통신 인프라를 위한 AI

v1.0

JS Lab

2021년 8월 27일

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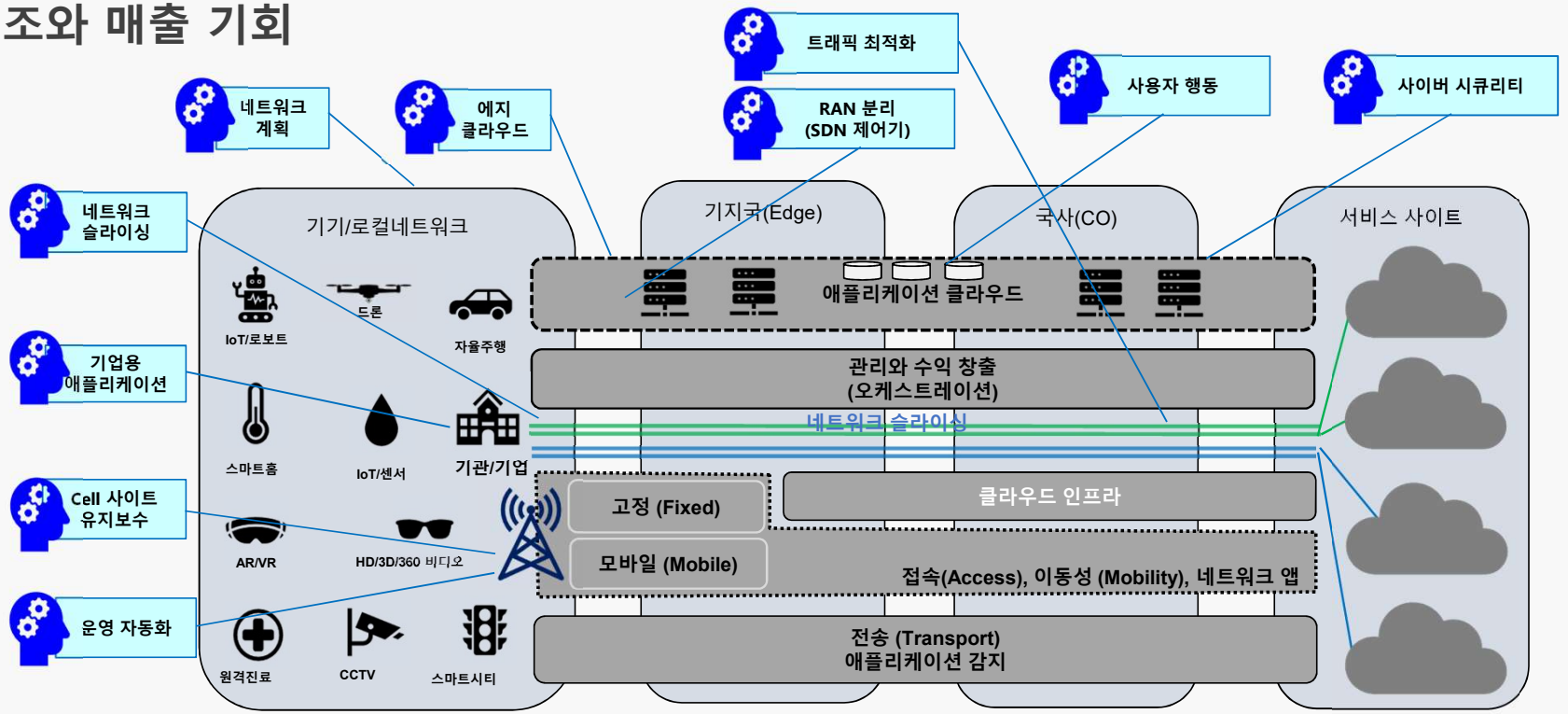
I. 통신 환경의 AI 개요

- ❑ 개요
- ❑ AI-ENABLED INTELLIGENT 6G NETWORKS
- ❑ 네트워크 인프라
- ❑ 5G의 4가지 기술적 한계
- ❑ The typical architecture of 6G network (ISAGUN)
- ❑ Overview of the existing and emerging ML frameworks
- ❑ 통신 환경을 위한 AI/ML의 기대

I. 통신 환경의 AI 개요

- ❑ 복잡한 연관 관계 학습
- ❑ 전체/선택적 제어
- ❑ 사전 예방적 자동 모드 운영
- ❑ 새로운 비용 구조와 매출 기회



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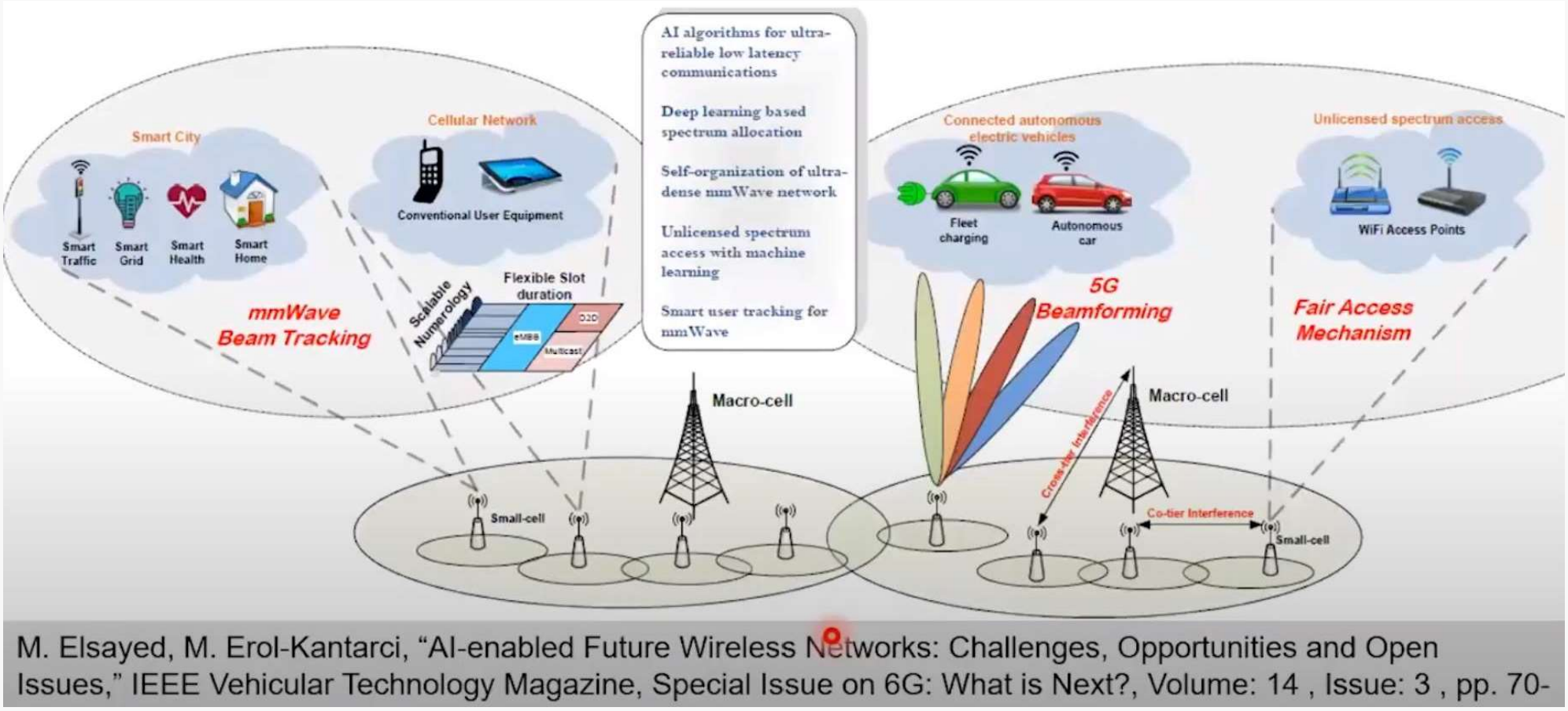
I. 통신 환경의 AI 개요

❑ AI-enabled 5G and 6G

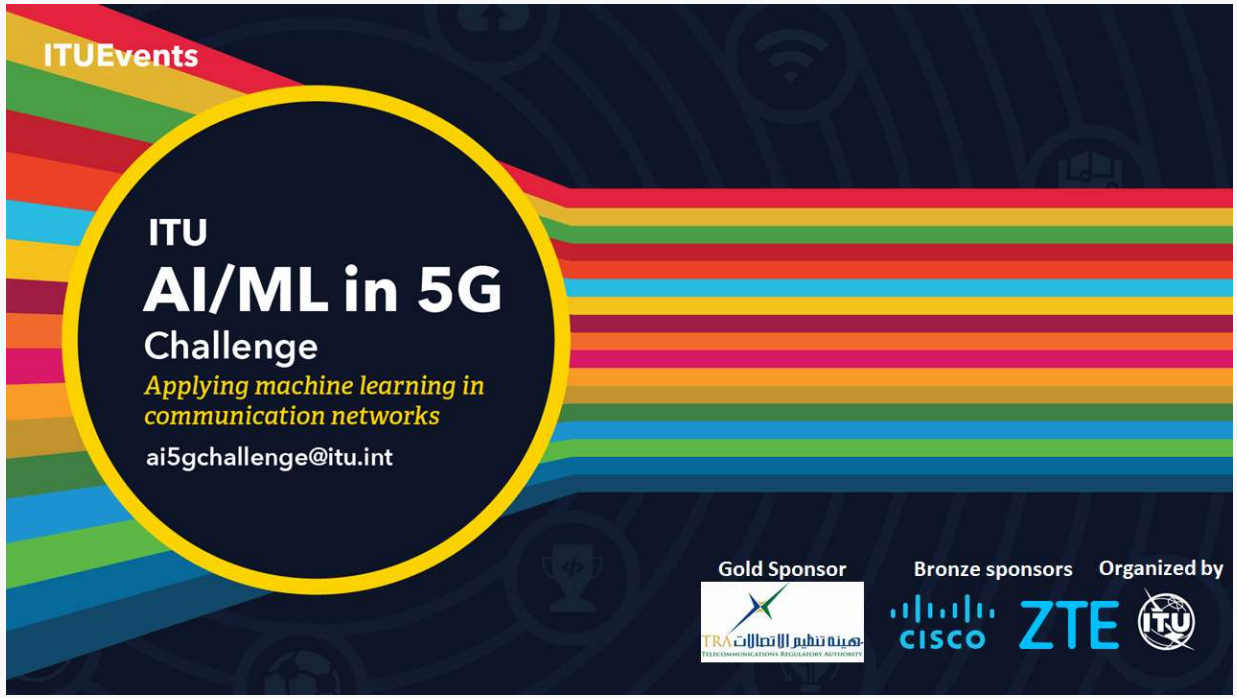


M. Elsayed, M. Erol-Kantarci, "AI-enabled Future Wireless Networks: Challenges, Opportunities and Open Issues," IEEE Vehicular Technology Magazine, Special Issue on 6G: What is Next?, Volume: 14 , Issue: 3 , pp. 70-

I. 통신 환경의 AI 개요

❑ AI/ML in 5G ChallengeAI-enabled functions

- Applying machine learning in communications networks.



출처: https://www.itu.int/en/ITU-T/AI/challenge/2020/Pages/default.aspx

I. 통신 환경의 AI 개요

❑ AI/ML in 5G Challenge

- **Applying machine learning in communications networks.**

AI for Good

16 September 2021

AI: A networking and communication perspective

10:00 - 11:00 CEST, Geneva | 16:00-17:00 Singapore Time

Tony Q.S. Quek

Discovery - AI/ML in 5G

VIEW DETAILS

23 September 2021

Engineering smart and secure networks using game theory and machine learning

09:00 - 10:00 CEST Geneva | 17:00-18:00 Melbourne

Tansu Alpcan

Discovery - AI/ML in 5G

VIEW DETAILS

28 September 2021

Learning to communicate (LeanCom): Deep learning based solutions for the physical layer of communications

10:00 - 11:00 CEST, Geneva | 09:00-10:00 UK Time

Christos Masouros

Discovery - AI/ML in 5G

VIEW DETAILS

22 October 2021

Reconfigurable intelligent surfaces: Model-based and data-driven optimization

14:00 - 15:00 CEST, Geneva

Marco Di Renzo

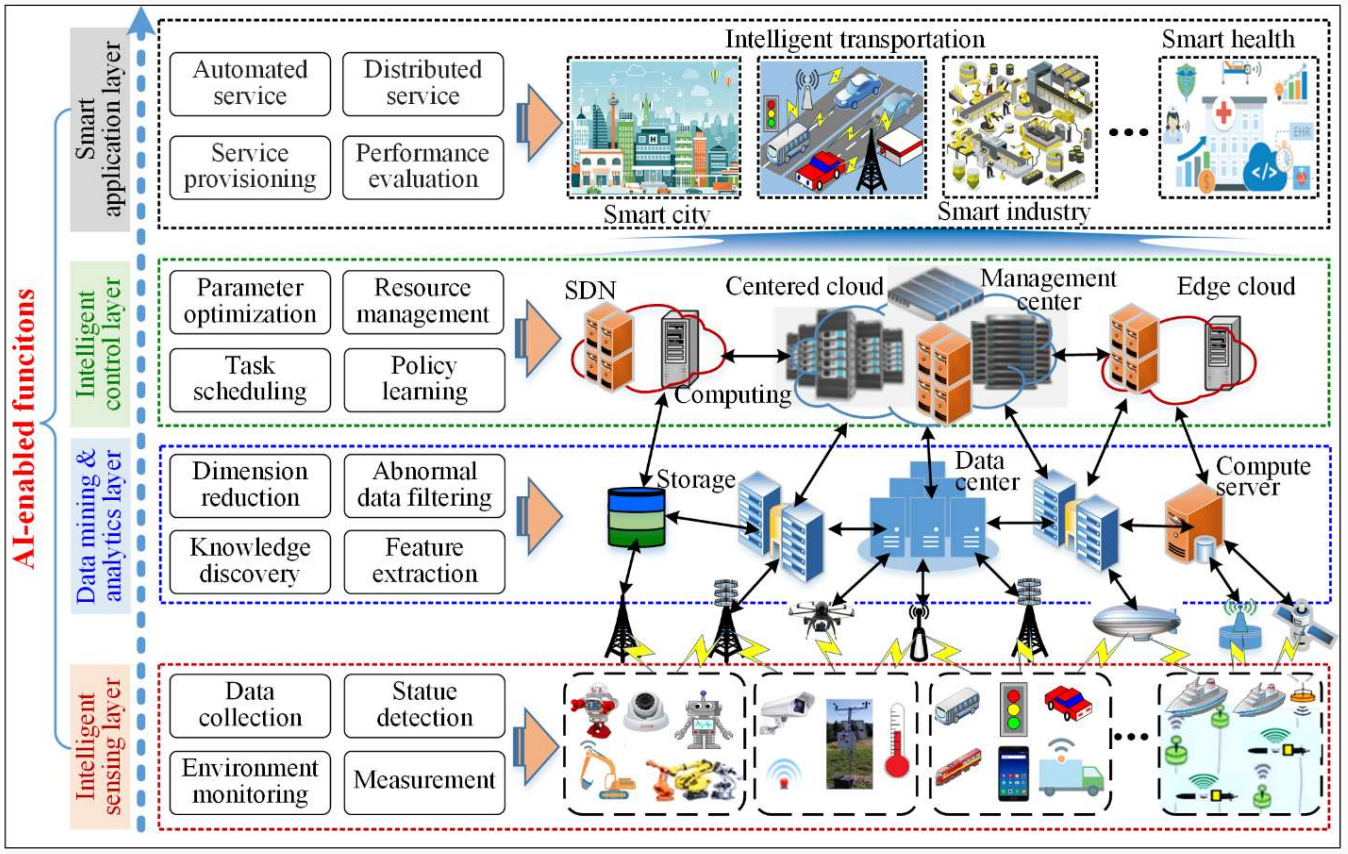
Discovery - AI/ML in 5G

VIEW DETAILS

출처: https://aiforgood.itu.int/about/aiml-in-5g-challenge/?fbclid=IwAR3I3pcSZ4f3V6jeWy5mUCJ4ScPrA3fm3FhxgJmx86R883W9XMP33NfpAtk

I. 통신 환경의 AI 개요

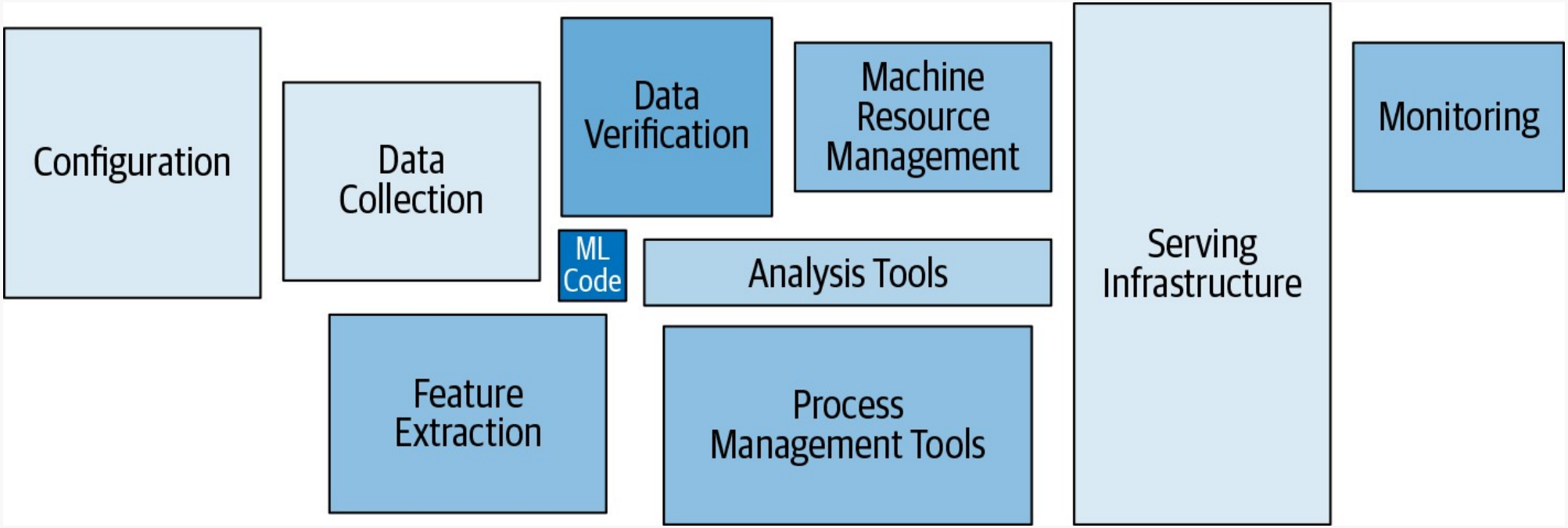
- ❑ AI-ENABLED INTELLIGENT 6G NETWORKS
- ❑ AI-enabled functions
  - Intelligent sensing layer
  - Data mining & analytics layer
  - Intelligent control layer
  - Smart application layer



출처: 'Artificial Intelligence-Enabled Intelligent 6G Networks', https://doi.org/10.1109/MNET.011.2000195 , IEEE Network, Volume: 34, Issue: 6, Nov./Dec. 2020

I. 통신 환경의 AI 개요

❑ Code is only a fraction of real- world machine learning systems



출처: D. Sculley et al.

I. 통신 환경의 AI 개요

❑ 네트워크 인프라

- 광네트워크
- 패킷네트워크/모바일코어
- 네트워크 서비스 및 제어 관리

출처: ETRI

I. 통신 환경의 AI 개요

❑ 5G의 4가지 기술적 한계

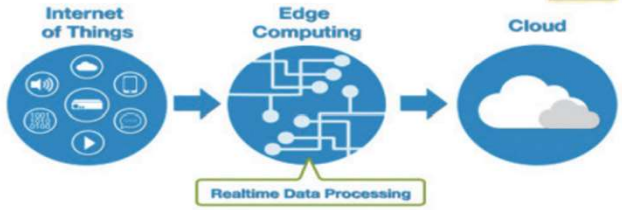
유선, 종단간 지연 미고려

무선위주의 성능개선, 유선 구간 종단간 지연 미고려
(5G 지연: 무선구간 10ms → 1ms, 유선구간 수십ms)

융합 서비스 실현 한계

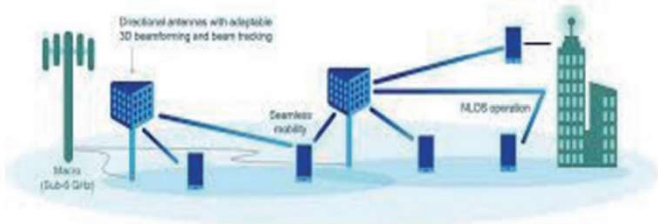
융합 서비스 지원을 위한 트래픽 용량 기술의 한계
(자율주행차 1대당 5~10Gbps, 6DoF AR/VR 0.2~5Gbps)

AI 적용 초기단계



부분적 네트워크 자원 관리 가능, AI 접목은 초기단계

공간활용 커버리지 미고려



지상 중심의 커버리지, 공간범위 확장성 미고려

출처: ICT R&D 기술로드맵 2025, IITP 정보통신기획평가원

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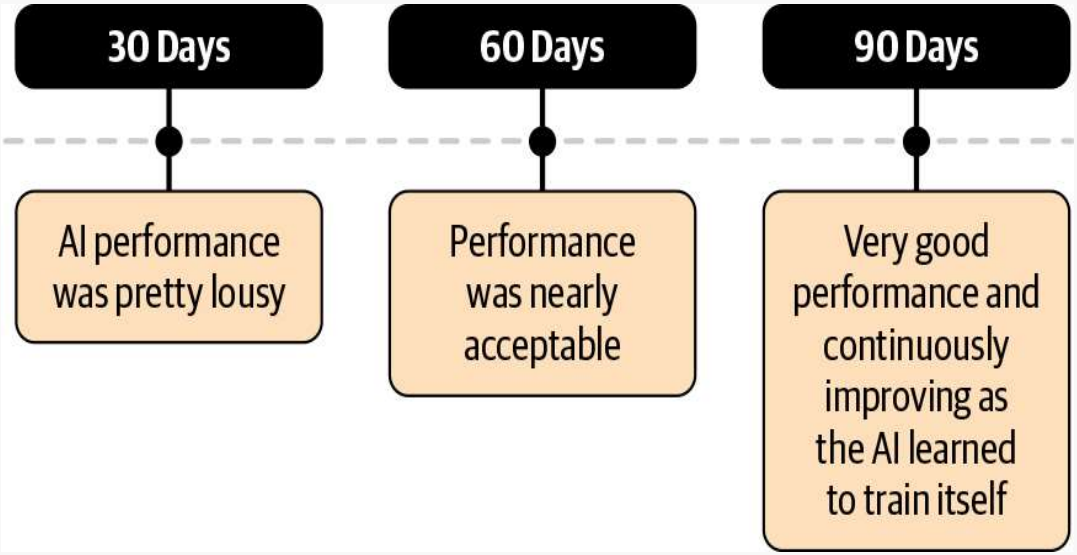
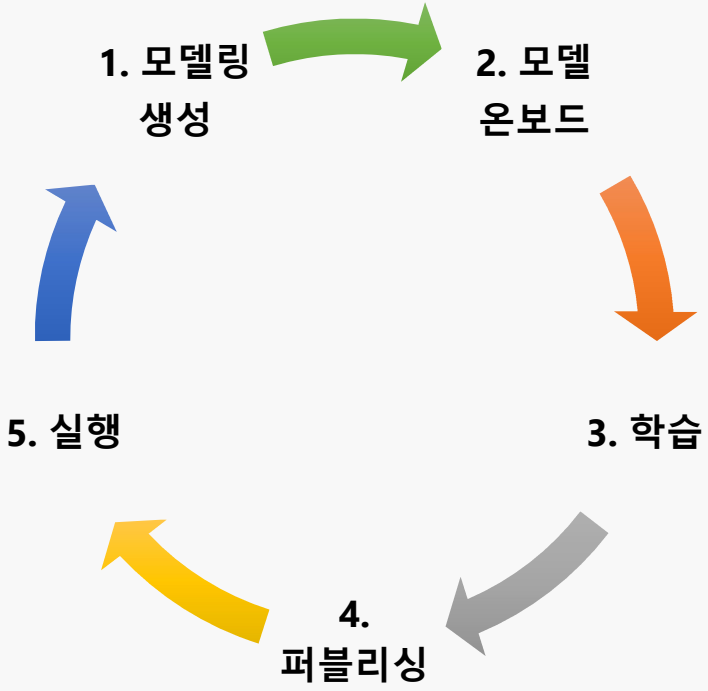
I. 통신 환경의 AI 개요

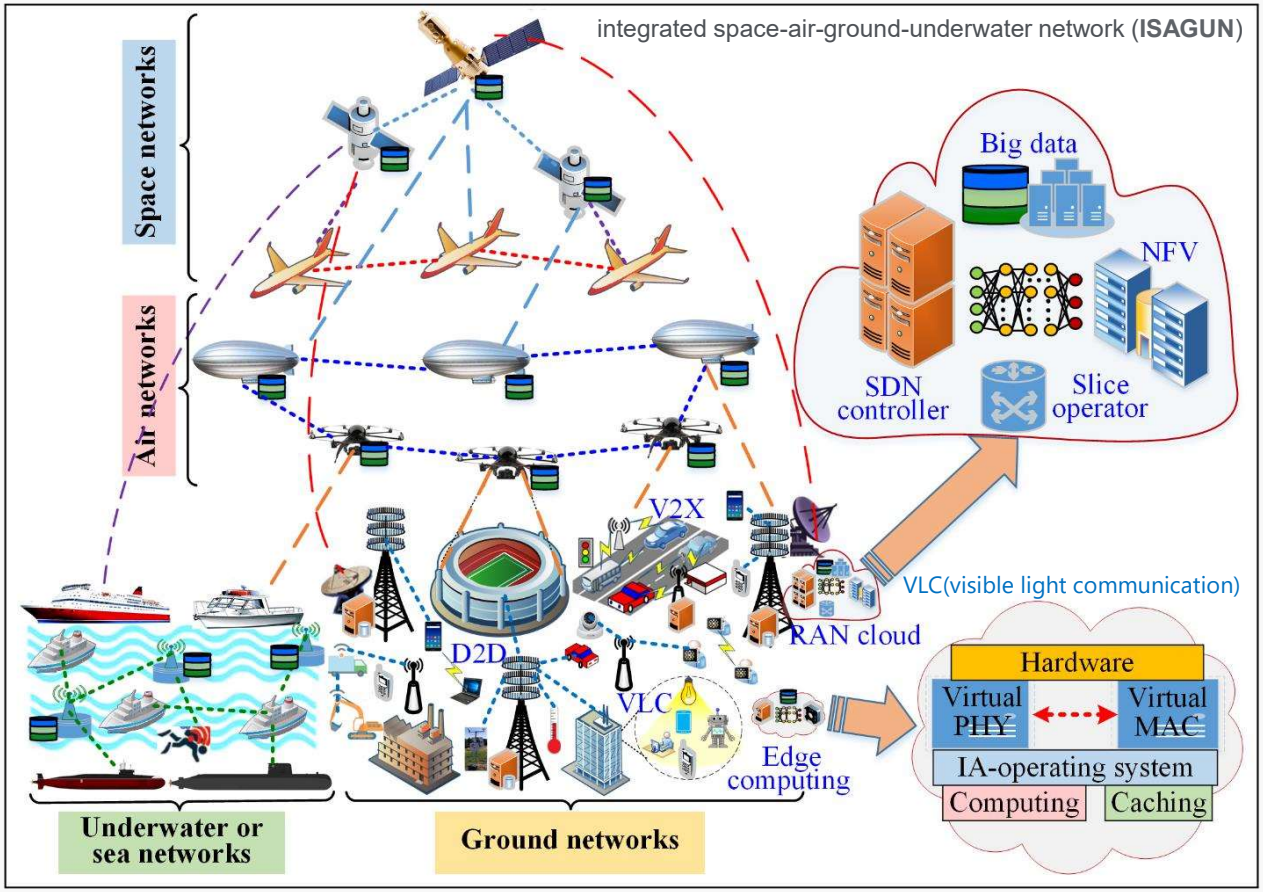
❑ Historical timeline for training AI models (AI 서비스 사이클)





I. 통신 환경의 AI 개요

- **The typical architecture of 6G network (ISAGUN). V2X, VLC, RAN, SDN, NFV, PHY, MAC**
  - Note: The objective of ISAGUN is to extremely broad coverage and seamless connectivity for space, airborne, ground, and underwater areas, such as flight in the sky, ship at sea, monitoring at remote areas or vehicles on land. As a result, human activity will dramatically expand from the ground to air, space, and deep sea. At the same time, centralized and edge computing are deployed at RAN with SDN and NFV to provide powerful computational processing and massive data acquisition for ISAGUN



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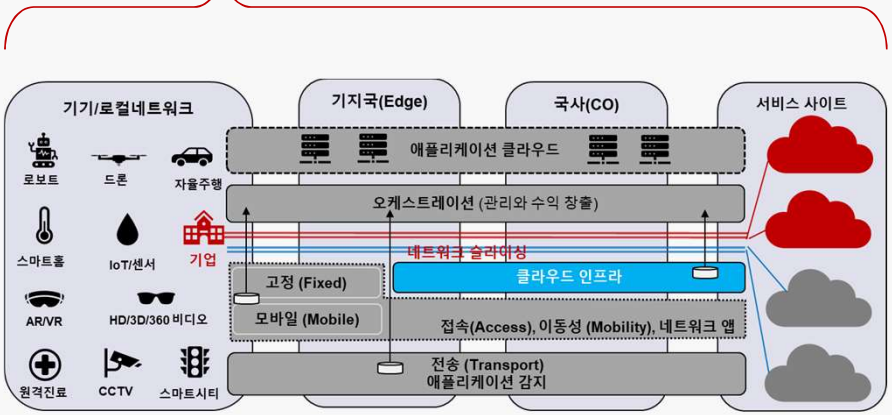
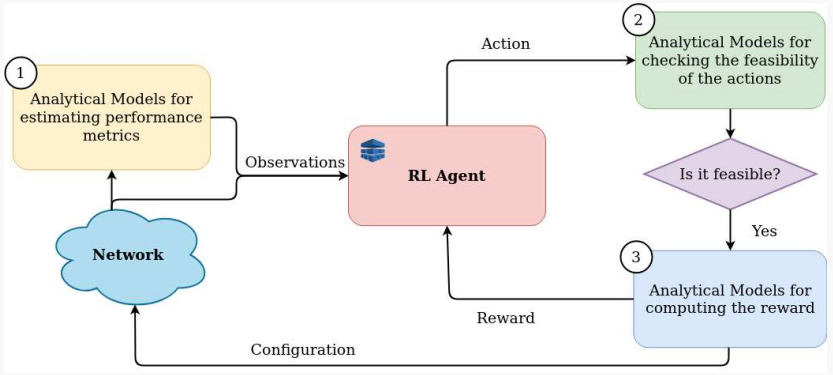
I. 통신 환경의 AI 개요

❑ Data Pipeline 스트림





Analytical models to assist Reinforcement Learning

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I. 통신 환경의 AI 개요

- ❑ Data Warehouse
- ❑ Data Lake

	Data Warehouse	Data Lake
Infrastructure	On-premise	Cloud-native
Data pipeline	ETL	ELT
Raw data layer	Staging area	Staging area
Historical data layer	Relational data vault	Relational data vault
Analytics data layer	Analytical database	Virtual views on top of historical data
Model training layer	-	Machine learning cluster
Streaming data layer	-	Streaming data cluster and stream processing engine

I. 통신 환경의 AI 개요

❑ 통신 환경을 위한 AI/ML의 기대

- **고객 관리**
  - 개인화 / 맞춤형 마케팅
  - 가입자 이탈 예측
  - 사전 예측 고객 케어
  - 맞춤형 고객 관리 가능
- **사전 예측**
  - 사전 예측 유지보수
  - 이상탐지 기반 운영,관리,
  - 프로비저닝
  - 용량 산정 및 최적화
- **새로운 서비스 제공**
  - Data-as-a-service
  - IoT 및 machine-to-machine
  - (M2M) 분석
- **인사이트 추출**

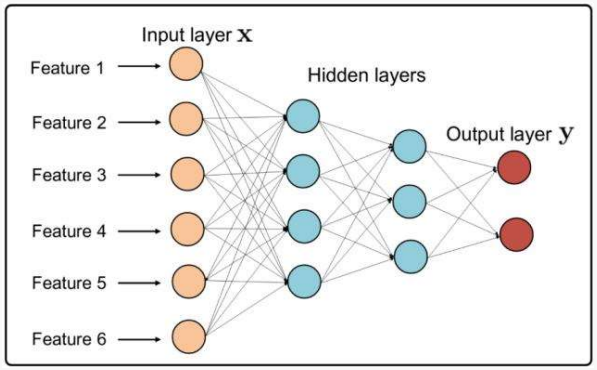
I. 통신 환경의 AI 개요

DNN은 은닉층을 2개이상 지닌 학습 방법

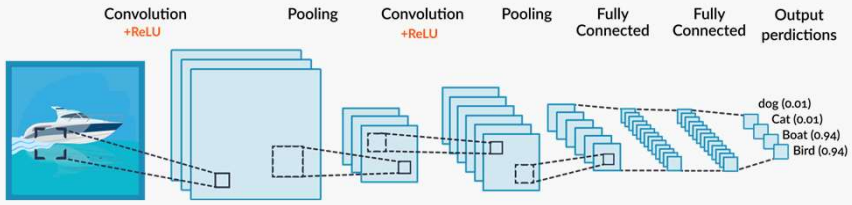
❑ Overview of the existing and emerging ML frameworks

- **Neural Networks**
  - Feed-forward neural networks
  - Deep neural networks (DNN)
  - Recurrent neural networks (RNN)
  - Convolutional neural networks (CNN)
- **Reinforcement Learning**
  - Basics/overview
  - Deep Reinforcement Learning
- **Hybrid Solutions**
  - Combined analytical and Machine Learning modelling
  - Expert knowledge aided Machine Learning
- **Further Specific Methods**
  - Generative adversarial networks (GAN)
  - Kalman type filtering – and it relation to AI
  - Unsupervised learning and clustering

AI 인프라의 자동화 진행중



Scheme of a deep neural network(dnn) with 2 hidden layers



CNN(합성곱신경망 : Convolution Neural Network)

출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

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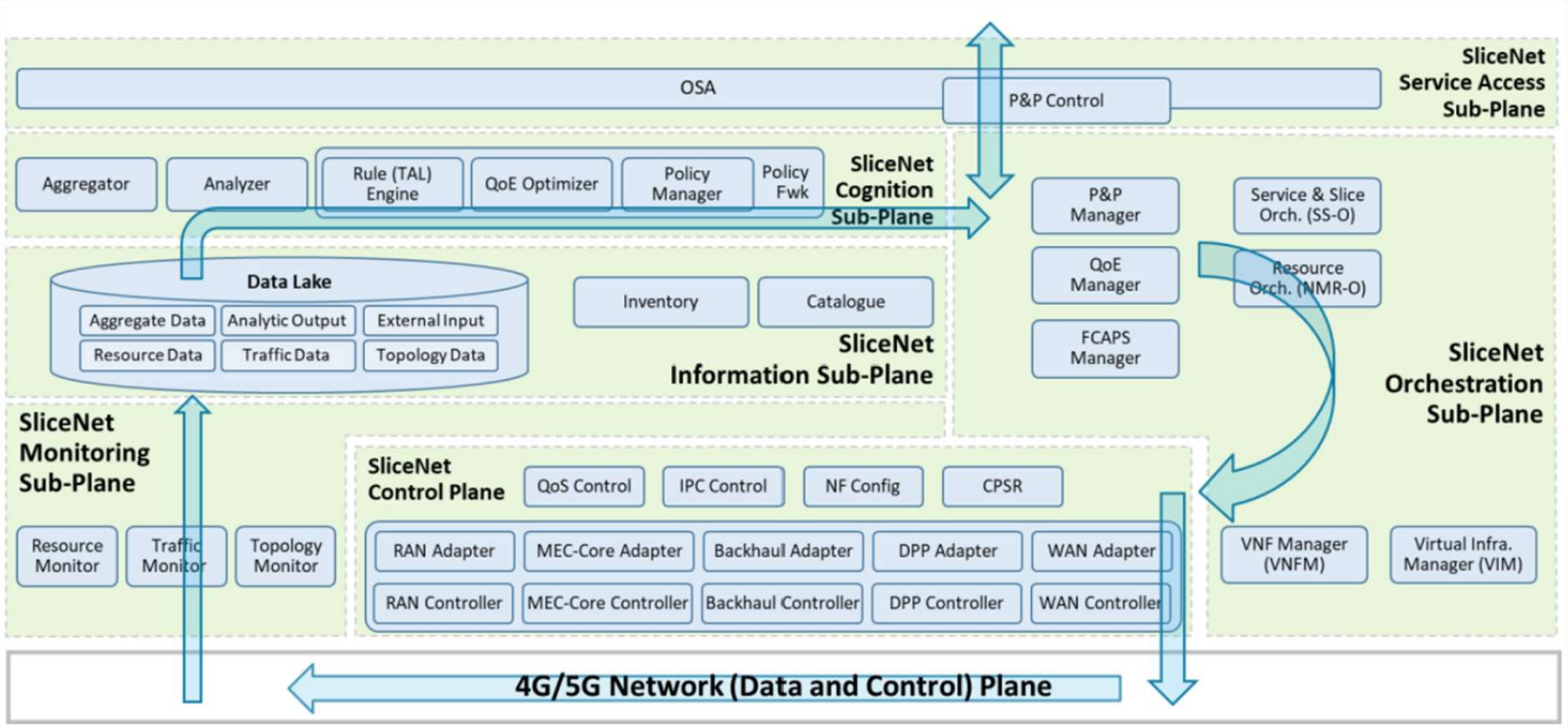
II. Architectural aspects

- ❑ AI-based autonomous slice management, control and orchestration
- ❑ AI-based flow management in 5G systems
- ❑ Cross-layer optimization framework using ML
- ❑ Management analytics function
- ❑ 3GPP network data analytics function
- ❑ ETSI: Simplified Functional Overview of the ENI System Architecture

II. Architectural aspects

❑ AI-based autonomous slice management, control and orchestration

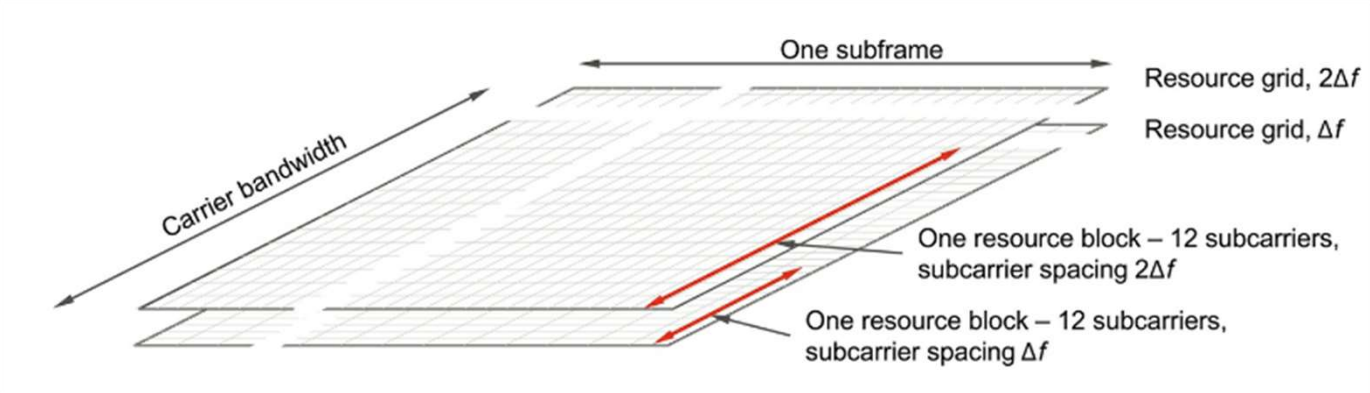
- Overall architecture for AI based autonomous management, control and orchestration

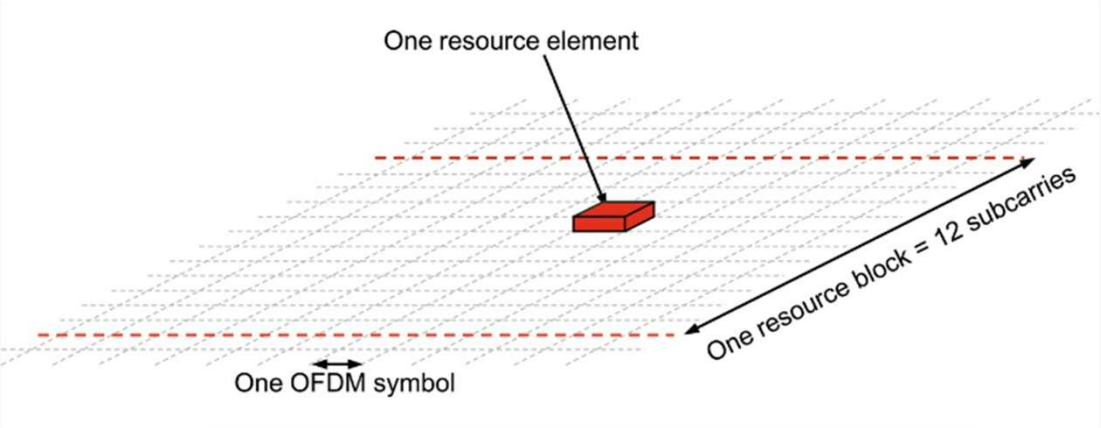


출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

II. Architectural aspects

❑ 스케쥴링 고려: Subframe / Slot / Symbol





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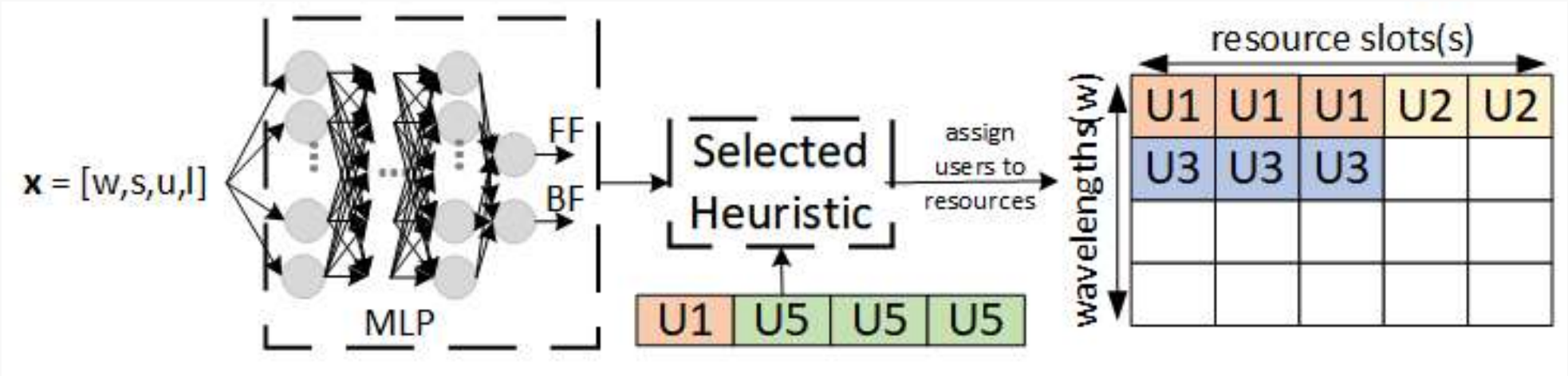
II. Architectural aspects

❑ AI-based flow management in 5G systems

- **Flowchart of the MLP-based scheduler**



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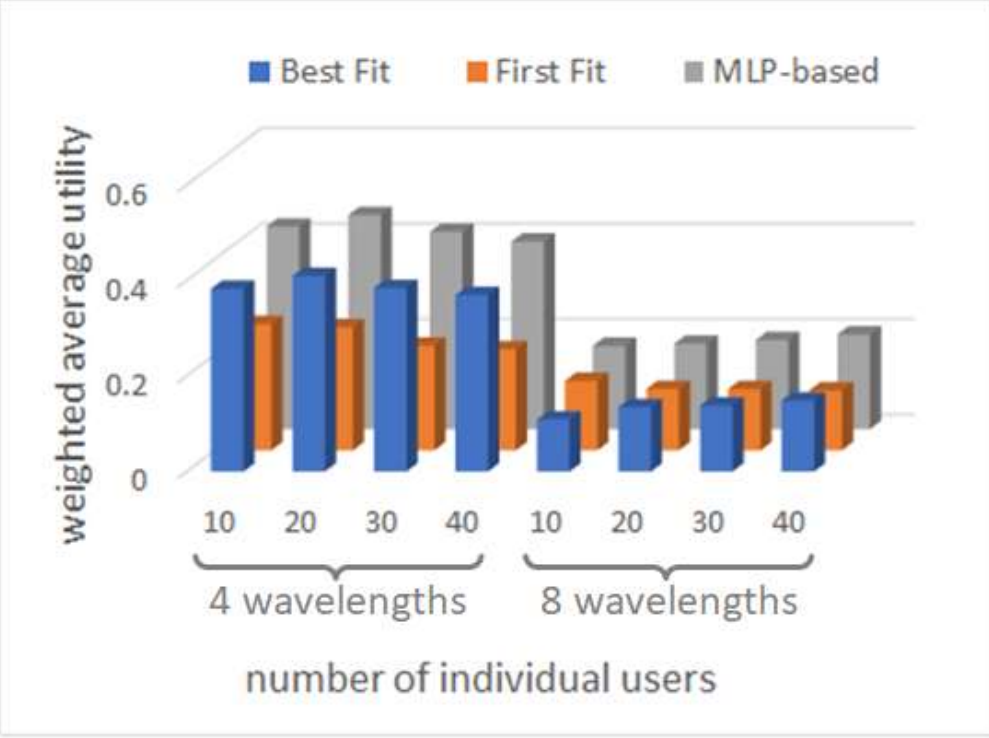
II. Architectural aspects

❑ AI-based flow management in 5G systems

- **Weighted utility for the best fit, first fit and MLP-based scheduler for {10, 20, 30, 40} users and {4, 8} wavelengths**



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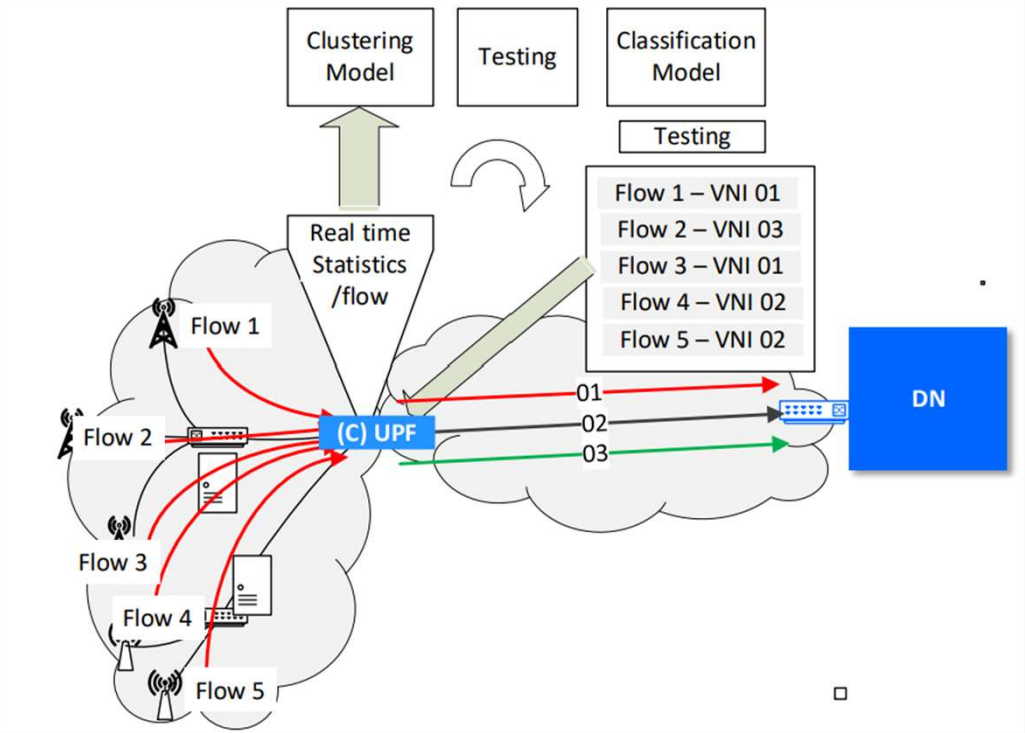
II. Architectural aspects

❑ AI-based flow management in 5G systems

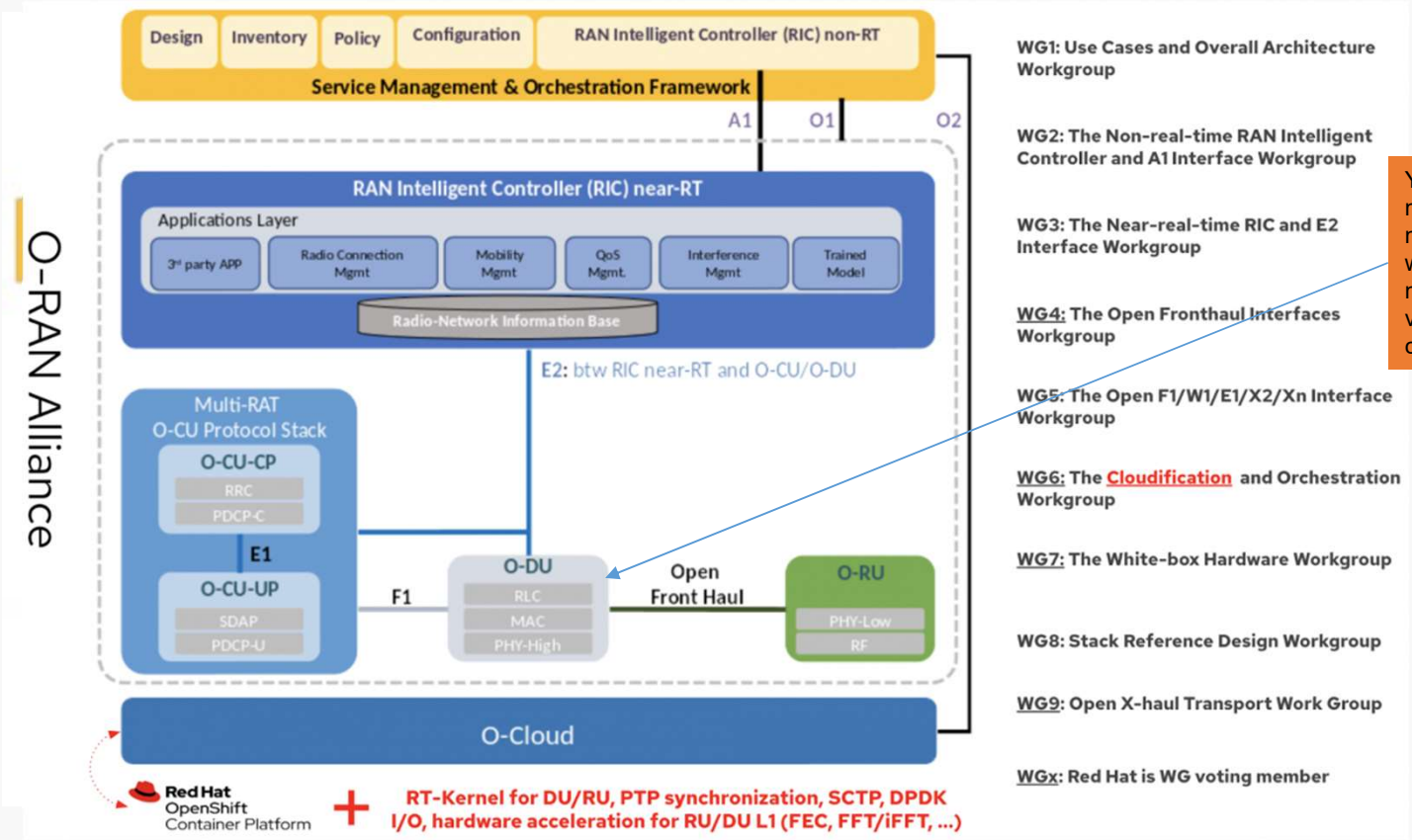
- **Monitoring, classification and tagging of network flows**



출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

II. Architectural aspects

❑ O-RAN Alliance



출처: https://www.redhat.com/en/blog/open-ran-and-o-ran-brief?fbclid=IwAR0V6fivK9xv2LEkXNTvjBeOSRVYB0cej4Q_zV6teY2Oh_GrVWmWDMS07js

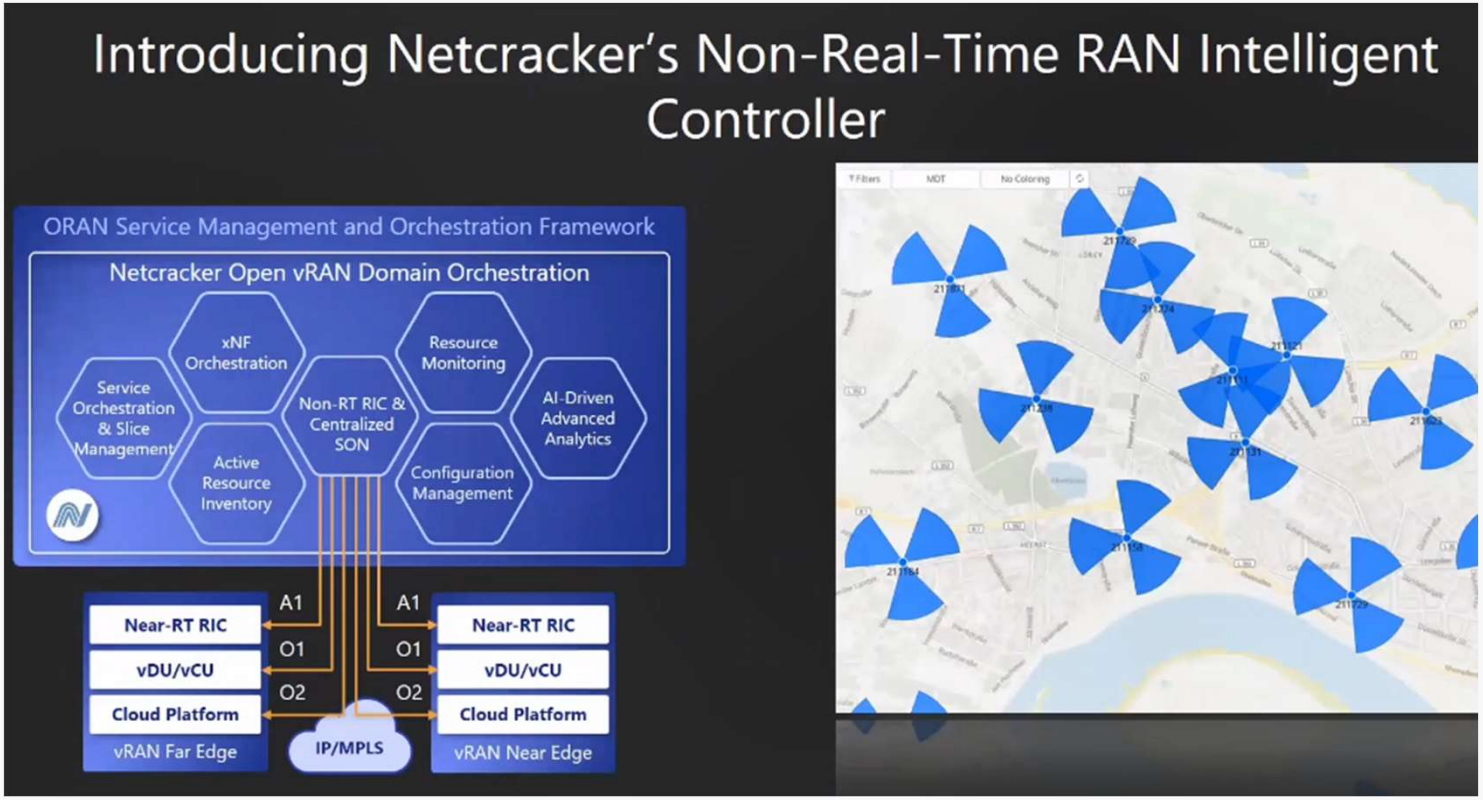
II. Architectural aspects

❑ The O-RAN plugfest/PoC in East Asia

출처: https://plugfestvirtualshowcase.o-ran.org/venue_east_asia.html

II. Architectural aspects

❑ AI-Driven mMIMO Beam Optimization

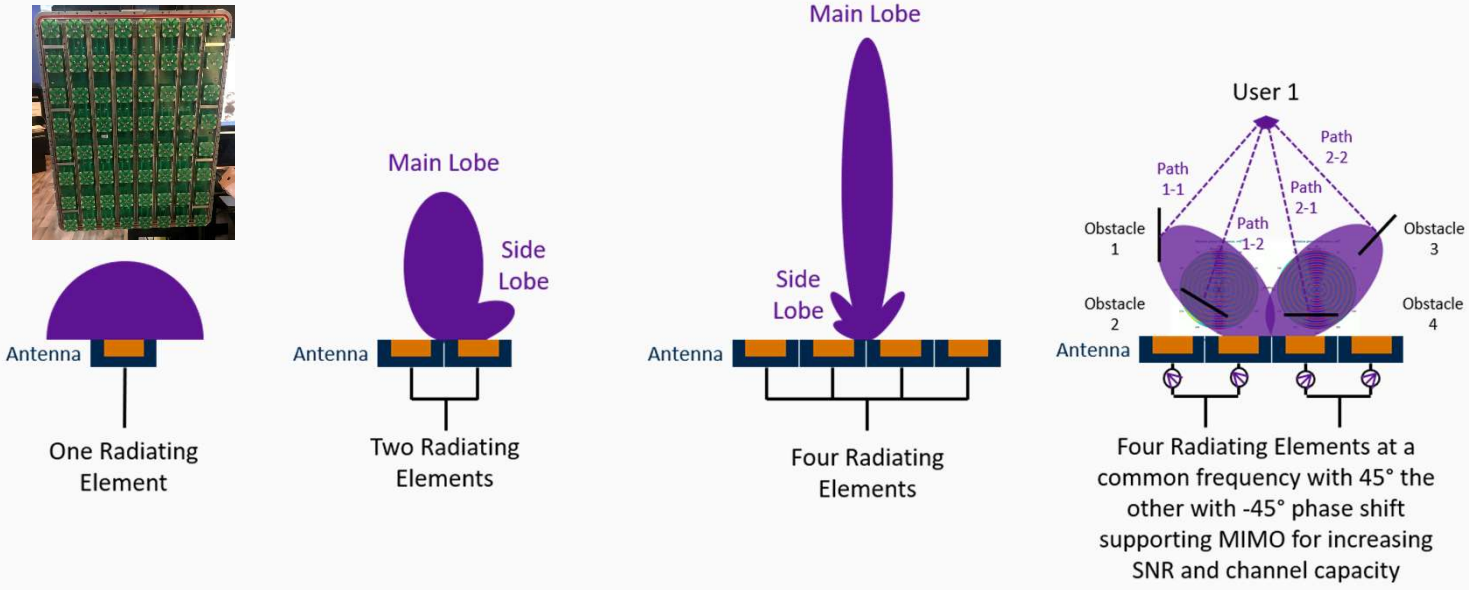


출처: https://plugfestvirtualshowcase.o-ran.org/venue_east_asia.html
https://stage-o-ran-v2.azurewebsites.net/classic/generation/2021/category/intelligent-ran-control-demonstrations/sub/intelligent-control/110

II. Architectural aspects

❑ 빔포밍 (What is 5G beamforming?)

- 무선의 위상제어(Beam steering): 위상변화를 수신자 목표로 지향성 무선 신호를 송신
- Massive MIMO: 일반 주파수를 동시에 여러 방향으로 전송
- 동일 주파수 중복 사용

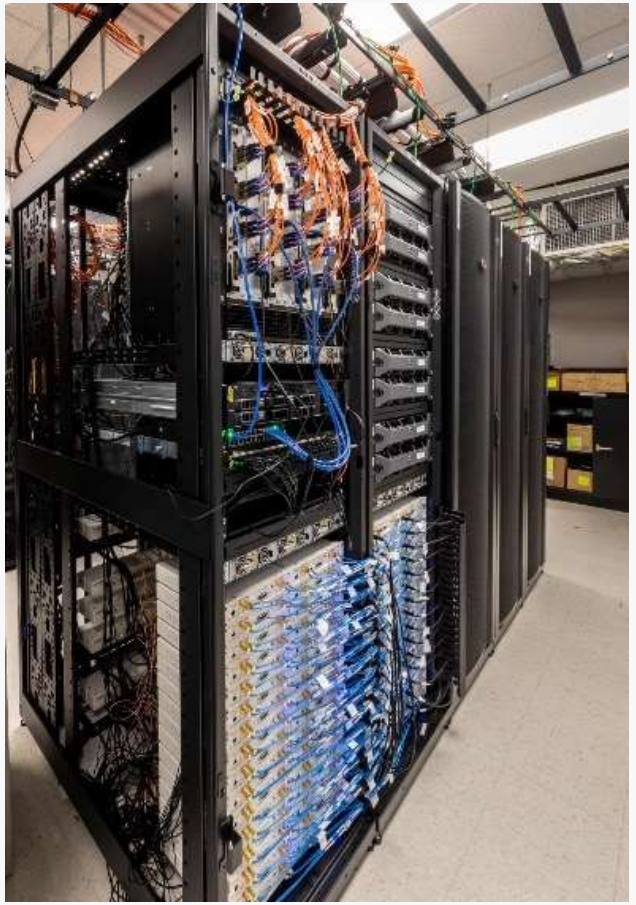


(출처: https://www.metaswitch.com/knowledge-center/reference/what-is-beamforming-beam-steering-and-beam-switching-with-massive-mimo)

II. Architectural aspects

❑ O-RAN 구성

- **256 software-defined radios**
- **25.6 GHz of emulated bandwidth, 52 TB/s RF data**
- **21 racks of radios, 171 high-performance servers w/ CPUs, GPUs**
- **Massive computing capabilities (CPU, GPU, FPGA):**
  - > 900 TB of storage
  - 320 FPGAs
  - 18 10G switches
  - 19 clock distribution systems
  - 52 TB/s of digital RF data

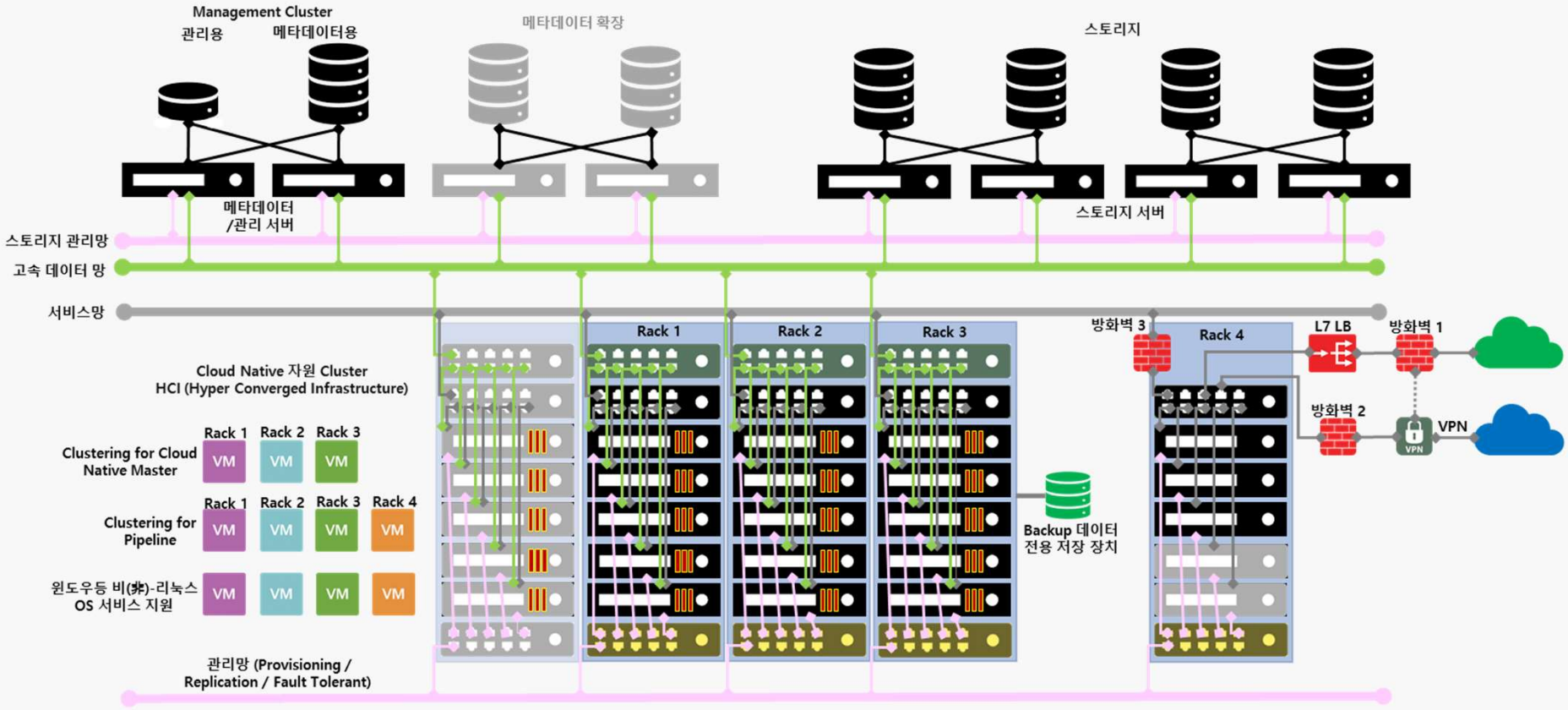


YANG models that help manage the radio units feature more than 6,000 parameters, with less than 3% of them mandatory, and network vendors also implement custom protocols.

Institute for the Wireless Internet of Things at Northeastern

II. Architectural aspects

❑ 오픈소스 기반 AI 인프라 구성 (예)



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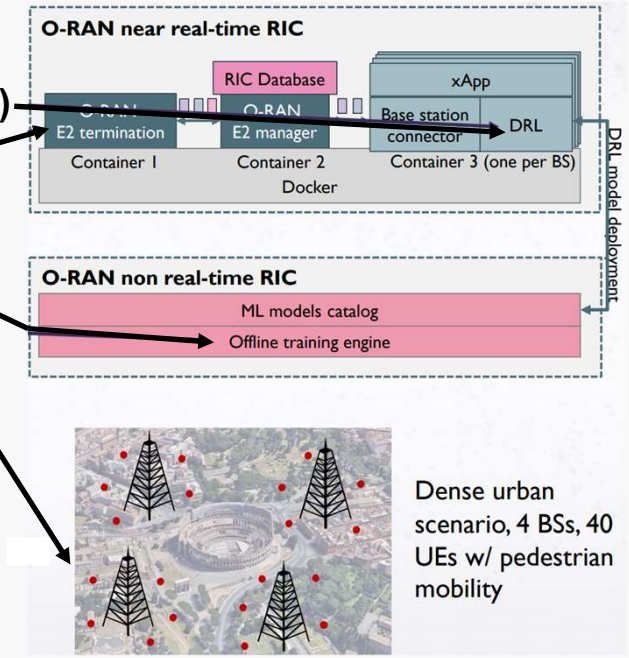
II. Architectural aspects

❑ DRL(Deep Re-inforcement Learning) 병렬처리

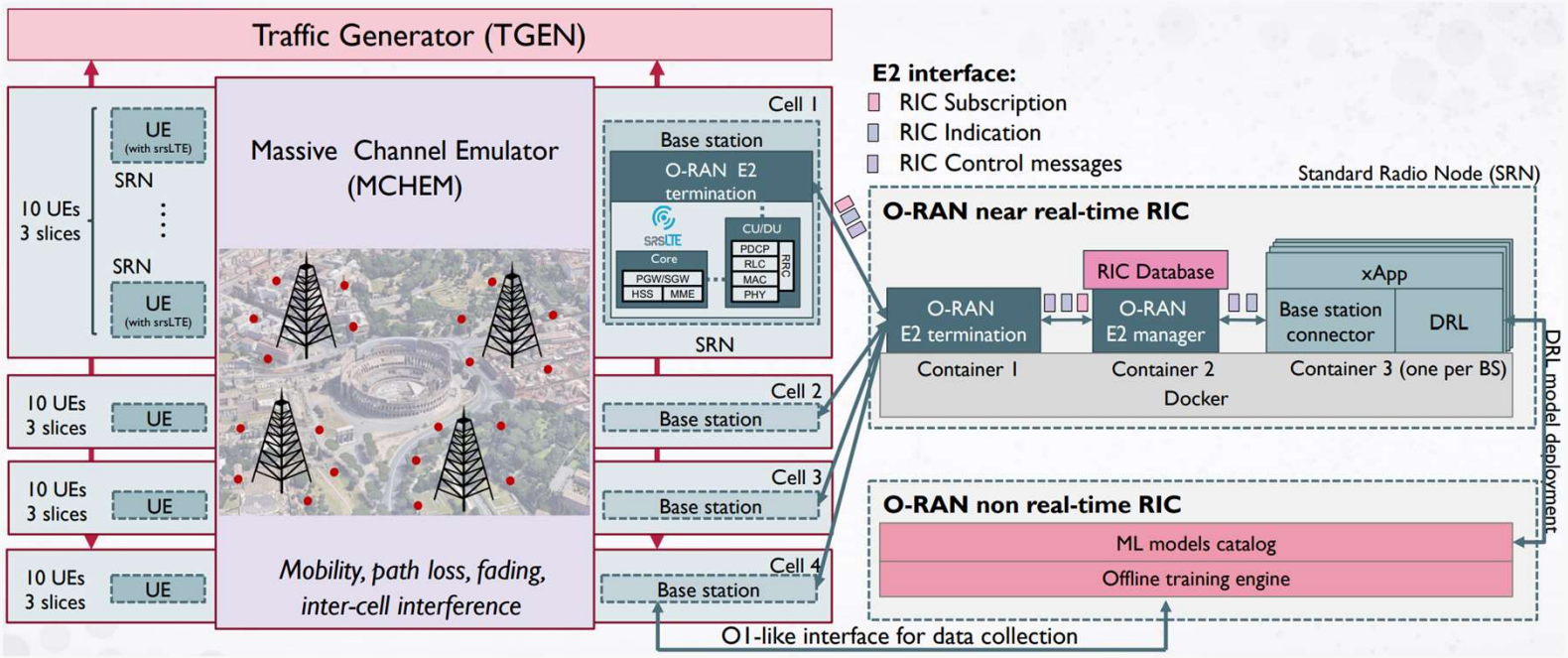
12 DRL(Deep Re-inforcement Learning) agents 병렬처리

- **Fully-connected neural network (5 layers & 30 neurons each)**
- **Online inference w/ real-time RAN performance data**
- **Trained offline on 6 GB of data & 63 hours of experiments**
- **Decisions on scheduling policies of each BS slice**
  - **Round-robin (RR)**
  - **Waterfilling (WF)**
  - **Proportional fair (PF)**



II. Architectural aspects

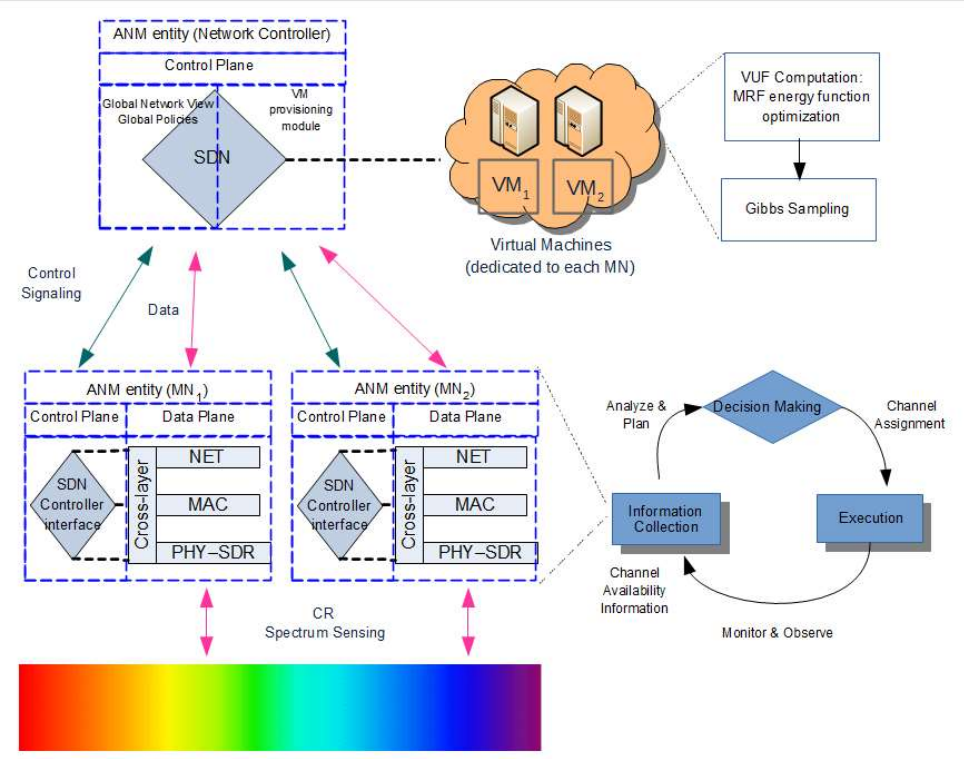
❑ O-RAN Integration in Colosseum



II. Architectural aspects

❑ Cross-layer optimization framework using ML

- **NMO-SDR cross-layer functionality**



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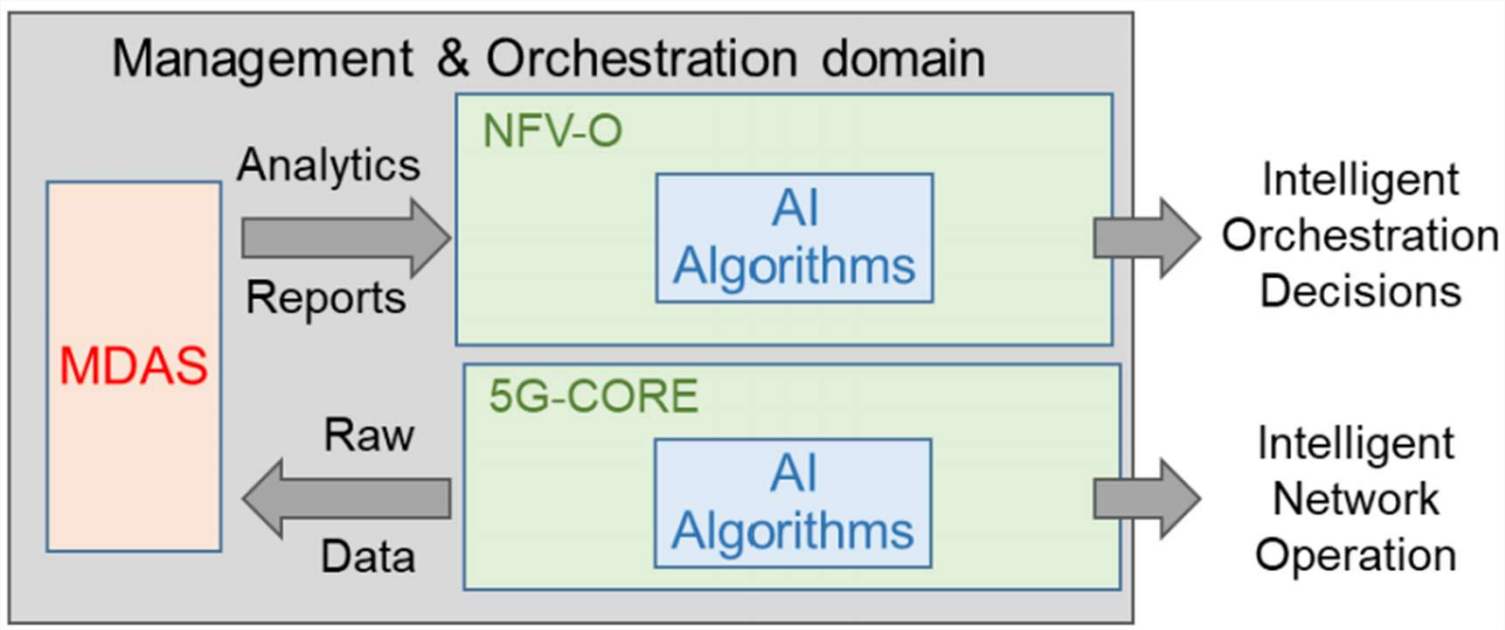
II. Architectural aspects

❑ Management analytics function

- **Management Data Analytics Service (MDAS)**
  - The MDAS main functions

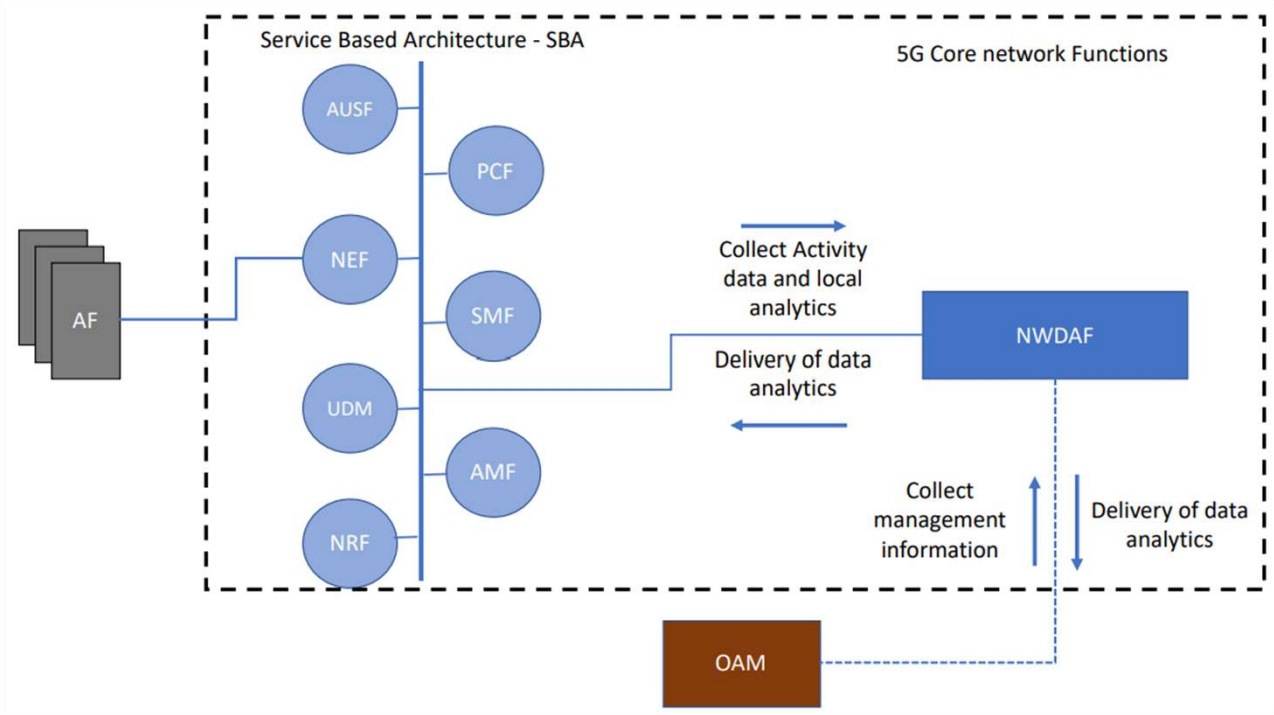


출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

II. Architectural aspects

❑ 3GPP network data analytics function

- 3GPP's Network Data Analytics Function



출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

II. Architectural aspects

❑ 3GPP network data analytics function

- **Observed events in NWDAF and potential consumers of analytics**

Observed events	Potential consumers
Network Slice load level information	PCF, NSSF
Service experience / QoE	PCF, OAM
Network Function load	AMF (SMF load), SMF (UPF load), OAM
Network performance	PCF, NEF, AF, OAM
Abnormal/Expected UE behaviour	PCF, AMF, SMF, NEF, AF, OAM
UE mobility	AMF, SMF, NEF, UDM, AF, OAM
UE communication pattern	AMF, SMF, NEF, UDM, AF, OAM
User data congestion	NEF, AF
QoS sustainability	PCF, NEF, AF

출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

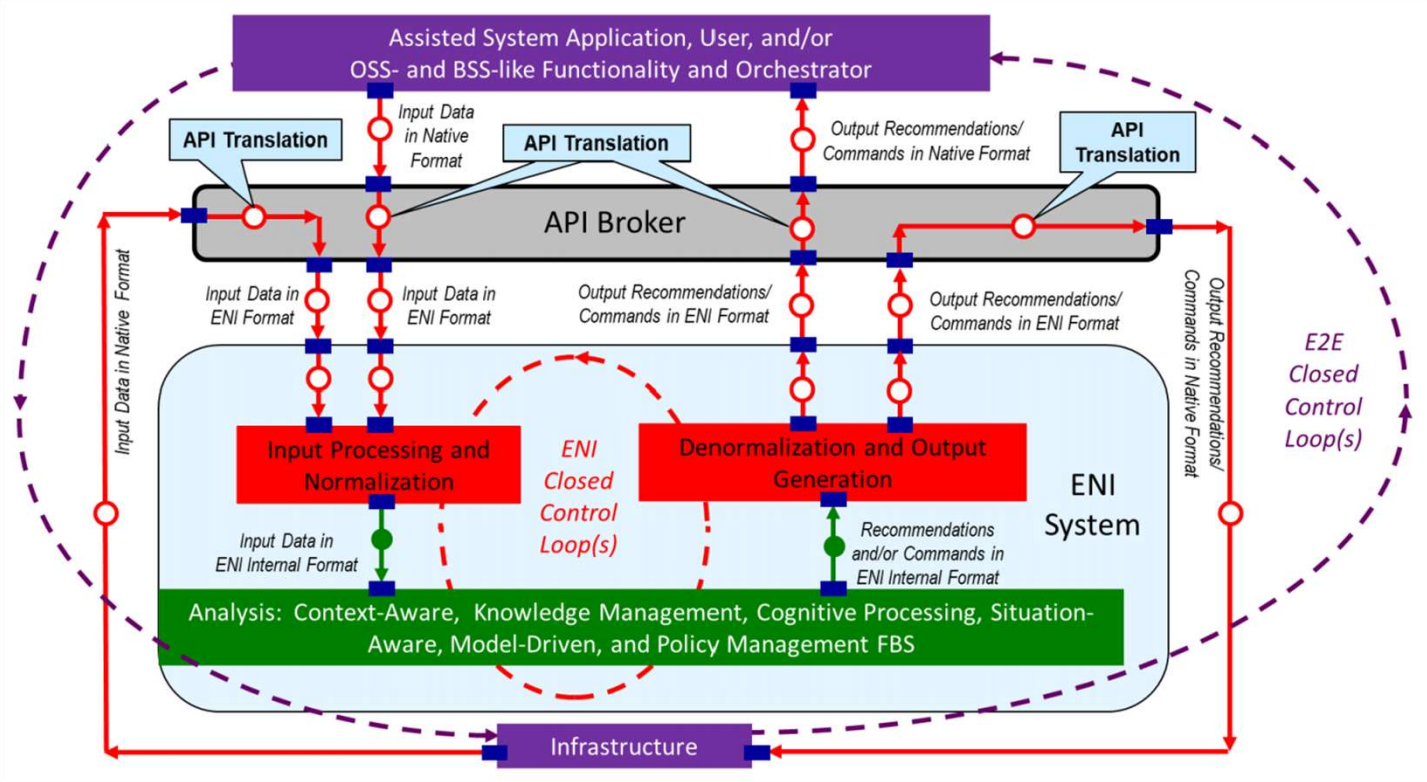
II. Architectural aspects

- 3GPP network data analytics function
- examples
  - The Policy Control Function (PCF) could use analytics inputs to (re-)configure policies for assignment of network resources and/or traffic steering
  - The Network Slice Selection Function (NSSF) could optimize Network Slice selection
  - The Access and Mobility Management Function (AMF) could improve SMF selection, monitoring of UE behaviour, adjustment of UE mobility
  - The Session Management Function (SMF) could improve UPF selection, monitoring of UE behaviour, adjustment of UE communication related network parameters
  - The Network Exposure Function (NEF) could optimize forwarding of NWDA information to the AFs
  - The Application Function (AF) could adjust service applications
  - The OAM could optimize operation and management actions

출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

II. Architectural aspects

❑ ETSI: Simplified Functional Overview of the ENI System Architecture



출처: https://www.etsi.org/images/files/ETSIWhitePapers/etsi-wp44_ENI_Vision.pdf

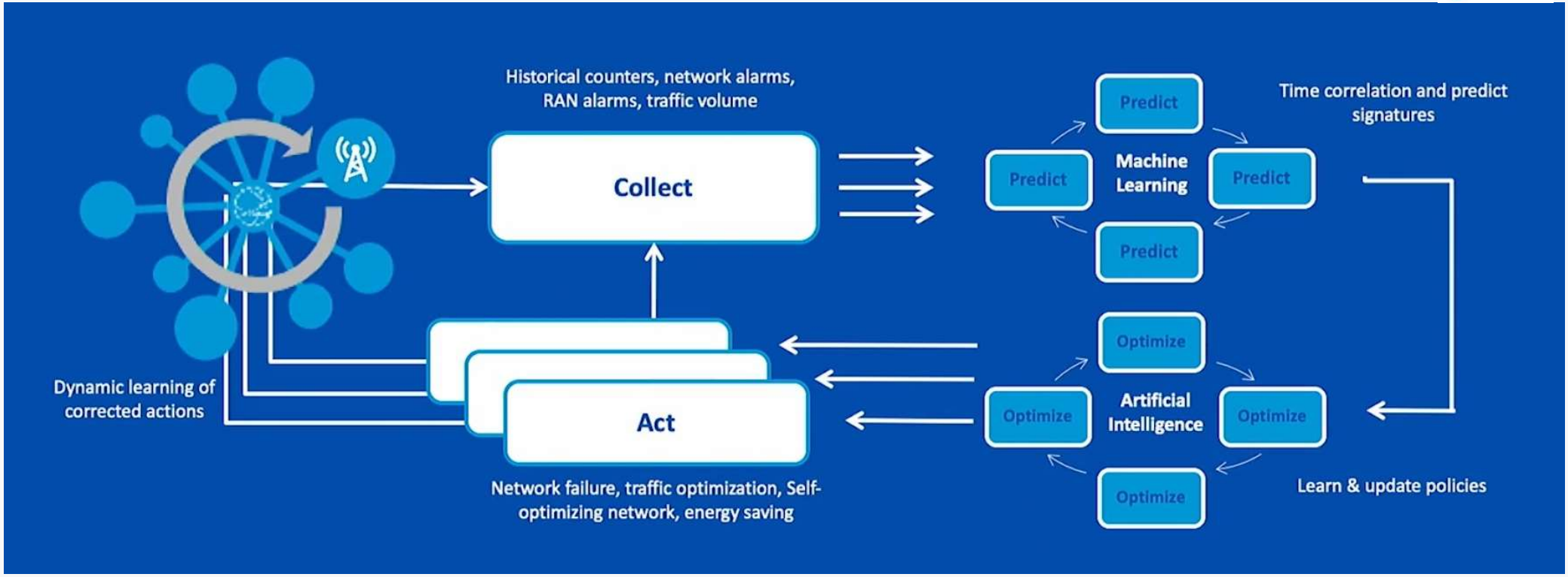
III. Use case

- ❑ Operation Automation
- ❑ 무선 시설 관리
- ❑ The Emergence and Practice of AIOps
- ❑ Network Planning Use cases
- ❑ Forecasting network characteristics and events
- ❑ Estimating user locations
- ❑ Transport networks, fronthaul and backhaul
- ❑ NFV infrastructures
- ❑ End-to-end slicing
- ❑ Security
- ❑ Intelligent Mobility and Handover Management
- ❑ AI assisted sensor fusion
- ❑ RAN
- ❑ .....

III. Use case

❑ Operation Automation

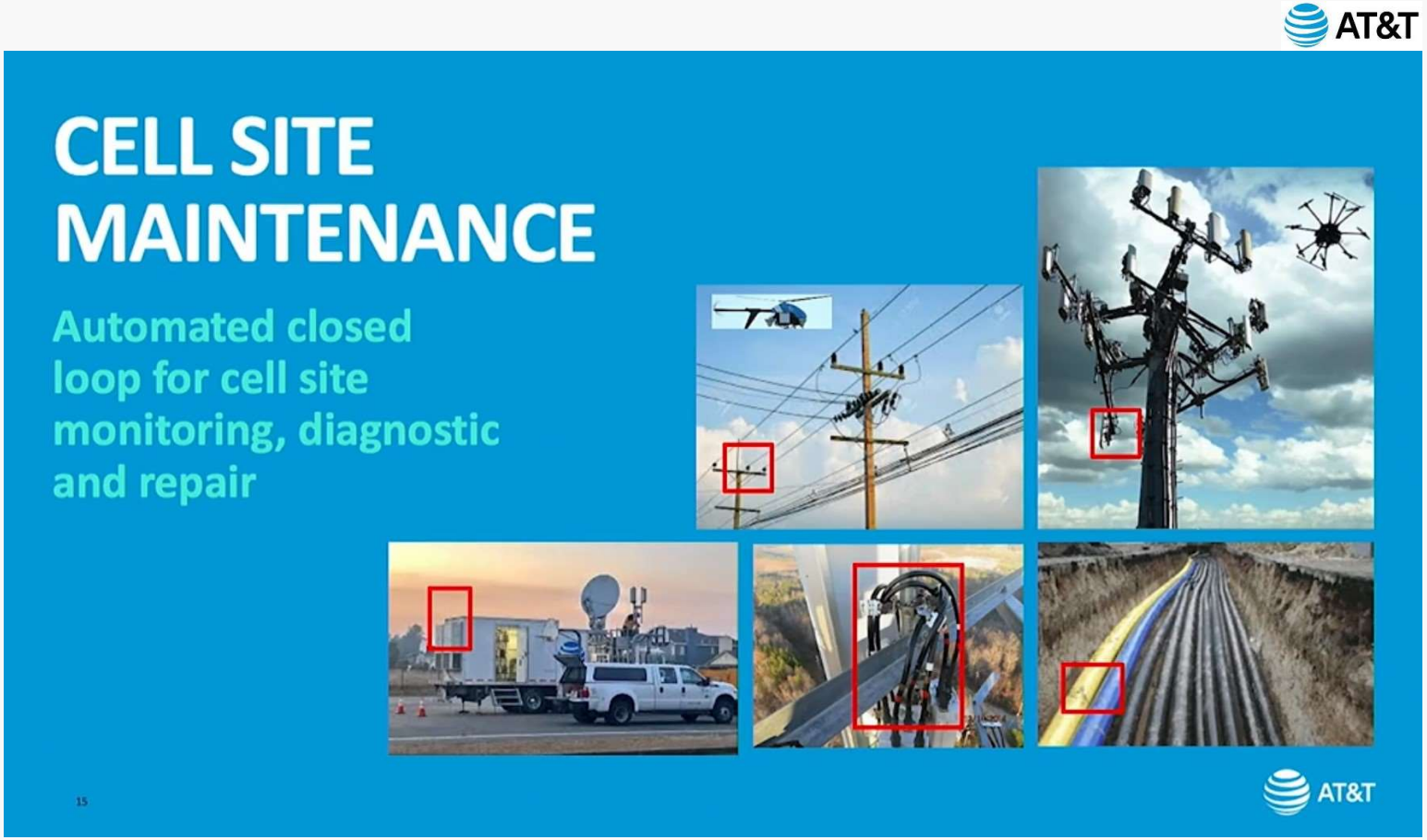
- Ex.) Sleep mode on/off



JS Lab

III. Use case

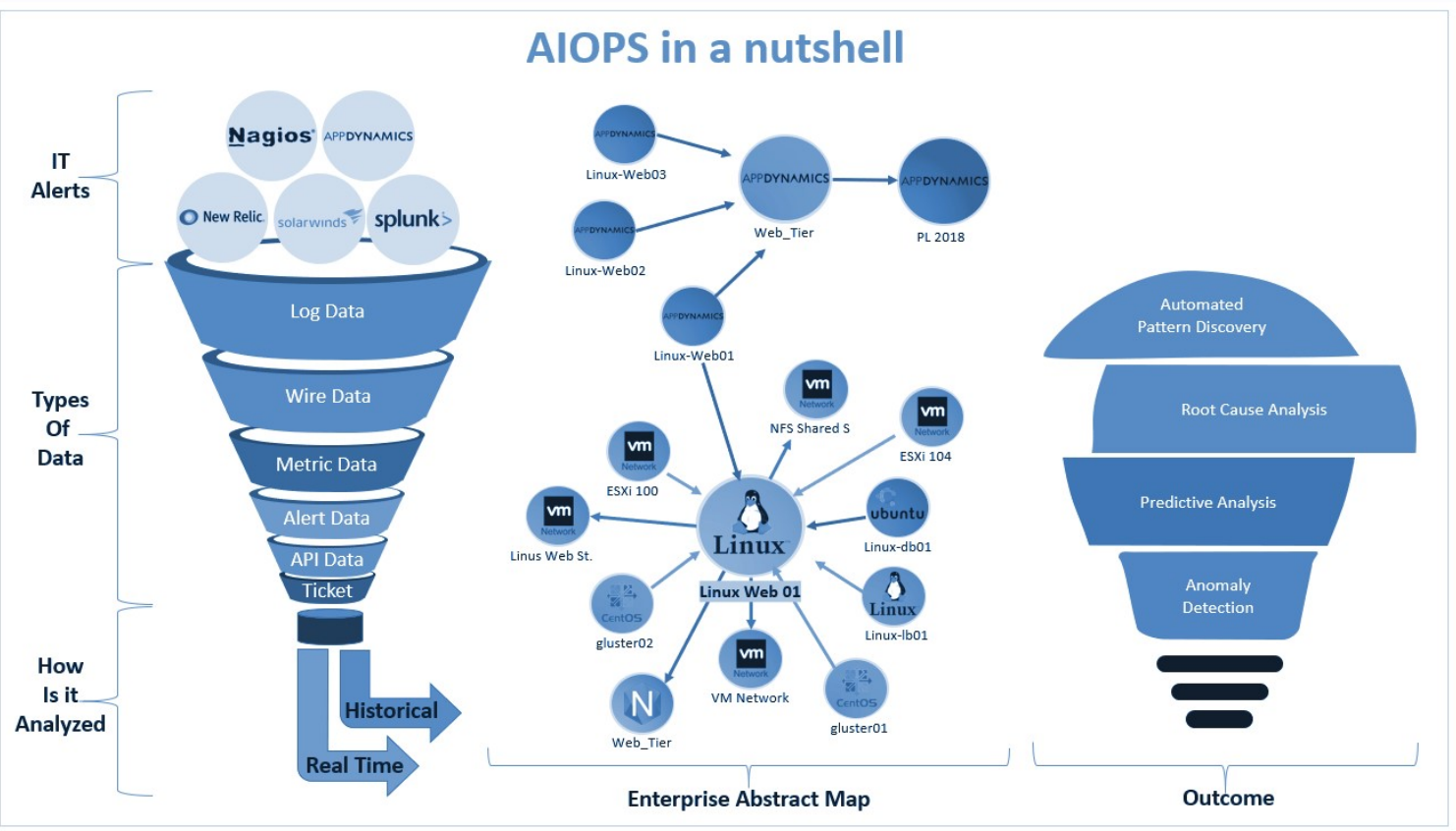
❑ 무선 시설 관리



JS Lab

III. Use case

❑ The Emergence and Practice of AIOps



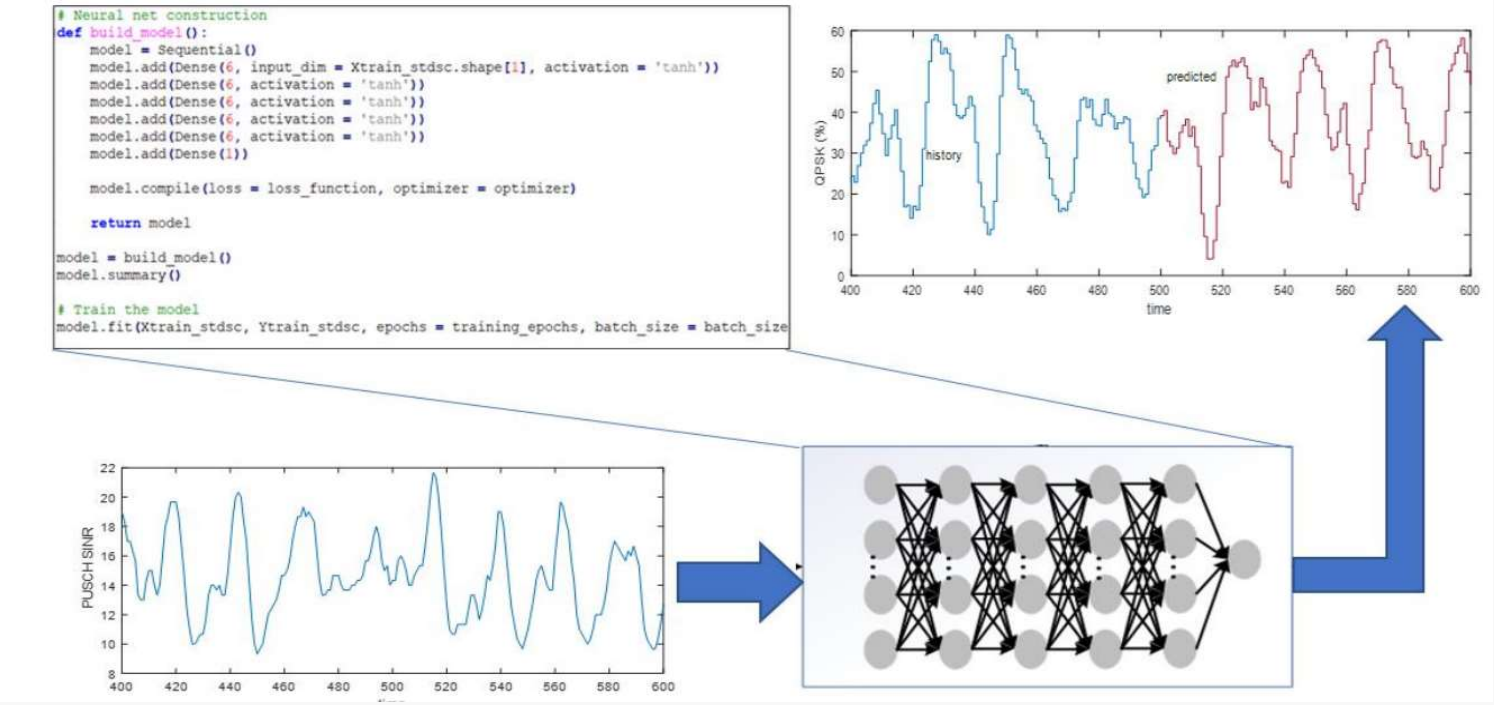
출처: https://www.addteq.com/blog/2020/10/what-is-ai-ops-and-how-ai-ops-can-help-companies-to-solve-it-infrastructure-challenges

III. Use case

❑ Network Planning Use cases

- **Network element placement problem**
  - Dimensioning considerations for C-RAN clusters

MLP-NN model which has been developed to predict the modulation using as input PUSCH SINR



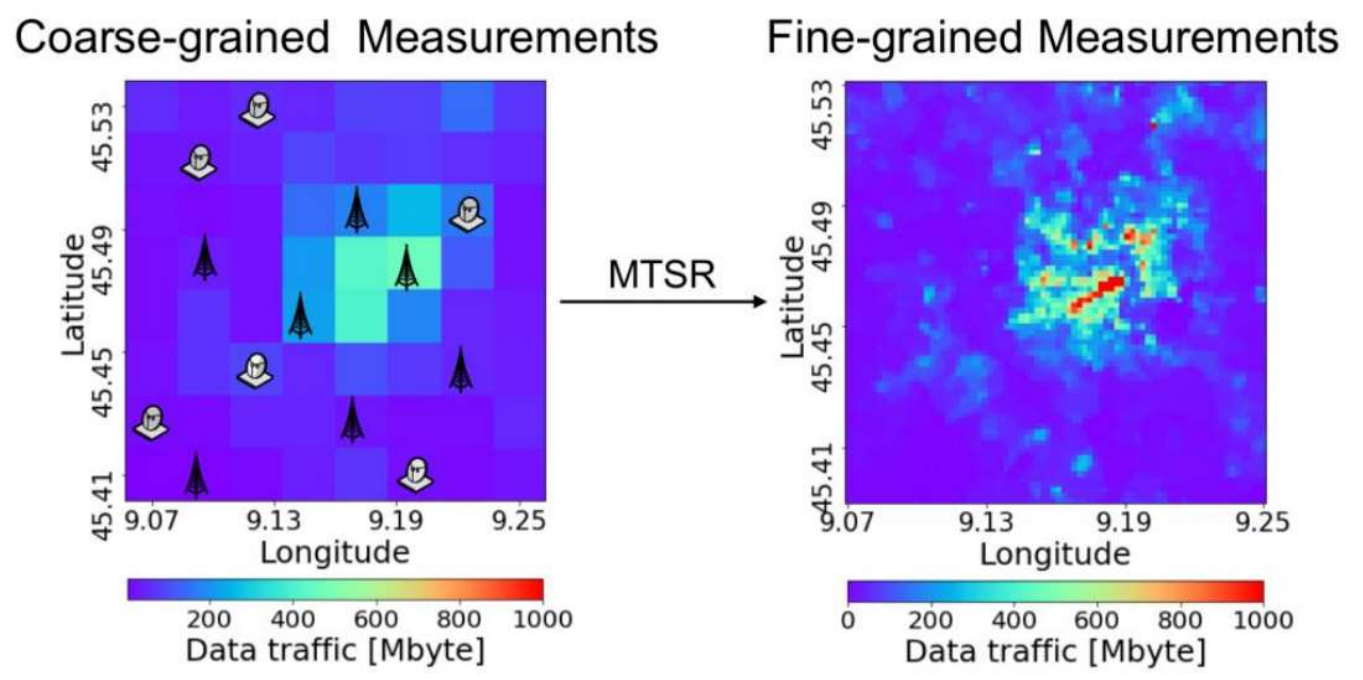
출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

JS Lab

III. Use case

❑ Forecasting network characteristics and events

- **Synthesising high resolution mobile traffic**
  - From coarse network measurements to high resolution synthetic mobile data traffic



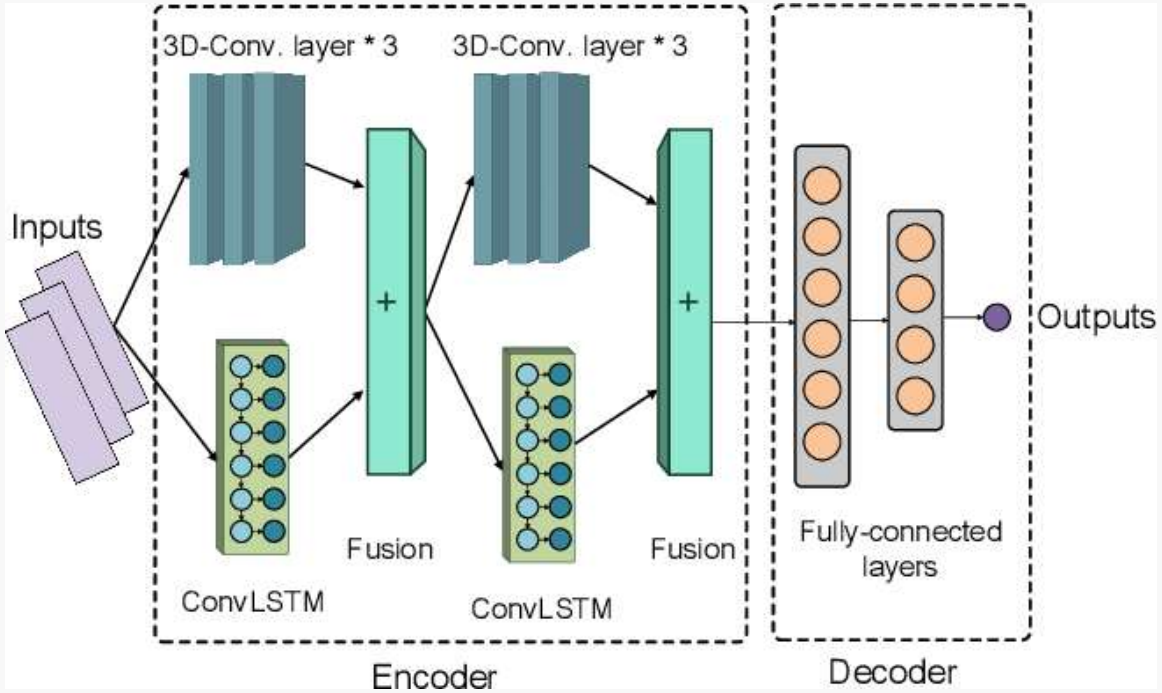
출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

JS Lab

III. Use case

❑ Forecasting network characteristics and events

- **Efficient mobile traffic forecasting**
  - Encoder/Decoder architecture used for mobile traffic forecasting

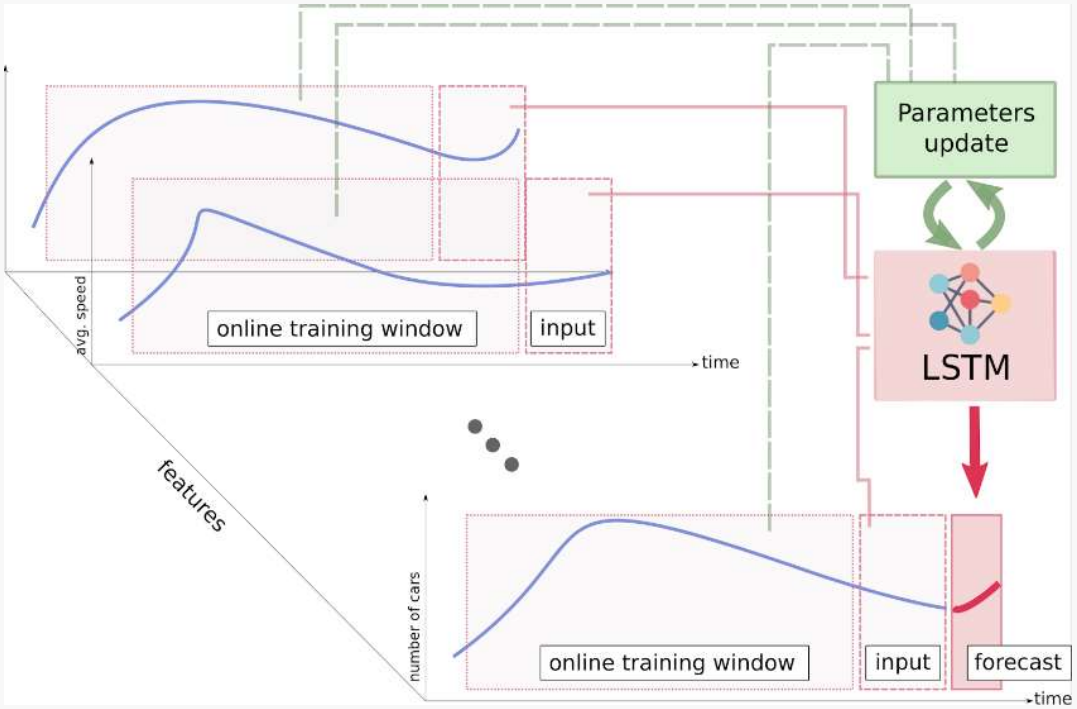


출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ Forecasting network characteristics and events

- **Improving QoS with forecasting techniques**
  - LSTM online training and forecasting of Neural Network structure

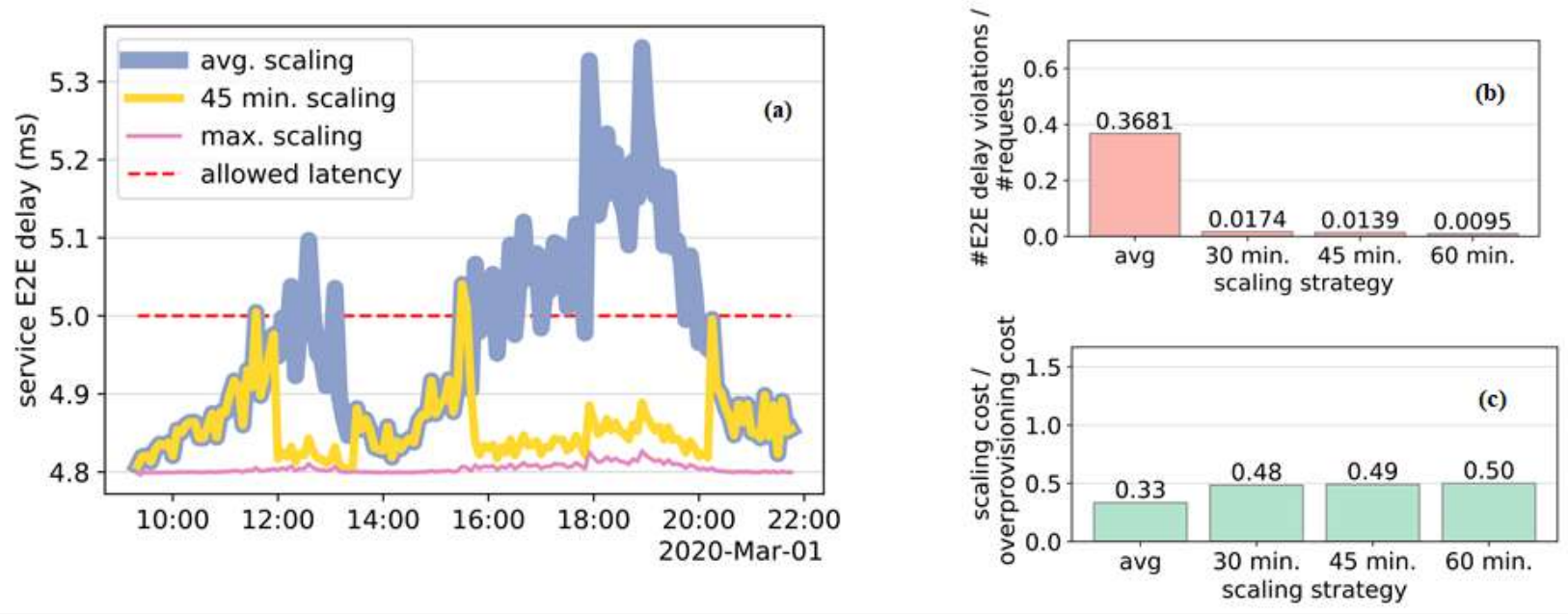


출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ Forecasting network characteristics and events

- **Improving QoS with forecasting techniques**



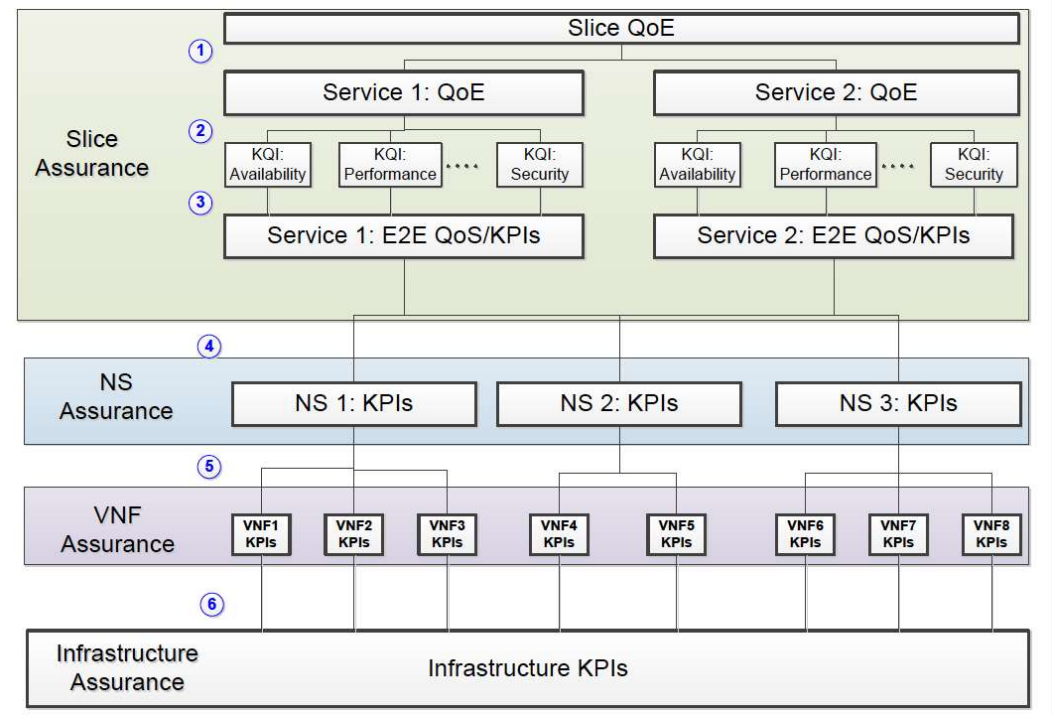
Remote driving scaling on (a) service E2E delay; (b) delay violations; (c) savings

출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ Forecasting network characteristics and events

- **Quality of experience inference**
  - Multi-layer QoS-QoE mapping in network slicing

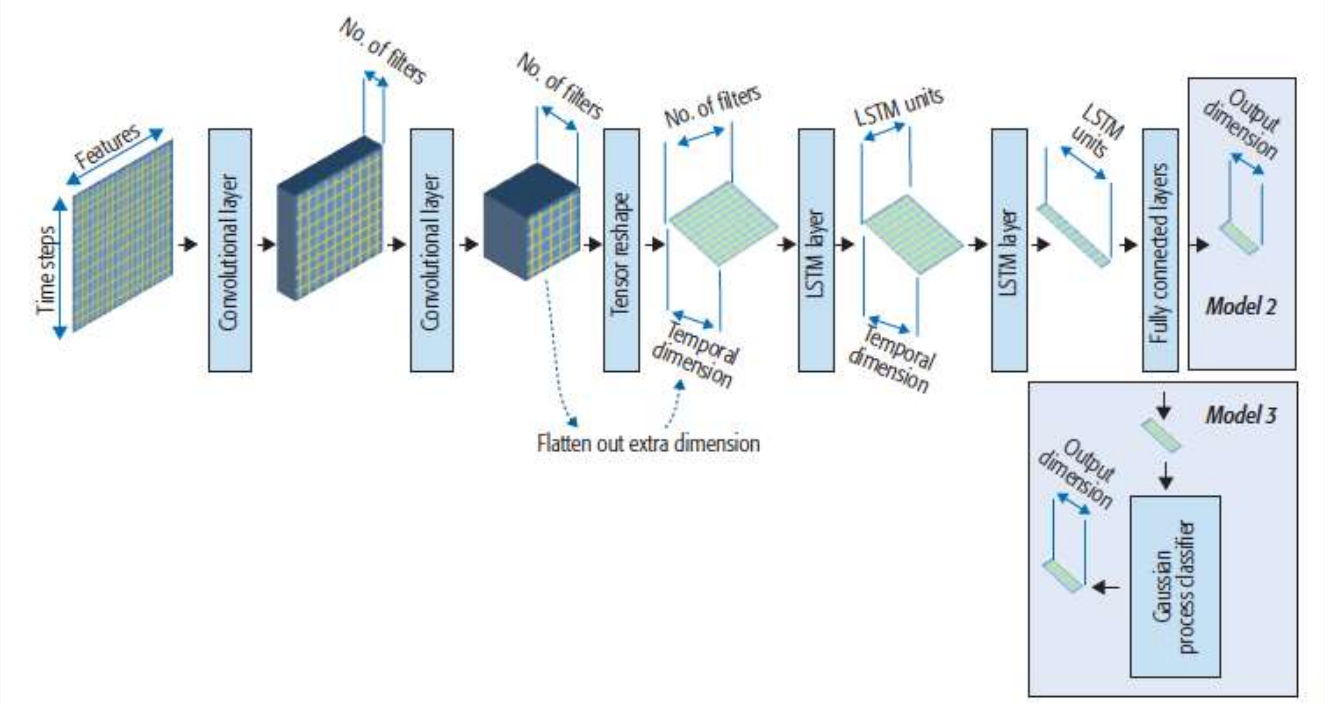


출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ Forecasting network characteristics and events

- **Quality of experience inference**
  - Architecture for the best DL network to predict QoE and classify anomalies in

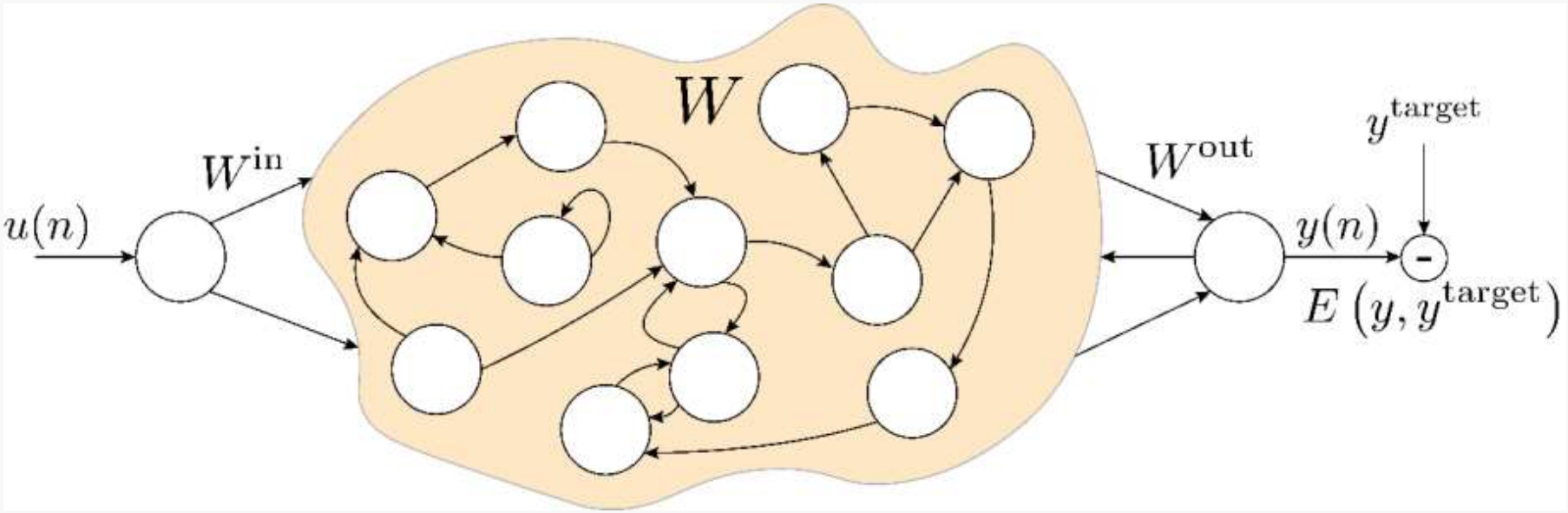


출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ Forecasting network characteristics and events

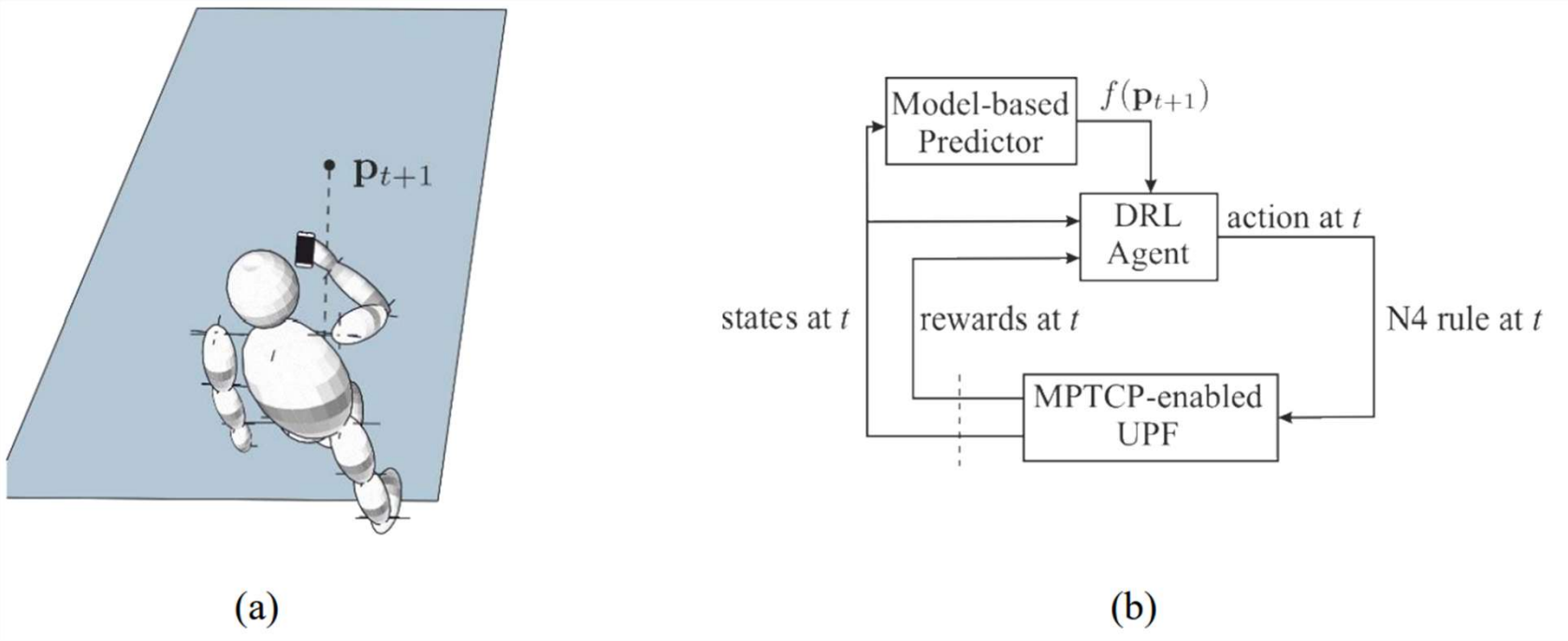
- **SLA prediction with echo state networks**
  - A high-level representation of an echo state networks (ESN) architecture



출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ Estimating user locations



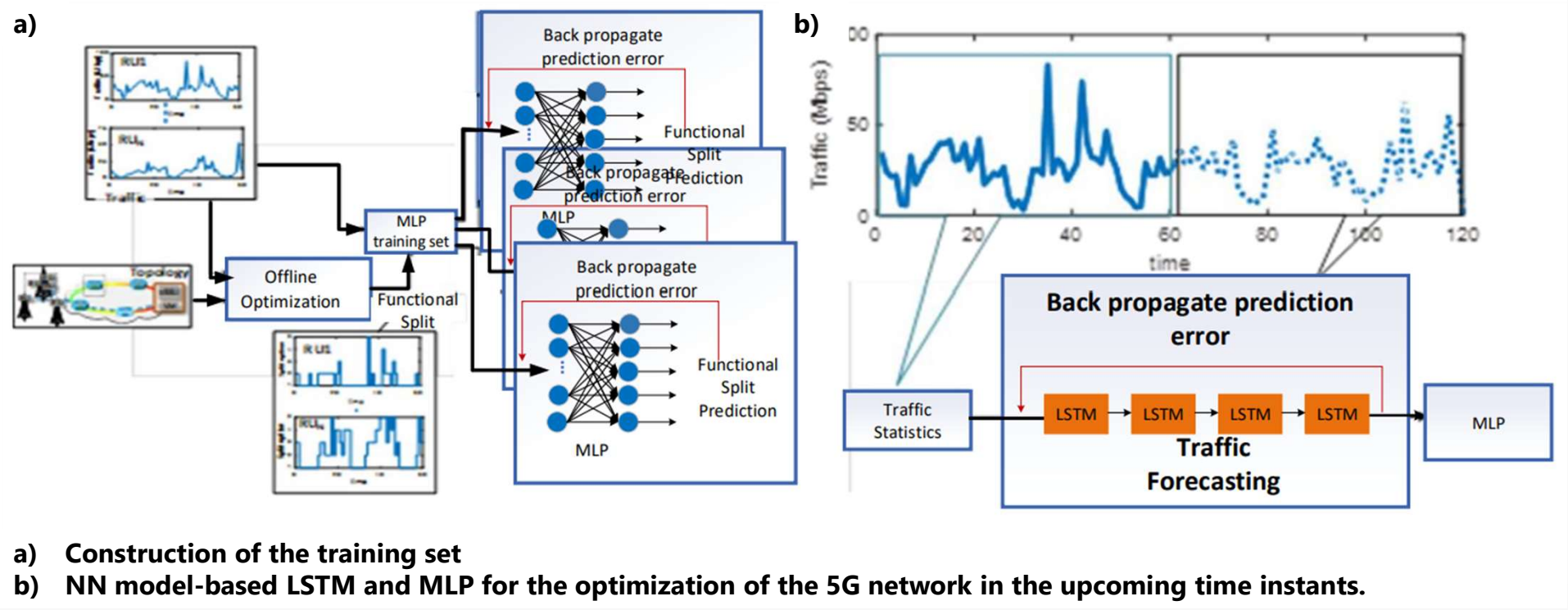
(a) An illustration of a new position vector, (b) a hybrid model-free and model-based DRL system

출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ Transport networks, fronthaul and backhaul

- **Determining optimal functional split according to fronthaul/backhaul capacity**



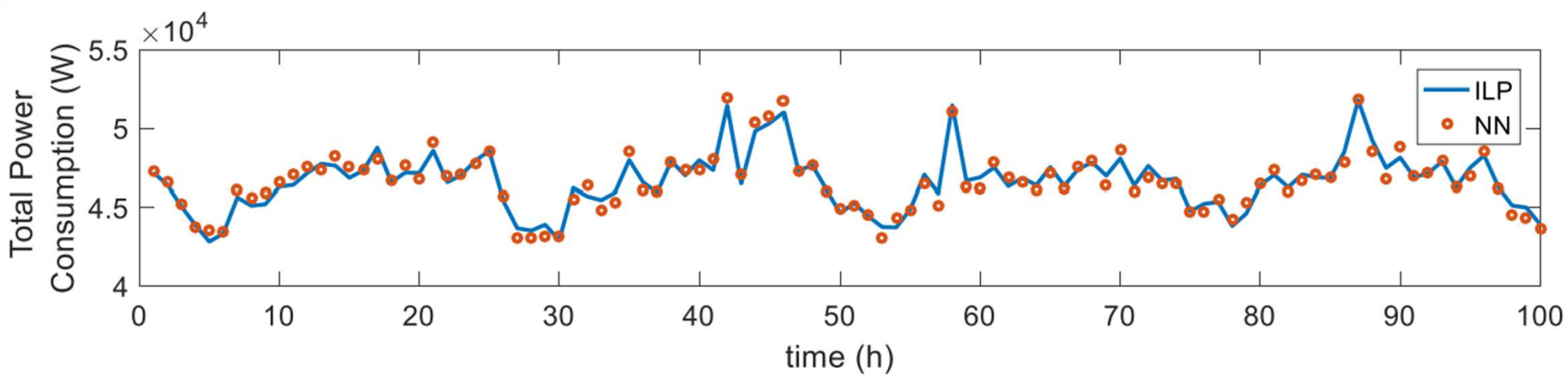
a) Construction of the training set
b) NN model-based LSTM and MLP for the optimization of the 5G network in the upcoming time instants.

출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ Transport networks, fronthaul and backhaul

- **Determining optimal functional split according to fronthaul/backhaul capacity**
  - Total Power consumption when applying the ILP and the proposed NN scheme

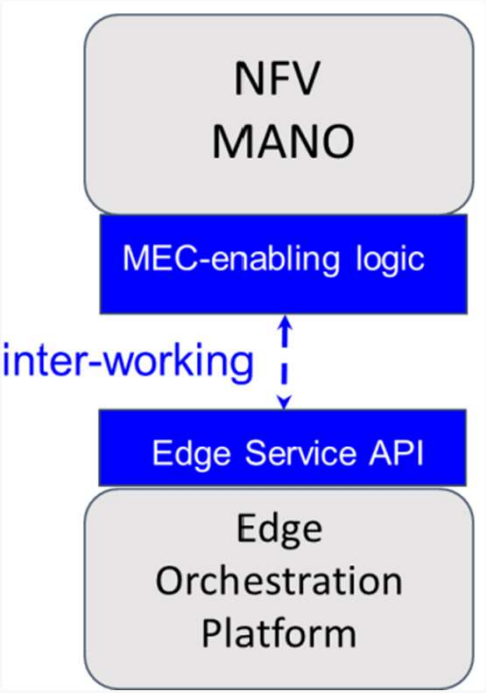


출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ NFV infrastructures

- **Federated learning across MEC and NFV orchestrators**
  - Automated interaction between Edge and NFV MANO through FL models

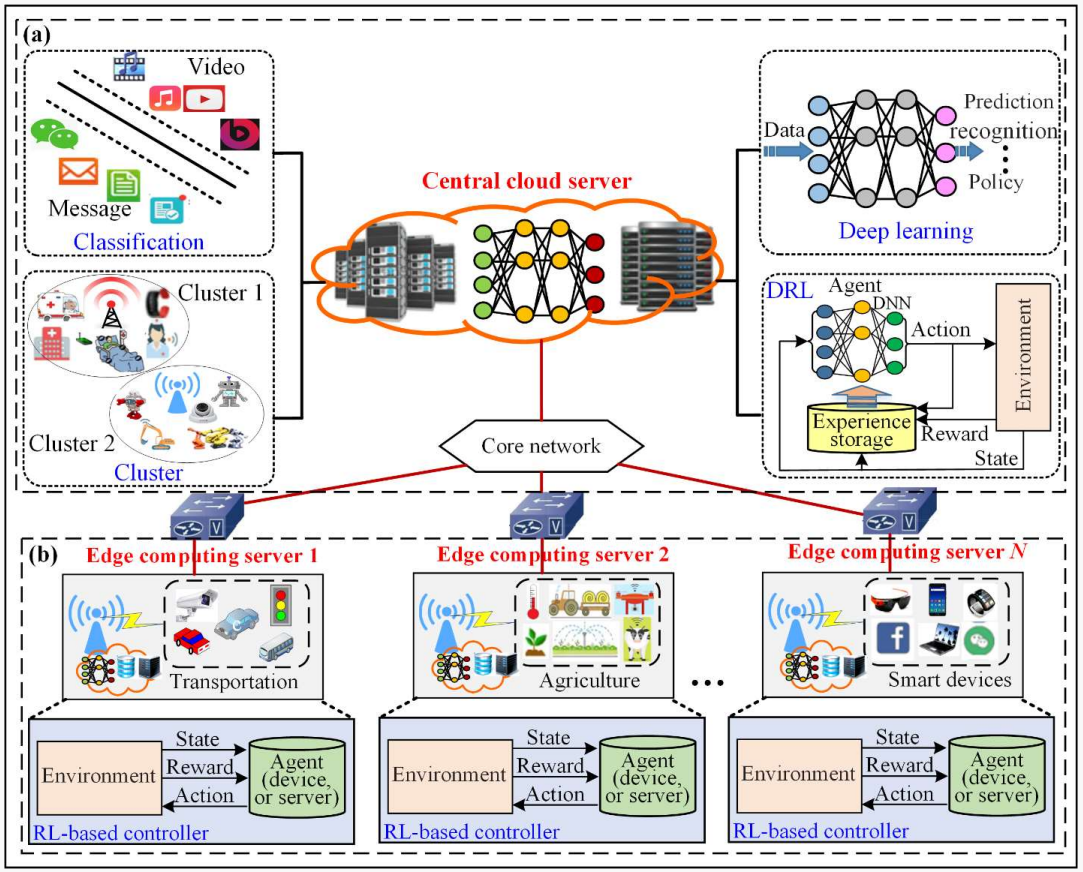


출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ NFV infrastructures

- **AI-Empowered Mobile Edge Computing (MEC)**
  - The framework of AI-empowered MEC

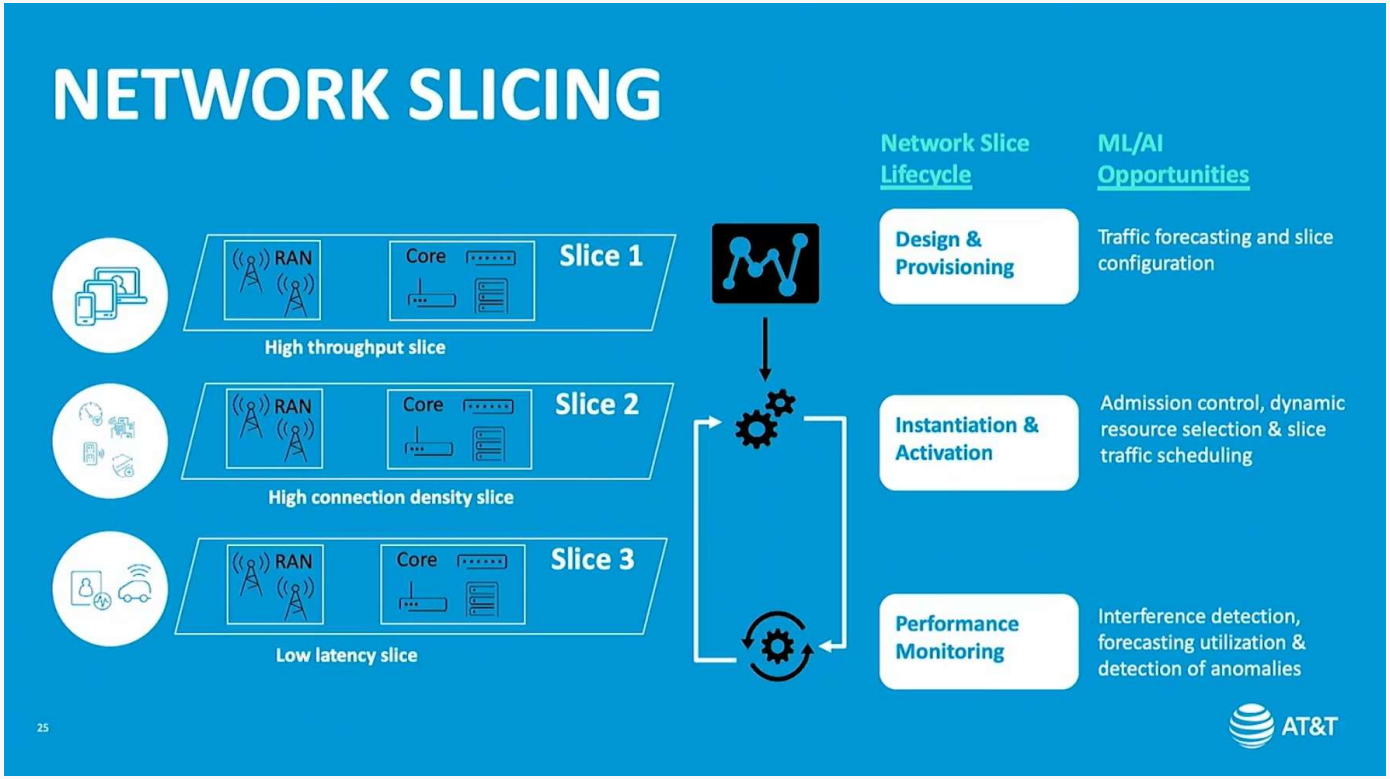


출처: 'Artificial Intelligence-Enabled Intelligent 6G Networks', https://doi.org/10.1109/MNET.011.2000195 , IEEE Network, Volume: 34, Issue: 6, Nov./Dec. 2020

III. Use case

❑ End-to-end slicing

- ML/AI Opportunities (트래픽 예상/구성, 자원 선택/스케듈링, 변화 감지)

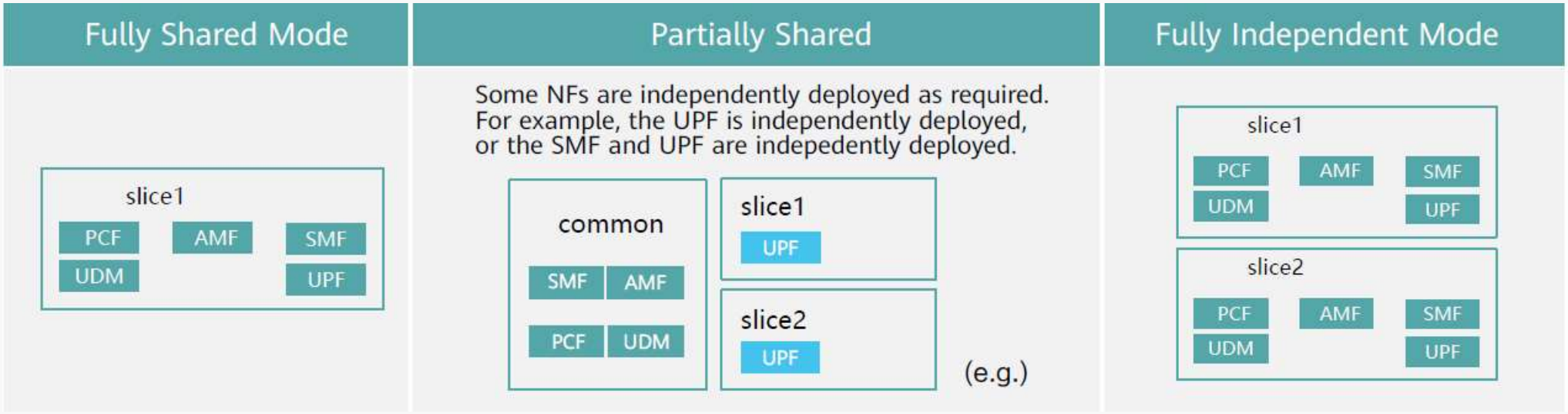


JS Lab

III. Use case

❑ End-to-end slicing

- **AI assisted slice isolation**
  - Resource isolation mechanisms for a network slice

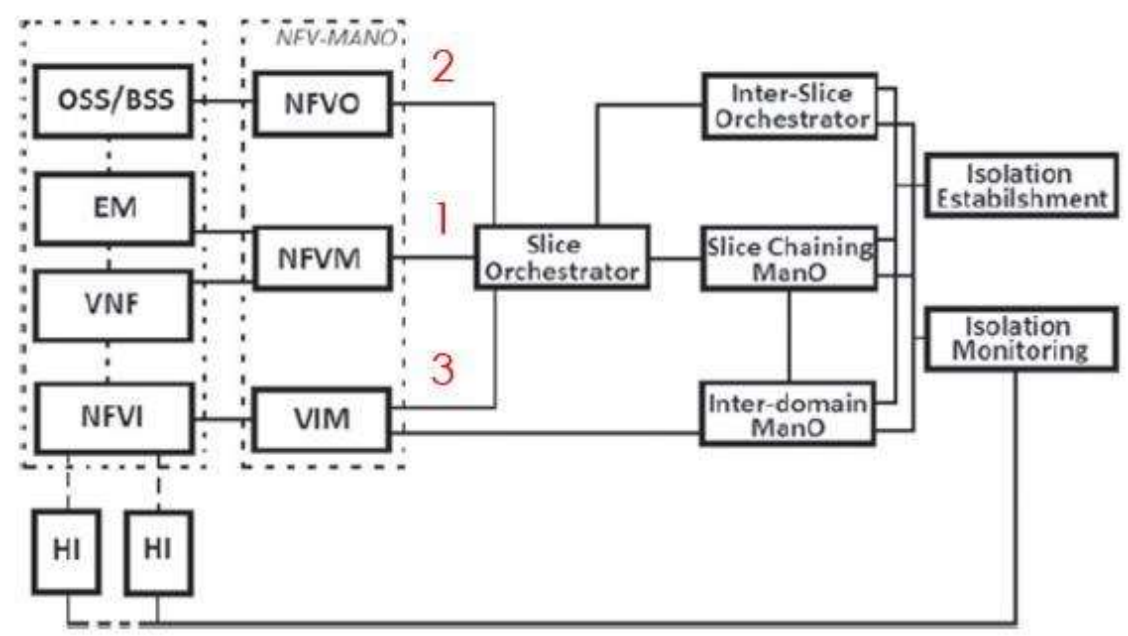


출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ End-to-end slicing

- **AI assisted slice isolation**
  - Slice Orchestrator interfaces for resource isolation

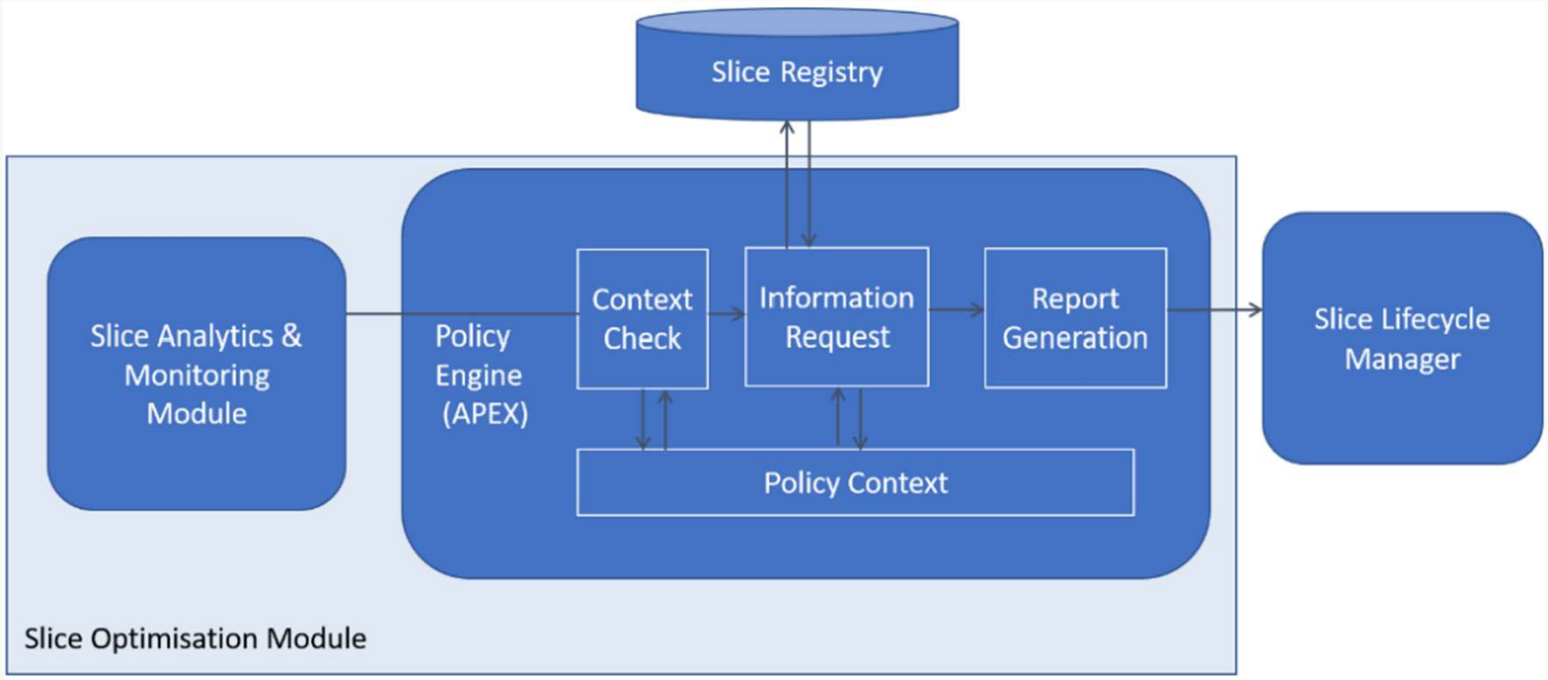


출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ End-to-end slicing

- **AI/ML-based decision making for slice optimization**
  - Example of using ML with a policy engine for slice optimization

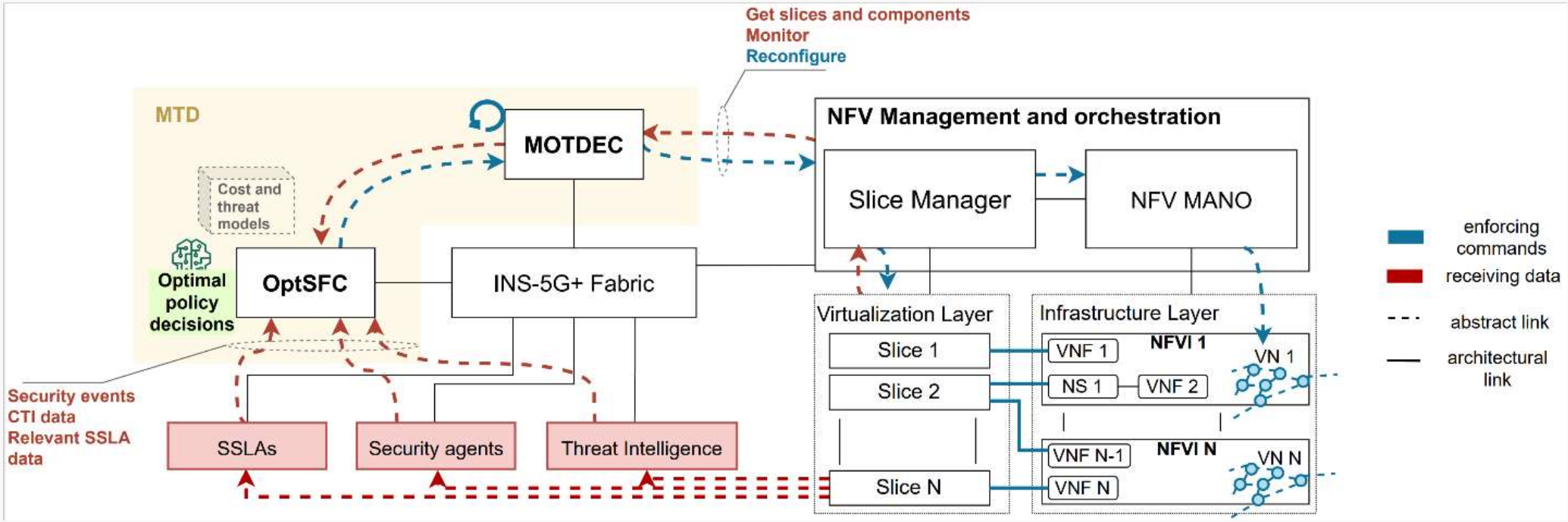


출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ Security

- **MTD for network slice protection**

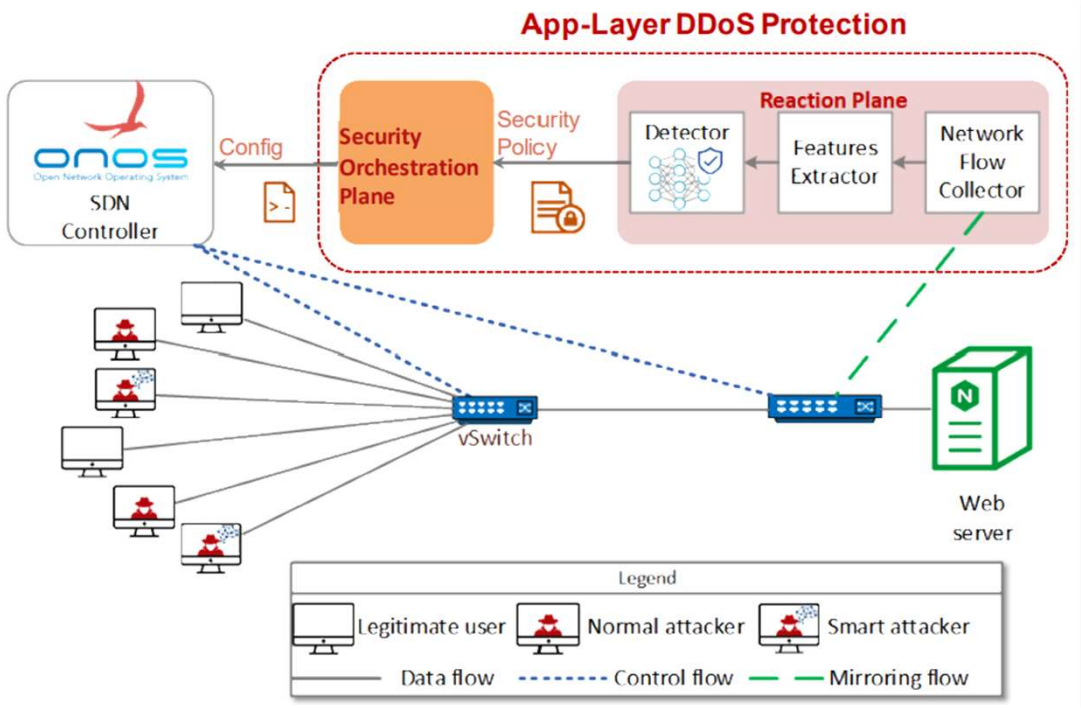


출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ Security

- **Robust self-protection against app-layer DDoS attacks**
  - The Robust App-Layer DDOS Self-Protection Framework's High- Level Architecture

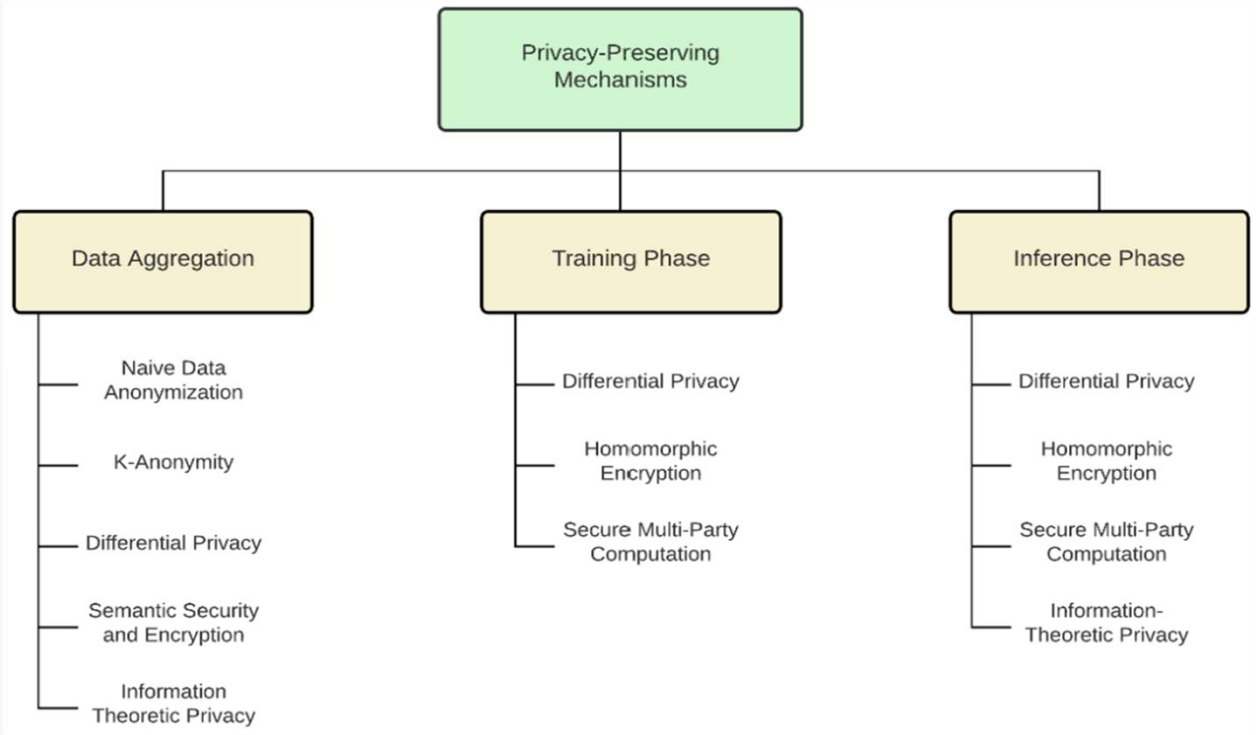


출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ Security

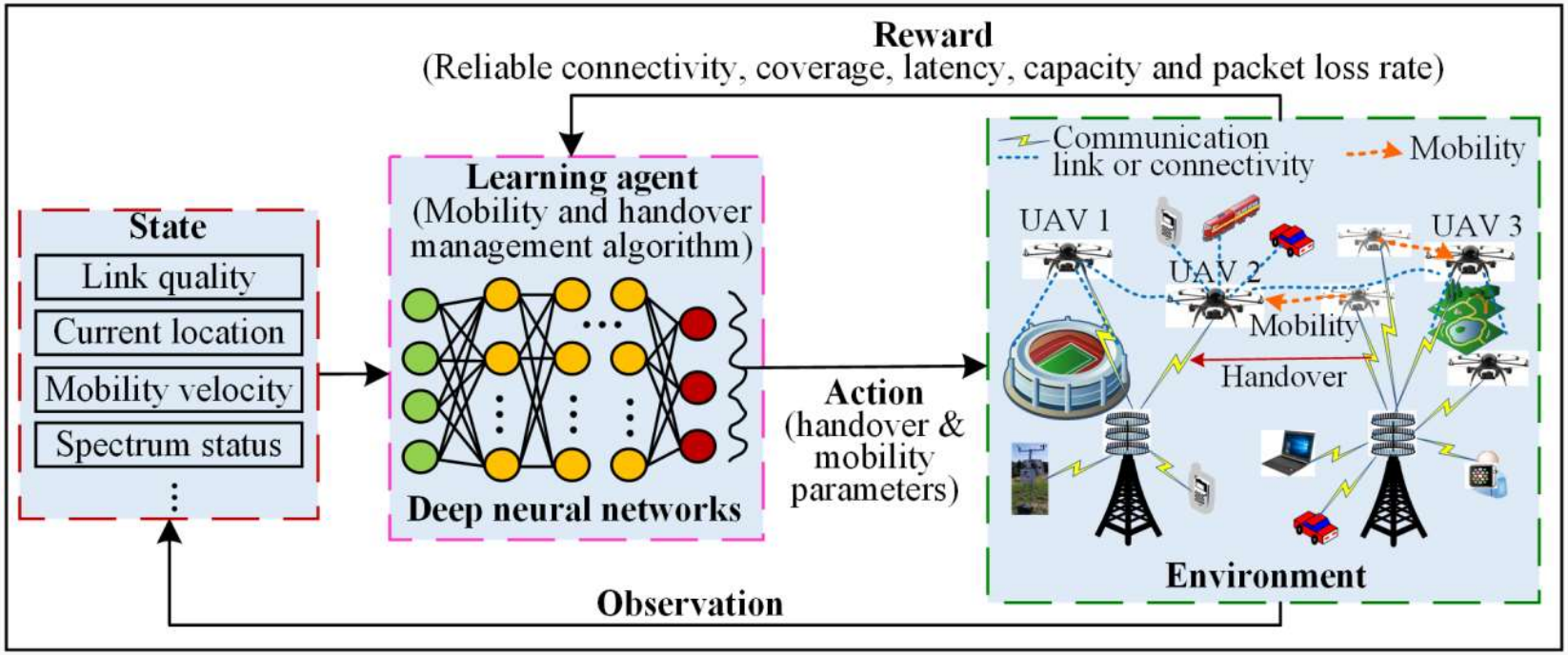
- **Categorization of privacy-preserving schemes for ML and DL**



출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ Intelligent Mobility and Handover Management



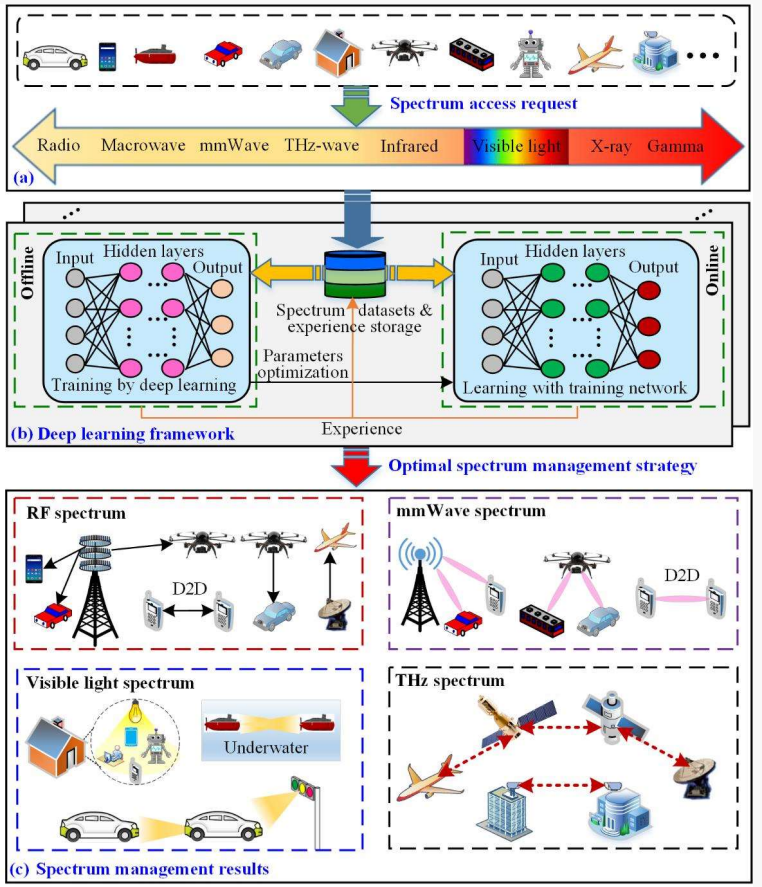
DRL in the context of mobility and handover management. Note: mobility and handover parameters include BS association, spectrum access, and trajectory

출처: 'Artificial Intelligence-Enabled Intelligent 6G Networks', https://doi.org/10.1109/MNET.011.2000195 , IEEE Network, Volume: 34, Issue: 6, Nov./Dec. 2020

III. Use case

❑ Intelligent Spectrum Management

- **Deep learning-based flexible spectrum management framework.**



Deep learning-based flexible spectrum management framework.

출처: 'Artificial Intelligence-Enabled Intelligent 6G Networks', https://doi.org/10.1109/MNET.011.2000195 , IEEE Network, Volume: 34, Issue: 6, Nov./Dec. 2020

III. Use case

❑ AI assisted sensor fusion

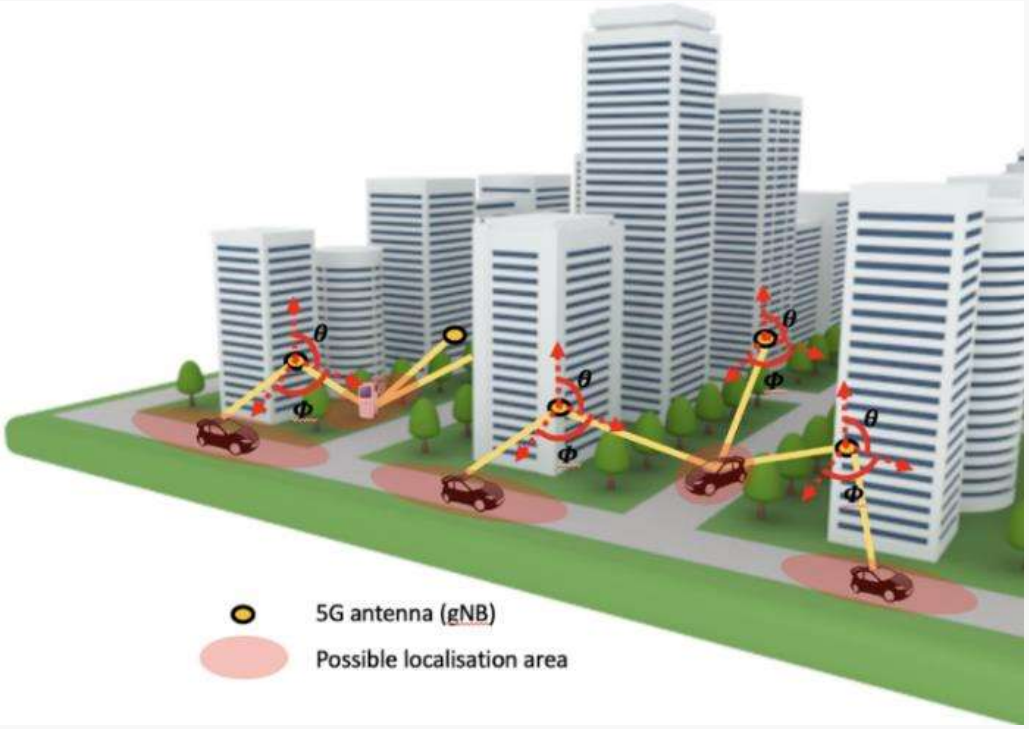
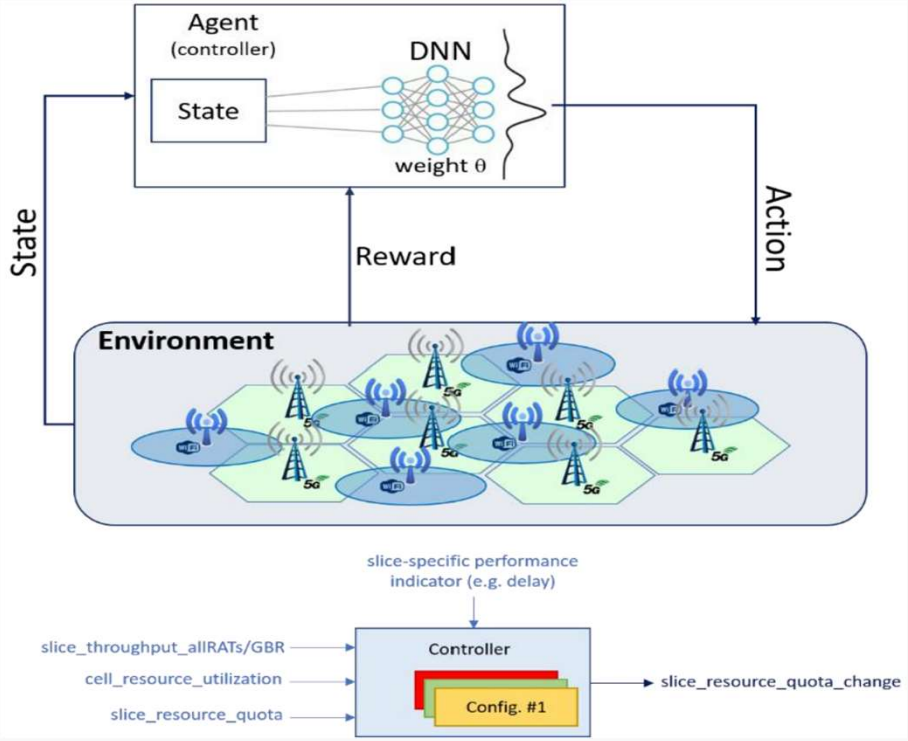


illustration of range reduction of the localization combining RAT-based positioning, map and UE's motion information

출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ Radio resource provisioning in a multi-technology RAN

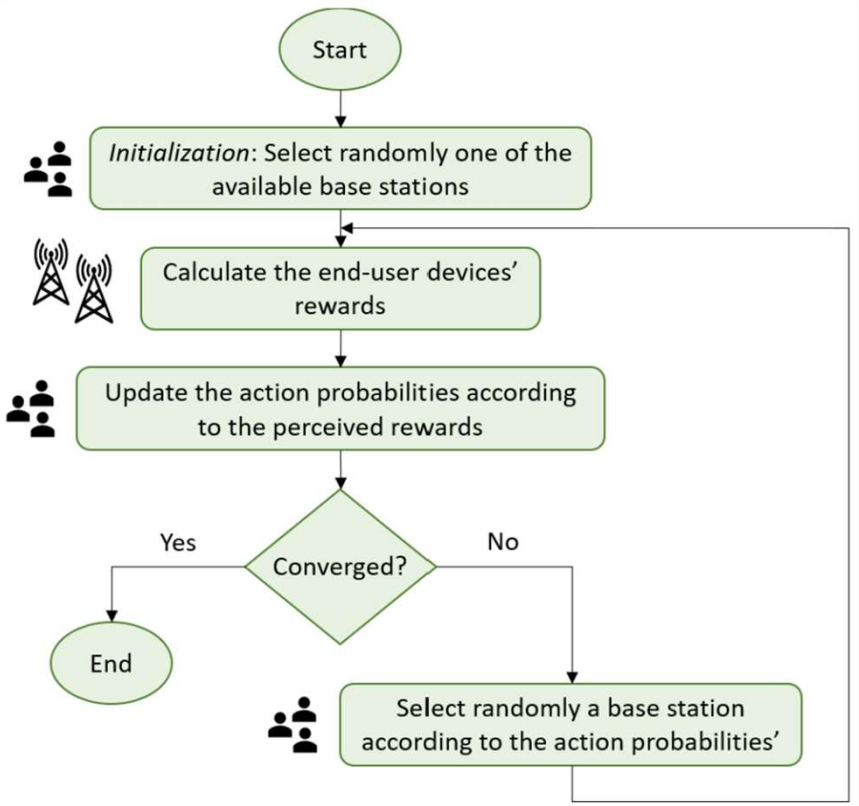


Radio resource provisioning using Reinforcement Learning

출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ RL-empowered user association

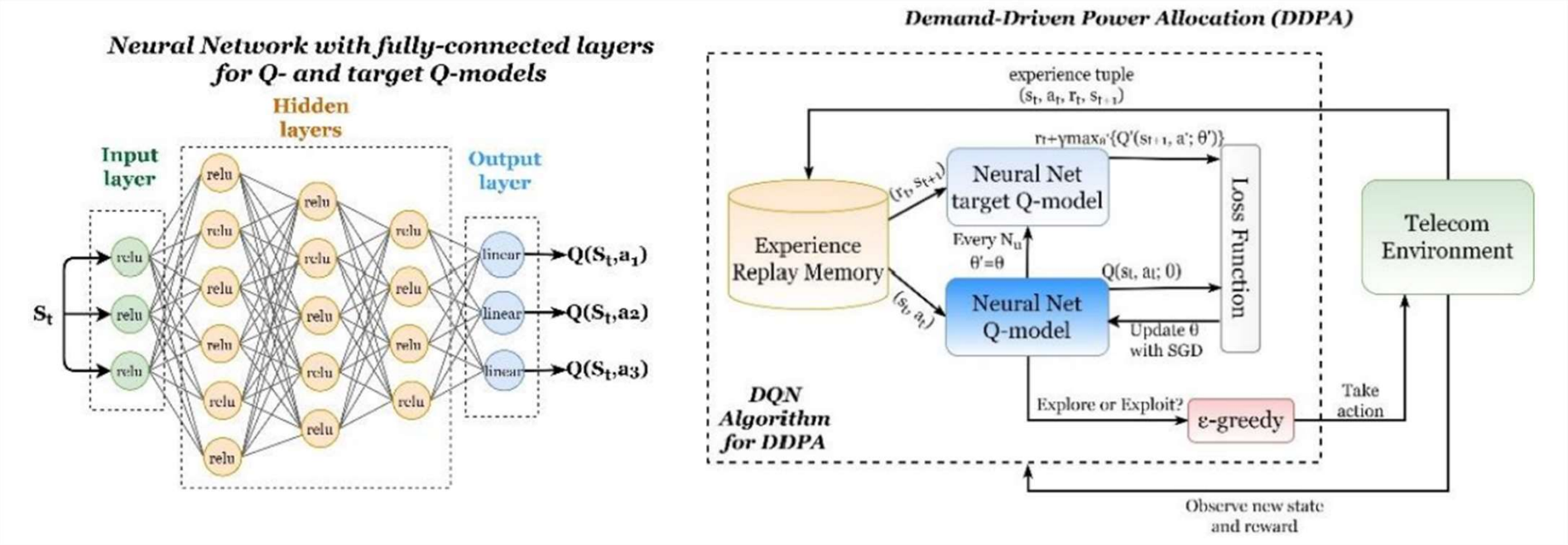


Stochastic learning automata algorithm for distributed end-user device-to-base station scheduling.

출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ Demand-driven power allocation in 5G-enabled wireless networks

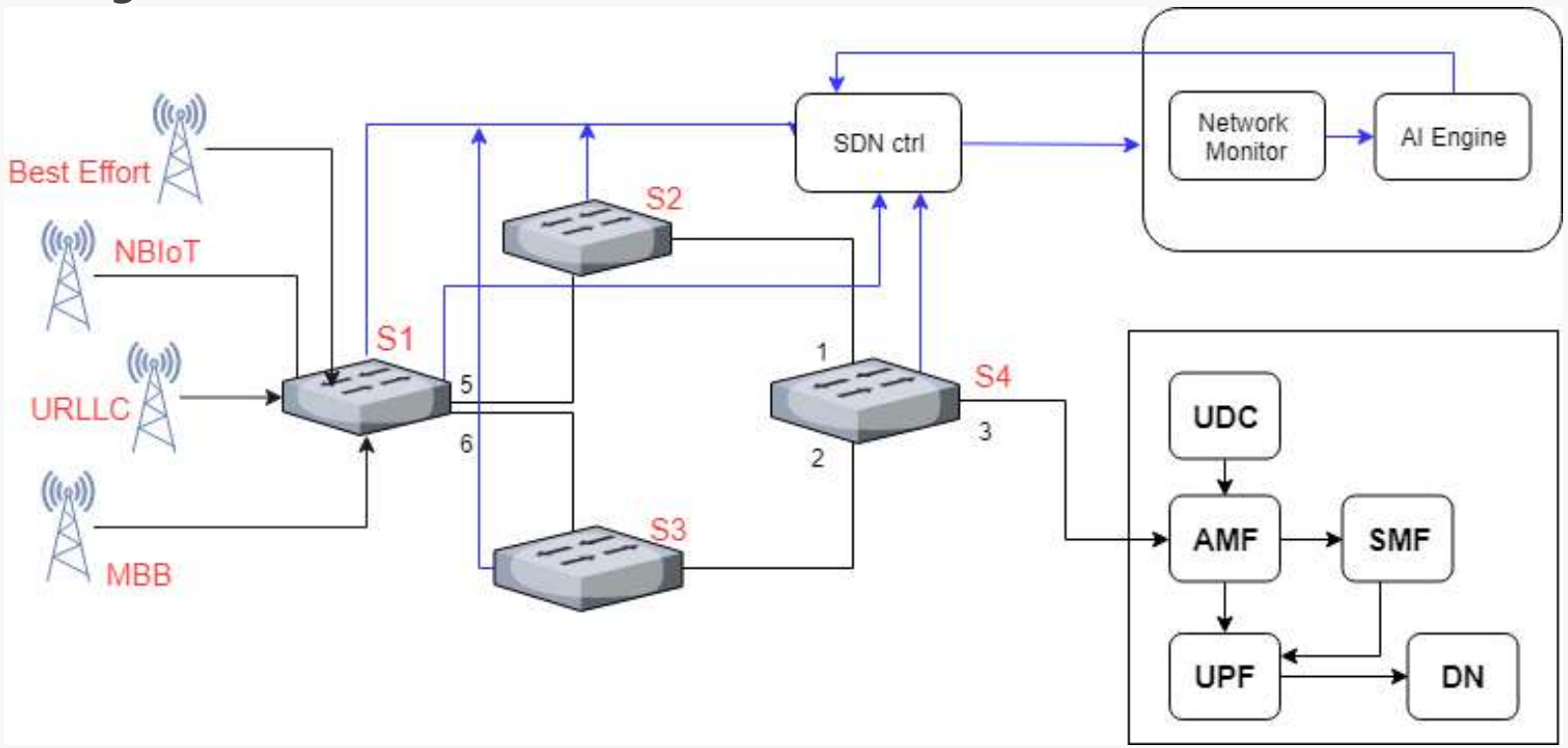


Neural network employed for training (left) and process of the DQL algorithm for DDPA (right).

출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ Dynamic load balancing

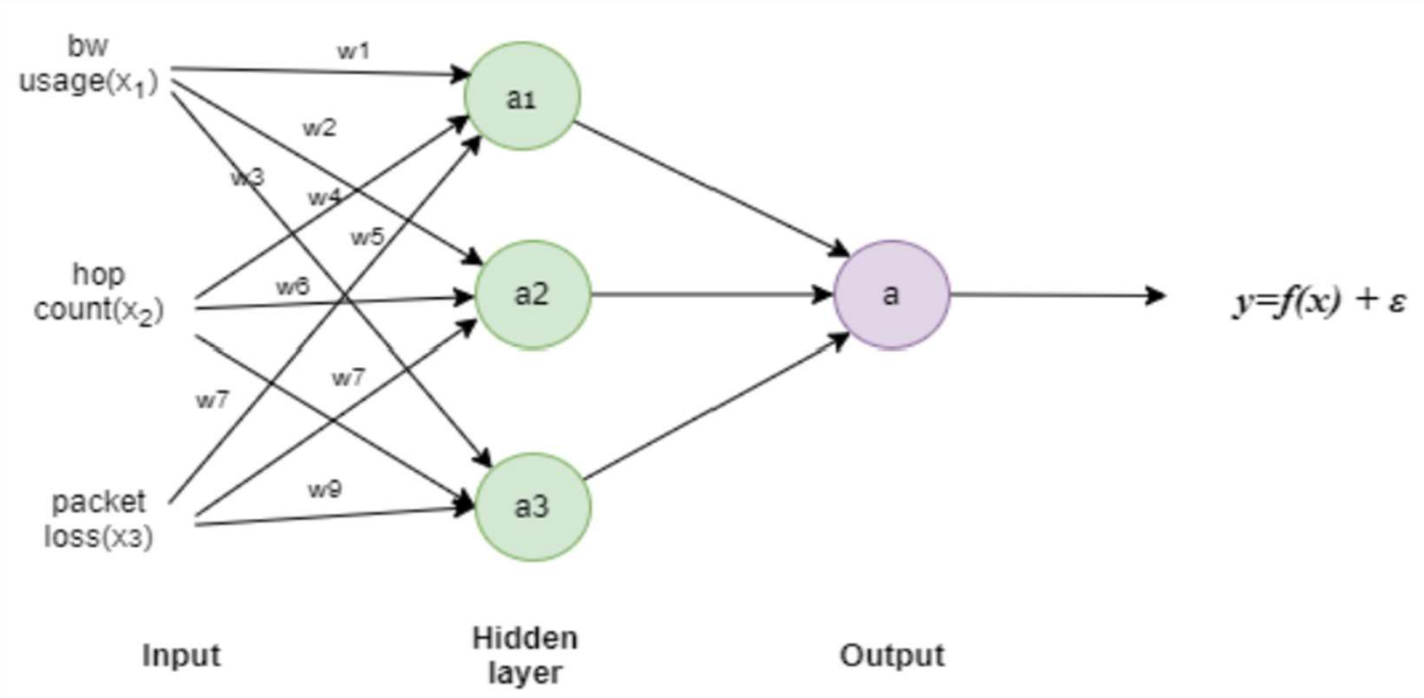


Mobile backhaul orchestration modules

출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ Dynamic load balancing

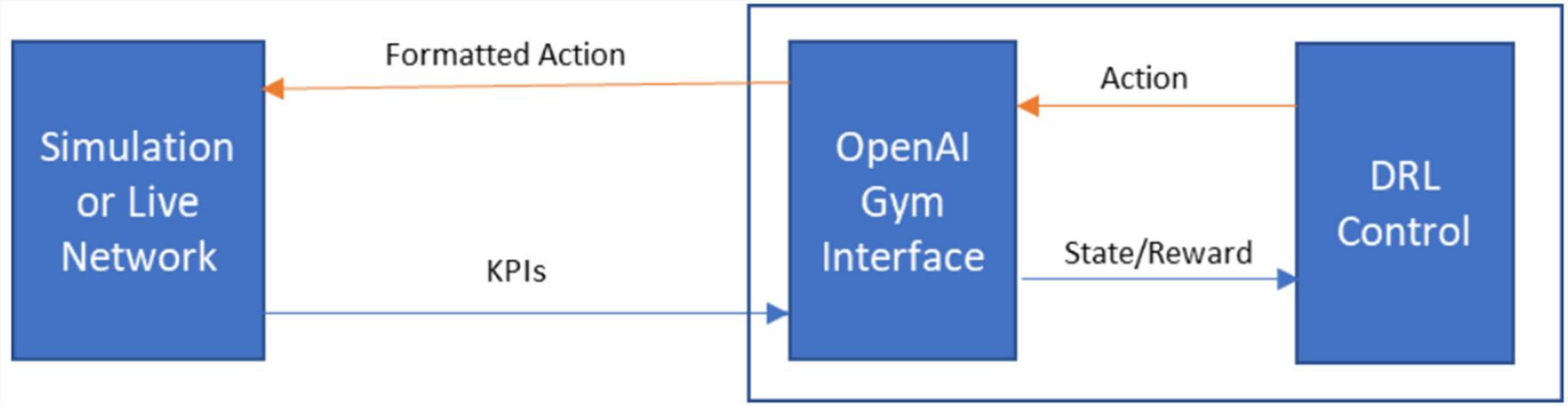


Single hidden layer NN

출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ **Continuous multi-objective reinforcement learning for joint slice admission control and resource allocation**

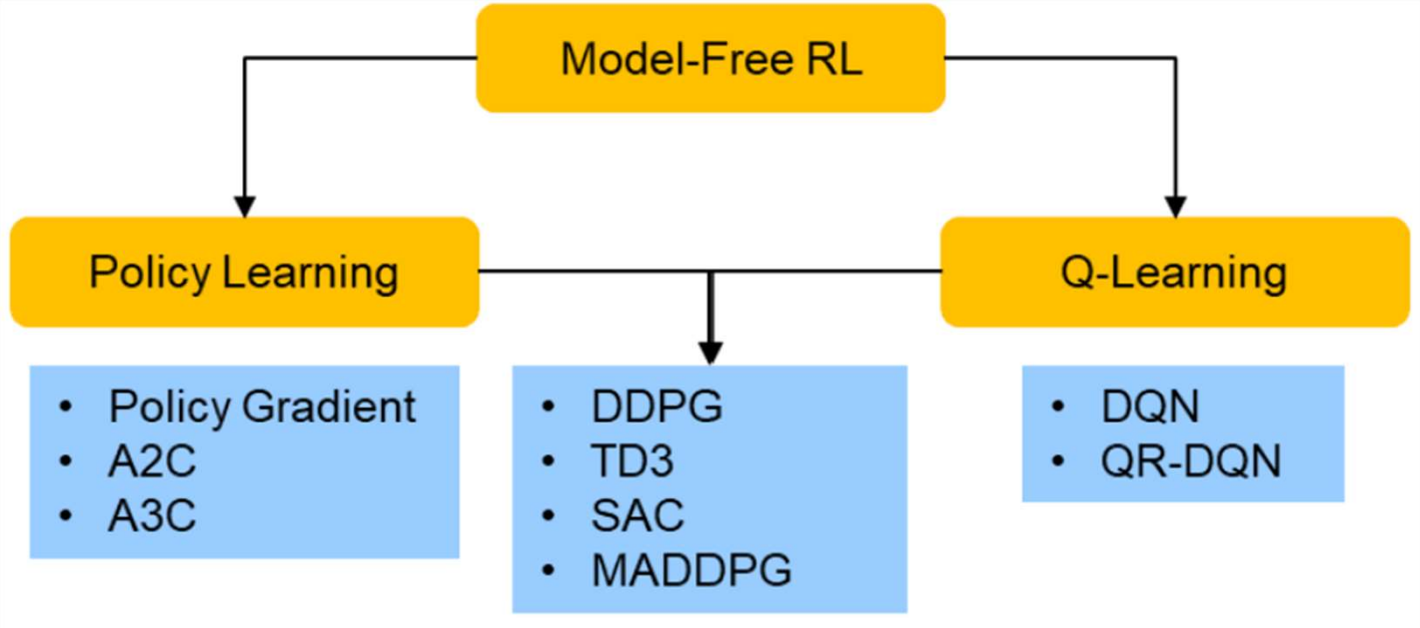


Slice-level admission control and resource allocation loop per domain

출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ **Continuous multi-objective reinforcement learning for joint slice admission control and resource allocation**

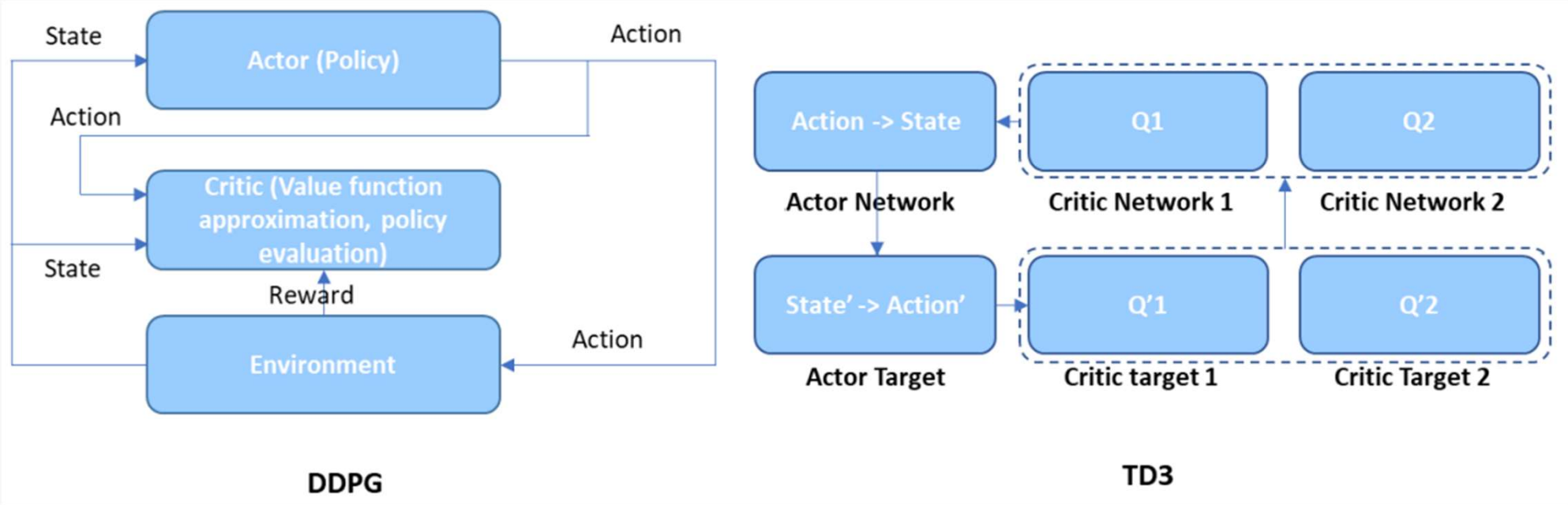


Model-free reinforcement learning

출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ **Continuous multi-objective reinforcement learning for joint slice admission control and resource allocation**

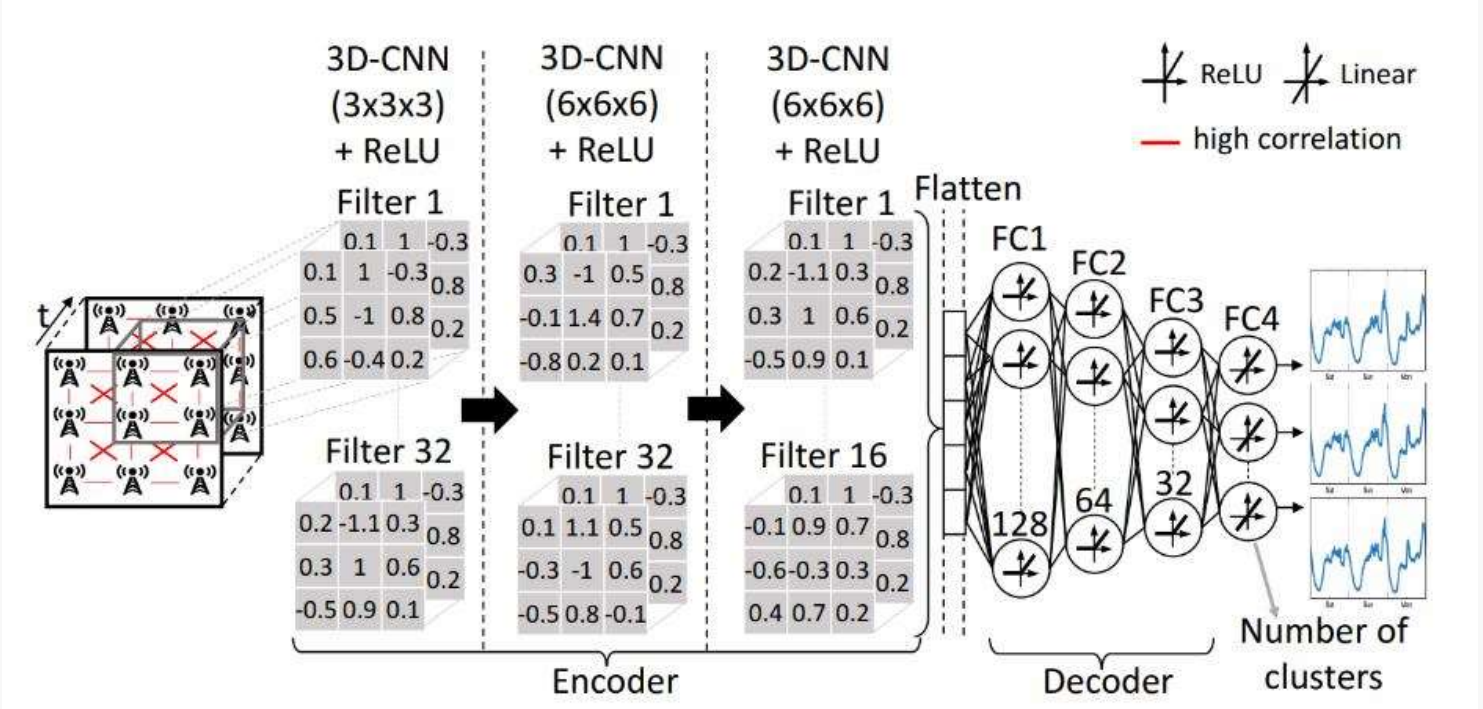


DPPG and TD3 diagrams

출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ Joint slice based demand prediction and resource allocation

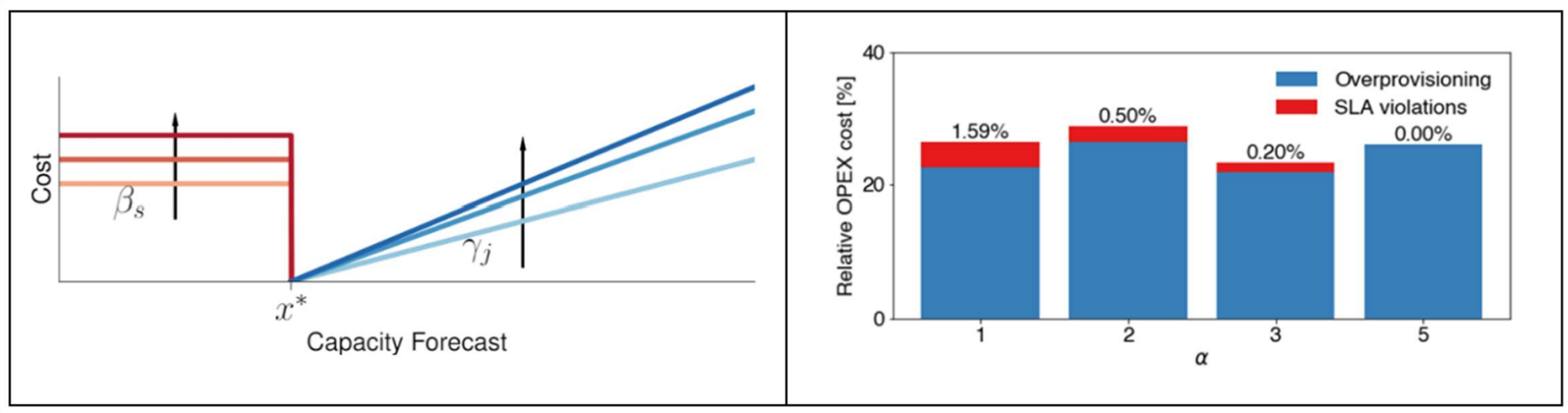


The DeepCog Neural Network Structure

출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

❑ Joint slice based demand prediction and resource allocation

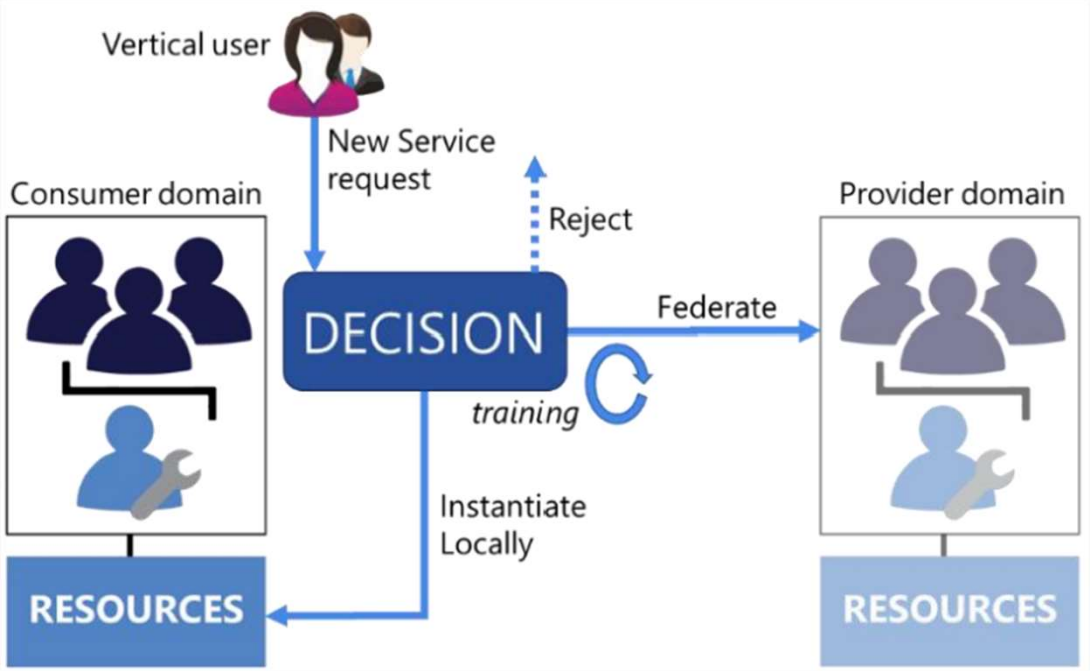


DeepCog cost function (left) and Overall result assessment (right)

출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

III. Use case

- ❑ Network diagnostics and insights
- ❑ Q-Learning application to federated scenarios



A Q-learning decision scenario to maximize operator's revenue

출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

IV. 오픈소스 프로젝트

- ❑ 리눅스 재단
- ❑ LF AI Foundation
- ❑ ACUMOS
- ❑ ONAP
- ❑ RAN
- ❑ AI 서비스 인프라 포털 서비스

IV. 오픈소스 프로젝트

❑ 리눅스 재단 (Linux Foundation)

❑ 통신사와 통신관련 제조사들은 다양한 오픈소스 프로젝트에서 활동

- LF AI Foundation (인공지능)
- LF Edge Foundation (에지)
- LF Networking Fund (오픈소스 네트워킹)
- Hyperledger (블록체인)

LF AI

LF EDGE

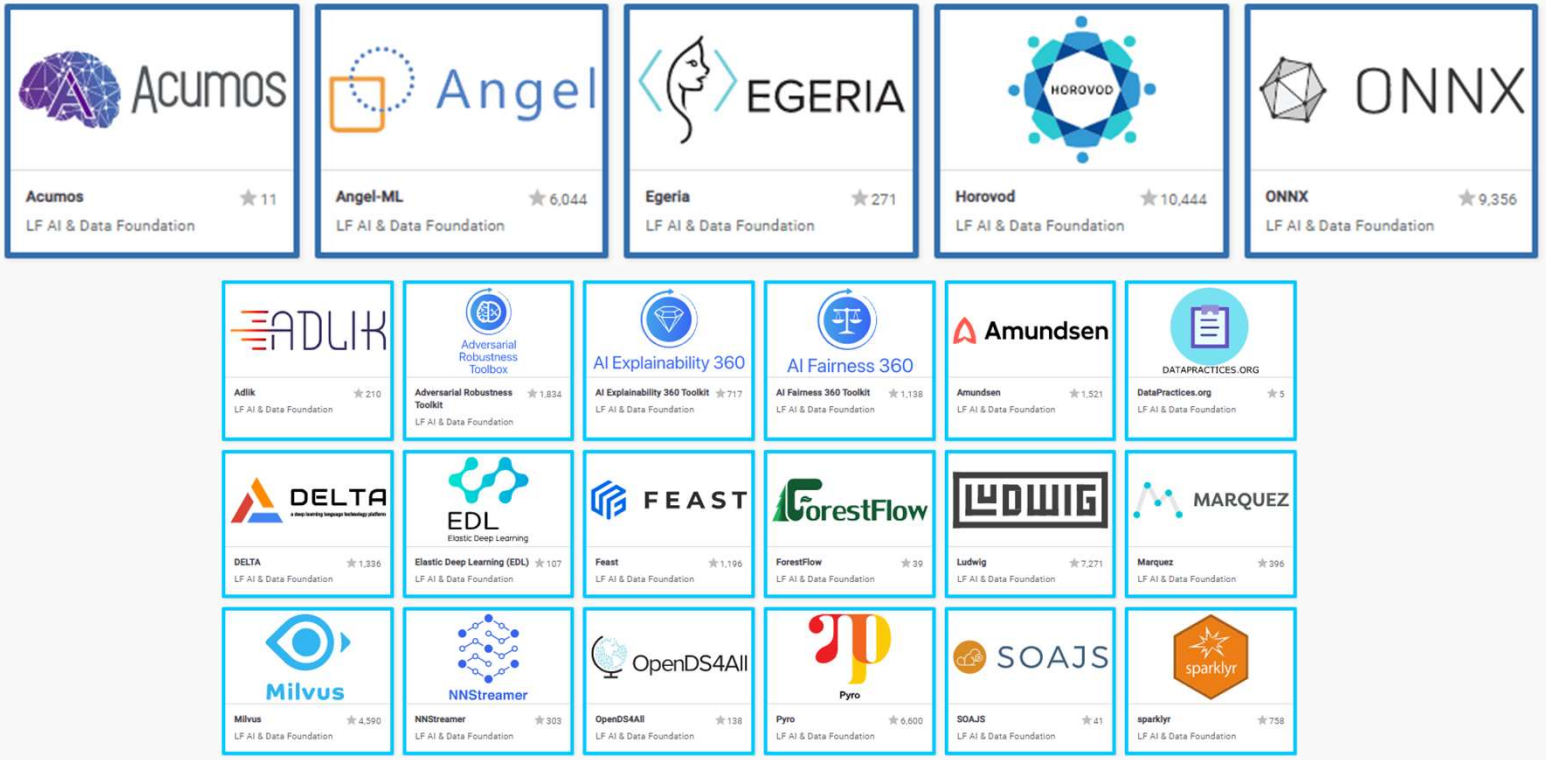
LF NETWORKING

HYPERLEDGER
BLOCKCHAIN TECHNOLOGIES FOR BUSINESS

IV. 오픈소스 프로젝트

❑ LF AI Foundation (인공지능)

- 실시간 데이터 처리
- 분산 환경

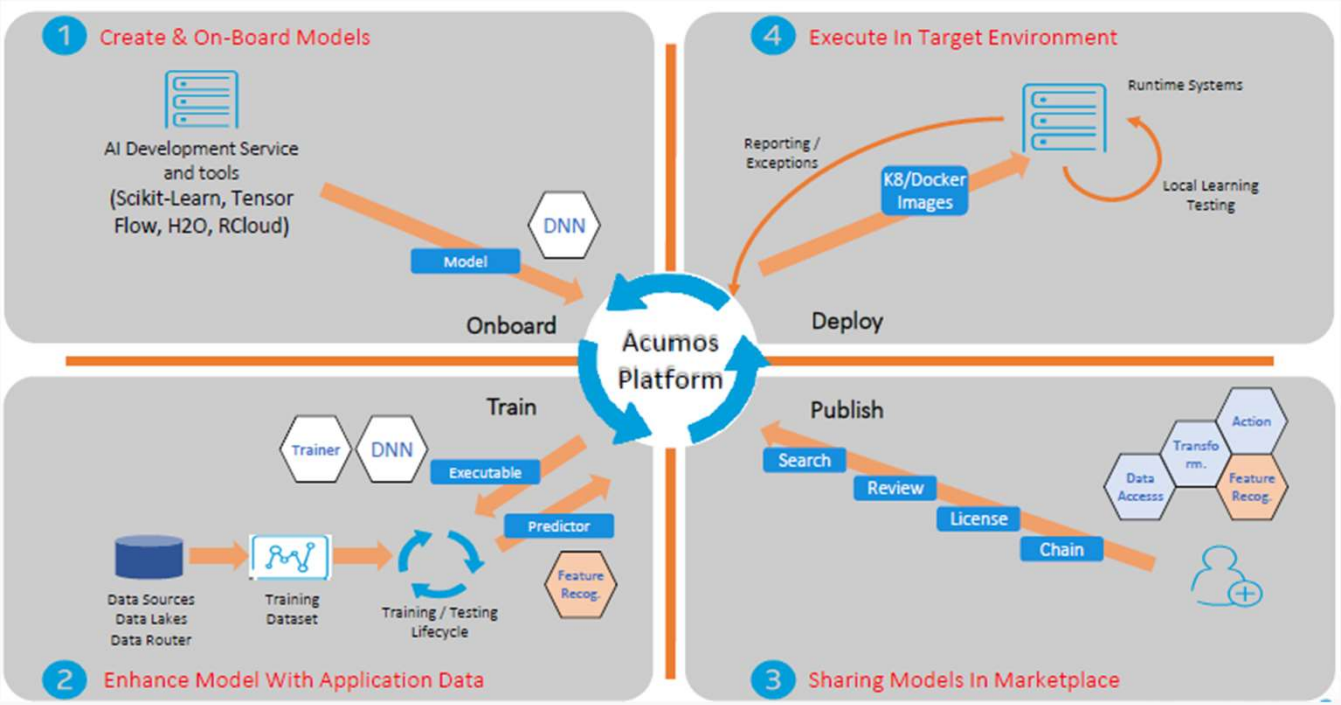


출처: https://landscape.lfai.foundation/

IV. 오픈소스 프로젝트

❑ ACUMOS

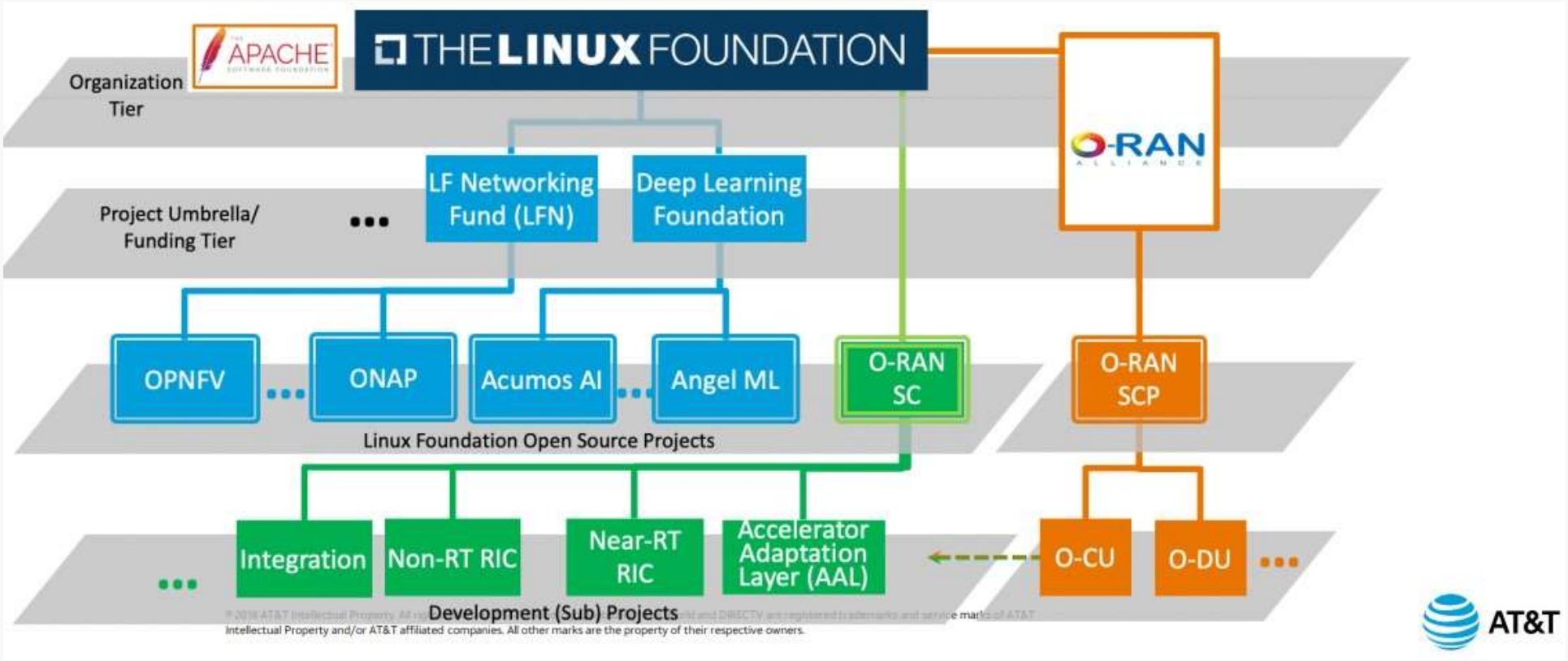
- An Open Source AI Machine Learning Platform
- By AT&T and The Linux Foundation



출처: https://www.acumos.org/wp-content/uploads/sites/61/2018/03/acumos_open_source_ai_platform_032518.pdf

IV. 오픈소스 프로젝트

❑ Acumos and Angel @ RAN

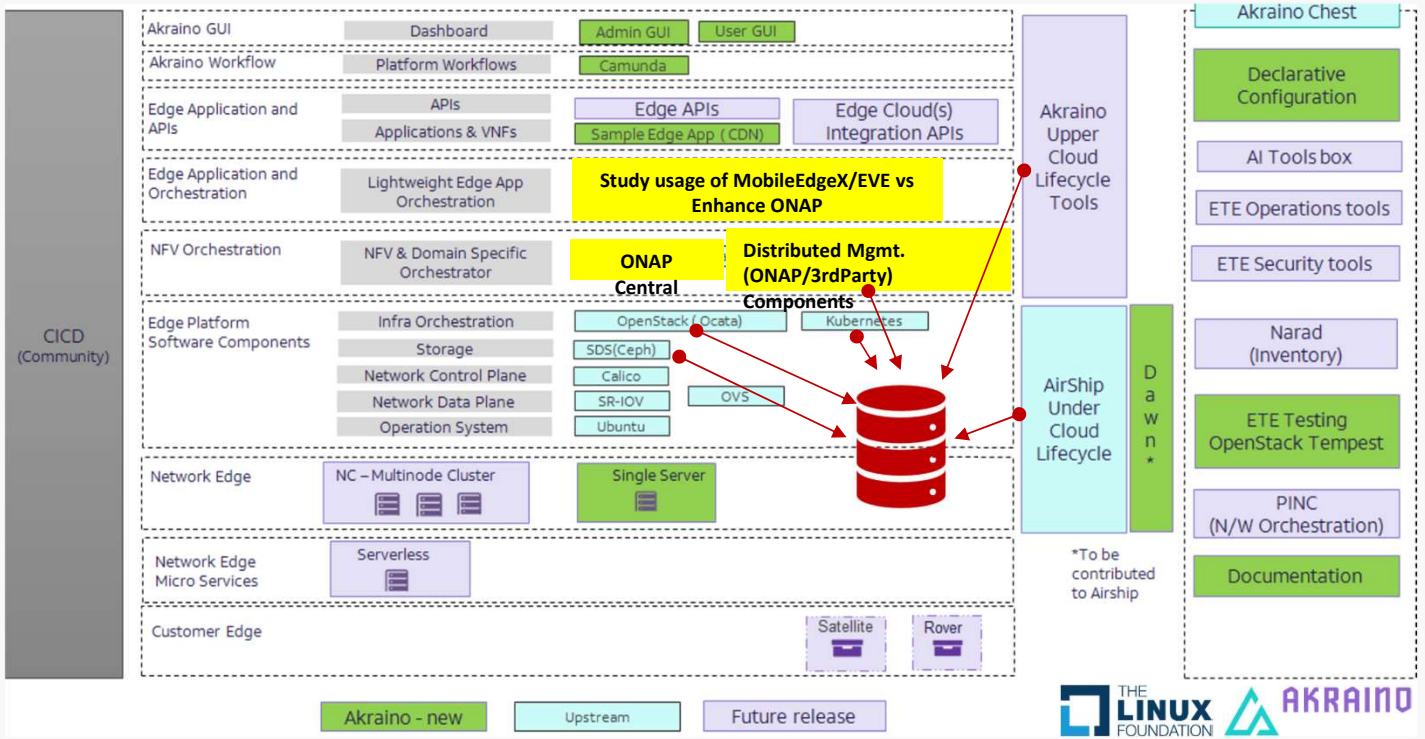


JS Lab

IV. 오픈소스 프로젝트

❑ 리눅스 재단의 에지 아키텍처 프로젝트 제안

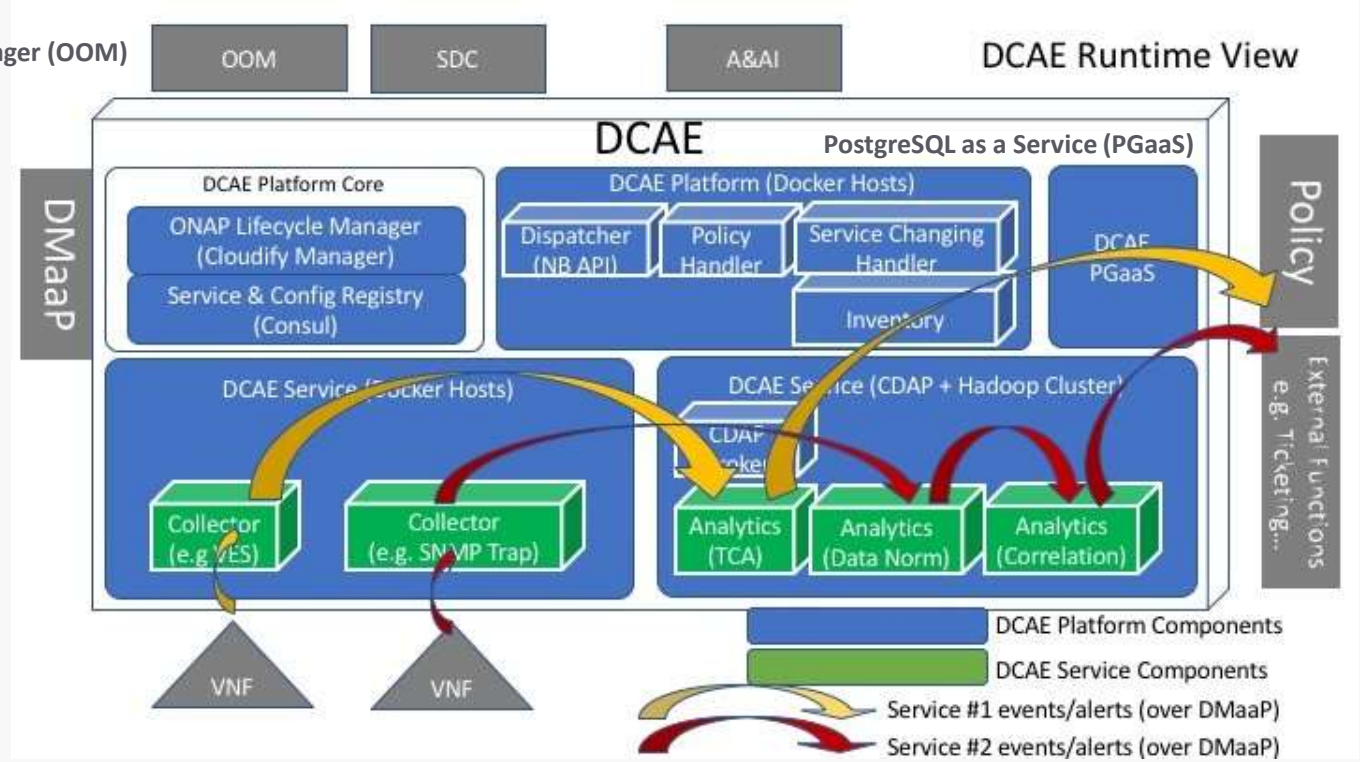
- 통신사의 기지국 및 기업 환경 API 제공 응용 시장 (예)
- Akraino Edge Stack: AT&T 와 Intel 제안



출처: www.akraino.org

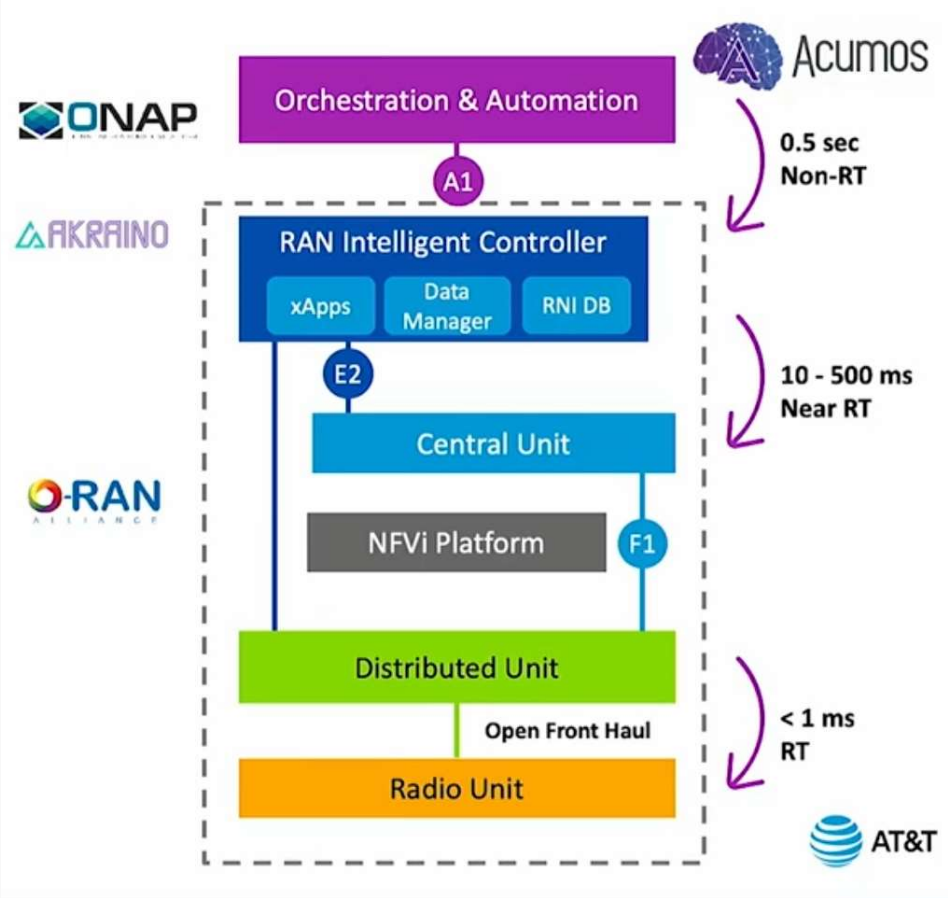
IV. 오픈소스 프로젝트

- ONAP(Open Network Automation Platform)
- DCAE(Data Collection Analytics and Events Project)



IV. 오픈소스 프로젝트

- ❑ Open source for RAN
- ❑ Disaggregate RAN
  - ▪ Ex.) 무선 접속 장비 DDoS 공격 탐지 후 즉시 차단



JS Lab

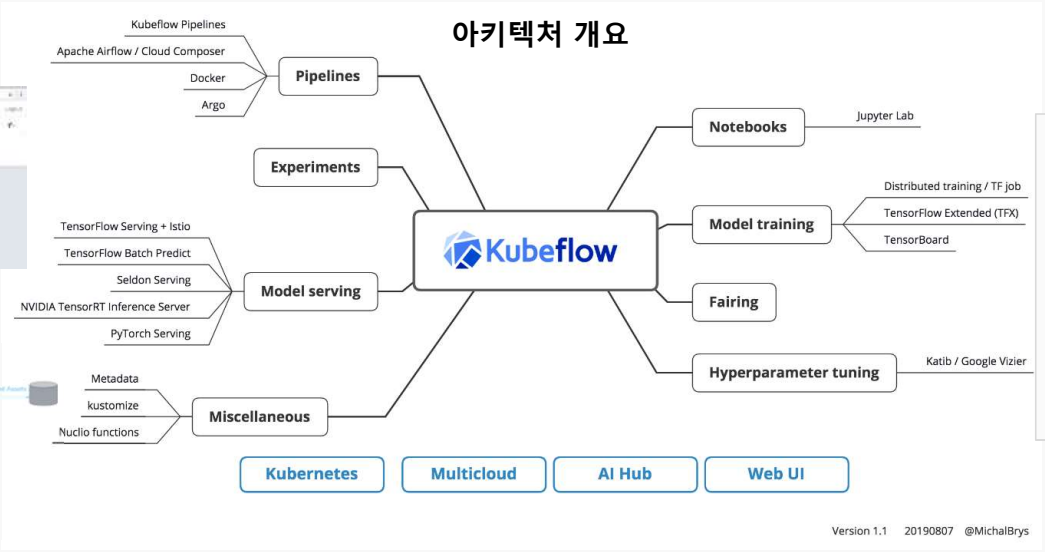
IV. 오픈소스 프로젝트

❑ AI 서비스 인프라 포털 서비스 (오픈소스 예)

- Jupyter Notebook: Easy GPU provisioning
- Katib: 하이퍼파라미터 튜닝
- Argo: Pipeline / ML Workflow 작성 (자동화)
- Fairing: building, training, and deploying ML models in a hybrid cloud
- TFJob, PyTorchJob: CRD
- Seldon, TF Serving: Model serving

Argo UI

KFServing(Serverless)



Katib UI

부록: 5G PPP의 AI/ML Use Case

- ❑ Network Planning Use cases
- ❑ Forecasting network characteristics and events
- ❑ Estimating user locations
- ❑ Non real-time use cases (>0.5 sec)
- ❑ Near real-time use cases (10 ms – 0.5 sec)
- ❑ Real-time uses cases (<10 ms)
- ❑ Transport networks, fronthaul and backhaul
- ❑ NFV infrastructures
- ❑ End-to-end slicing
- ❑ Forecasting security incidents
- ❑ Security
- ❑ Application functions

출처: 'AI and ML – Enablers for Beyond 5G Networks' (URL http://doi.org/10.5281/zenodo.4299895) , 5G PPP Technology Board, 2021-05-11

부록: 5G PPP의 AI/ML Use Case

❑ Network Planning Use cases

Use Case	5GPPP Project
Network element placement problem	ARIADNE
Application of ML to dimensioning C-RAN clusters	5G-COMPLETE

Network Planning Use cases

부록: 5G PPP의 AI/ML Use Case

❑ Forecasting network characteristics and events

- **Use cases for forecasting network characteristics and events**

Use Case	5GPPP Project
Synthetising high resolution mobile traffic	5GZORRO
Efficient mobile traffic forecasting	5GZORRO
Improving QoS with Forecasting Techniques	5GROWTH
QoE Inference	5GVINNI
SLA prediction in multi-tenant environments	5G-CLARITY
Complex event recognition (CER) & Forecasting	ARIADNE

부록: 5G PPP의 AI/ML Use Case

❑ Estimating user locations

- **Use cases for estimating user location**

Use Case	5GPPP Project
AI assisted sensor fusion	5GSOLUTIONS
5G Localization based on Soft Information	LOCUS
5G Localization based on Sequential Autoencoding	LOCUS
ML assisted LoS/NLoS discrimination	5G-CLARITY

부록: 5G PPP의 AI/ML Use Case

❑ Non real-time use cases (>0.5 sec)

- Use cases for non-real-time RAN aspects

Use Case	5GPPP Project
RAN slicing in multi-tenant networks	5G-CLARITY
Radio Resource Provisioning in multi-technology RAN	5G-CLARITY
RL-empowered User Association	5G-HEART

부록: 5G PPP의 AI/ML Use Case

❑ Near real-time use cases (10 ms – 0.5 sec)

- Use case for near-real time RAN aspects

Use Case	5GPPP Project
Near-real-time traffic steering on eAT3S	5G-CLARITY
Demand-Driven Power Allocation in 5G-enabled Wireless Networks	AFFORDABLE5G

부록: 5G PPP의 AI/ML Use Case

❑ Real-time uses cases (<10 ms)

- **Use cases for real time RAN aspects**

Use Case	5GPPP Project
AI/ML for joint MAC scheduling across gNBs	LOCUS
AI/ML for Channel Modelling	ARIADNE
Prescriptive Analytics and Channel Estimation to optimize Reconfigurable Intelligent Surfaces (RIS)	ARIADNE

부록: 5G PPP의 AI/ML Use Case

❑ Transport networks, fronthaul and backhaul

- **Use cases for transport network related aspects**

Use Case	5GPPP Project
Triggering path computation based on AI/ML inputs	5GROWTH
ML-based Traffic management using programmable switches	5GROWTH
Dynamic Load Balancing	TERAWAY
Efficient per flow scheduling in programmable transport networks	5G-COMPLETE
Determine optimal FH/BH functional split	5G-COMPLETE

부록: 5G PPP의 AI/ML Use Case

❑ NFV infrastructures

- **Use cases for virtual network infrastructure related aspects**

Use Case	5GPPP Project
Federated Learning across MEC and NFV orchestrators	5GZORRO
Resource allocation for Service Function Chaining	5G-CLARITY
Dynamic Resource Allocation in NFV infrastructures	5G-VINNI

부록: 5G PPP의 AI/ML Use Case

❑ End-to-end slicing

- **Use cases for E2E network slicing related aspects**

Use Case	5GPPP Project
Automated end-to-end service assurance	5GVINNI
Proactive resource reservation in e2e slicing	5GSOLUTIONS
Joint slice admission control and resource allocation	MONB5G
Joint slice-based demand prediction and resource allocation	5G-TOURS
AI assisted slice isolation	5GZORRO
AI/ML-based Decision Making for Slice Optimisation	5GENESIS

부록: 5G PPP의 AI/ML Use Case

❑ Forecasting security incidents

- **Use cases for security forecasting**

Use Case	5GPPP Project
Network Traffic Inspection	5GZORRO
Real-time detection of DDoS attacks	INSPIRE-5GPLUS

부록: 5G PPP의 AI/ML Use Case

❑ Security

- **Use cases for network security related aspects**

Use Case	5GPPP Project
Moving Target Defence for Network Slice Protection	INSPIRE-5GPLUS
Robust Self-Protection Against App-Layer DDoS Attacks	INSPIRE-5GPLUS

부록: 5G PPP의 AI/ML Use Case

❑ Application functions

- **Use cases for application function related aspects**

Use Case	5GPPP Project
Dash prefetching optimization	5GZORRO
Q-Learning application to federated scenarios	5GROWTH

감사합니다.