AI/ML DATA ANALYTICS AND DATA COLLECTION IN 5G/6G NETWORK

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ROHDE & SCHWARZ
Make ideas real
AGENDA

- AI/ML in Wireless Communication
- AI/ML in 5G Core Network
- AI/ML in 5G Air Interface
- Outlook for AI/ML in 6G Network
WHY AI/ML FOR WIRELESS COMMUNICATION?

AI/ML models complex relationships between parameters of a system and finds patterns in data.

Wireless communication needs to take complex decisions based on parameters & events.

AI/ML can help wireless technologies to find patterns, predictions, and classification on wireless parameters.
WHICH USECASES FOR AIML FOR WIRELESS?

- **Smart Metering**
  - By 2023 this installed base will double to reach 1.34 billion meters
  - ABI Research

- **Electric Cars**
  - Approximately 20 major cities worldwide have announced plans to ban fuel-cars by 2030 or sooner
  - Deloitte, 2019

- **Smart City Sensors**
  - Predictive sensor monitoring to prevent disasters

- **Retail and Services**
  - Customer behaviour analysis and consumption adoption, promotions

- **Sports and Entertainment**
  - Maximize over the top experiences

- **Utility Providers**
  - More efficient power generation and resource management

- **Healthcare**
  - Application prioritization, abnormality detection, monitoring

- **Traffic and Trade Management**
  - Complex traffic management and optimisation

- **Education**
  - Student analysis, modelling of courses, uptake and performance

- **Tourism and Restaurants**
  - Mobility prediction analysis, promotion and offers, planning

- **Financial**
  - Predictive modelling, market & investment analysis, anomaly detection

- **Manufacturing**
  - Automated low latency for robotic manufacturing plants

- **Outlook for AI/ML in 6G Network**
IMPORTANCE OF DATA COLLECTION

- Data is the new truth!
  - AI/ML Model Training need large amount of Data
  - AI/ML Data Collection is the key
  - AI/ML Data Collection needs domain and usecase specific knowledge

- Data can be:
  - Real field data (Confidentiality, Accessability, Labelling)
  - Synthetic generated
EXAMPLE OF CREATION OF SYNTHETIC DATA

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EXAMPLE OF CREATION OF SYNTHETIC DATA

The self-driving car depends on so-called self-learning algorithms, which require large amounts of “training data”.

Without this data, the ambitious goal of producing fully autonomous vehicles will remain out of reach.

The production of this training data or “ground truth data” requires vast amounts of manual labour in data annotation, performed by crowdworkers across the globe.

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<th>Company</th>
<th>Platform</th>
<th>Origin (est.)</th>
<th>Alexa rank</th>
<th>Crowd size</th>
<th>Funding</th>
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WORKING PAPER
FORSCHUNGSFÖRDERUNG
Number 185, August 2019
Crowdsourced Production of AI Training Data
How Human Workers Teach Self-Driving Cars How to See
Finian Alexander Schmidt
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AI/ML in 5G Core Network

- Network Resource Management
  - Prediction of traffic volume
  - Automation
    - Adaptation to triggers events
  - Monetisation
    - Prediction of customer & service adoptions

- Radio Load Balancing & Coverage
  - Predictions based on UE/MDT measurements

- Mobility Optimization
  - Inter-node information for Self Organizing Network

- Network Energy Saving

- Air Interface Performance
  - e.g., improved throughput, robustness, accuracy or reliability, etc.
  - Reduced complexity/overhead
    - e.g., number of parameters

Network Data Analytics Functions (NWDAF)
SON/MDT Enhancements for AI/ML
Air Interface Enhancements for AI/ML

Release 15/16
Release 17
Release 18/19
NWDAF IN 5G CORE NETWORK

AF: Application Function  
NF: Network Function  
NWDAF: Network Data Analytics Function  
OAM: Operation and Management  
UDR: Unified Data Repository
NWDAF IN 5G CORE NETWORK

5G Architecture with Distributed NWDAF

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NWDAF IN 5G CORE NETWORK

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NWDAF IN 5G CORE NETWORK

Report

1. NF Load
2. User Data Congestion
3. Abnormal Behavior
4. UE Mobility
5. Network Performance
6. Slice Load
7. Observed Service Experience
8. QoS Sustainability
9. Expected Behavior
10. UE Communication

Function delivered

- Load analytics information & predictions for NFs
- Congestion information - Current & Predicted for a specific location
- Abnormal behavior/Anomaly detection for a group/specific UE
- Mobility related information and prediction for a group/specific UE
- Network Load Performance computation and future Load prediction
- Load level Computation and Prediction of a Network Slice instance
- Service Experience Computation & Prediction for an Application/UE group
- QoS change statistics for an Analytics target period in the past or future by area
- Expected behavior prediction for a group/specific UE
- Communication pattern prediction for a specific UE
AI/ML FOR UE MOBILITY

The Access and Mobility Management Function (AMF) defines Registration Areas for UEs, and UEs send location updates (signaling messages) to the AMF when they leave the Registration Areas.

Consider a suburban tram following the same route through Barcelona every day.

Without NWDAF, the Registration Area (shaded red) is very small, and there will be many registration updates as the tram travels along its route.

With NWDAF, the Registration Area (shaded red) is much larger, and there will not be any registration updates as the tram travels along its route.
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USECASE : BEAM MANAGEMENT

► Why ML for beam management?
  ► Conventional: Exhaustive beam sweep
    – As propagation losses increase with 5G / 6G:
      – Larger number of narrower beams
      – More signalling overhead
      – Larger latency
**USECASE : BEAM MANAGEMENT**

▶ **Spatial Beam Prediction:**
- Infer from a subset of beams
- Selection based on *highest RSRP*
- With prediction → Less measurements required

▶ **Temporal Beam Prediction:**
- Allows lower beam measurement frequency
- Infer future RSRP or best beam index

![Diagram of beam information](image-url)

**AI/ML in Wireless Communication**

**AI/ML in 5G Core Network**

**AI/ML in 5G Air Interface**

**Outlook for AI/ML in 6G Network**
AI/ML DATA COLLECTION FOR BEAM MANAGEMENT

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USECASE: BEAM MANAGEMENT
AI/ML DATA COLLECTION FOR BEAM MANAGEMENT

Training | Test | Top-1 Accuracy | Top-3 Accuracy | Average RSRP Difference (dB)
--- | --- | --- | --- | ---
UMa 0% indoor | UMa 0% indoor | 74.7 % | 93.2 % | 1.08
UMa 0% indoor | UMa 80% indoor | 47.9 % | 74.8 % | 2.54
UMa 80% indoor | UMa 0% indoor | 69.4 % | 92.4 % | 1.25
UMa 80% indoor | UMa 80% indoor | 48.6 % | 76.3 % | 2.24
Mixed: UMa 0% indoor + UMa 80% indoor | UMa 0% indoor | 73.0 % | 93.0 % | 1.09
Mixed: UMa 0% indoor + UMa 80% indoor | UMa 80% indoor | 48.7 % | 76.1 % | 2.34

Mixed data set can get most information
Model Life Cycle include aspects of AI/ML model like model training, model deployment, model inference, model monitoring, model updating.

Include definition of Components needed i.e. Data Collection, Model Storage
DO WE NEED TO SHARE AI/ML DATA?

Federated learning brings on-device learning to new level

- Offline learning
- On-device learning
- Federated learning

Locally adapt once to a few samples (e.g., few shot learning) or continuously (e.g., unsupervised learning).

Aggregate model updates across multiple users to globally improve model from more diverse data.
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6G is the next-generation advanced mobile communications system, but it will go far beyond communications. 6G will serve as a distributed neural network that provides communication links to fuse the physical, cyber, and biological worlds, truly ushering in an era in which everything will be sensed, connected, and intelligent. This in turn will lay a solid foundation for Intelligence of Everything in the future.
WHAT POTENTIALLY COMES NEXT?
AI-NATIVE AIR INTERFACE FOR 6G?

For PHY/MAC the initial 6G research focuses mainly on the receiver

Ongoing research

Wireless Channel

ML applied to individual processing blocks
ML replaces multiple processing blocks
ML used to jointly optimize TX, RX and baseband processing;
ML designs part of 6G PHY/MAC itself

Further down the road!
Q&A