5G PPP White Paper
“AI/ML for Networks”

5G PPP Technology Board Workshop
9/10 December 2020

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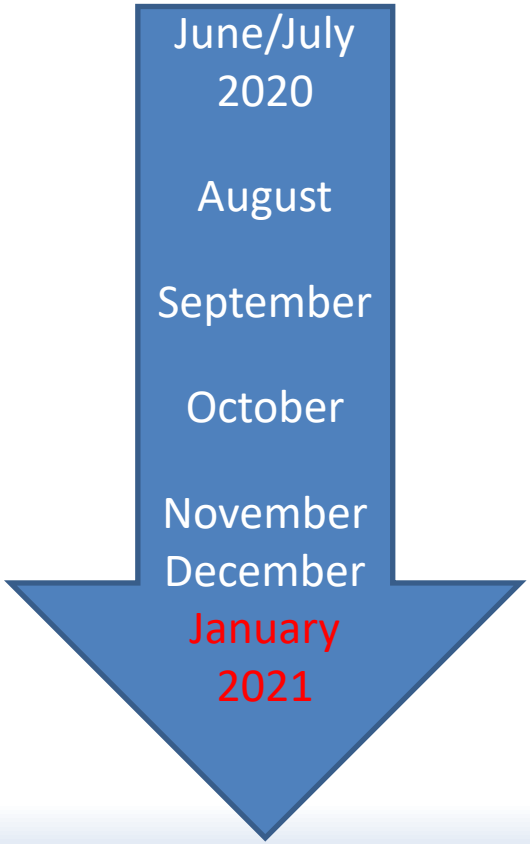
Scope of the White Paper

AI/ML – Point of Interests from the Communications Network Perspective

- Identification of areas of AI/ML applications optimizing **operation and design** of the future 5/6-G networks
  - addressing different network aspects, communications layers, and specific functions
    - possible cross-optimization opportunities
  - elaborating AI/ML methods from various areas of science and live, to identify the most suitable solutions for the networks
    - including discussion on availability and (re-)usability of data sets
    - management of appropriate AI/ML models and processes
- practical implementation issues and overall impact and perspectives

Time Plan



- Initiative and announcement
- Collection of interests to participate and initial ideas on potential contributions
- Launch by editorial group, mailing list and repository, clarification of expected contributions
- The main contribution/writing period
- **Finalization**
  - First round of consolidation finished
  - First complete draft to be released soon
  - Fine tuning of contribution – request for clarification / last inputs
  - Final draft -> January 2021

Involved 5G PPP Projects

- 5G-PPP / 5G IA
- SliceNet (phase 2)
- IoRL
- 5Growth
- 5G-VINNI
- LOCUS
- 5G-TOURS
- 5G-HEARTH
- 5GZORRO
- 5GENESIS
- TERAWAY
- MonB5G
- 5G-COMPLETE
- INSPIRE-5Gplus
- 5G SOLUTIONS
- 5G DRONE
- 5G-CLARITY **(WP editors)**
- ARIADNE **(WP editors)**

Initial Structure

- Motivation
- Optimization issues requiring AI/ML intervention
  - Network planning
  - Network operation and optimization
  - Network control functions
  - Specific network and service functions
  - Network transmission (low-layer) functions

- AI/ML methods and requirements for network optimization
  - Suitable AI/ML methods
  - Data-sets – availability and usage
  - Keeping control on networks
  - Cross-optimization
  - Management of ML models / functions

- Evolution of ecosystem for AI/ML optimized 5G

Evolved Document Structure

1) Introduction
2) **AI/ML Methods for Network Optimization – An Overview**
   - Neural Networks, Reinforcement Learning, Hybrid Solutions, Further Specific Methods
3) **Optimization Issues / Use Cases**
   - Network planning, Network diagnostics/insights, Network optimization and control
4) **Architectural Aspects**
   - Data-sets – availability and usage, Management of ML models / functions, Keeping control on networks
5) Conclusions/outlook

AI/ML Methods for Network Optimization – **Scope**

- Overview on AI/ML methods in consideration
- Already in use or to be used (promising solutions) for network design, planning, and optimization
- No intention to provide yet another classification
- No intention to include/exclude AI/ML methods
- **Focus is on overview**
  - Reference to literature
  - Reference to networking use cases (Section 3)

AI/ML Methods for Network Optimization – **An Overview**

- Neural Networks
  - **Feed-forward** neural networks
  - **Deep neural** networks
  - **Recurrent neural** networks
  - **Convolutional neural** networks
- Reinforcement Learning
  - Basics/overview
  - **Deep** Reinforcement Learning
- Hybrid Solutions
  - Combined analytical and Machine Learning modeling
  - Expert knowledge aided Machine Learning
- Further Specific Methods
  - Generative adversarial networks
  - Kalman type filtering
    - Is it AI?
  - Unsupervised learning and clustering

Use Cases

Use Case Overview

	AI/ML domain		
Network Domain	**Planning**	**Forecast & Diagnostics**	**Optimization and Control**
Radio Access Network			
Non real time	ARIADNE, 5G Complete	5GZORRO	5G CLARITY, 5G HEART
Near real-time			5G CLARITY
Real-time			LOCUS, ARIADNE
Transport Network			
Fronthaul			5G Complete
Programmable Switches			5GROWTH, 5G Complete
Path computation, Traffic matrix		5G HEART	5GROWTH, TERAWAY
NFV infrastructure			
Dynamic Resource Allocation			5G CLARITY, 5G-VINNI
MEC & NFV			5GZORRO
E2E slicing			
Service assurance, slice config.			5G-VINNI, SOLUTIONS
Admission control & resource allocation			SOLUTIONS, MonB5G, 5GROWTH, 5GZORRO, Slicenet
Security		5GZORRO, INSPIRE-5Gplus	INSPIRE-5Gplus
Application and vertical domain		5GROWTH, 5G-VINNI, 5G CLARITY	5GZORRO, 5GROWTH
Positioning		LOCUS, SOLUTIONS, 5G CLARITY	

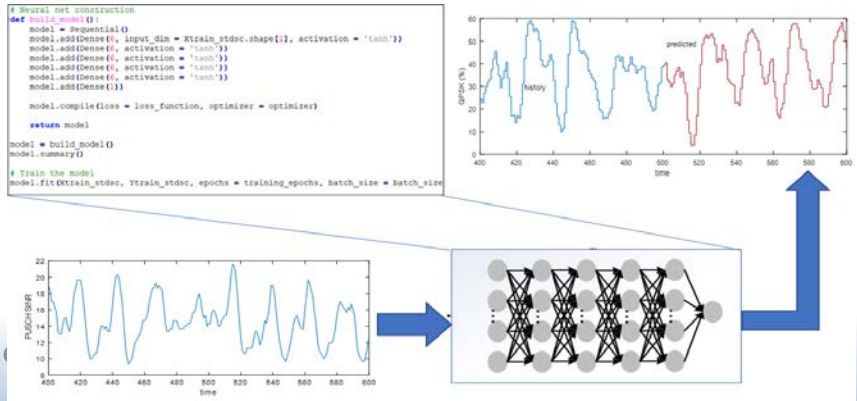
Planning Selected Examples

ARIADNE

- **Network element placement**
  - Optimal base station placement will become harder in B5G systems with high frequency APS, relays or RIS
  - Domain experts can pre-identify set of potential AP locations
  - RL techniques used to identify AP locations while keeping deployment costs bounded

5G Complete

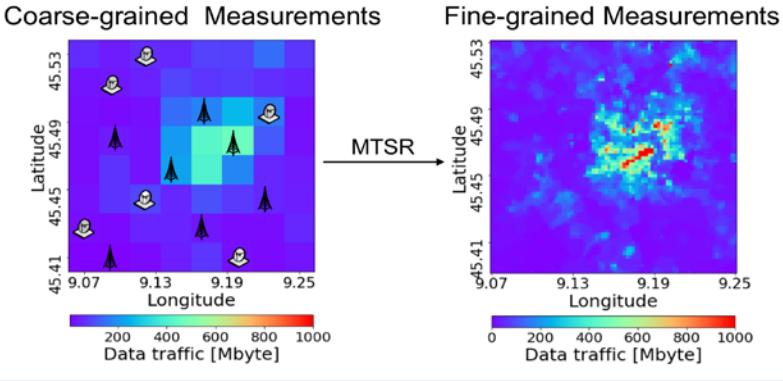
- **BBU cluster dimensioning**
  - Employs NN to estimate processing requirements of different BBU functions according to load
  - Example: Based on PUSCH SINR measurements predict % users with given MCS → Cluster compute requirements



Forecasting Selected Examples

5GZORRO

- **Forecasting traffic dynamics**
  - Goal is to provide high accuracy predictions from coarse grained traffic probes
  - Super Resolution or GAN techniques are used

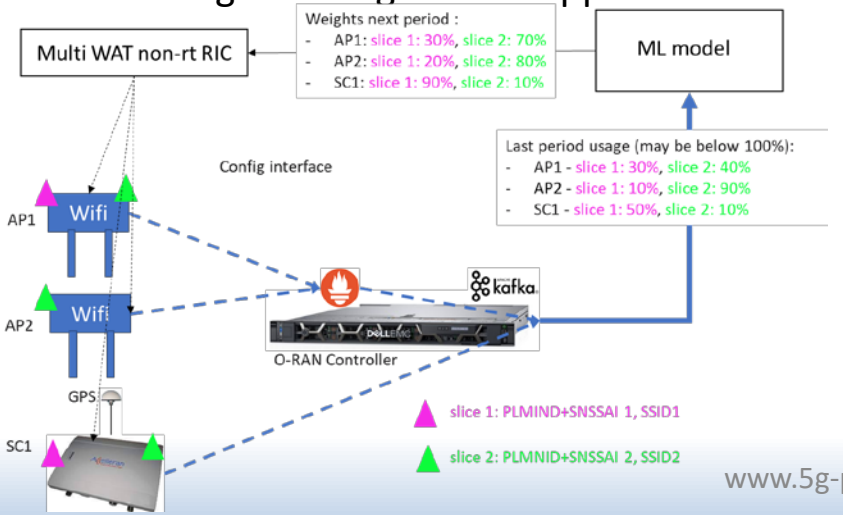


INSPIRE-5Gplus

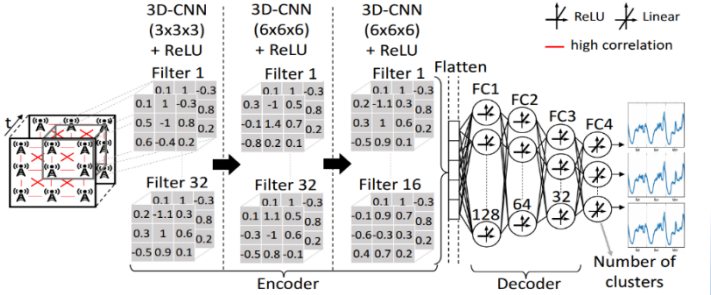
- **Real-time network attack detection**
  - Target is DDoS
  - Traffic classified in coversations (flows)
  - AI technique determines if conversation constitutes an attack

Optimization & Control Selected Examples

- **RAN slicing in multi-tenant networks**
  - Allocate slice weights based on geographic SLA
  - Using Multi-Agent DRL approach



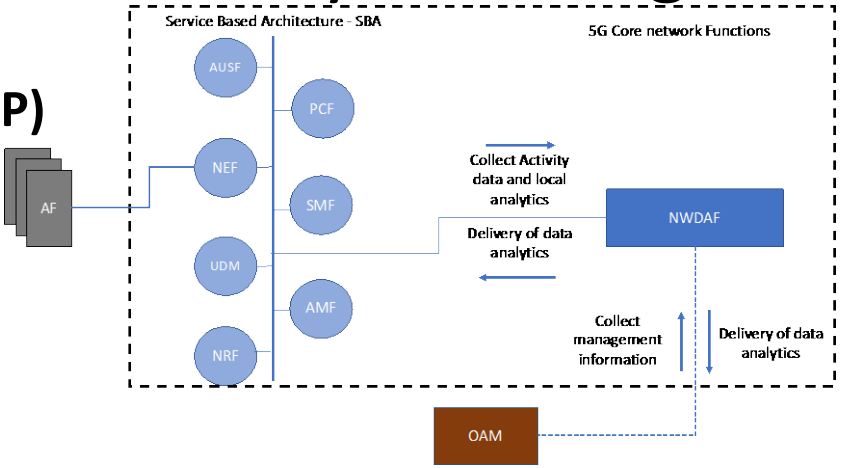
- **Joint slice based demand prediction and resource allocation**
  - Goal: Allocate computation resources to slice software functions (BBU, 5GC, applications)
  - Approach: DNN forecasts computational demand generating a feedback signal that drives the MANO resource allocation function



Architecture aspects

Data sets – availability and usage

- **Network Data Analytics Function (3GPP)**



- Experiential Networked Intelligence (ETSI ENI)
  - Five categories - Infrastructure Management, Network Operations, Service Orchestration and Management, Assurance, Network Security
- Management Data Analytics Service
- Widely available data-sets and open source solutions

Management of models/functions

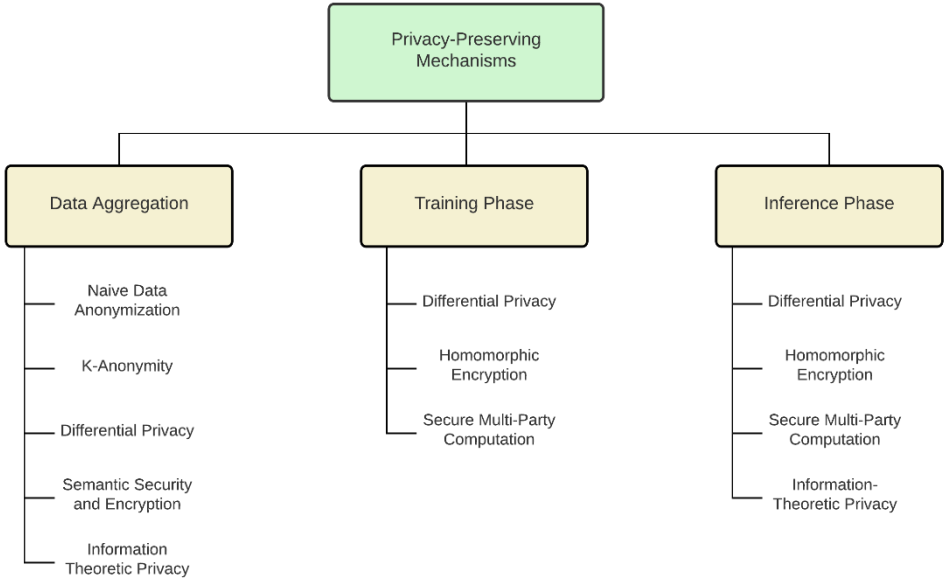
- Requirements for model management
- **Model lifecycle management**
  - Model training
  - On-boarding / deployment of models
  - Monitoring, evaluation and reconfiguration
- Interface management

ITU-T Y.3172 (Architectural framework for machine learning in future networks including IMT-2020) REQ-ML-MNG-004 states that “The ML architecture is required to support an orchestration functionality to manage all the ML functionalities in the network”.

According to REQ-ML-MNG-004, ML model management includes (i) training, (ii) monitoring, (iii) evaluation, (iv) performance-based selection and (v) reconfiguration / updating of the ML models.

Keeping control on networks

- Zero Trust Management
- **Privacy concerns**



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- Anomaly detection
- Cross-optimisation
- Scaling operations in a network service orchestration platform
- Enabling AI/ML in vertical domains

Thank you for your attention

Thank you for your contributions!!