Challenges and opportunities in machine learning and data analytics for network monitoring and QoE assurance

Renato L. G. Cavalcante

Joint work with D. A. Awan, M. Kasparick, L. Miretti, and S. Stanczak
Outline

- Selected enablers for QoE assurance
  - Traffic prediction
  - Radio maps
  - Interference management
  - Localization

- Anomaly detection
  - Human-in-the-loop
Examples

Video streaming

- User starts video stream
- High data rate
- Buffer is being filled

- User moves to highly loaded cell
- Video stream from filled buffer

- User enters active cell
- Buffer almost empty
- Video streaming from base station

Key ingredients:
- Traffic prediction
- Radio maps
- Interference management / self-organizing networks
- Localization

mmWave Networks

Wireless Communications and Networks
Useful information is spread over a large area

Questions:
1) Size of the training sets
2) Distributed, centralized, or hybrid approaches
3) Standards for information exchange among network elements

Networks are complex systems with highly coupled and dynamic interference patterns
1) Improving QoE/QoS in a given region may decrease the performance in every other region of the network
2) Traditional models can be inaccurate – should we discard them?
Message 1: Do not try to learn too much
Forecasts

Short/medium term traffic forecasts

Exact values are hard to predict, but upper bounds (with strong statistical guarantees) are easy.

Message 2: Use knowledge gained from models and any available side information
Objective: Given a traffic demand, what is the load at each cell (fraction of used resources)?

Challenge: Highly dynamic wireless environment (propagation loss, interference patterns, etc.)
→ Not enough time to train traditional learning tools

Models can be inaccurate, but they reveal important features of the function being learned:
→ Monotonicity (load increases with increasing rates)
→ Lipschitz continuity

We should exploit these properties in machine learning tools:
→ Reduced training time and increased robustness
Load prediction

Pathloss reconstruction

Message 3: Do not ignore the lower layers of the communication stack

The physical layer has a lot of useful information (currently unavailable at the network layer). Example: Channel covariance matrices and the angular power spectrum for localization.

Message 4: Experts can beat machine learning tools (depending on the application)
Anomaly detection in networks

- Challenges
  - Huge number of KPIs (spurious correlations are likely to be observed)
  - Missing and unreliable data (software bugs, overflowing counters, etc.)

- Many state-of-the-art machine learning tools do not provide statistical guarantees

- Let machines explain humans why each action is appropriate
Visualization (1)

○ Time-series analysis (cluster operators with similar performance)
○ Evolution of the performance of network elements over time.

Objective: Detect network regions with performance issues

Challenges: Large number of (unreliable) time-series, misaligned data
Anomaly detection (1)

- Automatic extraction of atypical network regions and key performance indicators

KPI index (detected region/KPI)

Time-series of other regions (reconstructed)
Anomaly detection (2)

Short/medium term forecasts

- Detect atypical days by also considering long term trends
Thank you for your attention!

Contact:

www.hhi.fraunhofer.de/wn
Fraunhofer Heinrich Hertz Institute
Berlin, Germany