Fighting Fire with Fire

Survey of strategies for counteracting the complexity of future networks management

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SCOPE

- *Survey of advanced analytics and machine learning techniques to address 5G networks management complexity*

- Outline
  - New requirements for 5G systems management
  - Advanced machine learning techniques & trends
  - Implications and recommendations for using advanced ML in 5G management systems

5G LANDSCAPE

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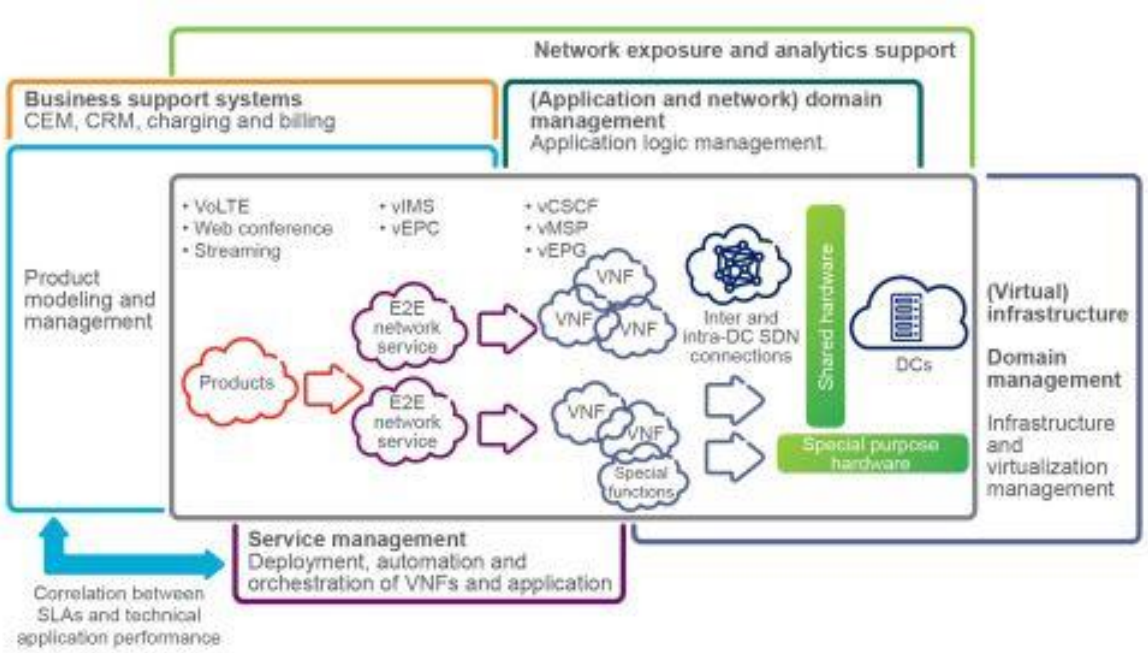
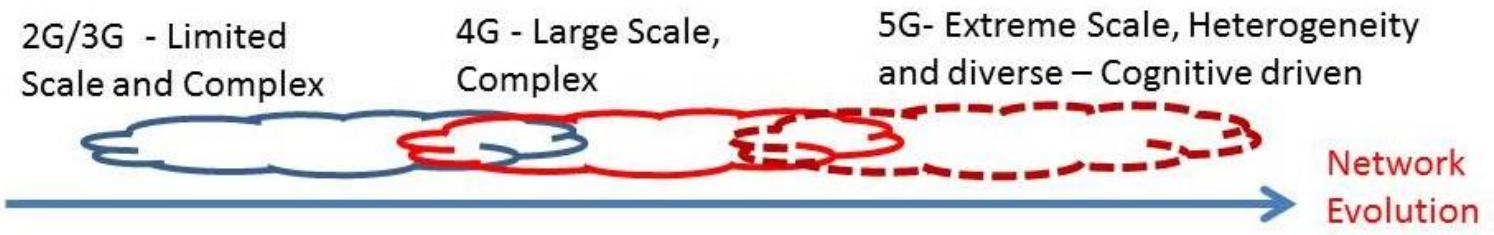
MANAGEMENT OF 5G NETWORKS

- 5G networks properties:
  - High degree of change
  - High degree of automation
  - Unprecedented scale
- All these properties manifest on several levels



EVOLUTION OF TELECOM NETWORKS AND ML USE CASES



- Limited use
- Simple statistics
- Limited Data Size
- Manual Work Flow Development
- Historical/Batch Analysis
- Reactive
- Expert driven Automations/Decisions

- Wider use
- Advanced A/ML
- Big Data Systems
- Parallel Processing
- Manual Work Flow Development
- Heavy Feature Engineering
- Historical/Batch, Limited Real time
- Limited Data Driven Automated Decisions

- Intensive use is necessary
- Highly Complex A/ML
- Very Large Data sets
- Parallel Proc. & Special Hardware
- Difficulty in Building Manual Workflows
- Automated Feature Engineering
- Real Time
- Proactive
- Heavily Data Driven and Automated Decisions

5G MANAGEMENT

- New management use cases, such as:
  - Auto-configuration of network slices
  - Optimized deployment of network slices
  - Efficient spectrum usage
  - Rectifying interferences of different cell types
  - Advanced automated troubleshooting of complex 5G networks
  - Emerging and E2E SON
- New management systems features
  - ML-based frameworks with automated feature engineering
  - Real time
  - Provide heavily data-driven automated decisions
  - Automatically provide insights from data to drive adaptability to changes in the environment
  - Cope with unprecedented scale

ADVANCED MACHINE LEARNING

- Deep learning
- Active learning
- Hybrid learning

- Common trends in advanced ML systems

DEEP LEARNING

WHAT IS IT?	› Learning takes place on several layers, with higher layers learning more complex concepts, based on the output of the lower levels › Using several layers improves the accuracy of the learning process › Parallel computation & GPU technology

CURRENT APPLICATION DOMAINS / TOOLS	› Image recognition, Speech recognition
	› Many existing toolkits, e.g.:
	  › Deeplearning4j (integrated with CUDA)
	  › R package Deepnet

WHY USE IT?	› Improves training automation and prediction accuracy › Proved to provide better accuracy in production systems in many companies (Netflix, Google, Facebook) › Can be used in telecom ML use cases, for example, to classify types of network slice behavior and accordingly optimize resource usage

ACTIVE LEARNING

WHAT IS IT?	› Allows the algorithm to choose its input samples for efficient learning › Training is supervised (based on human annotator input) › Algorithm for picking the input samples is automated › Improved learning speed
CURRENT APPLICATION DOMAINS	› Image retrieval & recognition › Natural Language Processing › Adversarial situations (e.g., detecting malicious ads and phishing pages)
WHY USE IT?	› Shown to be efficient if the human annotator has very good domain knowledge › Helpful for incorporating domain knowledge into the system and re-training the system to adapt to changes (when used as part of a hybrid learning system) › Can be used, for example, to speed up rolling and tuning of new services on newly defined network slices (learning behavior using real traffic)

HYBRID LEARNING
ML & CROWD-SOURCING

WHAT IS IT?	› Crowd-sourced input helps to add new type of information to the learning process (e.g., additional features to learn along) › More agile learning methodology › Improved learning accuracy
CURRENT APPLICATION DOMAINS	› Re-train algorithms for data collection & cleaning › Amazon book recommendations › Augment under-performing classification models
WHY USE IT?	› To incorporate expert knowledge into the learning system › Ability to learn more complex scenarios with improved accuracy › Can be used to improve automation and provide human input to support resolving conflicts in automated management loops (e.g., for SON, or for rectifying interferences between different cell types)

HYBRID LEARNING
ML & ANALYTICAL MODELING

WHAT IS IT?	› Analytical models used for modelling known aspects of the internal behavior of the system
	› Data driven ML approaches depend on the accuracy, size and quality of input data set
	› By combining:
	  › We can bootstrap the ML system using the analytical model, to improve training time and provide relevant learning features to ML
	  › Use ML to improve performance over time, as more data becomes available

CURRENT APPLICATION DOMAINS	› Gray-box approaches for modeling complex distributed systems
WHY USE IT?	› Improve the performance and speed of learning in the context of highly complex and dynamic systems › Can be used for creating a service catalog based on learnt behaviors, or for efficient management of spectrum usage

HYBRID LEARNING
ML & RULE-BASED SYSTEMS

WHAT IS IT?	› Combine the rules from a rule-based system with ML to:
	  › Enhance the output of the rule-based system (e.g., in a classification problem) with additional learnt knowledge from the ML system (when the ML system is used after the rule-based component)
	  › Handle any under-performing output from the ML system through rules (when the ML system is the first one in the analytical flow)

CURRENT APPLICATION DOMAINS	› Classification problems
WHY USE IT?	› Re-use existing knowledge captured at the moment in telecom rule-based systems › Use ML to cover more complex situations than those covered by current rule-based systems › ML to replace some policy-based systems › Can be used to improve control loops over time

COMMON TRENDS IN ADVANCED ML SYSTEMS

- Improve accuracy and speed of learning
  - E.g., deep learning, active learning
- Improve capabilities and adaptability of algorithms
  - E.g., hybrid learning
- Improve ease of use and automation
  - E.g., by embedding analytics knowledge into the system, providing non-expert readable reports, automatically taking care of scalability aspects, etc.

ADVANCED ML & 5G MANAGEMENT

1. Minimize need for analytics/ML knowledge by embedding more into the tools
   - Move away from traditional expert analytics tools (R, SAS)
   - Embed more knowledge into the tools (either by offering a limited number of ML algorithms, or offering non-expert readable reports, etc.)
   - This direction improves automation; should be considered together with incorporating expert knowledge into the system

2. Automate expert knowledge capturing
   - Increase automation and adaptability of 5G management system
   - Active learning, hybrid learning, interactive learning

ADVANCED ML & 5G MANAGEMENT

3. Provide new insights from data to drive automated decision-taking
   - By combining rich data sources with advanced ML algorithms
   - Deep learning, active learning

4. Adaptability of algorithms to changing environment
   - Can be improved by using more agile methods than the traditional ones, e.g., active learning and hybrid methods
   - Trade-off between generality and specialized technique

5. Scalability of complex ML algorithms
   - Efficient scaling or parallelizing of ML algorithms working on large-scale data
   - Deep learning

CONCLUSION

- New requirements for the management of 5G networks can be met by some advanced machine learning technologies

- Deep/Active/Hybrid Learning can address aspects such as:
  - Heavy automation
  - Incorporating expert knowledge into the automatic management system and minimizing need for analytic knowledge on the user side
  - Providing new insights
  - Adaptable and scalable algorithms

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Thank you!

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