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TTDD 2024 CONFERENCE (7th EDITION)

REALIZING THE 6G VISION :
SOCIETAL NEEDS, USAGE SCENARIOS & TECHNOLOGIES

 **Date:** 16-19 July 2024

Session #3: Ubiquitous Intelligence: AI/ML enabled Future Networks

17 July 2024

Ubiquitous Intelligence in Next Gen Networks

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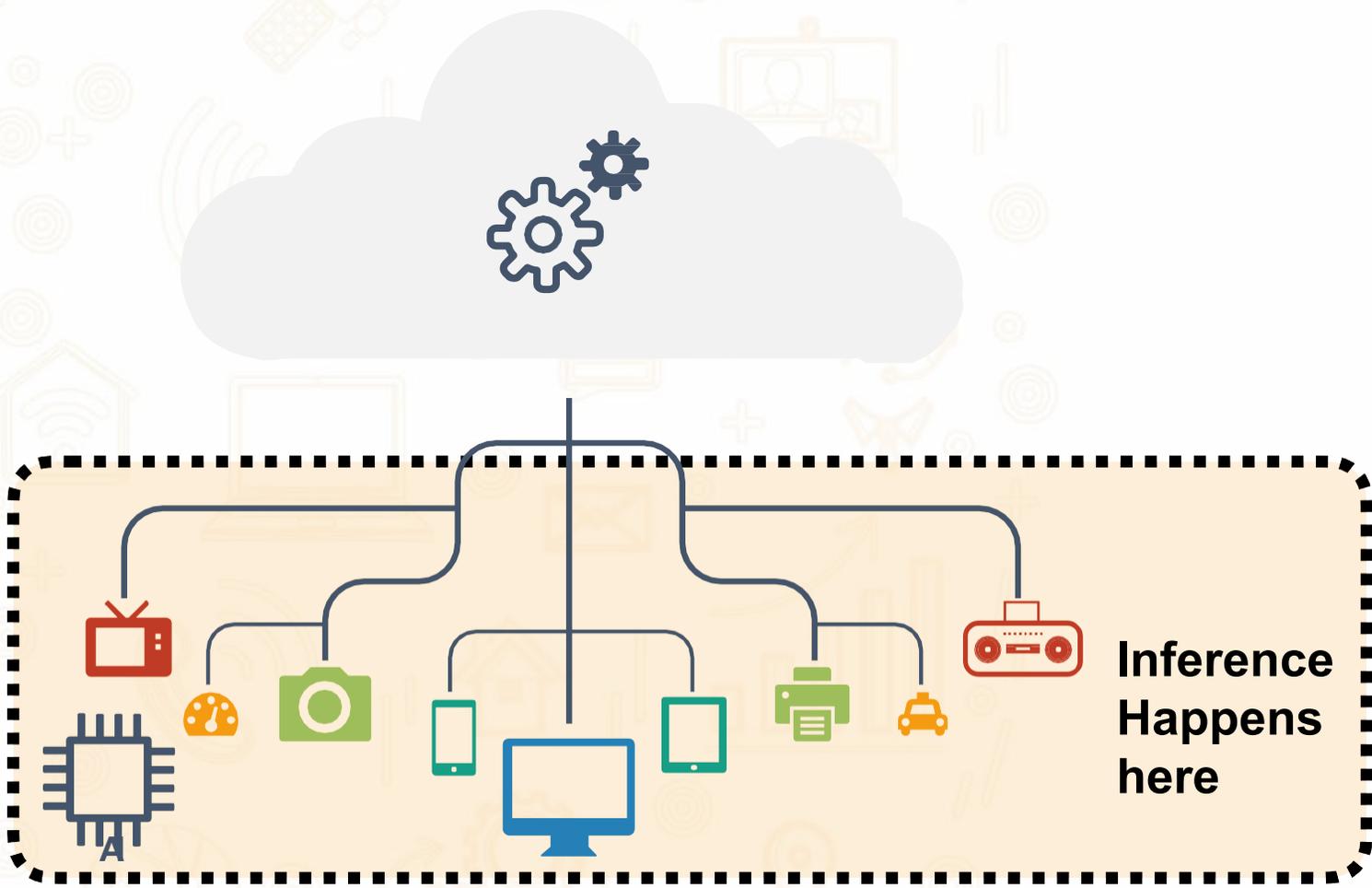
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Introduction

- In the near future, AI is expected to be available everywhere — even if we're unaware of its existence
- Ubiquitous AI
 - Existing or being everywhere at the same time
 - Constantly encountered
 - Widespread
 - Omnipresent, all over, universal, constantly available
 - Pervasive to the point of subconscious
- Ubiquitous AI enabled by Next Gen Networks
 - A network of connected systems for data collection, processing, learning and inferencing, actuation

Edge AI



Instrument the person
Instrument the physical surroundings

- 1  **Low Latency**
Local processing significantly reduces response times and improves the performance of real-time applications.
- 2  **Reduced Bandwidth**
By processing data on the device itself, Edge AI decreases the volume of data transmitted over the network.
- 3  **Enhanced Privacy and Security**
Local data processing means sensitive information does not have to leave the device, enhancing data privacy.
- 4  **Operational Reliability**
Edge AI allows devices to operate uninterrupted, independently of the cloud or central servers.
- 5  **Energy Efficiency**
Processing data locally can be more energy-efficient than sending data to a cloud for analysis.

Edge AI Examples

Example in different domains



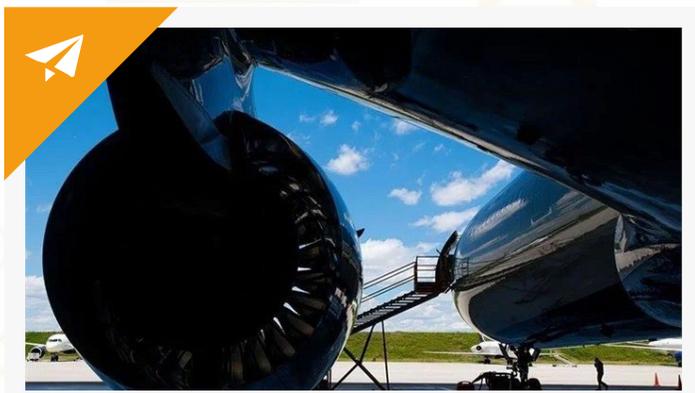
Tesla Full Self Driving
By Tesla



See and Spray
By John Deere



Apple Watch
By Apple



Delta Airlines Predictive Maintenance
By Delta Airlines



Jabra PanaCast 50
By Jabra

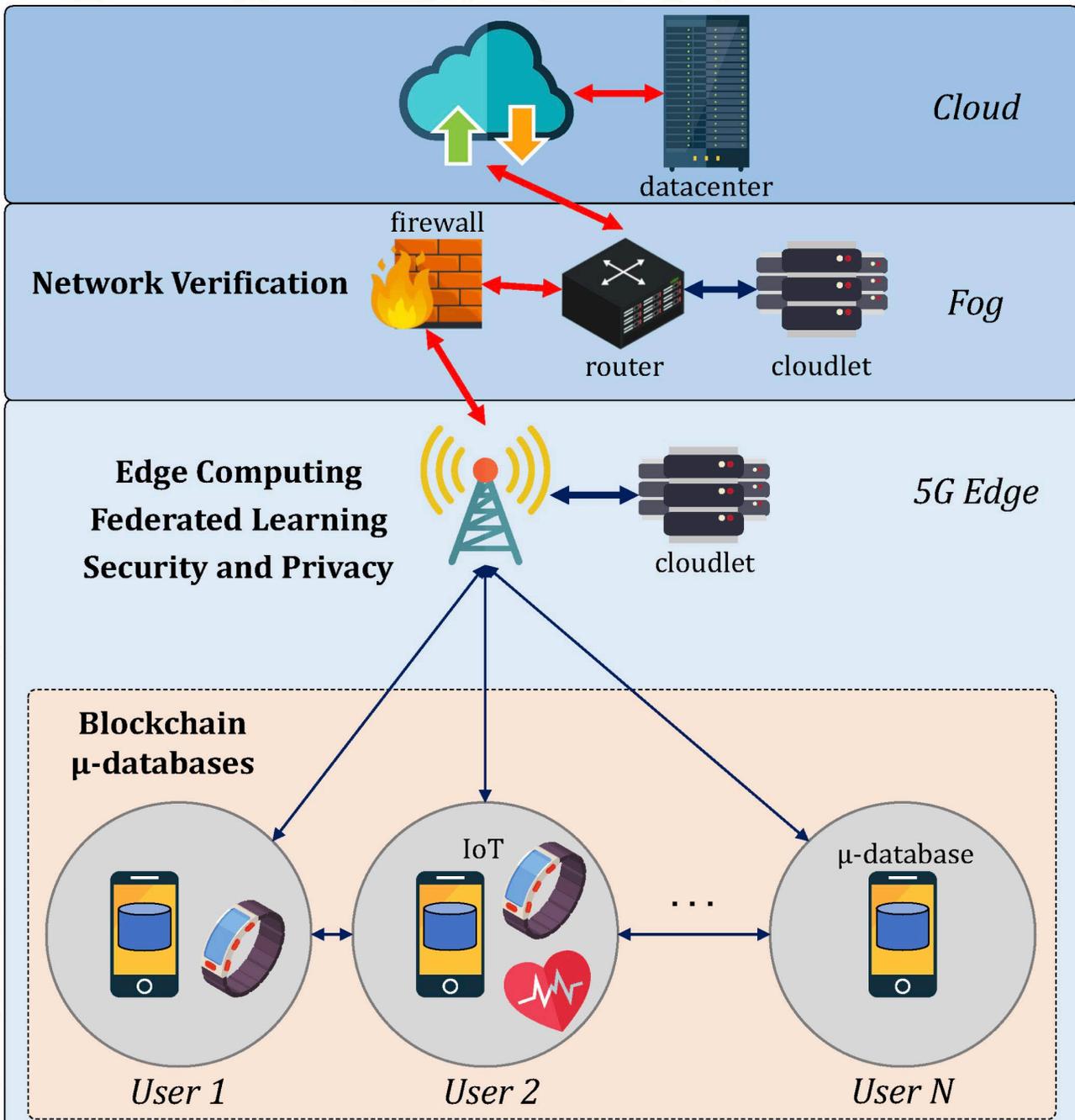


Perseverance Mars Rover
By NASA

Components of Edge AI

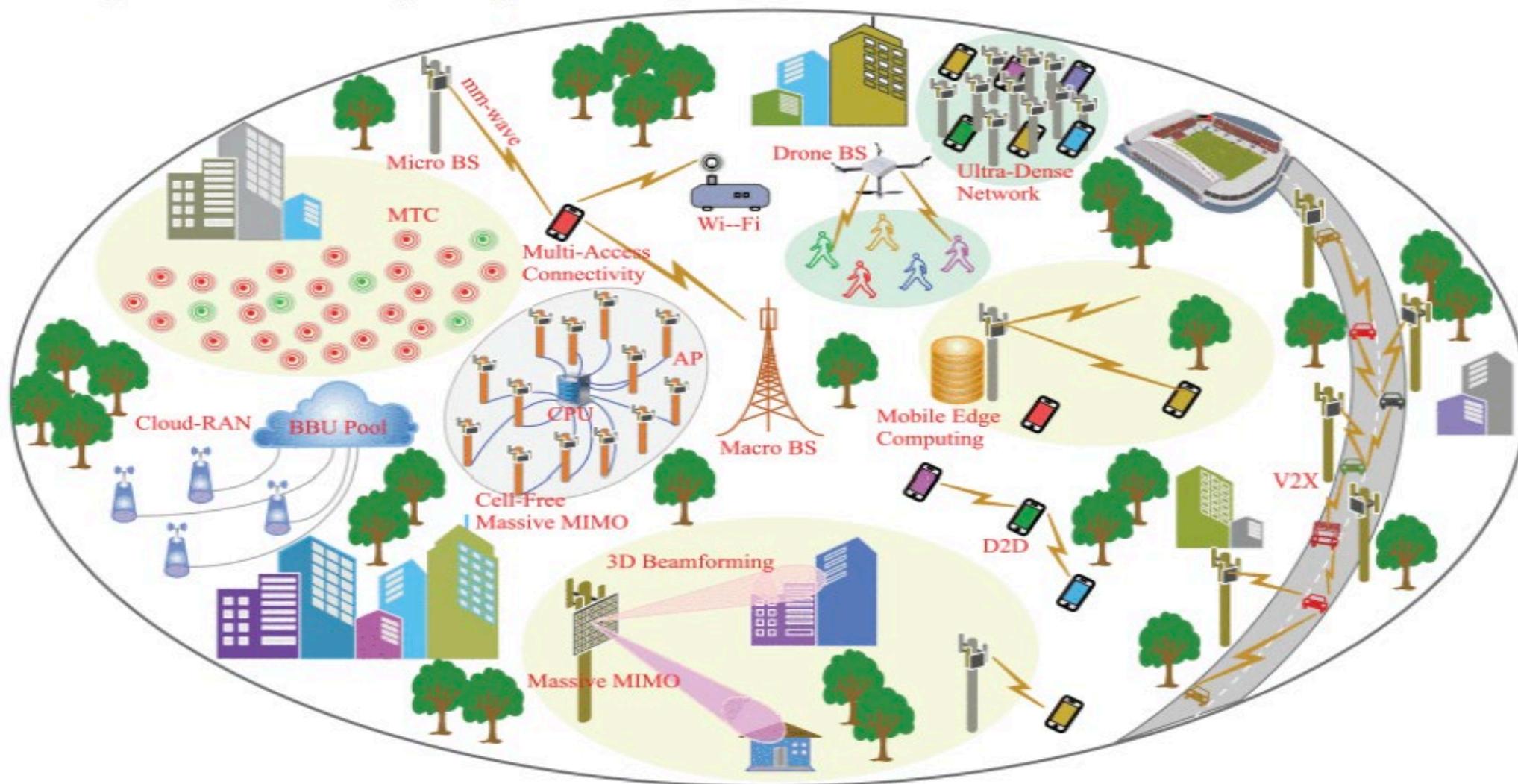
Specialized Hardware and Software





Edge AI Application Architecture

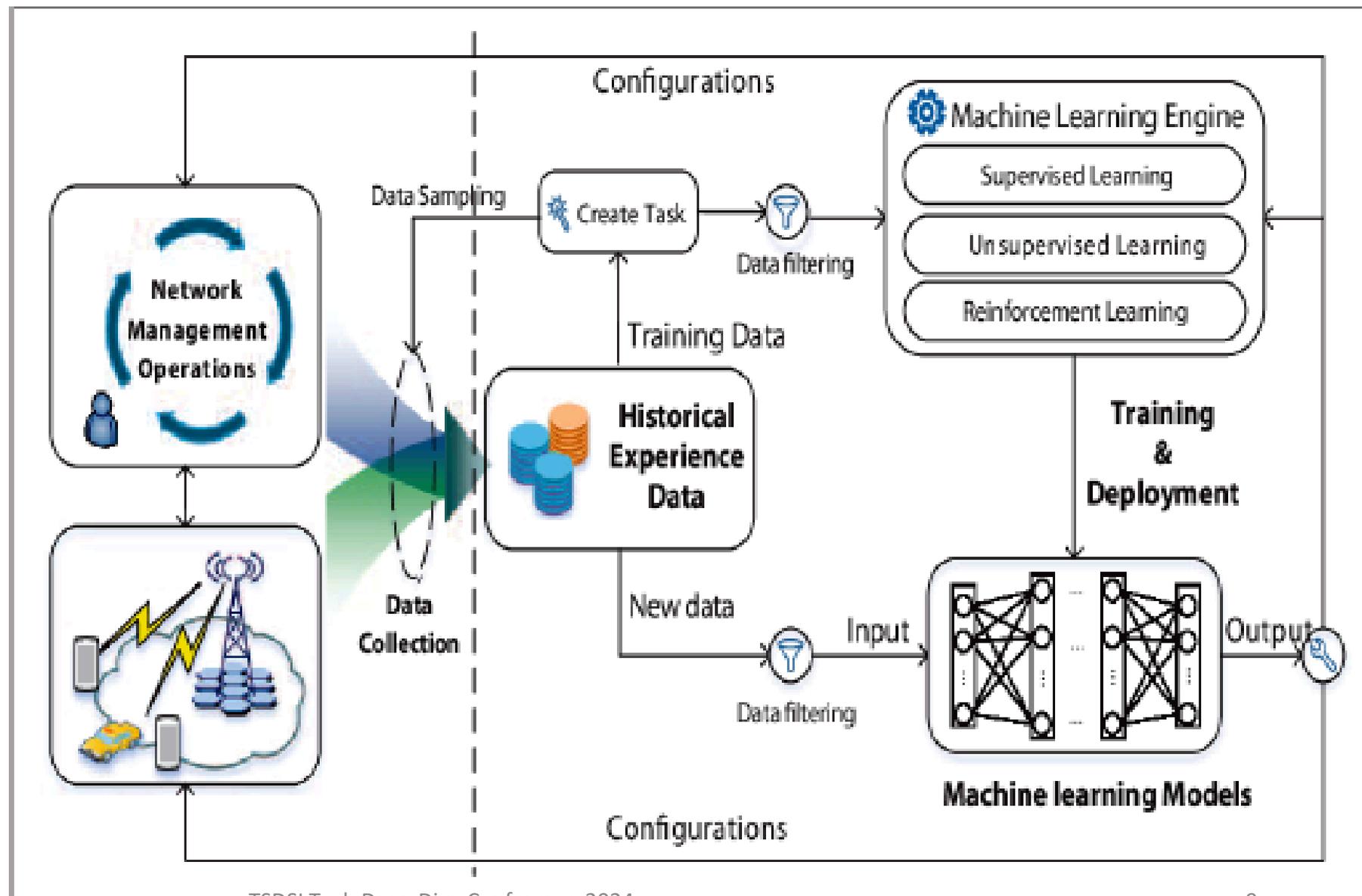
NextGen Network: Technology Landscape



AI for Next Gen Network: Drivers for AI

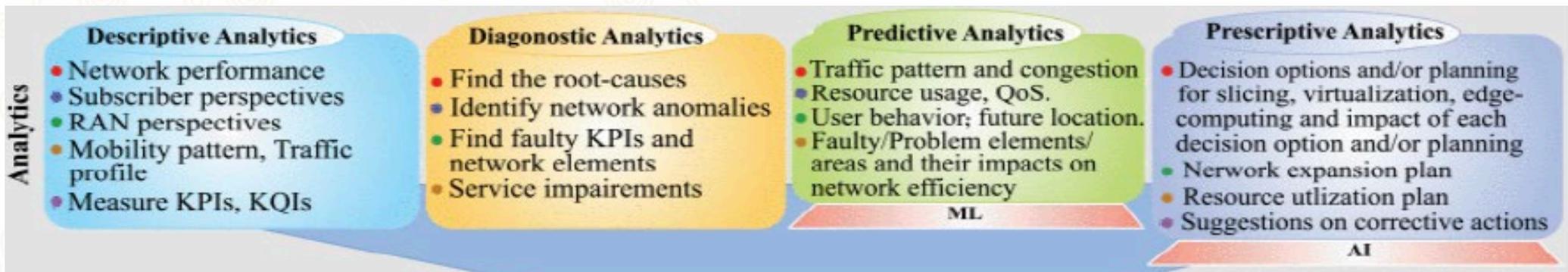
- Services and Expense
 - Customer Demand : High Speed data at low cost
 - Increase Capacity at low cost using AI
- Usage of the network
 - Variety of devices and diversity of data on the work
 - Operators need to interpret traffic to provide optimal service
- Use of New Technology
 - Various kinds of users' cases such as edge computing, network Slicing.
 - Use of big data analytics can allow the network operators to divide the cases and the network slicing into multiple layers and provide the best services to the consumer.
 - Not possible without artificial intelligence because of complexity and volume of the technological advancements and increased network traffic

- Autolearning network to get the automation of the network processes with the help of machine intelligence for the wireless network communication

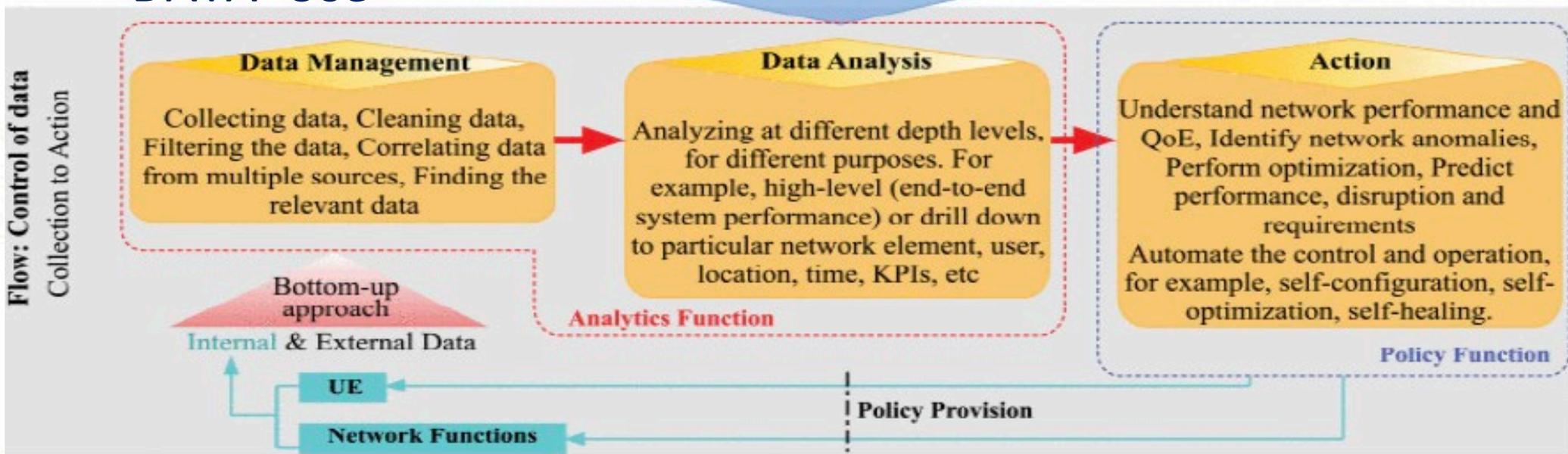


Big Data and NGWN

- The complex patterns of the network traffic and the increasing complications of the wireless system attracting towards big data analytics.
- Increasing importance of artificial intelligence for optimizing the efficiency and performance of the network.
- As the result of growing optimization because of big data, the network operators start in-depth AI usage



• DATA Use



Structured Data

Network-related

Technical-fault, link availability, network latency, backhaul status, connection set-up time, drive-test, data-plane traffic flow statistics, control-plane protocol and interface, traffic (by type, by application), data, deployment, sensor data

Subscriber-related

Handset data, customer account data, usage history, calling-pattern locations, mobility patterns, etc.

Unstructured Data

Call center transcripts, text-messages, personal assistant data, etc.

Internal Data

Collected from network (network-related, subscriber-related)

External Data

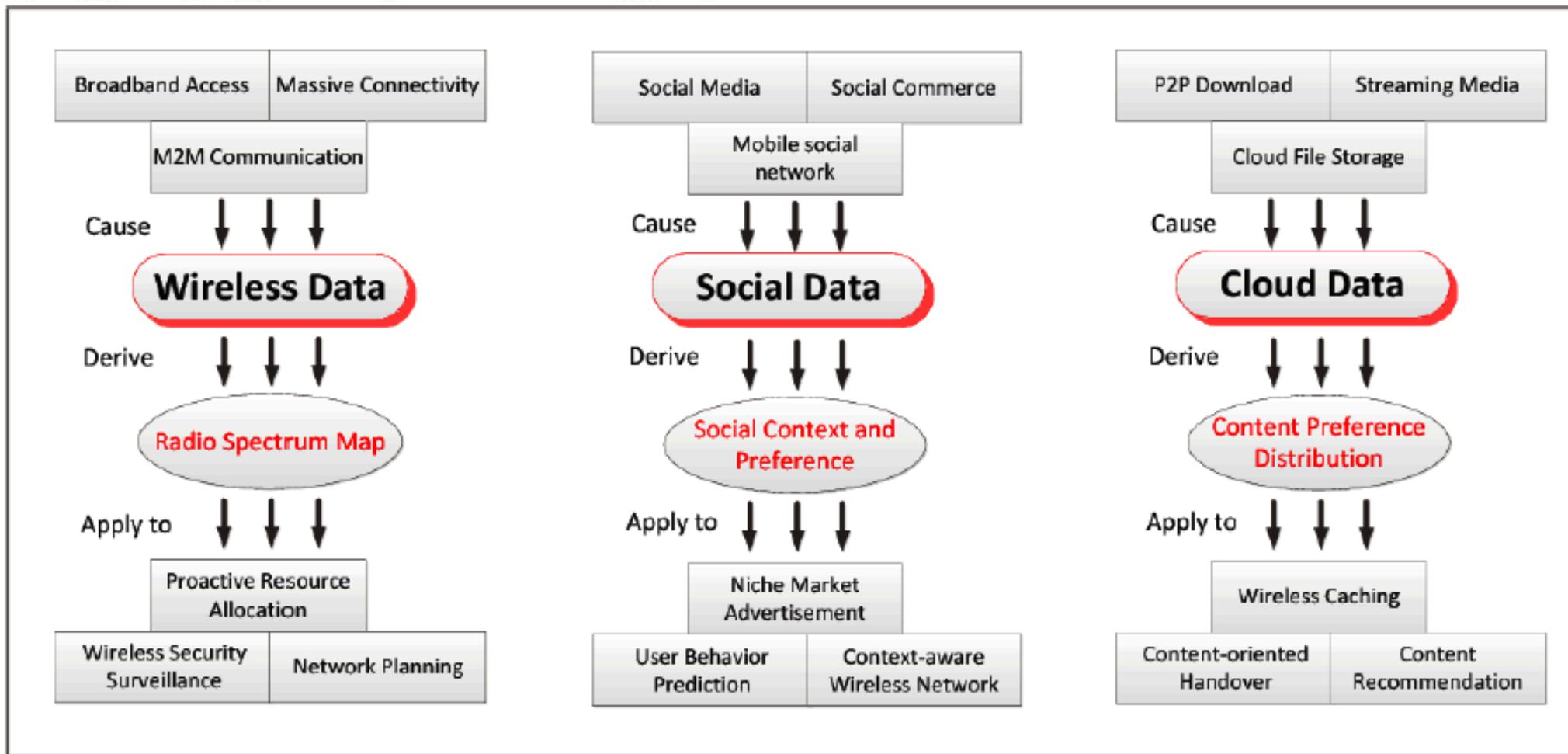
Collected from third parties (external factors, subscriber-related)

Structured Data

Demographic data, mapping data (terrain, in-building, etc), public data (traffic, weather).

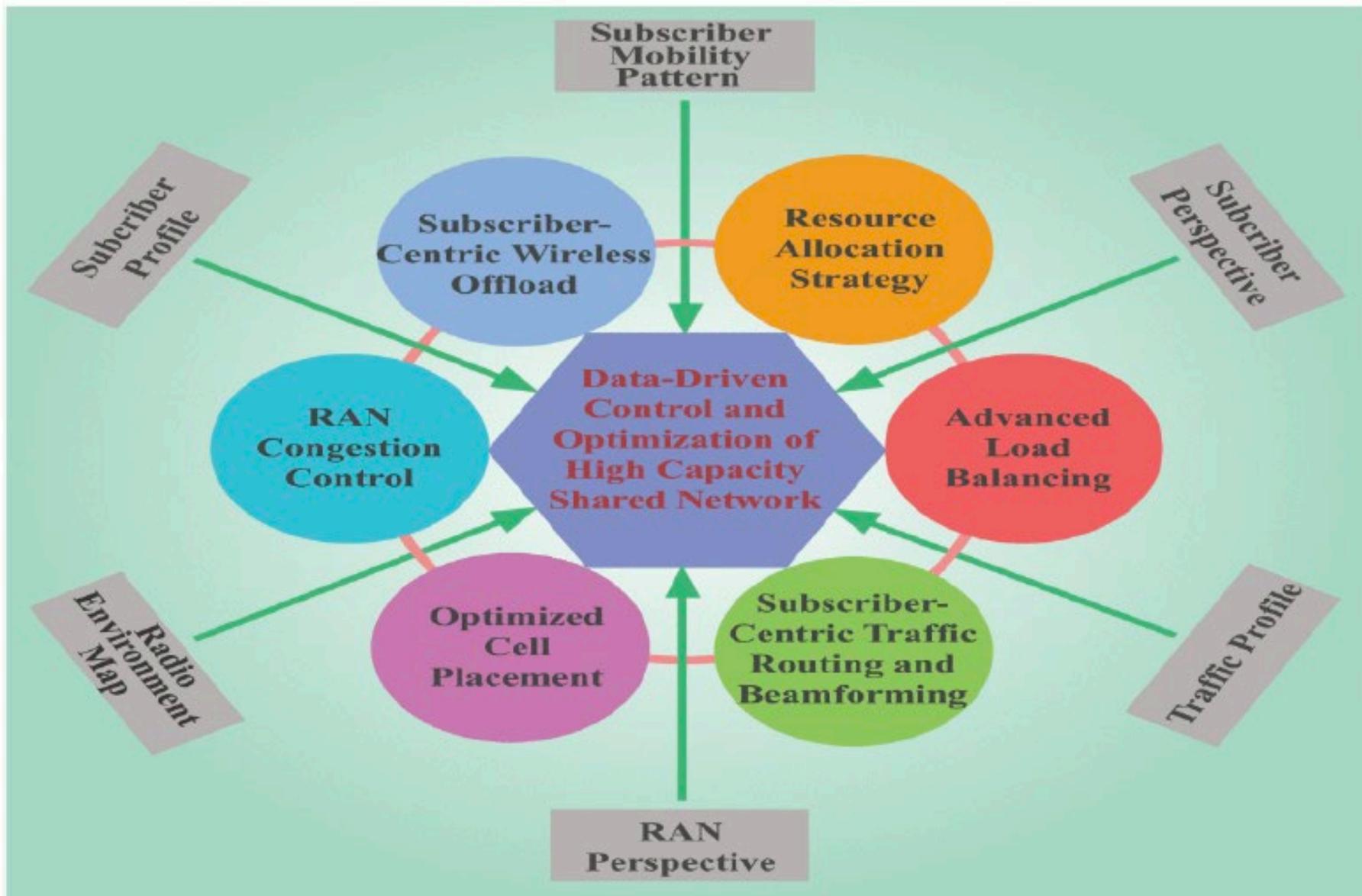
Unstructured Data

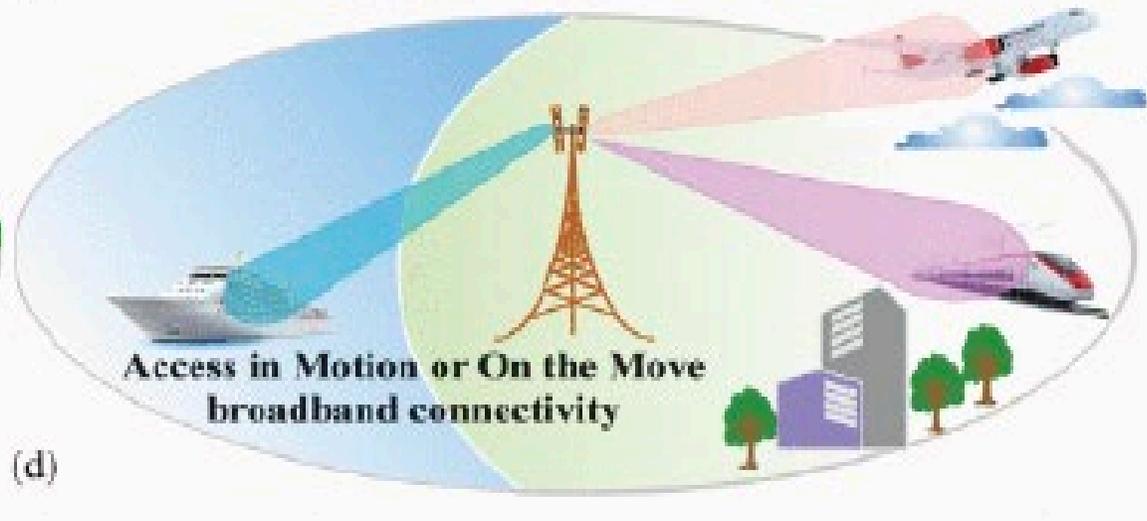
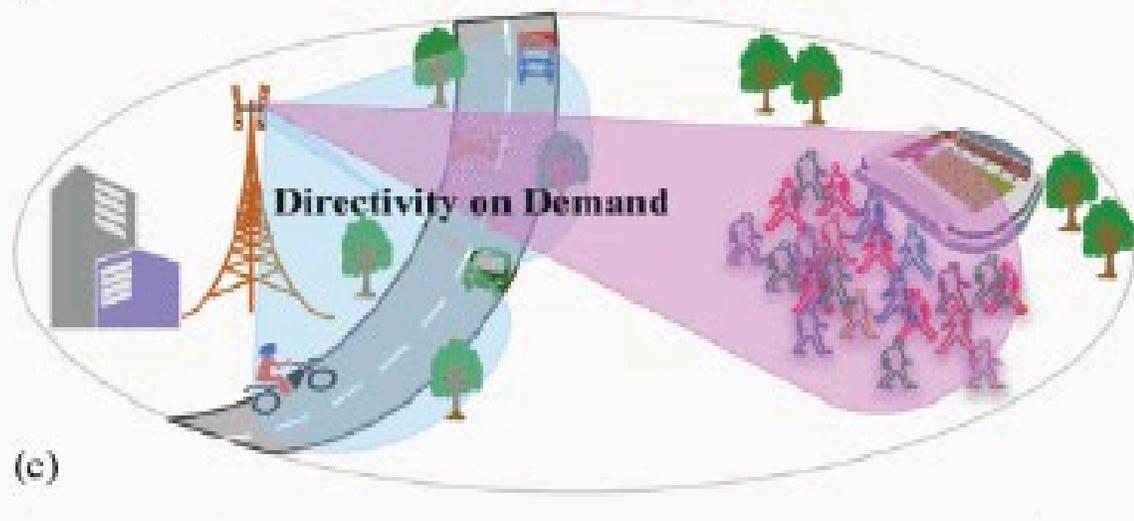
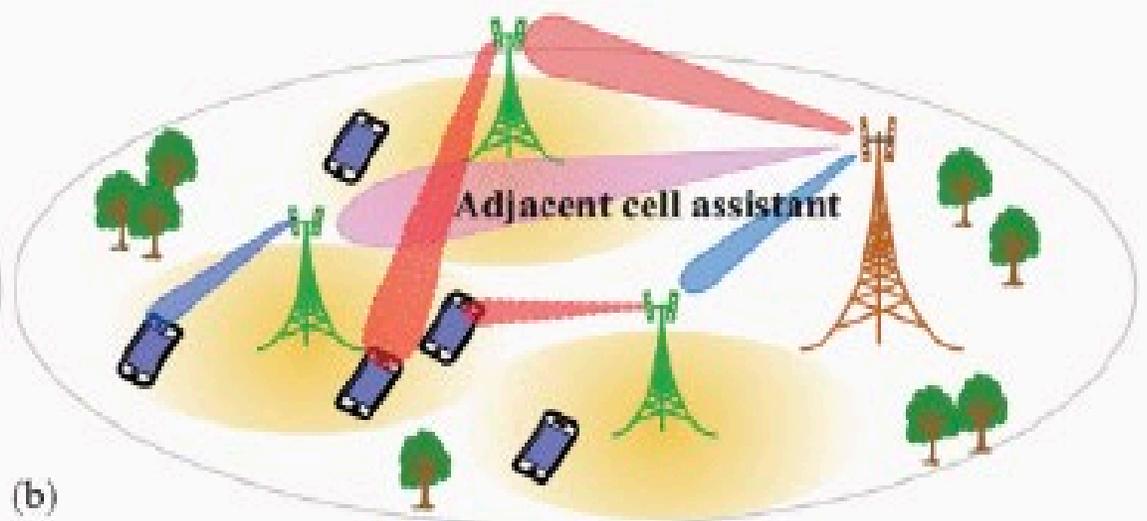
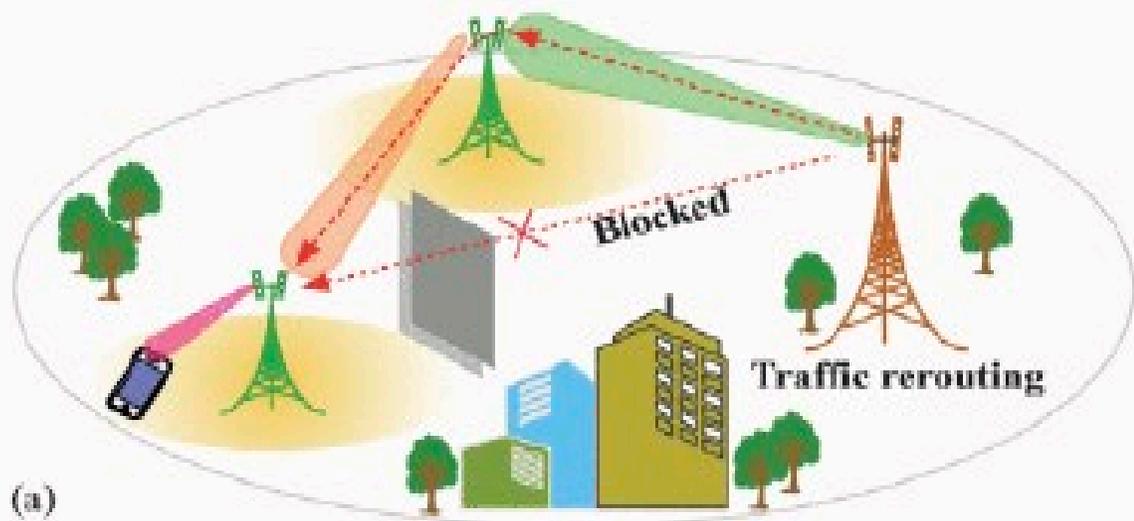
Social media data- Facebook, Twitter, online forums, text documents, Google+, blogs, e-mails, video, etc.



The sources of the wireless big data, its applications, and the hidden information in the networks

How AI applications can help in enhancing the effectiveness in the next-generation wireless networks





Guided by AI, technologies can help in beamforming and adjusting in the next-generation wireless network

AI4Net

- Artificial Intelligence (AI) for communication networks (AI4Net),
 - On how the network can profit from AI or Machine Learning (ML).
- Example
 - Network Data Analytics Function (NWDAF) of **5G Advanced**.
 - Control Plane (CP) Network Function (NF) provides (AI/ML-generated) analytics to other NFs, which leverage them to improve network operation.
 - Example: predictions about expected traffic loads or users' mobility patterns

Net4AI

Communication Network for AI

- Complexities inherent in emerging AI applications challenging edge devices
 - Storing data and Performing local inference
- Split-AI Paradigm vertically split Neural Networks (NN) into two (or more) parts.
- While one part is executed at a first node (e.g. the UE), the other part is executed at a second node (e.g. the mobile base station, or alternative edge devices).
- The potential of Split-AI to improve Key Performance Indicators (KPI)
 - UE energy consumption, inference latency, or network traffic overhead
 - Recognized by standardization bodies

INCaS-AI

- In-Network Computing (INC), computations are moved to the network elements.
- Offering compute capabilities along the path data traverse, and within networking elements, could reduce the inference time.
- INC offers excellent potential for Split-AI, enhancing expected KPIs.
- Combination of INC and Split-AI as INC-assisted Split-AI (INCaS-AI), and analyze its architectural requirements on 6G.
- In 6G network, INCaS-AI is an example of use case for Net4AI

Integrated Sensing and Communication

- With the advent of the multimodal immersive communication system, people can interact with each other using multiple devices for sensing, communication and/or application-level control either onsite or remotely.
- A distributed sensing, computing, communications, and control (DS3C) fabric is conceived for provisioning this 6G service
- The DS3C fabric can be further enhanced by natively incorporating intelligent algorithms for network automation and managing networking, computing, and sensing resources efficiently to serve vertical use cases with extreme and/or conflicting requirements.

Use Case : Robot fleet Control

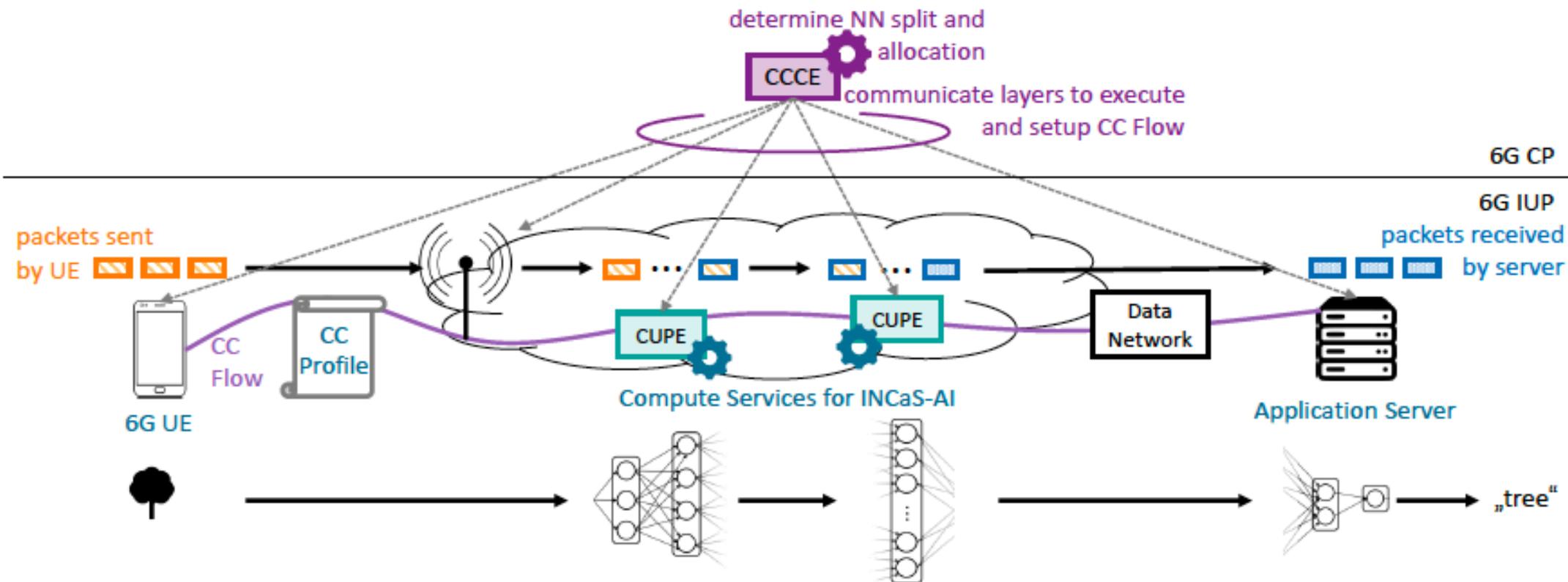
- Robot fleets can be defined as groups of agents that act autonomously based on information from their sensors but are coordinated to perform several tasks (e.g., motion planning).
- Instead of centralised controller, in decentralised management each agent takes its own decisions (self-management), providing improvements in terms of fleet scalability.
- Limited embedded computation resources in mobile robots and reduced perception from the environment make its implementation difficult.
- The use of INC and Split-AI techniques can solve these drawbacks by offering access to AI algorithms from the mobile robots at the lowest latency.
- This application could improve accuracy in task execution, considering the current use of ML for task allocation and path planning.

Using ISAC in 6G

- **Integrated Sensing and Communications (ISAC), when added to Split-AI**
 - provide improved environmental information that enhances individual agent navigation.
- This ensure higher accuracy in movements, even in dynamic environments where improved self-localization and fast response are necessary to avoid collisions with mobile obstacles.
- All these developments may reduce energy costs for industry verticals and positively impact socio-economic factors

Net4AI Architecture

- Example: Object Recognition



Distributed Sensing, Computing, Communication, and Control in 6G

Projected Scenario -1

- Sumit is at Gate 23 of an airport and would like to e-mail his edited files through wireless connection, but the bandwidth is miserable
- Byapto, the pervasive computing environment, detects the situation, consults airport servers, and finds Gate 15 will have no flight in 1.5 hour
- Byapto suggests Sumit to go to Gate 15 and prioritize his email
- Sumit accepts the suggestions
- Files are transmitted at Gate 15 and Byapto informs Sumit when he needs to be back to gate

Projected Scenario-2

- Pooja has to walk to a meeting from her office to give a presentation, but she is not quite ready yet
- Pooja grabs a handheld computer and starts walking to the meeting
- Byapto transfers her state from desktop to handheld, and Pooja does final editing with voice
- Byapto infers Pooja's schedule, downloads materials to projection computer and warms up projector
- Room's face detection system recognizes some unfamiliar faces and advises Pooja not to show sensitive data

Key Aspects

- Scenario 1:
 - Proactivity: Byapto can estimate how long the whole process takes and look ahead on his behalf
 - Combining knowledge from different layers: wireless congestion and boarding time
 - Smart space: provide information of wireless BW, flight time and gates, distance between gates
- Scenario 2:
 - Moving execution state across diverse platforms
 - Automatic adjusting behavior to fit circumstances: voice inputs
 - Pro-activity and smart space

The Model

- Each user is immersed in a sensing, communication & computing space that mediates all interactions with the pervasive elements in surroundings
- Design aspects
 - System design: wearable computer? personal assistant? what sensors and networking?
 - Context aware: how to know user's state and surrounding, and modify behavior
 - How to cooperate and interact with infrastructure? with other persons?

Conclusions

- AI has become an integral ubiquitous part of the next-Gen network
- 6G can make AI available as service - AlaS
- Expected to make disruptive impact in industry, health, fintech, agriculture – social fabric
- Ethical management and trustworthy services are questions which need deeper deliberations

References

- *Native Support of AI Applications in 6G Mobile Networks via an Intelligent User Plane* IEEE Conf. on Communication and Wireless Networks 2024
- *Distributed Sensing, Computing, Communication, and Control Fabric: A Unified Architecture for new 6G era*, IEEE Conf. on Communication and Wireless Networks 2024

Thank you