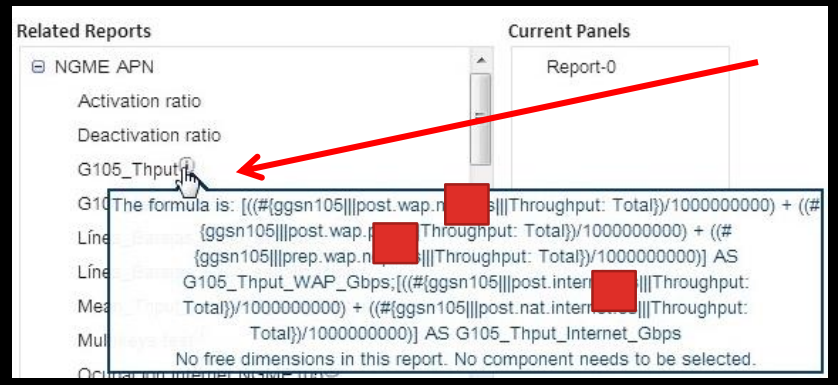


PROBABILITY DISTRIBUTION FUNCTIONS: OUTLIERS



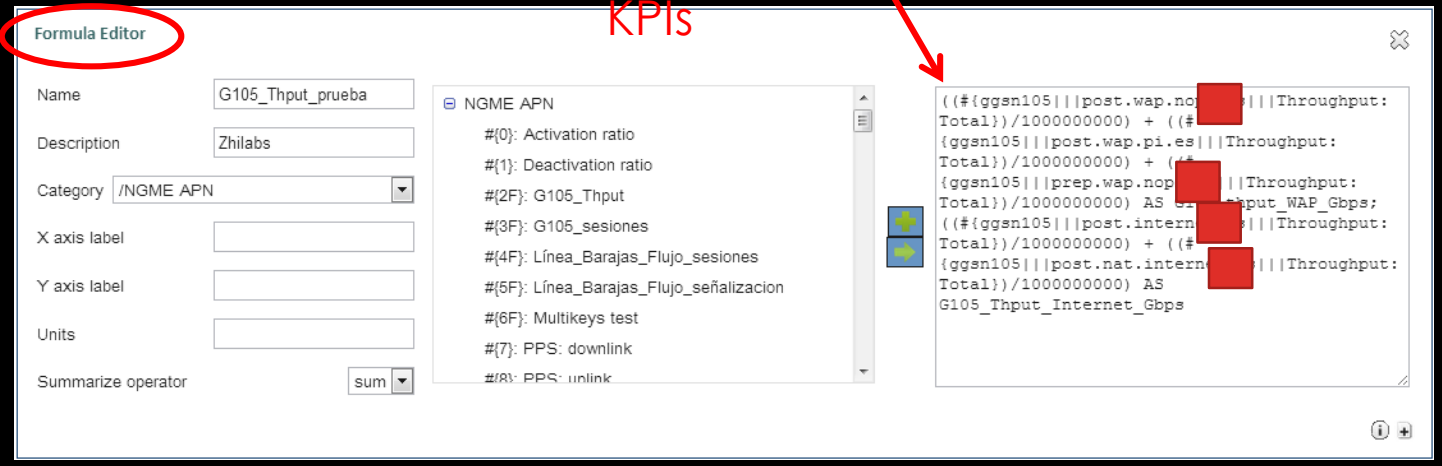
Long tails are explored by the automatic RCA

EXPERT RULES: FORMULAS



Clicking over a KPI shows the corresponding formula

The Formula Editor allows an operator to flexibly define complex KPIs



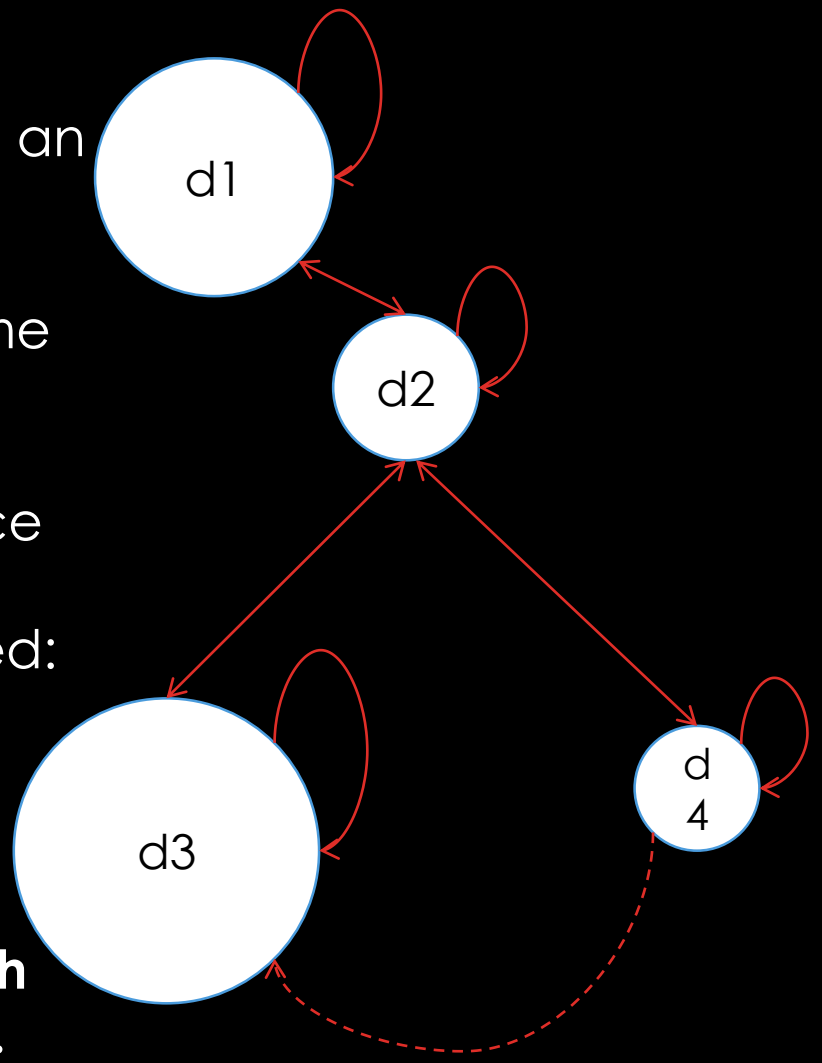
AUTOMATIC RCA: DETAILS

1. **Proactive Analysis:**
   - Input: Nodes, Service Path, Devices, OTT
   - Additional inputs (multi-facet analysis):
     - Operational logs / Work logs (detailing changes performed in the network)
     - Performance Mgmt / Fault Mgmt / Logs from the different nodes
   - Multi-dimensional Indicator production
   - Four elements:
     - Anomaly detection (autoregressive and cyclostationary algorithms)
     - Thresholds
     - PDF outliers
     - Expert Rules

2. **Multi-dimensional Search:**
   - Multi-dimensional analysis of deviation to locate commonalities
   - Determination of most probable root-cause (ranking process)
3. **Interactive RCA report:**
   - Details steps (1) and (2) via clickable reports
   - Allows an engineer to validate the RCA and/or further investigate from the machine-produced baseline

ROOT CAUSE ANALYSIS MULTI-DIMENSIONAL SEARCH

1. **Pattern similarity:**
   - Uses time-range/indicator that signaled the anomaly as an input
   - Computes similarity for that scope in other dimensions
   - Correlation used as a similarity function between the time series
2. **Ranking:**
   - Dimensions effectively become a loosely-coupled service graph graded by the similarity function
   - A variation of Personalized PageRank algorithm is applied:
     - Random walk
     - Similarity score used to modulate transitions and teleportation

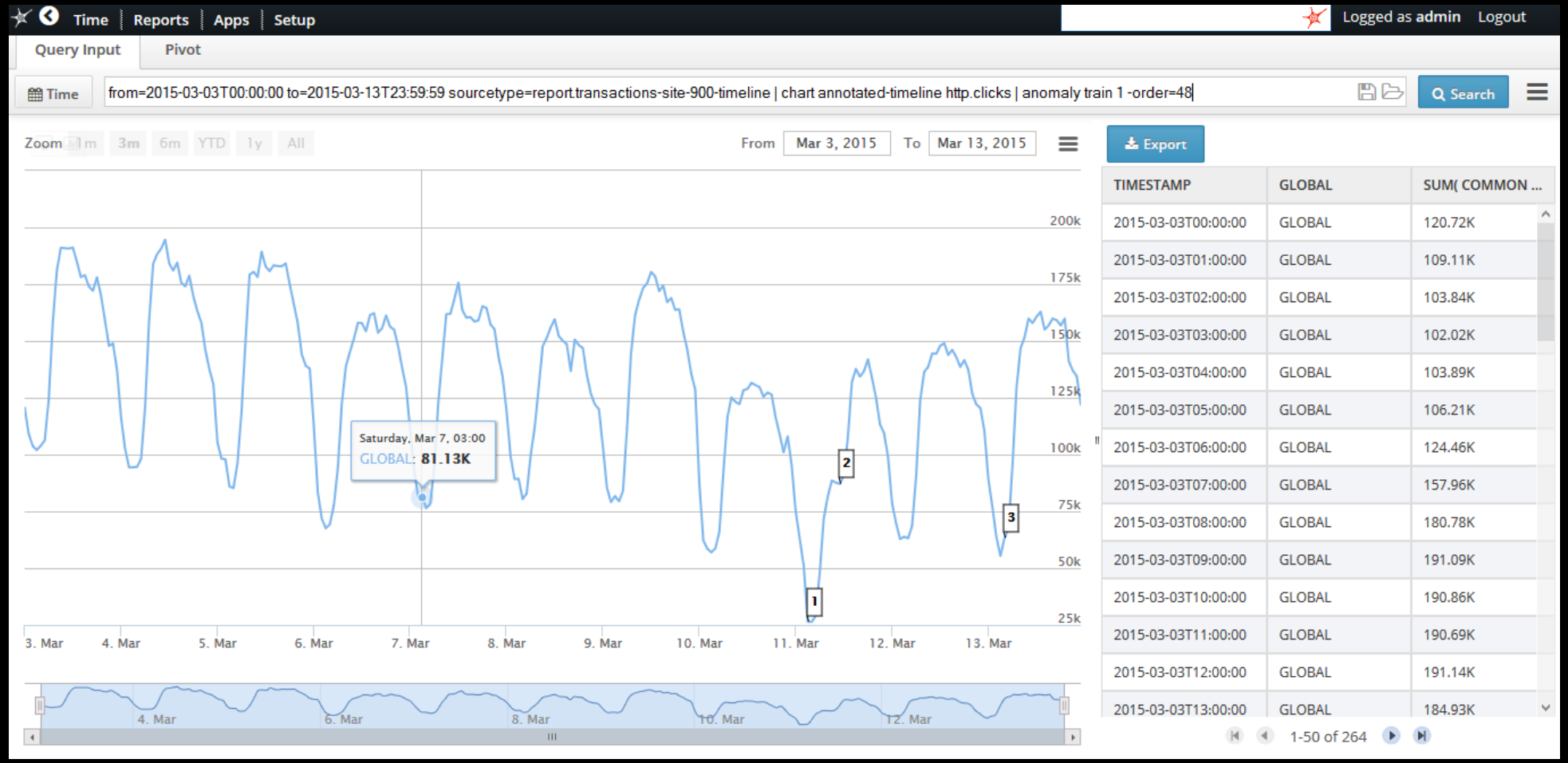


Intuitively equivalent to several Engineers drilling-down through the different dimensions driven by similarities in the time series.

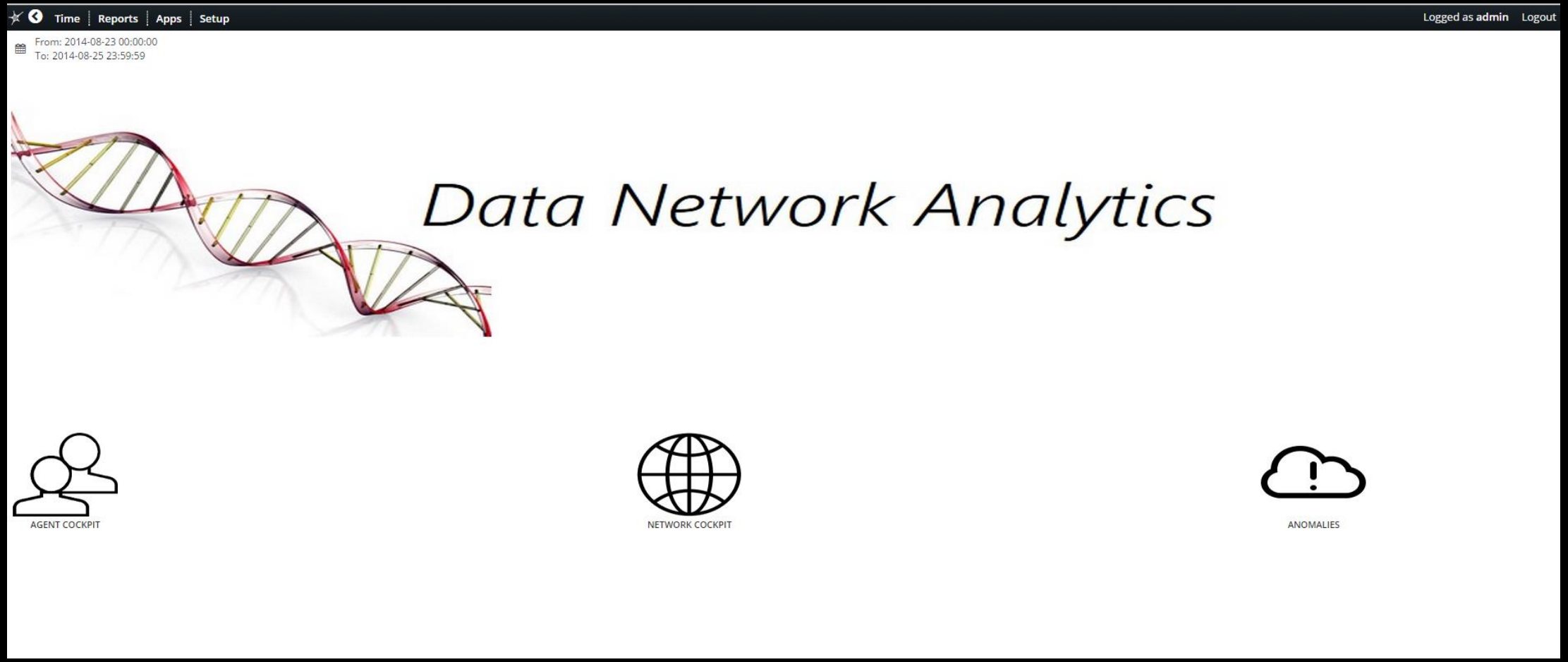
THE ANALYSIS

Automatic Root Cause Analysis Demos

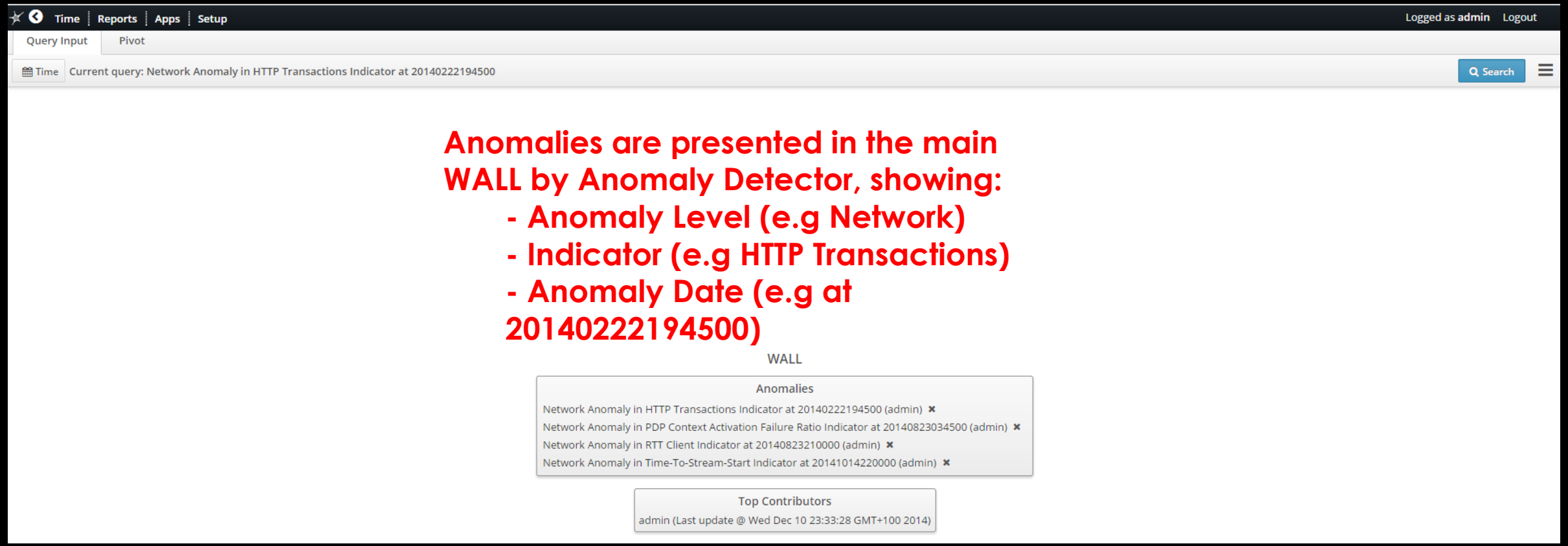
AUTOMATIC ANOMALY DETECTION APPLE SERVICES DOWN



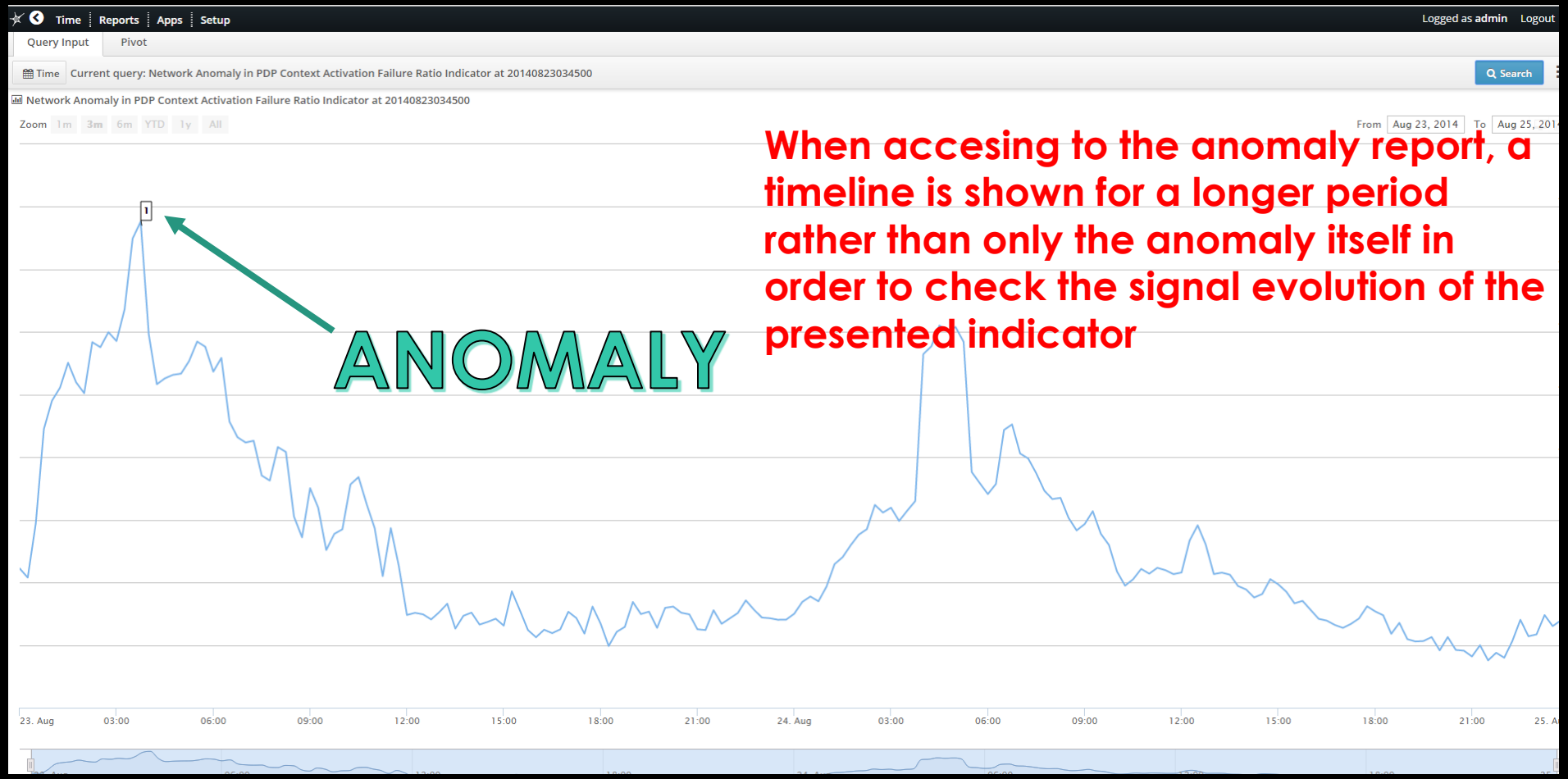
RCA: USE CASES INTRODUCTION



RCA WALL



RCA
NETWORK ANOMALY IN PDP CONTEXT ACTIVATION FAILURE RATIO INDICATOR



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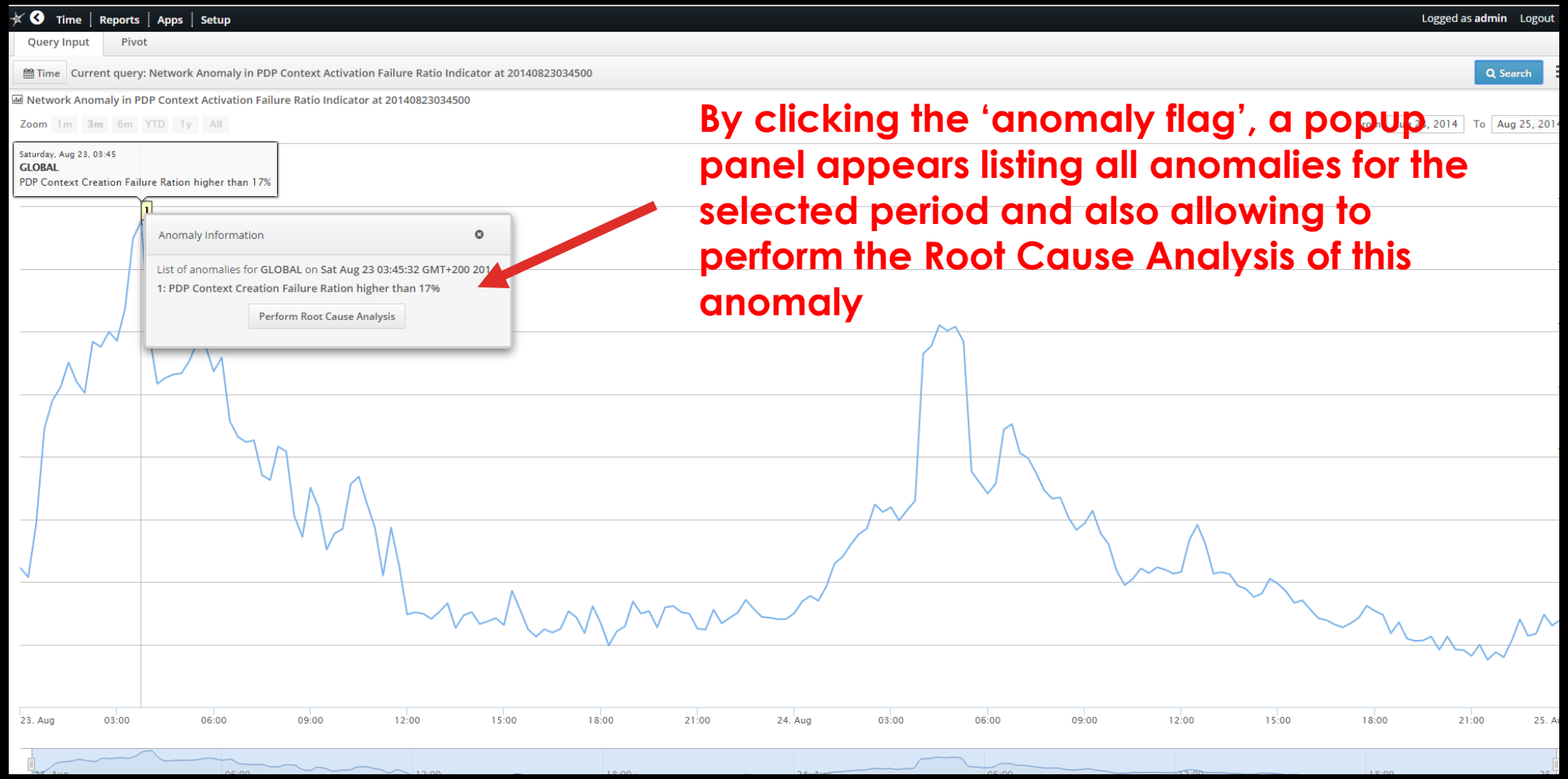
NETWORK ANOMALY IN PDP CONTEXT ACTIVATION FAILURE RATIO INDICATOR



By clicking the 'anomaly flag', a popup panel appears listing all anomalies for the selected period and also allowing to perform the Root Cause Analysis of this anomaly

RCA
NETWORK ANOMALY IN PDP CONTEXT ACTIVATION FAILURE RATIO INDICATOR

Time | Reports | Apps | Setup — Logged as admin Logout

PROACTIVE ANALYSIS

FACT #1: PDP Context Creation Failure Ratio higher than 17% from 2014-08-23T03:45:00 to 2014-08-2

MULTI-DIMENSIONAL ANALYSIS

FACT #1: PDP Context Creation Failure Ratio higher than 17%

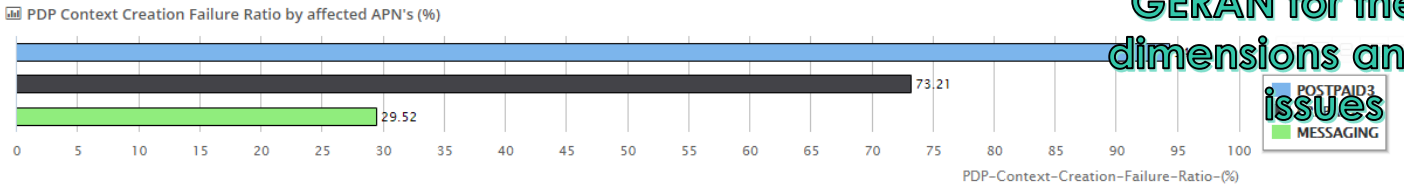
Item	Value
Dimension	RAT
Affected Values	GERAN
Time Range	2014-08-23T03:45:00 to 2014-08-25T03:59:59

In this case, RAT-TYPE = GERAN shows the highest correlation

Root cause analysis is performed and system shows as a dashboard the FACTS and the Possible Issues found for the anomaly

FACT #2: PDP Context Creation Failure Ratio with RAT=GERAN higher than 20%

Item	Value
Dimension	APN
Affected Values	POSTPAID3 PREPAID MESSAGING
Time Range	2014-08-23T03:45:00 to 2014-08-25T03:59:59



System drills-downs on GERAN for the APN dimensions and finds issues

ROOT-CAUSE ANALYSIS

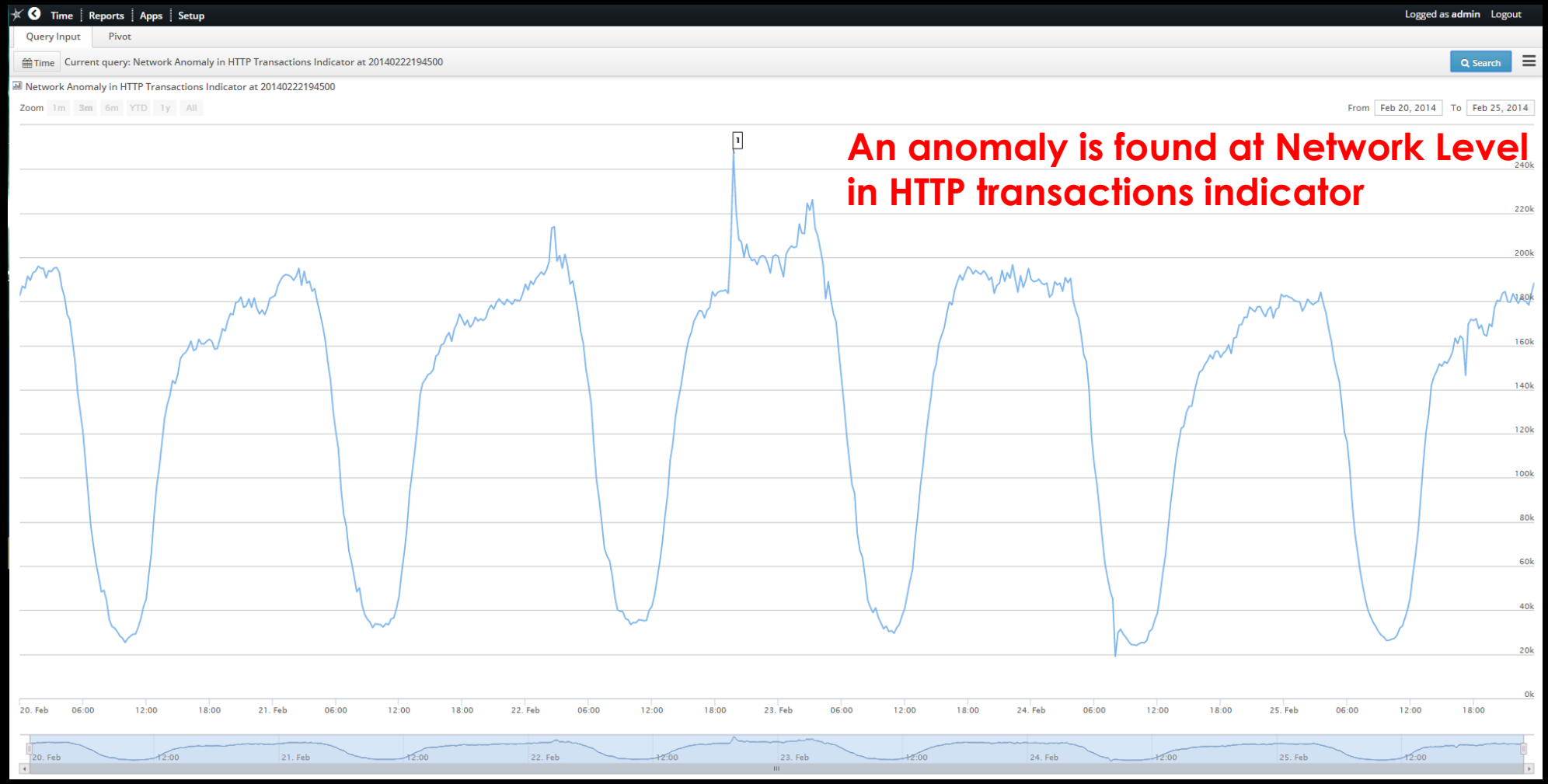
Ranking #1	Possible issue at
Dimension	RAT & APN
Affected Values	GERAN & POSTPAID3
Time Range	2014-08-23T03:45:00 to 2014-08-25T03:59:59

Ranking #2	Possible issue at
Dimension	RAT & APN
Affected Values	GERAN & PREPAID
Time Range	2014-08-23T03:45:00 to 2014-08-25T03:59:59

Ranking #3	Possible issue at
Dimension	RAT & APN
Affected Values	GERAN & MESSAGING
Time Range	2014-08-23T03:45:00 to 2014-08-25T03:59:59

And APNs found by RAT are presented in a set of ranked results

RCA
NETWORK ANOMALY IN HTTP TRANSACTIONS INDICATOR



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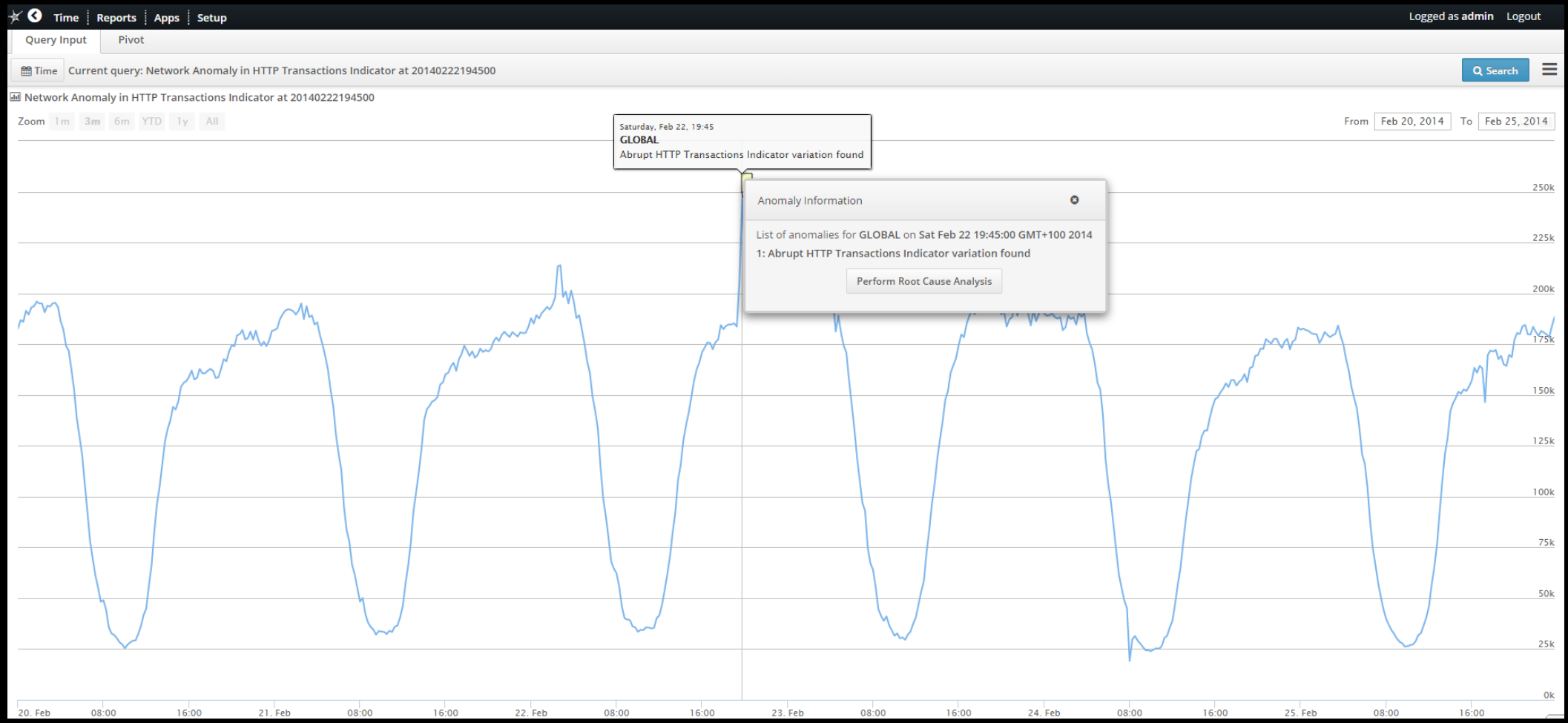
NETWORK ANOMALY IN HTTP TRANSACTIONS INDICATOR



RCA
NETWORK ANOMALY IN HTTP TRANSACTIONS INDICATOR

Time | Reports | Apps | Setup — Logged as **admin** Logout

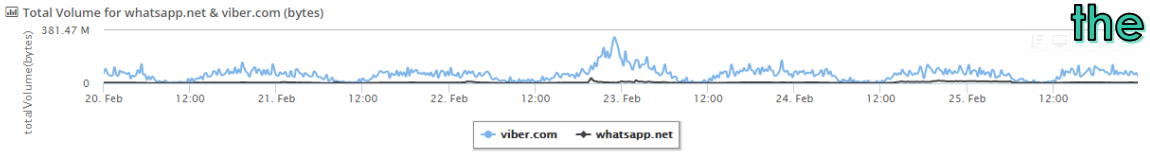
PROACTIVE ANALYSIS

FACT #1: Volume variation found from 2014-02-22T19:45:00 to 2014-02-22T19:59:59

MULTI-DIMENSIONAL ANALYSIS

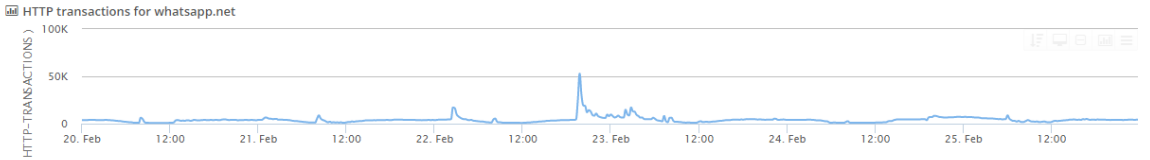
FACT #1: Volume variation found for whatsapp.net & viber.com sites

Item	Value
Dimension	SITE
Affected Values	whatsapp.net & viber.com
Time Range	2014-02-22T19:45:00 to 2014-02-22T19:59:59



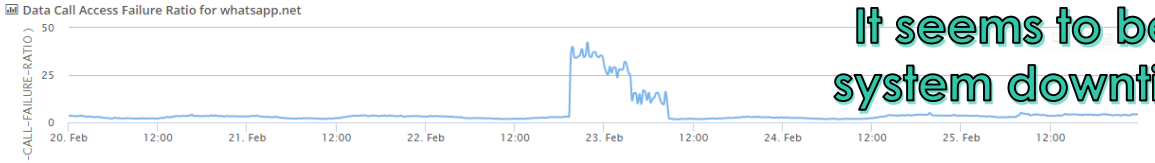
FACT #2: Variation in HTTP Transactions indicator found for whatsapp.net

Item	Value
Dimension	SITE
Affected Values	whatsapp.net
Time Range	2014-02-22T19:45:00 to 2014-02-22T19:59:59



FACT #3: Variation in Data Call Access Failure Ratio found for whatsapp.net site

Item	Value
Dimension	SITE
Affected Values	whatsapp.net
Time Range	2014-02-22T19:45:00 to 2014-02-22T19:59:59



ROOT-CAUSE ANALYSIS

Ranking #1	Possible issue at
Dimension	SITE
Affected Values	whatsapp.net & viber.com
Affected Indicator	Total Volume
Time Range	2014-02-22T19:45:00 to 2014-02-22T19:59:59

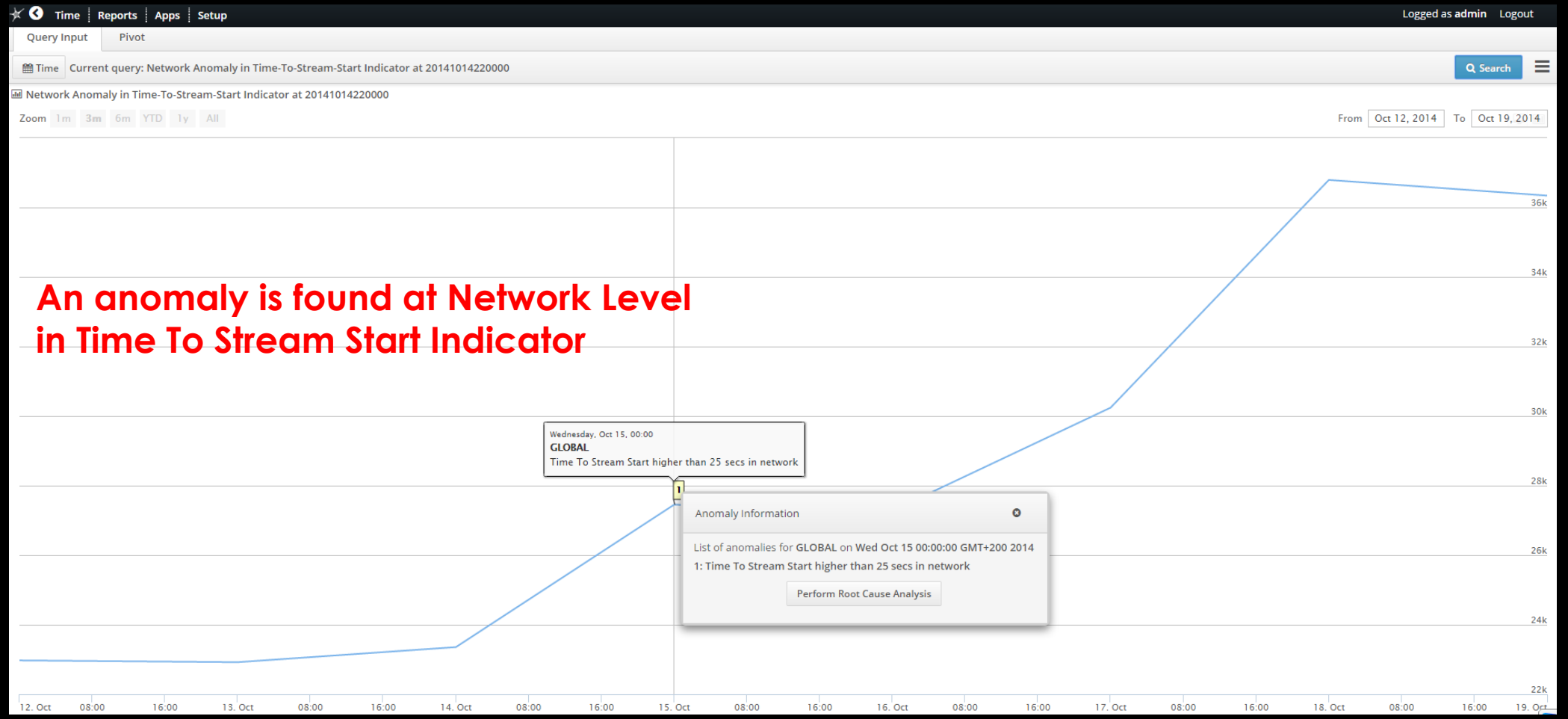
Ranking #2	Possible issue at
Dimension	SITE
Affected Values	whatsapp.net
Affected Indicator	HTTP Transactions
Time Range	2014-02-22T19:45:00 to 2014-02-22T19:59:59

Ranking #3	Possible issue at
Dimension	SITE
Affected Values	whatsapp.net
Affected Indicator	Data Call Access Failure Ratio
Time Range	2014-02-22T19:45:00 to 2014-02-22T19:59:59

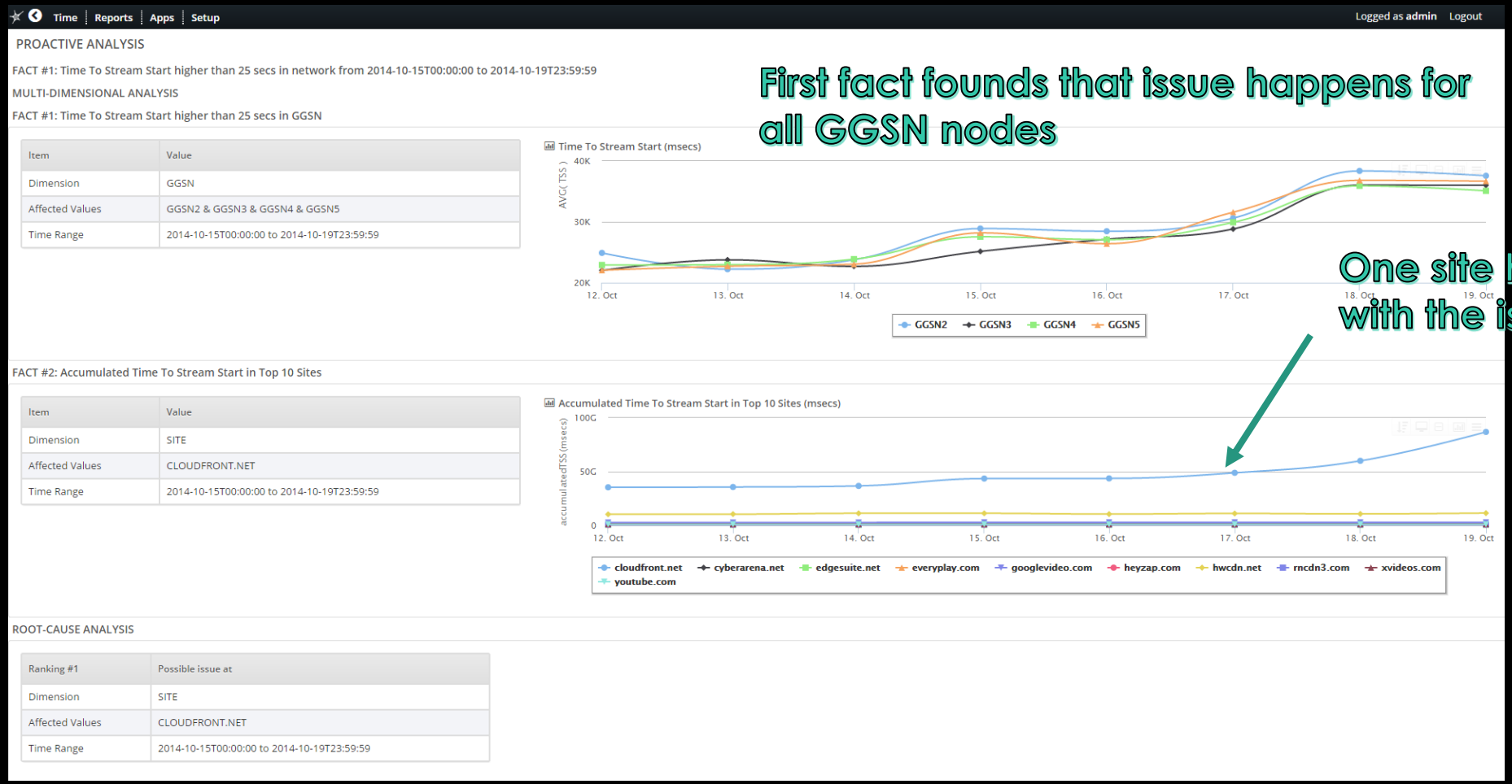
It is posible to see how volume for whatsapp and viber increase during the anomaly period

It seems to be whatsapp, suffering a system downtime during the anomaly period

RCA
NETWORK ANOMALY IN TIME-TO-STREAM-START INDICATOR



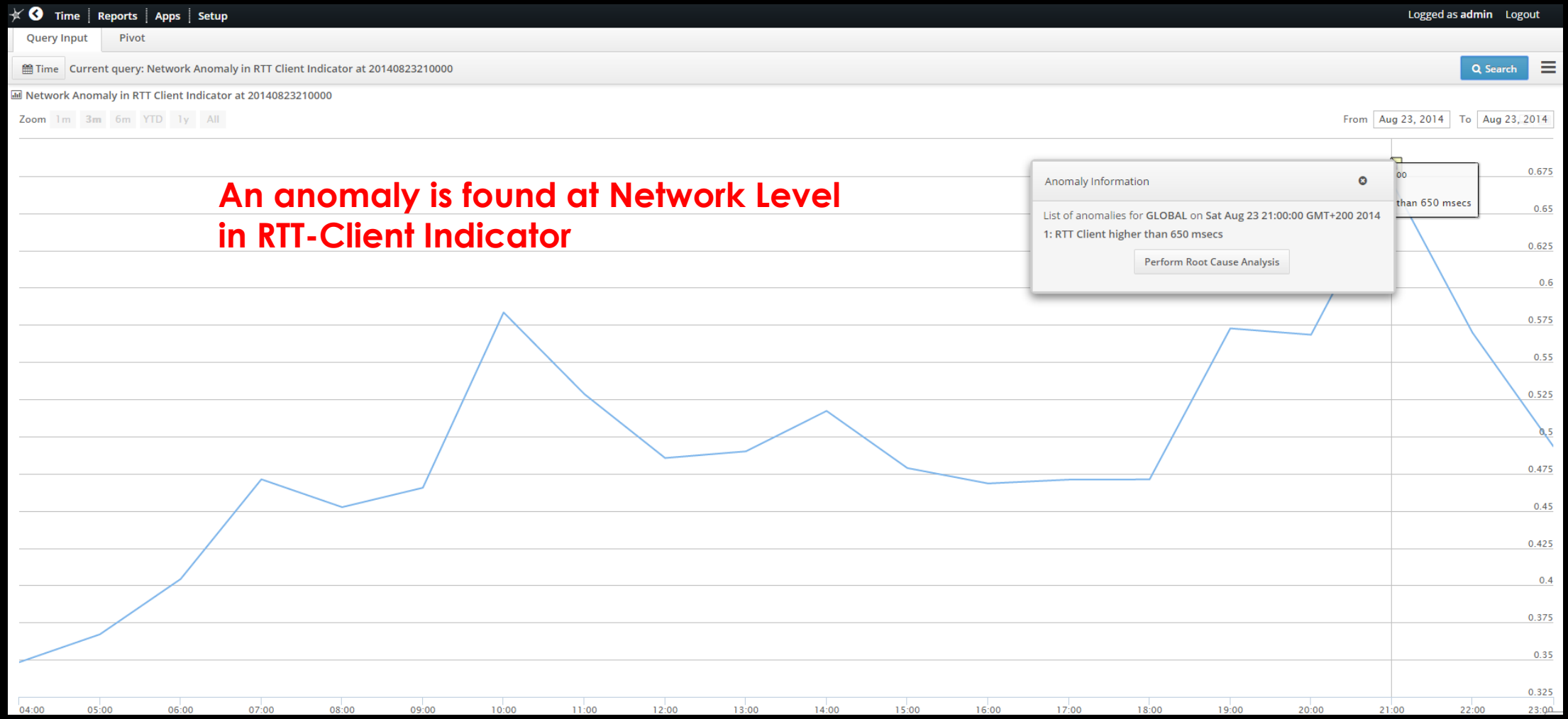
RCA
NETWORK ANOMALY IN TIME-TO-STREAM-START INDICATOR



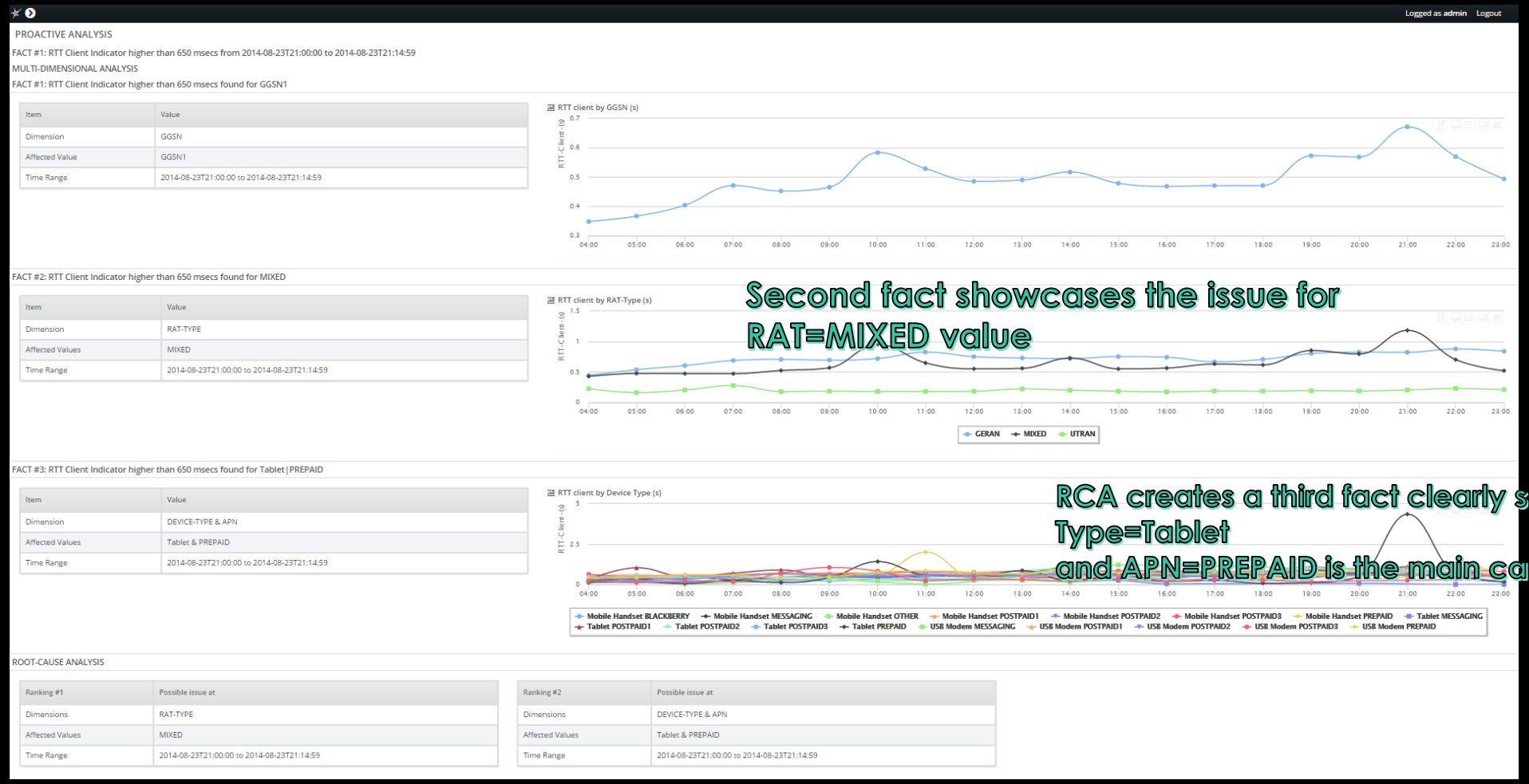
First fact founds that issue happens for all GGSN nodes

One site has high correlation with the issue. Top 10 are shown.

RCA
NETWORK ANOMALY IN RTT CLIENT INDICATOR



RCA
NETWORK ANOMALY IN RTT CLIENT INDICATOR



THE CONCLUSIONS

- Root Cause Analysis can be seen as a search in a huge multi-dimensional space
- Different approaches are possible
  - Human experience (e.g. rule-based systems)
  - Fully automatic root-cause analysis (ML-aided systems, like time-series correlation techniques)
  - Mixed
- Once fully automatic tools are in place, the network can become self-repairing and adaptive, realizing the vision of self-organizing networks
- Root Cause Analysis applications do not only cover the network but also individual subscribers (e.g. Customer Care where call-dispatch time should be as short as possible)

THE CONCLUSIONS TOWARDS THE FUTURE

- Machine-Learning to the rescue!
  - To speed up troubleshooting
  - To detect offending elements before they become a real problem
- Close the Loop in the Network automatically
  - To fix problems
  - And also, to make your network a Chameleon! The so-called Self Organizing Network (SON)!
  - The network will adapt to the changing conditions and adapt itself by using the required resources (NFV)!

THANK YOU!