XG Mobile Promotion Forum

Beyond 5G White Paper
6G Radio Technology Project
“AI/ML and Digital Twin Technologies”
【Version 1.0, Overview (Short version)】

XG Mobile Promotion Forum

AI and Digital Twin Working Group

September 30, 2025

AI and Digital Twin WG

- Organization
  - Chair: Tomoaki Otsuki (Keio Univ.)
  - Vice Chair: Takahiro Yamazaki (NTT)，Tetsuya Yamamoto (Panasonic Holdings)
  - WG members: 37 members
- Activities
  - Researching technology and standardization trends，and creating white papers
  - Disseminating information both domestically and internally (e.g., by organizing workshops)，and exchanging opinions with overseas organizations
  - Establishing a shared database for AI training
  - Sharing a platform for leveraging AI and digital twins
- Examples of outputs
  - Beyond 5G white paper
  - Shared database for AI training
  - Collaborative projects in conjunction with international conferences

Outline of White Paper

- Preface
- I. Trends of AI/ML and Digital Twin towards 6G
  - I-1. Standardization in 3GPP and O-RAN for AI/ML
    - A summary of the standardization trends related to AI/ML within the 3rd Generation Partnership Project (3GPP) and the Open Radio Access Network (O-RAN) Alliance
  - I-2. Introduction of AI and Digital Twin Technologies for 6G
    - A brief summary of technological trends in the following technology fields, which are primarily associated with the content of Chapter II
      - AI for Signal Processing / Air-interface
      - AI for RAN
      - AI for Radio Propagation / Digital Twin
      - Network Architecture for AI/ML Usage in RAN
- II. Recent Activities of AI/ML and Digital Twin in Japan
  - An introduction to Japan's advanced research and development initiatives and achievements related to the utilization of AI/ML and digital twin for 6G

https://xgmf.jp/wp-content/uploads/2025/05/Beyond-5G-White-Paper-AI-and-Digital-Twin_v1.pdf

Preface

- Communication networks are evolving rapidly in the Beyond 5G(B5G)/6G era, and AI/ML technologies will play a significant role in this evolution.
- In the 6G era, digital twin (DT) technology is considered to be very important, in which the real world is reproduced in cyberspace, and data collected from the real world is used to simulate/emulate beyond the constraints of the real world using AI, etc., to gain new knowledge, and to feedback to the real world.

- AI/ML and DT technologies are expected to be used in various fields to enhance B5G/6G capabilities.
- The existing Beyond 5G White Paper Supplementary Volume "AI/ML Technologies" presents AI/ML technologies in network operation and management, optimization of radio access resource management, AI/ML technologies for user/application-centric communication.
- This white paper targets expands the content on the utilization of AI/ML technologies in the field of wireless technology in addition to that of mentioned above, and also focuses on the utilization of DT technologies. This white paper summarizes the latest trends, R&D activities, standardization and status of global technology studies.

- This white paper aims to provide a comprehensive overview of the potential, challenges and future direction of AI/ML and DT technologies, and to provide useful information for future discussions on business creation and solving social issues through collaboration between industry, academia and government.
- This white paper was prepared with the generous support of many people who participated in the AI and Digital Twin WG of 6G Radio Technology Project, XGMF.

I. Trends of AI/ML and Digital Twin towards 6G

- Outline
  - I-1. Standardization in 3GPP and O-RAN for AI/ML
    - I-1.1. Standardization in 3GPP
      - I-1.1.1. Framework of AI/ML to Air-interface
      - I-1.1.2. CSI Feedback Enhancement
      - I-1.1.3. Beam Management
      - I-1.1.4. Positioning
      - I-1.1.5. Mobility
    - I-1.2. Standardization in O-RAN
      - I-1.2.1. AI/ML Framework
      - I-1.2.2. Massive MIMO Beamforming Optimization
      - I-1.2.3. RAN Slice SLA Assurance
      - I-1.2.4. Energy Saving
  - I-2. Introduction of AI and Digital Twin technologies for 6G
    - I-2.1. AI for Signal Processing / Air-interface
    - I-2.2. AI for RAN
    - I-2.3. AI for Radio Propagation / Digital Twin
    - I-2.4. Network Architecture for AI/ML Usage in RAN

I-1.1 Standardization in 3GPP

- Use cases (Specified in Rel.19 or to be specified in Rel.20 (under discussion))

Application of AI/ML to air-interface

- Channel state information (CSI) feedback enhancement
  - Time-domain CSI prediction
  - Spatial-frequency (+time) domain CSI compression
- Beam management
  - Spatial domain beam estimation
  - Time domain beam prediction
- Positioning
  - Direction location information estimation
  - Intermediate statistical information (e.g., timing and LOS/NLOS conditions) estimation for positioning estimation
- Mobility (e.g., cell selection)
  - Measurement reduction for mobility
  - Handover event prediction

Application of AI/ML within RAN

- Network energy saving
- Load balancing
- Mobility optimization
- Network slicing
- Optimization of coverage and capacity
- QoE optimization

This white paper provides details on the application of AI/ML technologies mainly to air-interface.

I-1.2 Standardization in O-RAN

- One of the key innovations driven by O-RAN is the concept of RAN intelligent controller (RIC).
  - RIC: Role in automatic optimization of parameter design and operation
- Integration of AI/ML in O-RAN with RIC for intelligent RAN
  - Improvement of communication performance, optimization of resource allocation, and improvement of user experience quality, etc.
  - Multiple scenarios considering the arrangement on combination of training, model management and inference, etc.
- Use cases
  - Massive MIMO beamforming optimization
    - Application of AI/ML technologies to advanced network management techniques such as beam shaping, beam-based load balancing, optimized beam mobility, and adaptive cell coverage areas
  - RAN slice SLA assurance
    - Application of AI/ML technologies to the network control function by RIC to efficiency control network slides and guarantee requirements such as quality and low latency, etc.
  - Energy saving
    - Application of AI/ML technologies to cell and RF channel ON/OFF and sleep control

This white paper provides details on the AI/ML framework (e.g., deployment scenarios) and each use case in O-RAN.

I-2. Introduction of AI and Digital Twin Technologies for 6G

- I-2.1: AI for Signal Processing / Air Interface
  - Optimization of wireless signal processing and air-interfaces by solving complex non-linear problems and analyzing huge amount of data
    - Physical-layer signal processing (channel coding，channel estimation，beamforming，transmit power control, etc.)
    - AI-native air-interface
    - Application to high-frequency areas such as millimeter-wave and terahertz bands
    - Performance indicators considering both communication and AI/ML perspective, integrated system design

- I-2.2: AI for RAN
  - Application to OAM (Operations Administration and Maintenance) of RAN for reducing human operation resources and human errors.
  - Dynamic control of RAN to improve quality of communication and power efficiency
    - Traffic offloading, resource allocation and power control, etc.

- I-2.3: AI for Radio Propagation / Digital Twin
  - Evolving radio propagation and radio simulation in digital virtual environments such as digital twin
    - Application to radio propagation (channel parameter estimation, channel modelling, channel prediction and LOS / NLOS identification, etc.)
    - AI/ML technologies can make ML models with multimodal value, which can support more flexible radio propagation situations and scenarios.
    - Many AI/ML approaches have been investigated to implement more realistic and cost-effective radio simulation.

- I-2.4: Network Architecture for AI/ML Usage in RAN
  - Placing AI/ML application functions to RAN side, such as MEC or computing infrastructure for vRAN
  - NW architecture which distributes AI/ML application functions to core NW, RAN, user devices and all of the NW functions.

II. Recent Activities of AI/ML and Digital Twin in Japan (1/2)

This section introduces leading-edge R&D efforts on AI/ML and Digital Twin for Beyond 5G in Japan.

AI for signal processing / air-interface

	Contributor (Affiliation of first author)	Contents Title
II-1	Nokia	Scalable AI/ML for Radio Cellular Access
II-2	Panasonic Holdings	Study on Training Collaboration at UE- / NW-side for CSI Compression with Two-sided AI/ML Model
II-3	NTT	Proof-of-concept for AI-native Air Interface toward 6G
II-4	KDDI Research	Neural Network-based Digital Pre-distortion for Wideband Power Amplifiers using DeepShift
II-5	NTT	AI Calibration Network under Hardware Limitations
II-6	Huawei Technologies Japan	Performance Requirements and Evaluation Methodology for AI and Communication in 6G

AI/ML for RAN

	Contributor (Affiliation of first author)	Contents Title
II-7	KDDI Research	Study on AP Clustering with Deep Reinforcement Learning for Cell-Free Massive MIMO
II-8	Sharp	Cross-layer Access Control Techniques using AI
II-9	NEC	AI-based Application-aware RAN Optimization
II-10	KDDI Research	AIOps for Autonomous Network
II-11	NEC	Logic-oriented Generative AI Technology for Autonomous Networks
II-12	Huawei Technologies Japan	In-Network Learning for Distributed RAN AI, ~Distributed LLMs via Latent Structure Distillation~

II. Recent Activities of AI/ML and Digital Twin in Japan (2/2)

This section introduces leading-edge R&D efforts on AI/ML and Digital Twin for Beyond 5G in Japan.

AI/ML for radio propagation and / digital twin

	Contributor (Affiliation of first author)	Contents Title
II-13	NTT	Throughput Prediction Technology for 28 GHz Channels using Physical Space Information
II-14	Tokyo Denki University	AI/ML-based Radio Propagation Prediction Technology
II-15	KDDI Research	AI-Based Radio Propagation Modeling for Wireless Emulator
II-16	NTT DOCOMO	6G Simulator Utilizing Future Prediction Control Technology Based on AI/ML
II-17	NTT DOCOMO	Optimization of 6G Radio Access Using Digital Twin
II-18	Osaka University	Digital-Twin for and by Beyond 5G

Network architecture for AI/ML usage in RAN

	Contributor (Affiliation of first author)	Contents Title
II-19	Huawei Technologies Japan	Task-Oriented 6G Native-AI Network Architecture