Automatic root cause (anomaly) detection – 3GPP ETSI 4G LTE RAN KPIs

Machine learning model

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Agenda

1. Motivation

- Context: *"Why optimize 4G networks?"*
- Automation: "Why AI/*machine learning*?"
- Objective

2. Case study

- Network performance metrics and evaluation criteria
- 4G LTE 3GPP solution
- Anomaly and network issues

3. Development

- 4G solution
- Data strategy
- Machine learning algorithm selection
- Proof of concept (*PoC*)

4. Results

- *Cell I example*
- *Cell II example*

1. Motivation

Why optimization?

- Maximize MNO OPEX and CAPEX
  - Seasonality
  - Traffic behavior and user type
  - Network engineering resource strategy
- QoS improvement and user live network experience

Expansion & Deployment	→	Optimization management	→	Design/Planning

Source: GSMA Mobile Economy – Global, June 2020

Why automate?

- Human error→ Process loop impact

- Complexity → Heave amount of data and parameters to analyze and improve

- Autonomous network concept → Digital transformation

- Increase cost efficiency and resource productivity

- **Automatic anomaly detection/root cause → AI/*Machine Learning***
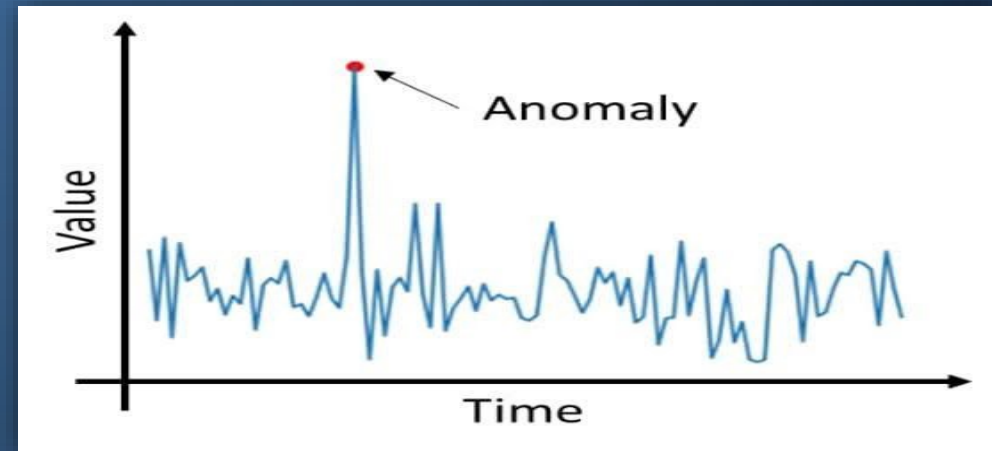
Source: How Machine Learning Can Enable Anomaly Detection, 2020

1. Motivation

Objective

ML model for 4G 3GPP Radio Network Performance management (automatic anomaly detection)

- Identify network performance anomalies

- Identify potential root cause (diagnostics)

- Automate the process (digital transformation)

- Increase efficiency (time reduction per activity)

→ ICT (Telco) + IA

2. Study case

Network performance metrics and evaluation criteria for 3GPP 4G LTE Radio Acces Network (RAN)

- 3GPP ETSI TS 132 451 → *"User experience and QoS based on Key Performance Indicators"*

  - Accessibility

  - Retention capacity

  - Integrity

  - Traffic

  - Utilization

Name	Average Uplink Interference
Object	4G Cell
KPI Formula	UL.Interference.Avg (unique counter)
Unit	Power (dBm)

KPI – Uplink interference

Name	RRC Setup Success Rate
Object	4G Cell
KPI Formula	$RRC\_SSR = RRC.Connection.Success/RRC.Connection.Attempt \times 100\%$
Unit	Percentage (%)

KPI - Accessibility

Name	Max User Number
Object	4G Cell
KPI Formula	Max.User.Number (unique counter)
Unit	N/A

KPI – User traffic
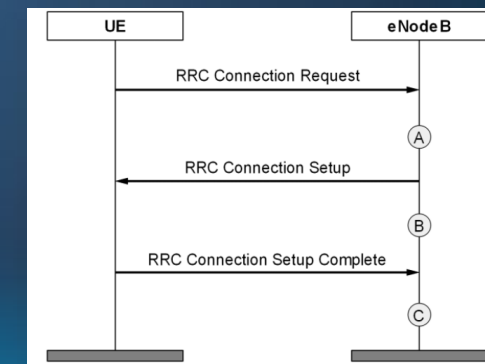
2. Case study

Counters aggregation (formula) and commercial network acceptance based on technical performance metrics

Counters of different categories (e.g. network failure, external events, etc)
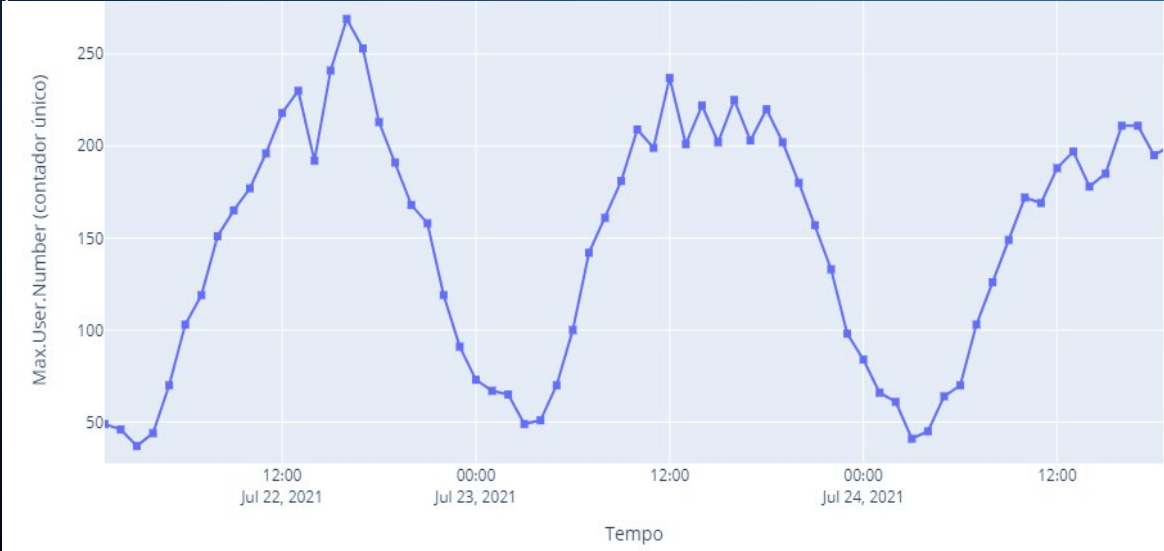
Traffic behavior(seasonality)

Time (mm/dd/yyyy) hh:mm	4G Cell	Counter1	Counter2	...	Counter or KPI formula of interest
6/01/2021 12:00	Cell1	1424	422	...	0
6/01/2021 12:00	Cell2	533	328	...	6
...	...	...	...	...	...
8/14/2021 21:00	Cell1	1621	457	...	7
8/14/2021 21:00	Cell2	1111	127	...	9

Global standard 3GPP → Time series, extracted by hour

2. Case study

4G common anomalies and network issues

- Hardware malfunction on live network (site to backhaul-core)

- Human error → Network parameterization

- External interference, decreasing the performance of 4G active carrier
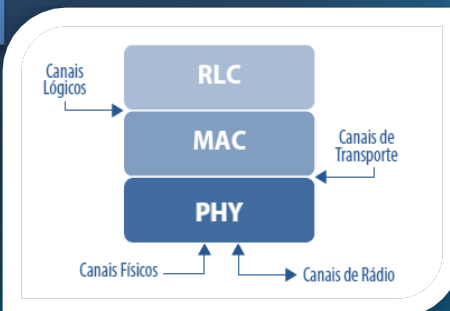
- 4G network traffic congestion

3. Development

4G Solution – Access Network:

- *LTE 1800MHz – 3GPP Band 3 FDD*
- *BW = 10MHz*
- *1 antenna per sector*
- *1 LTE cell per sector*
- *3 antennas per eNodeB*
- *256QAM algorithm switch downlink feature*
- *64QAM uplink*

Backhaul network

RLC
MAC
PHY

Canais Lógicos
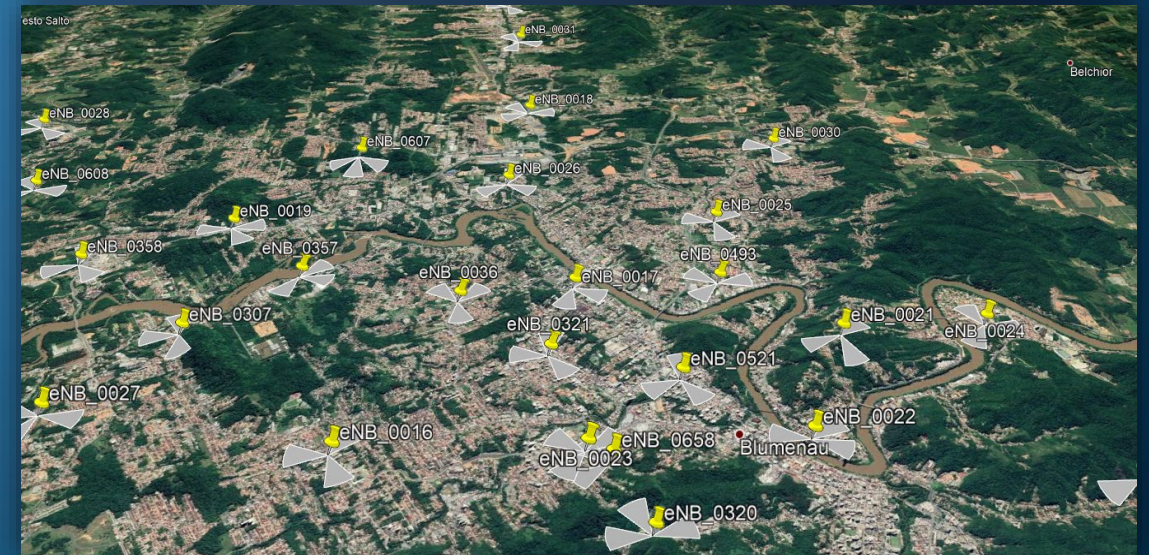Canais de Transporte
Canais Físicos
Canais de Rádio

eNodeB (4G site)

Scenario:

- Blumenau city – SC (South Brazil)

- 2020/H2

- Total of 95 performance indicator counters → KPI formula of interest is *RRC Setup Succcess Rate (97.5% acceptance metric)*

- Collected for two 4G cells *(Cell1 e Cell2)*, different sites (06/1/2022 to 8/18/2022)

- 1785 samples (rows) for each 4G cell *(dataset.csv)*

3. Development

Acceptance metric and KPI evaluation criteria for RRC Setup Success Rate (%)

- 3GPP → 97.5% for network acceptance

Data strategy → Anomaly identification

- Automatic metric labeling (by hour)

Time (mm/dd/yyyy) hh:mm	4G Cell	Counter1	Counter2	…	RRC Setup Success Rate (%)	KPI anomaly?
6/01/2021 12:00	Cell1	1424	422	...	97	1
6/01/2021 12:00	Cell2	533	328	...	99	0
…	...	…	…	…	…	…
8/14/2021 21:00	Cell1	1621	457	...	100	0
8/14/2021 21:00	Cell2	1111	127	...	75	1

3. Development

Machine learning model selection → Supervised classification (binary)

- *Naive Bayes*

- *Decision tree*

- *Python (scikit-learn)*

- *Feature importance extraction*

dataset.csv → **Input** → **ML model** → **Output** → *Anomaly (0 or 1) and feature Importance extraction*

Time (mm/dd/yyyy) hh:mm	4G Cell	Counter1	Counter2	…	RRC Setup Success Rate (%)	KPI anomaly?
6/01/2021 12:00	Cell1	1424	422	...	97	1
6/01/2021 12:00	Cell2	533	328	...	99	0
…	...	…	…	…	…	…
8/14/2021 21:00	Cell1	1621	457	...	100	0
8/14/2021 21:00	Cell2	1111	127	...	75	1

Input

Output

4. Results

Proof of concept (*PoC*) → RRC Setup Success Rate (%) for new data (*Cell1 e Cell2*)

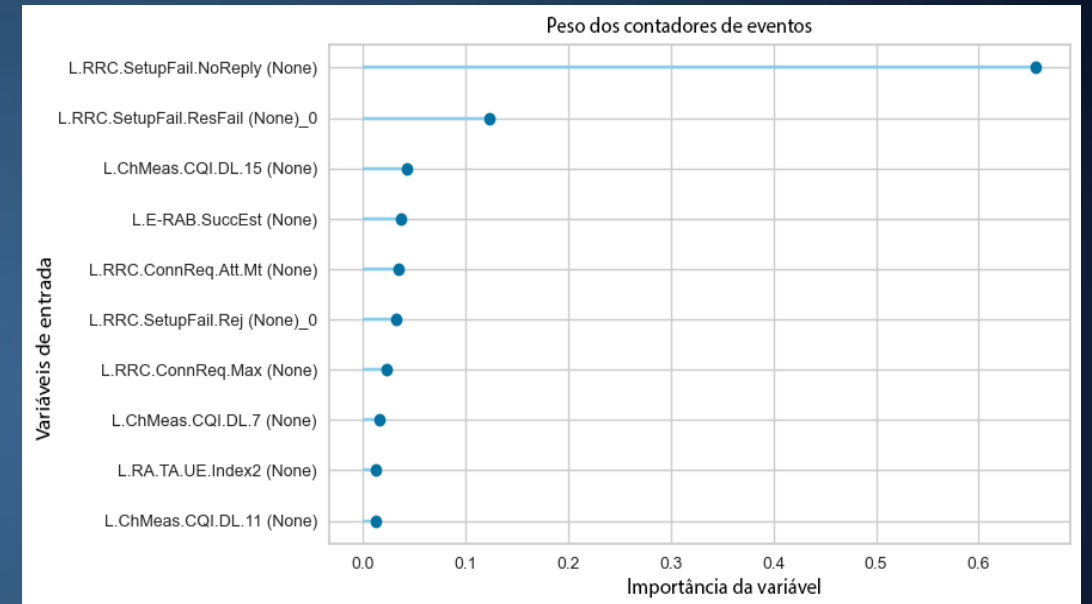| Model	Accuracy	Precision
Decision Tree Classifier	99.64%	96.67%
Naive Bayes	82.42%	18.58%

Notes:

- *Decision Tree* → Better performance (correlated features)

- *Feature importance* extraction as the most correlated root cause

4. Results

Proof of concept (*PoC*) → RRC Setup Success Rate (%) for *Cell1*
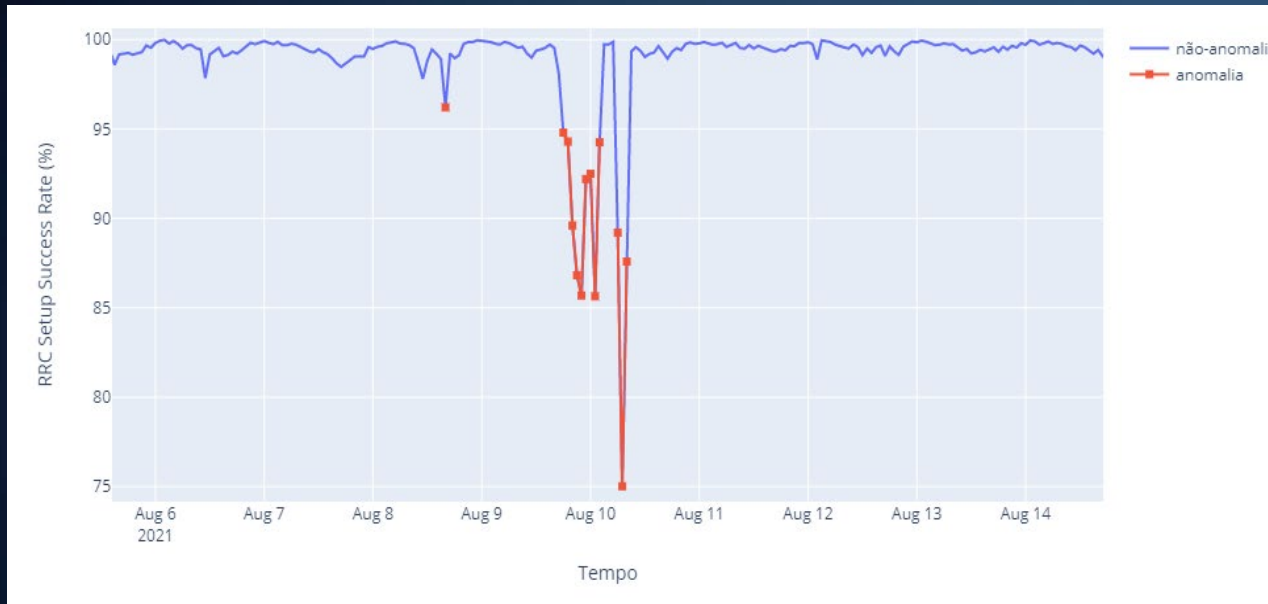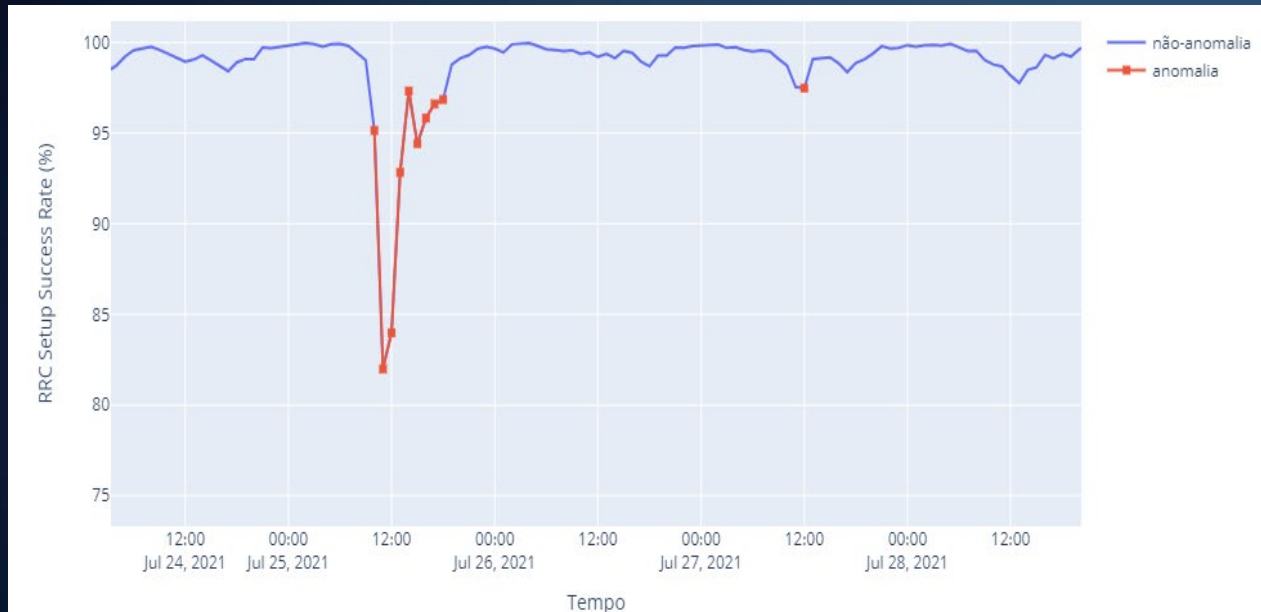

KPI identified as anomaly
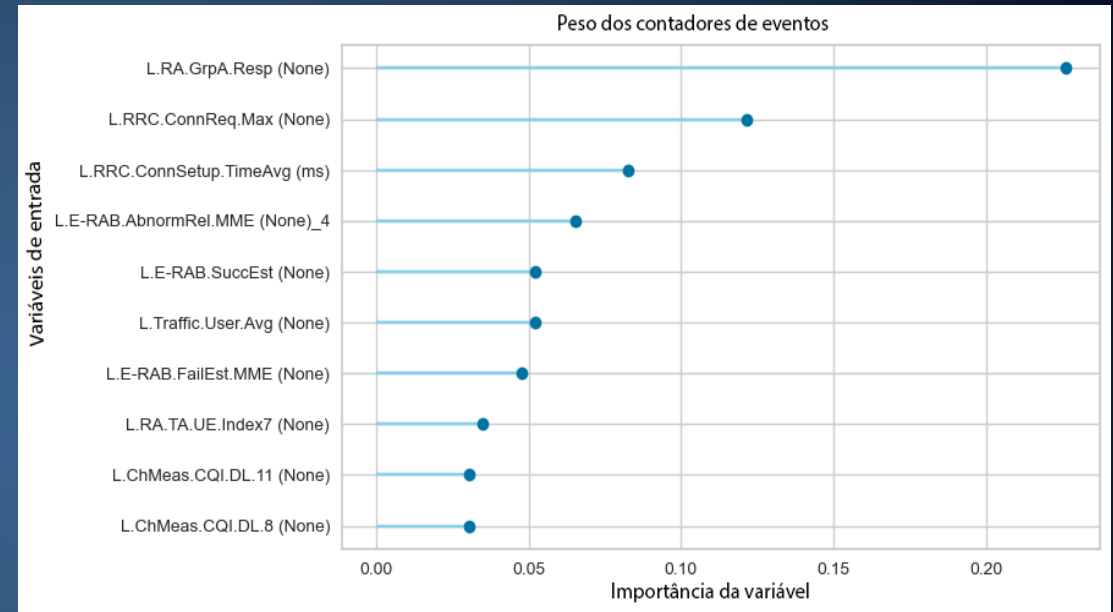

Feature importance

Notes:

- Possible to identify anomaly and its root cause

- 3GPP → *L.RRC.SetupFailNoReply counter indicator*

4. Results

Proof of concept (*PoC*) → RRC Setup Success Rate (%) for *Cell2*

KPI identified as anomaly

Feature importance

Notes:

▪ Possible to identify anomaly and its root cause

▪ 3GPP → *L.RA.GrpA.Resp counter indicator*

Thank you