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| AIML activities in 3GPP |
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# Abstract

 This document is a summary of current and anticipated activities in 3GPP that incorporate or reference AIML technology.

# Background

 Research into using AIML techniques in the radio layers of wireless systems has been of interest for many years [1] and has migrated into wireless standards bodies. 3GPP is the prime organization that develops standards for cellular communications; there had been some early exploratory work to investigate ways AIML could be used in mobile communication standards going back to 2020, but the work picked up steam with the approval of document RP-213599 [2] in the Radio Access Networks (RAN) meeting in December 2021, which defined specific study items that 3GPP members are investigating for inclusion in 5G systems. The SI proposal was updated in March 2024 [3]. Over the last several years, 3GPP members have brought in hundreds of presentations that analyzed various aspects of AIML use in cellular systems. As these initial studies wind down, 3GPP is looking to begin deployment of some initial AIML features in what is called 5G-Advanced. With the kickoff of work on 6G that happened in March 2025 [4], AIML techniques have gotten an increased focus and are not only expected to have some impact on 5G-Advanced deployments but also form an even greater foundation for 6G standards and beyond.

# Use Cases and Current Work

 The 3GPP studies outlined in reference [3] which is the latest revision of the original Work Item Description [2], describe several use cases that are the near-term focus of AIML Work Items for both the base station (also called the gNodeB or Network side) and the User Equipment (UE). The studies have focused on the following use cases:

* Beam Management
* Positioning
* Channel State Information (CSI) Prediction
* CSI Compression
* Model delivery/transfer
* Integrated Sensing and Communication (ISAC)

A comprehensive summary of work in 3GPP on AIML is given in a presentation by Juan Montojo of Qualcomm, who was the rapporteur of the Study Items for Release-19 in 3GPP [5].

## Beam Management

 Beam management refers to use of AIML to aid in beamforming; there are two techniques that have been the focus of work in 3GPP RAN1:

* Spatial-domain downlink beam prediction (BM-Case1) leverages measurement outcomes from a designated set of downlink beams, denoted as ‘Set B,’ to predict the best beam within another set of downlink beams, termed ‘Set A,’ at the present moment.
* Time-domain downlink beam prediction (BM-Case2) harnesses historical measurement results derived from ‘Set B’ to anticipate the best beam in ‘Set A’ for one or more future time instances



## Positioning

 Positioning using 5G/6G signals is a use case that is complementary to some other use cases. This use case leverages MIMO antennas in the base station to determine the position of a UE; early work on sensing began in Rel-16 and was used to aid in locating E911 callers. Later releases have improved accuracy; Rel-18 can achieve position accuracy of well under 1 meter in good conditions[[1]](#footnote-1)[6]. Use of AIML techniques in Rel-19 and beyond aim to not only improve accuracy but also make the measurements more robust to channel impairments.

## CSI Prediction

 One of the challenges in characterizing the channel in order to optimize the link quality is estimating the Channel State Information (CSI). In 3GPP, CSI typically refers to channel quality indicator (CQI), precoding matrix indicator (PMI), and rank indicator (RI) for multiple input multiple output (MIMO) systems as defined in [7]. The state of the channel can change rapidly in a mobile communications environment, since the UE can be on a vehicle or train with a relatively small coherence time. The current and ongoing work being presented in 3GPP [8] include use of AIML techniques to predict the CSI based on past history; this ability to ensure that the CSI is as accurate as possible is important for MIMO performance.

## CSI Compression

The block of data generated when measuring CSI can be significant, especially for a massive MIMO system that can have dozens of antenna ports. While traditional compression techniques could be employed, a particularly promising area for application of AIML techniques is CSI compression. Autoencoder techniques based on AIML enable more robust compression of CSI data and reduce overhead[[2]](#footnote-2). AIML autoencoder based CSI compression techniques are expected to be incorporated into 3GPP Release-19 and will likely get deployed in 5G-Adbanced.

## Model Delivery/Transfer

 All use cases that employ AIML will need to use either a one-sided or two-sided model. In 3GPP, they have examined use cases assuming: 1) the UE does its own training (unlikely) and inference (one-sided), 2) the base station does both inference and training (one sided), and 3) each side has its own model (two sided). Another option is that the UE sends CSI data to the Base station, and receives model parameters (or a codebook entry) from the base station; the UE could also send some CSI data to the base station for model updates, or the UE could tweak its own models locally if it has sufficient processing power. So while the UE is not expected to full training of its models, some amount of local model adjustment is considered a possibility.

 Sending raw CSI data to the base station may create excessive overhead, even if compressed. As mentioned above, 3GPP has explored the possibility of using a codebook system where the UE uses one of N models for inference/demodulation; the base station just has to instruct the UE which codebook entry to use.

 The framework for how 3GPP expects AIML to operate in practice is given by ETSI 38.843 [9]; this is shown diagrammatically in Figure 1.



Figure 1: Assumed training and inference model for 3GPP Rel-19 Study Items [9, p.17]

## Integrated Sensing and Communication (ISAC)

 Integrated Sensing and Communication (ISAC) is a special set of use cases that are focused on detecting and tracking people or objects and locating them in space[[3]](#footnote-3) although the primary focus is detection. ETSI has a document that describes the use cases in detail [10], but the primary use cases are detection of vehicles, people, and UAVs (drones); these use cases are illustrated in Figure 2 [11]. The two primary geometries that have been studied in 3GPP [12] are monostatic, where the same radio system acts as transmitter and receiver, and bistatic, where the transmitter and sensing receiver are separate devices, as shown in Figures 3a and 3b. Reference [13] also has some technical details and additional information about use cases.



Figure 2: ISAC use cases (From [11])



Figure 3a: Monostatic ISAC use case



Figure 3b: Bistatic ISAC use case (From [13])

 Work in 3GPP has focused on monostatic operation, but there have been some studies on bistatic and multistatic. There has been some discussion about developing customized waveforms specifically designed for sensing, but most of the studies have focused on known reference signals such as DMRS. [14]

# 6G Activities (Rel-20, Rel-21)

In March 2025, 3GPP held a 6G Workshop that was the kickoff for formal work on what will become 5G-Advanced and 6G standards [4]; the outcome of this workshop gave general direction to Study Items and Work Items that will become part of Release-20 and 21. The approved work plan for the various RAN groups is in document RP-251881 [15].

##  Overview of 6G Air Interface

The goals for 6G Study Items described in [15] and further detailed in [16] are:

* RAN for AI
* Sensing
* Immersive communication
* Energy efficiency
* Enhanced spectrum efficiency
* Cost reduction.
* Performance improvement of pain point scenarios
* Flexible UE feature design
* Bilateral beneficial UE feature framework

##  Evaluation assumptions for 6G Air Interface

This group of study items will capture expected performance of 6G using antenna modeling, general system level and link level simulation based on deployment scenarios in ETSI document TR38.914. Link budget and traffic models will also be discussed.

## Waveform and frame structure for 6GR air interface

### Waveform

* CP-OFDM and DFT-s-OFDM waveforms as defined in 5G NR are supported as the basis for 6GR for uplink
* Enhancements/modifications on CP-OFDM/DFT-s-OFDM will be studied as potential additions
* Other OFDM based waveforms are not precluded.

### Frame structure

* Including numerology and frame structure (for all duplex types), as well as compatibility with 5G NR to allow for efficient 5G-6G Multi-RAT Spectrum Sharing (MRSS).

## Channel coding and modulation for 6GR interface

Including metrics/criteria that can be used for evaluating technology proposals and for down selecting proposals.

### Channel coding

For 6GR DL, 5G uniform QPSK, 16QAM, 64QAM, 256QAM and 1024QAM are supported as basis for study. Other modulation schemes may also be studied.

For 6GR UL, 5G NR uniform QPSK, 16QAM, 64QAM, and 256QAM are supported as basis for study for CP-OFDM for data channel. Other modulation schemes may also be studied.

For 6GR UL, 5G NR pi/2 BPSK, uniform QPSK, 16QAM, 64QAM, and 256QAM are supported as basis for study for DFT-s-OFDM for data channel. Other modulation schemes may also be studied.

### Energy efficiency

Sustainability and energy efficiency are explicit goals for 6G; Study Item proposals anticipate discussion of proposals for NW power saving, UE power saving, and joint mechanisms taking both NW and UE into account for power saving.

## AI/ML in 6GR interface

For 6GR AI/ML use cases identification/categorization, for each use case proposed, proponent companies are encouraged to study and report the following:

* Definition of each (sub-)use case, including at least AI/ML model input/output
* The evaluation assumption, methodology, KPIs, benchmark, and preliminary simulation results
* Assumption on training types, e.g., offline training, online training/finetuning
* Label construction (if applicable), including whether/how to obtain label data for model training
* Assumption on model location for inference, e.g., UE-sided model, NW-sided model, and two-sided model
* Collaboration/interaction between UE and NW, e.g., no collaboration/interaction, UE/Network collaboration targeting at separate or joint ML operation
* High level potential specification impact

## Expected evolution of radio technology to full AIML

The work going on in Rel-20/21 (6G) is expected to result in the first mass market wireless technology to incorporate AIML technology in Layer 1 and Layer 2 as a fundamental building block in the radio. This is a trend that is expected to eventually lead to a fully AI-Native system in both the transmitter and receiver, as discussed in [17]. The figure below from that paper shows the expected evolutionary path to a system where the AIML system designs part of the air interface itself and then synthesizes the modulation and coding schemes to optimize the link performance.



Figure 4: Projected Evolution Path of 6G and beyond to full AI-Native architecture [17]

Other industry groups are doing work that is complementary to the standards work in 3GPP and are either enabling or advocating use of AIML in next generation mobile communications standards.

* AI-RAN – This organization was specifically founded to explore, define, and promote use of AIML technology in 3GPP. From their website: “Realizing and harnessing the potential of an AI-native RAN” <https://ai-ran.org/>
* O-RAN – This organization is developing open standards for interoperable building blocks that can be assembled into a complete base station infrastructure from multiple vendors. From their website: “‍O-RAN ALLIANCE’s mission is to re-shape the RAN industry towards more intelligent, open, virtualized and fully interoperable mobile networks. O-RAN specifications enable a more competitive and vibrant RAN supplier ecosystem with faster innovation to improve user experience. O-RAN based mobile networks improve the efficiency of RAN deployments as well as operations by the mobile operators.” <https://www.o-ran.org/>
* OCUDU – Paraphrasing the OCUDO website: The current Open RAN Solutions focus on interfaces aligned with the O-RAN Alliance, with open source components such as RIC, CU and DU. However, CU/DU cannot be built with Open Source Software for commercial deployment. OCUDU is enabling the solution to this gap and will leverage AIML technology in these open platforms. <https://ocudu.org/>

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1. There are some claims of centimeter level accuracy, but that is likely achieved only in very pristine environments. [↑](#footnote-ref-1)
2. Use of autoencoder techniques for CSI compression is also described in a submission to the 802.11 AIML TIG/SC: <https://mentor.ieee.org/802.11/dcn/24/11-24-1743-01-aiml-unified-autoencoder-based-csi-feedback-in-mu-mimo-for-next-generation-wlans.pptx> [↑](#footnote-ref-2)
3. These use cases are similar to those defined for 802.11az and 802.11bf. [↑](#footnote-ref-3)