Federated Learning in O-RAN Architecture

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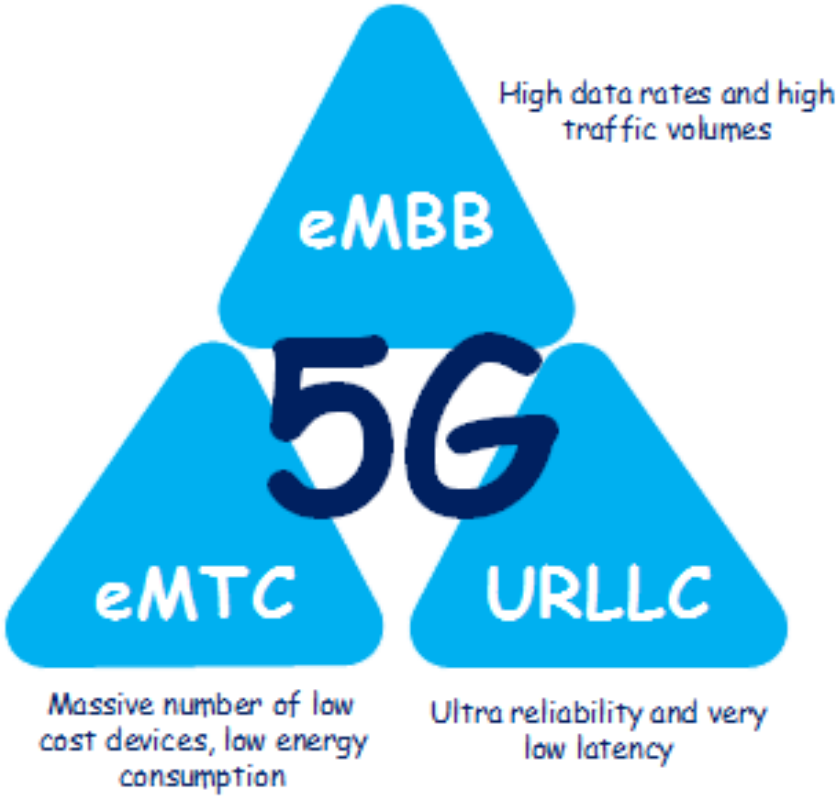
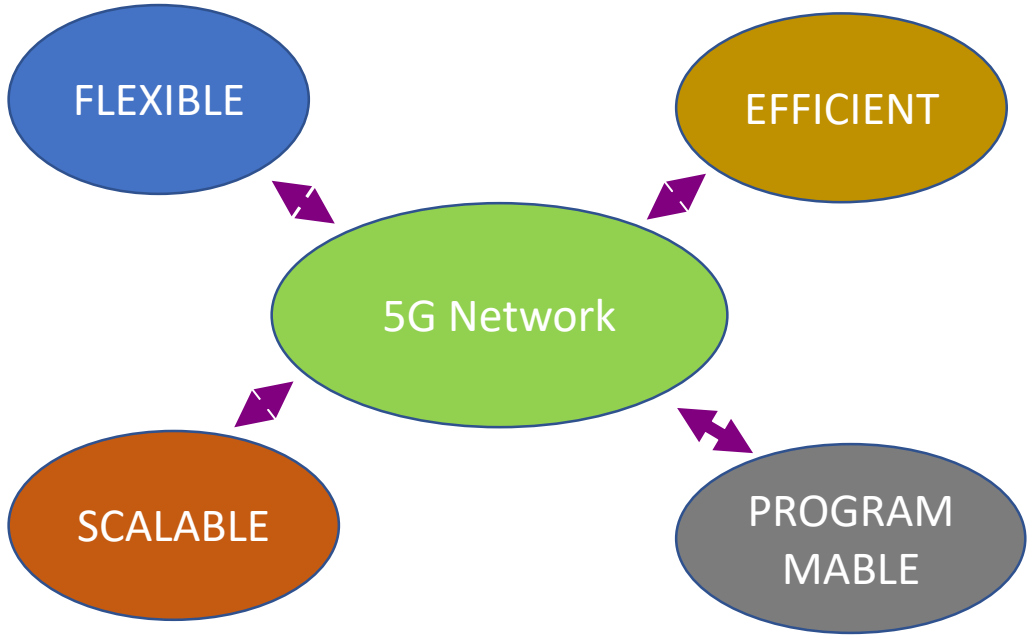
Topics Covered

- Need of AI in 5G
- Centralized learning Architecture and its Challenges
- Federated learning Architecture
- Federated learning in ORAN
- Example Use Cases
- Challenges of Federated Learning

5G Network Characteristics



5G Use Cases



5G Network Characteristics

- 2000+ Parameter for Configuration
- SA and NSA Deployments
- Increased Complexity Increase from 4G to 5G

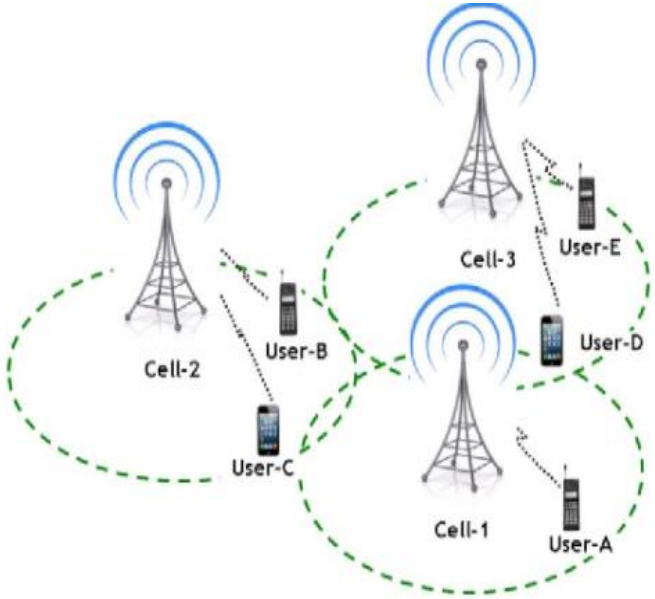
Application of AI in Wireless Communication

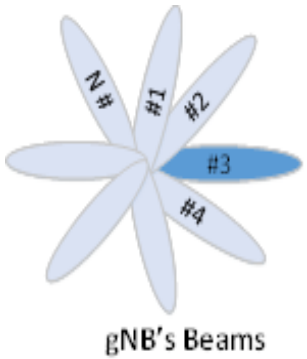
- Network Planning
- Network Security
- Radio Resource Management
- Mobility Analysis
- PHY Layer Optimization
- Network Operation Control
- Power Control
- Predictive Maintenance
- QOE\QOS Optimization
- Beam Management
- Radio Control
- Scheduling Control

Example Use Case : Initial Beam Selection in 5G

- In 5G initial Synchronization Signal i.e., SSB is Beam formed.
- There will be multiple transmit Beams from gNb side. Similarly, there will be multiple Received Beams at UE side.
- UE has to scan all the possible beam pairs and to find the appropriate beam pair.
- As a result, Initial Cell Selection take considerable amount of time compared to 4G.

- Depending upon the geographical location and UE distribution it is not necessary that gNb need to send all the TX Beams.
- If the desired TX Beams will be scheduled, then it will help in reducing TX beams.
- By looking into the communication system data distribution AI\ML can help in reducing the possible beam pair
- As a result, AI\ML will help in reducing the possible beam pair and cell selection time.

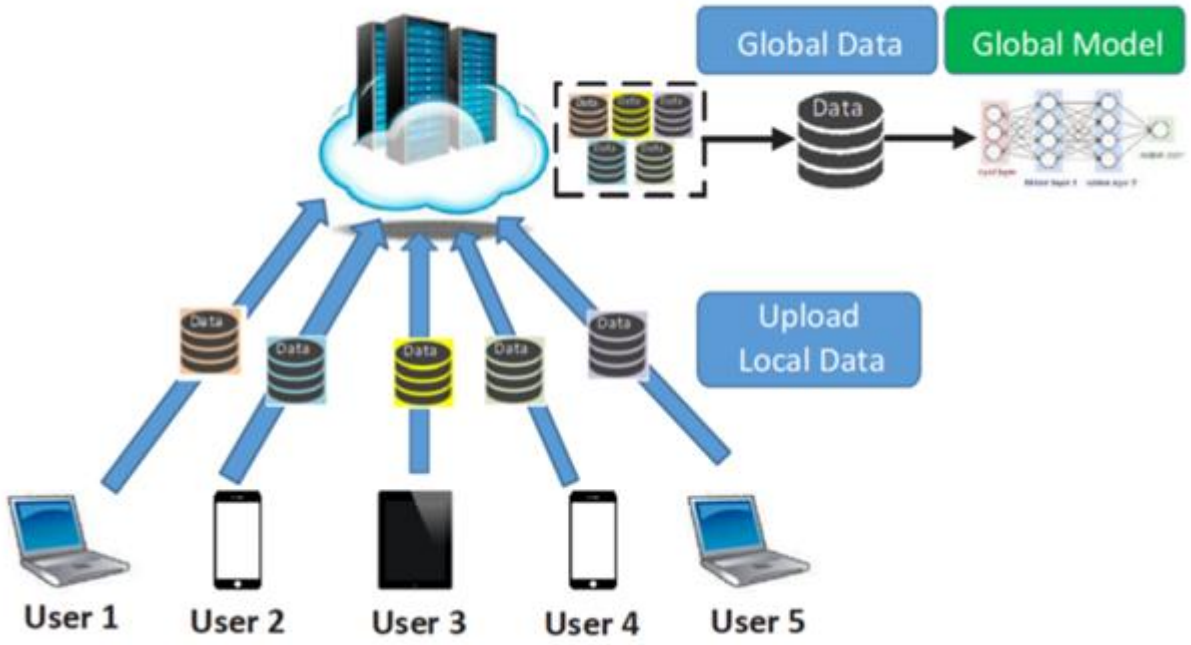




gNB's Beams

UE's Beams

Centralized Learning Architecture and Challenges



Centralized learning Architecture

Challenges of Centralized learning

Decentralized Data

- In wireless Communication Data is distributed across different entities. All the data at the centralized place is generally not available.

Computational complexity

- Deep learning algorithms are well known to be prodigious consumers of both computing power and energy.

Tight response time requirement

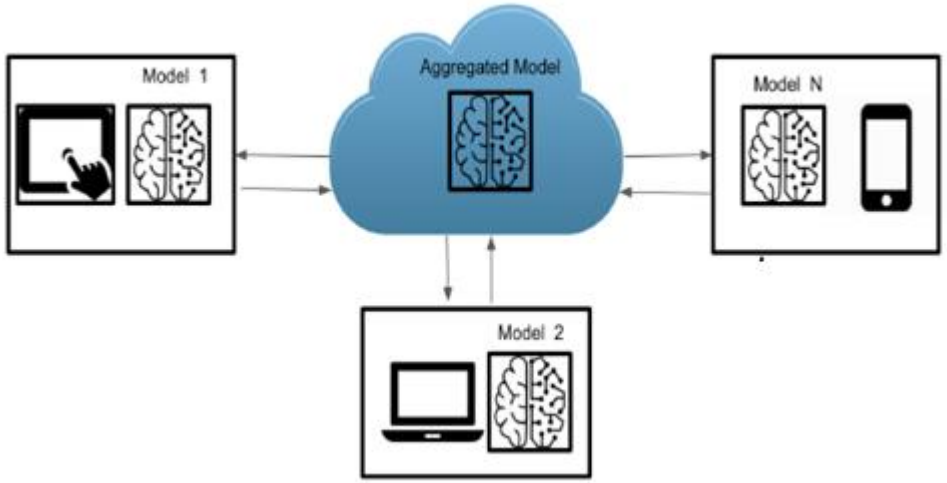
- 5G supporting URLLC and mMTC use cases have very stringent round trip time requirement.

Privacy Issue

- Due to privacy constraint, it will not be practical to send the user data via wireless links directly.

Federated Learning Architecture

- The Federated Learning is introduced by Google in 2016, where they first applied in google keyboard to collaboratively learn from several android phones.
- Federated learning is an efficient method to generate learning models without sending the stream of raw data back to the computing servers.
- In Federated Learning a local model can be trained by each user based on its own data.
- These locally trained models are then sent from the devices back to the central server where they are aggregated.
- Federated learning leaves the raw data distributed on the client devices and trains a shared model on the server by aggregating locally computed updates.
- Federated learning makes it possible for AI algorithms to gain experience from a vast range of data located at different sites.
- It will help in maintaining privacy by Secure Aggregation Principle.



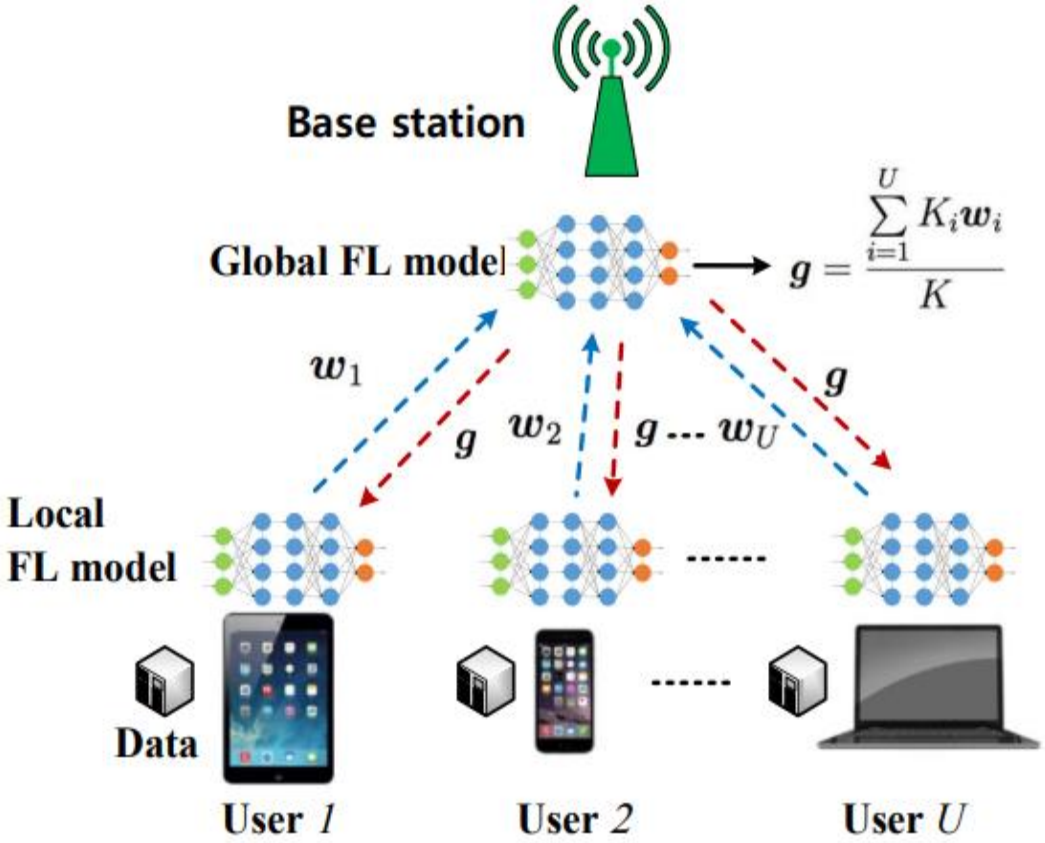
Federated learning Architecture

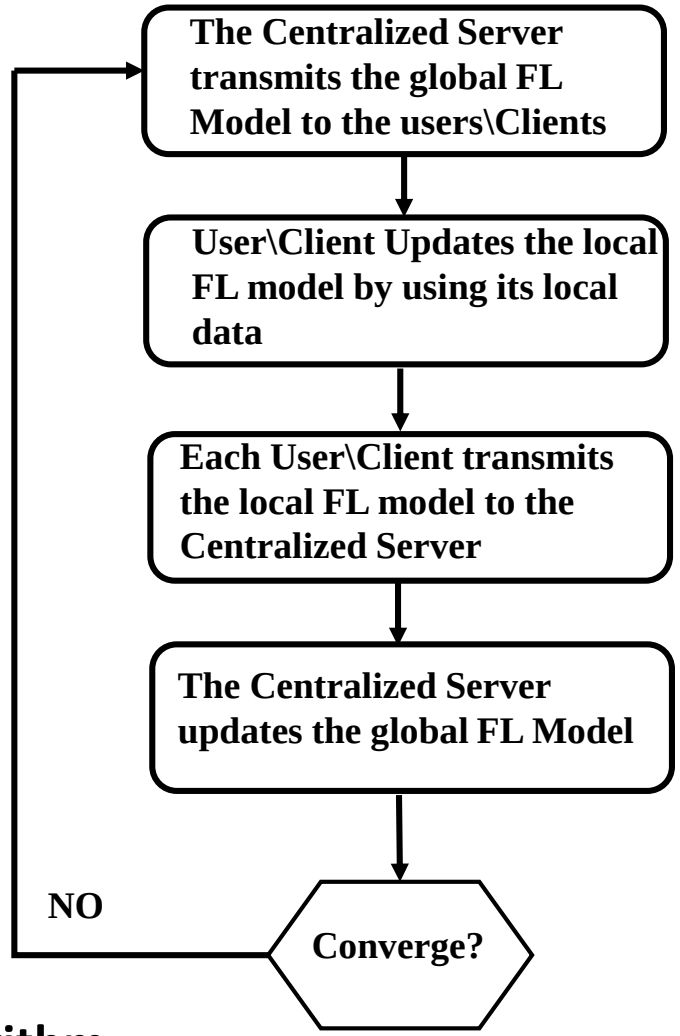
Federated learning Framework

Global Model Averaging: After receiving the Weights of the local models, the computing server updates the global model by averaging local model weights.

Local Model Feedback: When the update of the local model is finished, the results should be transmitted to the computing server

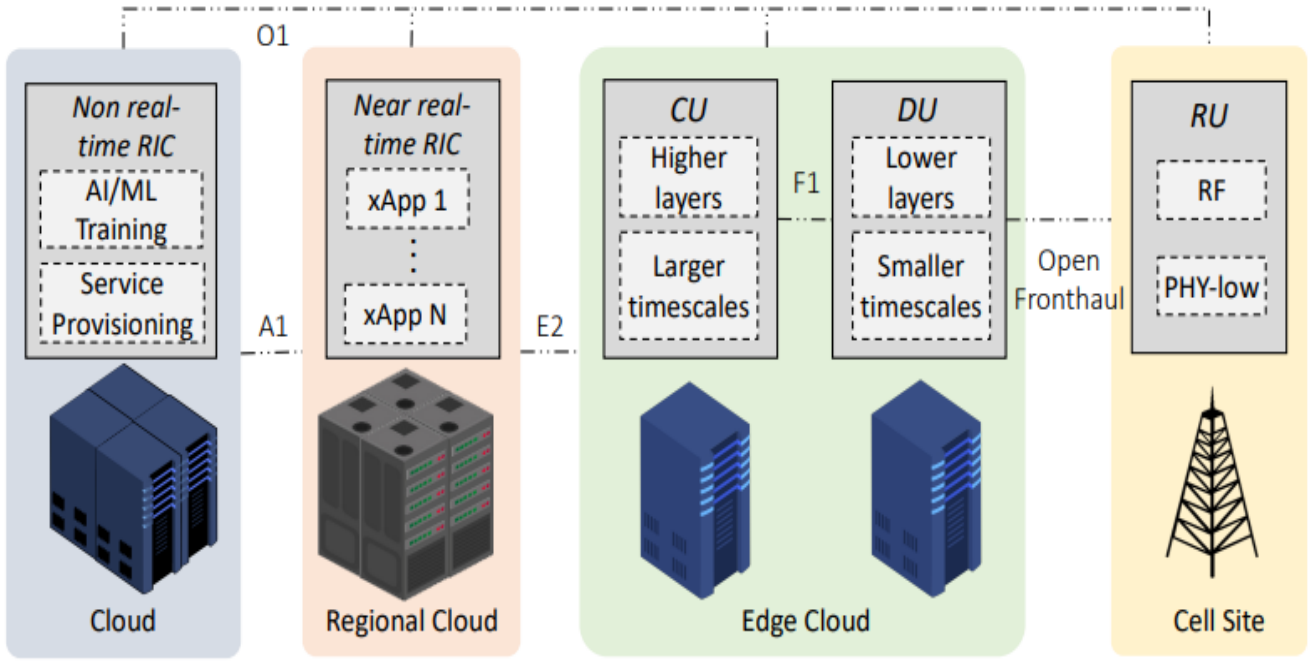
Local Model Update: each user updates its local model based on a dataset that consists of the locally collected data items.

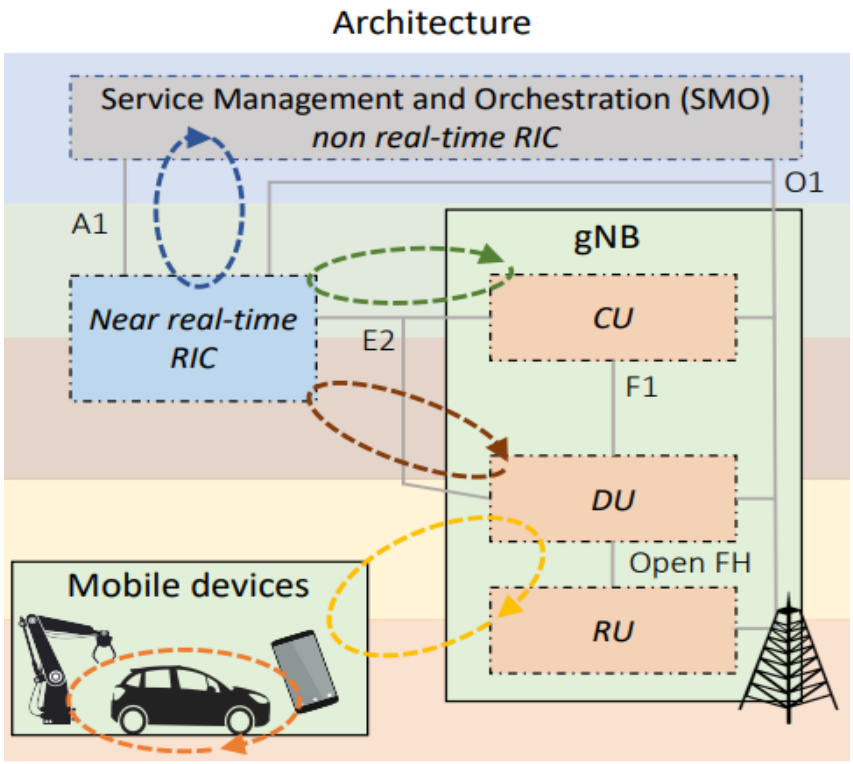




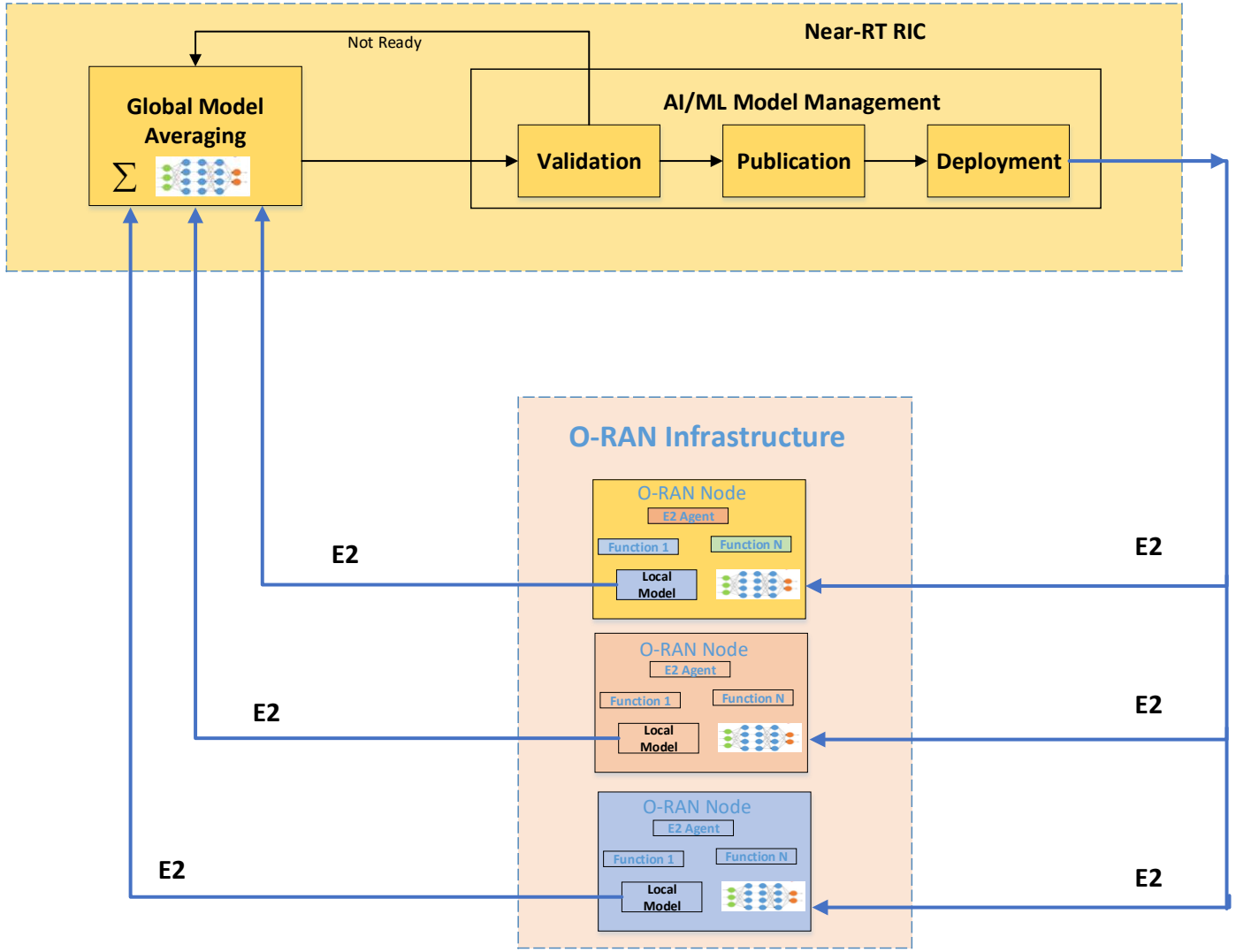
The learning procedure of an FL algorithm.

ORAN Deployment and Interface

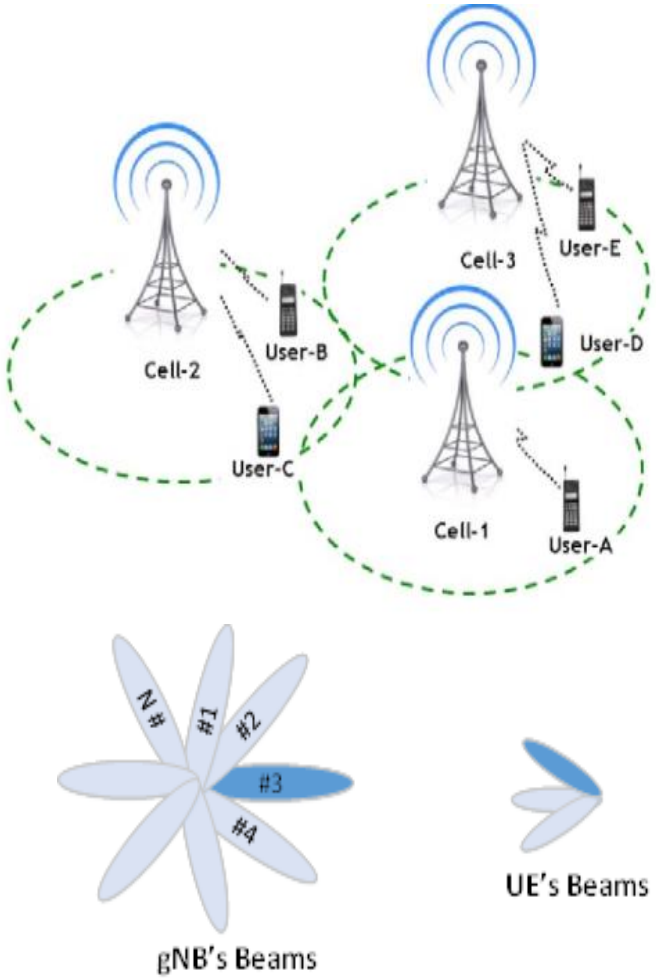




Federated Learning in ORAN Architecture

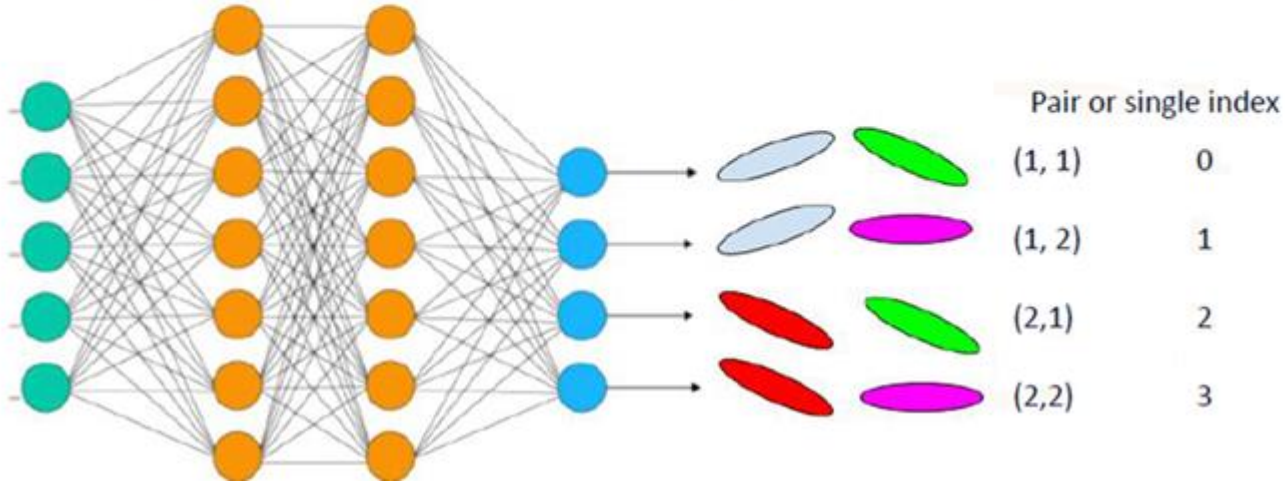


Application to the Initial Beam Selection in 5G



Example with $M_t = M_r = 2$ vectors per codebook

INPUT



Input Communication Parameters

Received power (dBm)

Time of arrival (seconds)

Elevation angle of departure (degrees)

Azimuth angle of departure (degrees)

Elevation angle of arrival(degrees)

Azimuth angle of arrival(degrees)

Ray phase (degrees)

Challenges of Federated Learning

Systems Heterogeneity:

- The storage, computational, and communication capabilities of each device in federated networks may differ due to variability in hardware (CPU, memory), network connectivity, and power (battery level).

Statistical Heterogeneity:

- Devices frequently generate and collect data in a non-identically distributed manner across the network. This data generation paradigm will not be aligned with frequently-used I.I.D distribution of data.

Security

Any Malicious user can add the security threat by Poisoning. Poisoning comes in two forms.

- Data Poisoning: During a Federated training process, multiple clients can participate by contributing their on-device training data, and it is difficult to detect/prevent malicious clients from sending malicious/fake data to poison the training process which in turn poison the model.
- Model Poisoning: Contrary to data poisoning, malicious clients modify the received model by tampering its gradient/parameters before sending back to the central server for aggregation, as a result, the global model can be severely poisoned with invalid gradients during the aggregation process.

THANKS