Unleashing the Power of 6G-'beyond 5G'

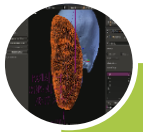
A ROBERT J RAVI. I.T.S
Dy Director General
Department of Telecom
Ministry of Communication

02 fEB 2024

6G: Driving Applications

Digital Agriculture and industrial

Smart hydro power vehicles



Digital Replica

Av/VR multisensory applications

Bio-Nano Internet of things Molecular Communication

Tangible internet

Holographic communication

Man, machine, object, genie -semantic?

6G: Driving Applications

Multisensory XR Applications

Connected robotics and Autonomous Systems

Wireless Brain-Computer Interactions

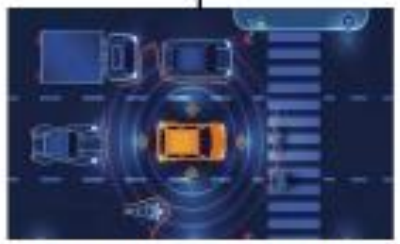
Blockchain and Distributed Ledger Technologies

Immersion education

Telecommuting

Metaverse applications

Smart cities

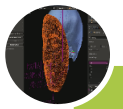


Product testing

Production optimization

Digital Agriculture and industrial

Smart hydro power vehicles

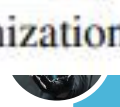


Digital Replica

Av/VR multisensory applications

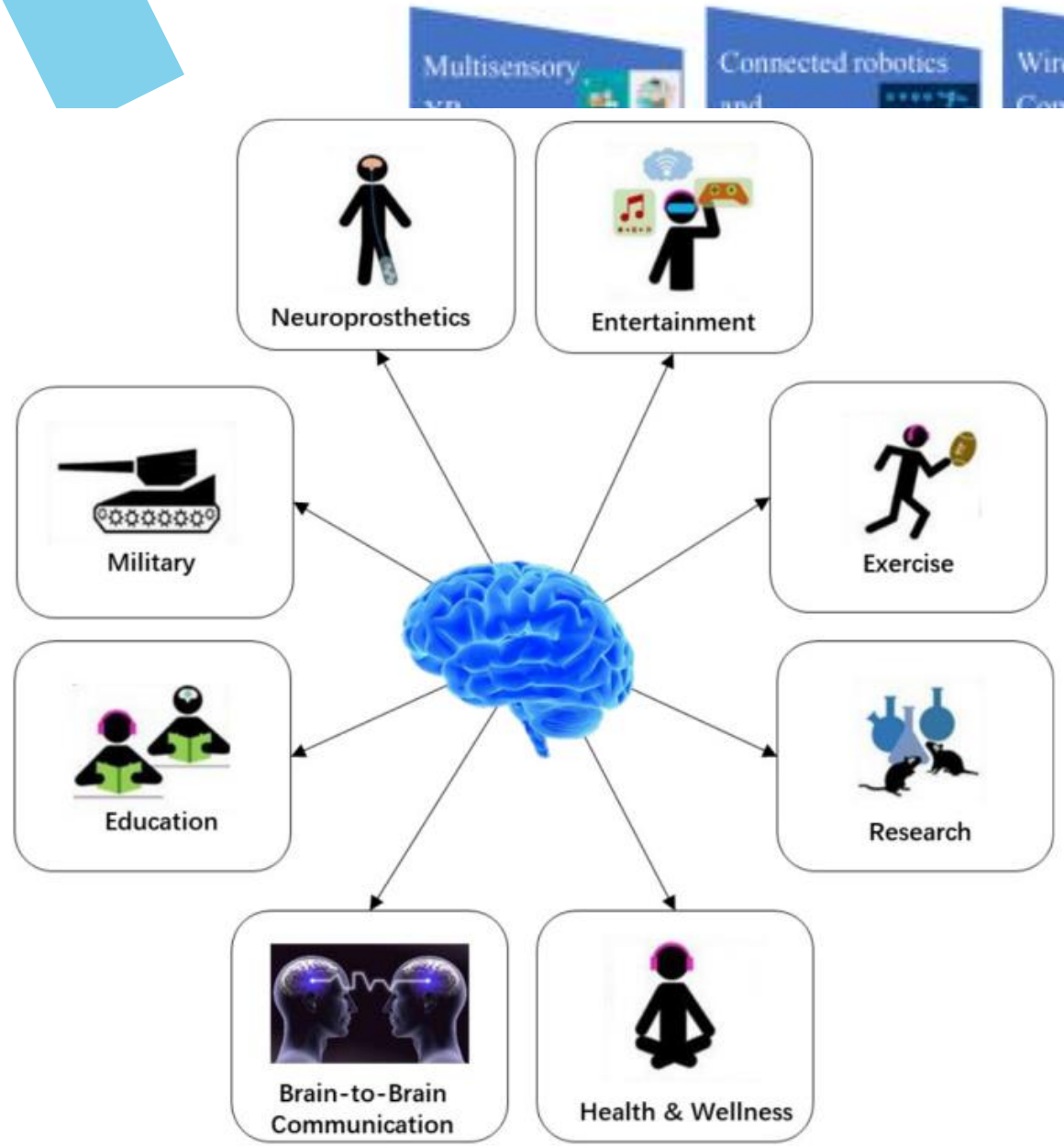
Bio-Nano Internet of things Molecular Communication

Tangible internet



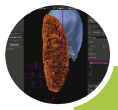
Holographic communication

6G: Driving Applications



Digital Agriculture and industrial

Smart hydro power vehicles



Digital Replica

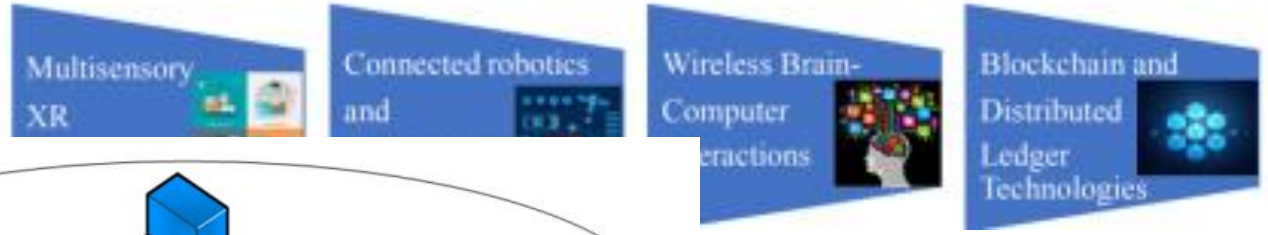
Av/VR multisensory applications

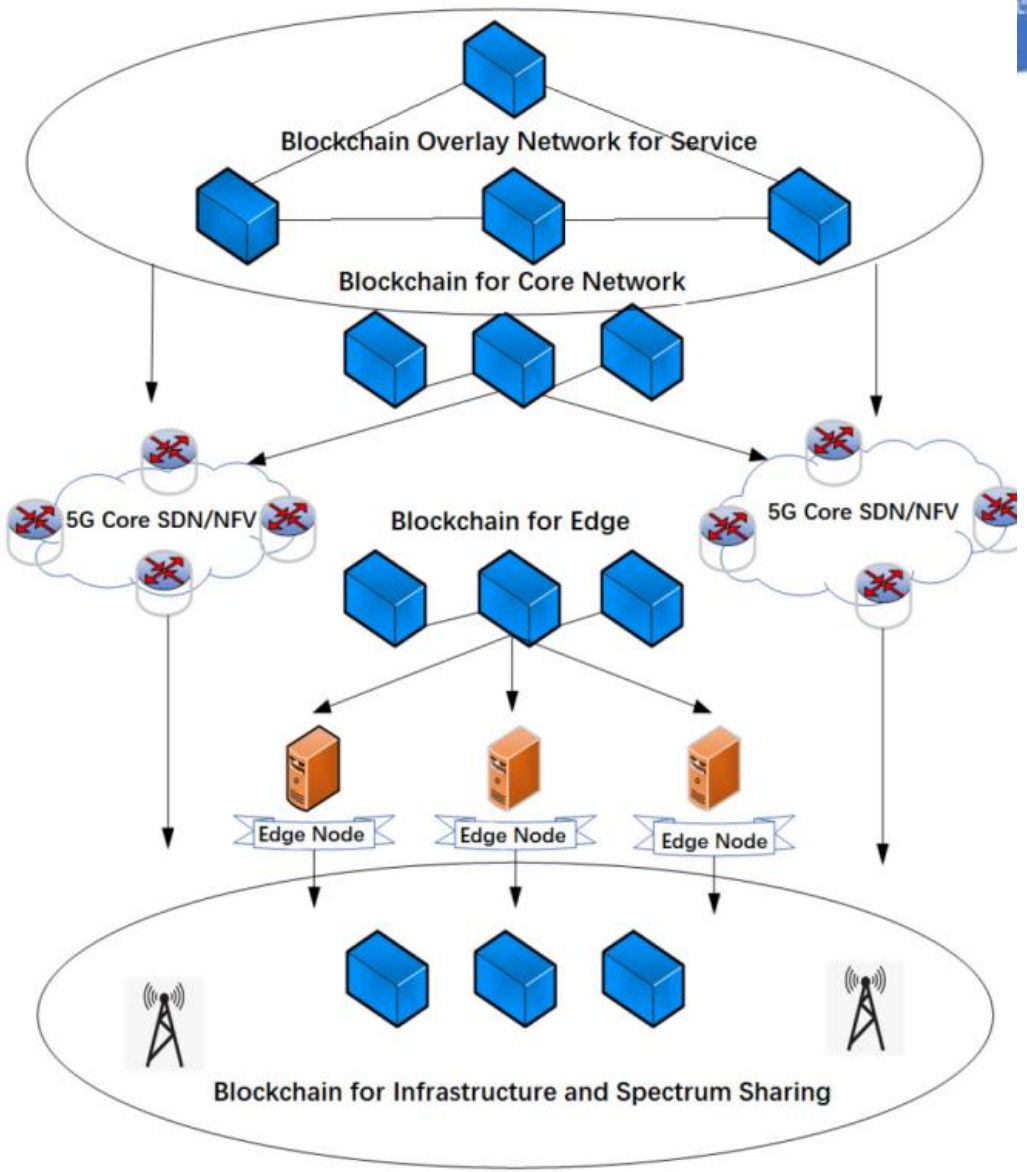
Bio-Nano Internet of things Molecular Communication

Tangible internet

Holographic communication

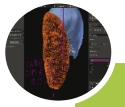
6G: Driving Applications





Digital Agriculture and industrial

Smart hydro power vehicles



Digital Replica

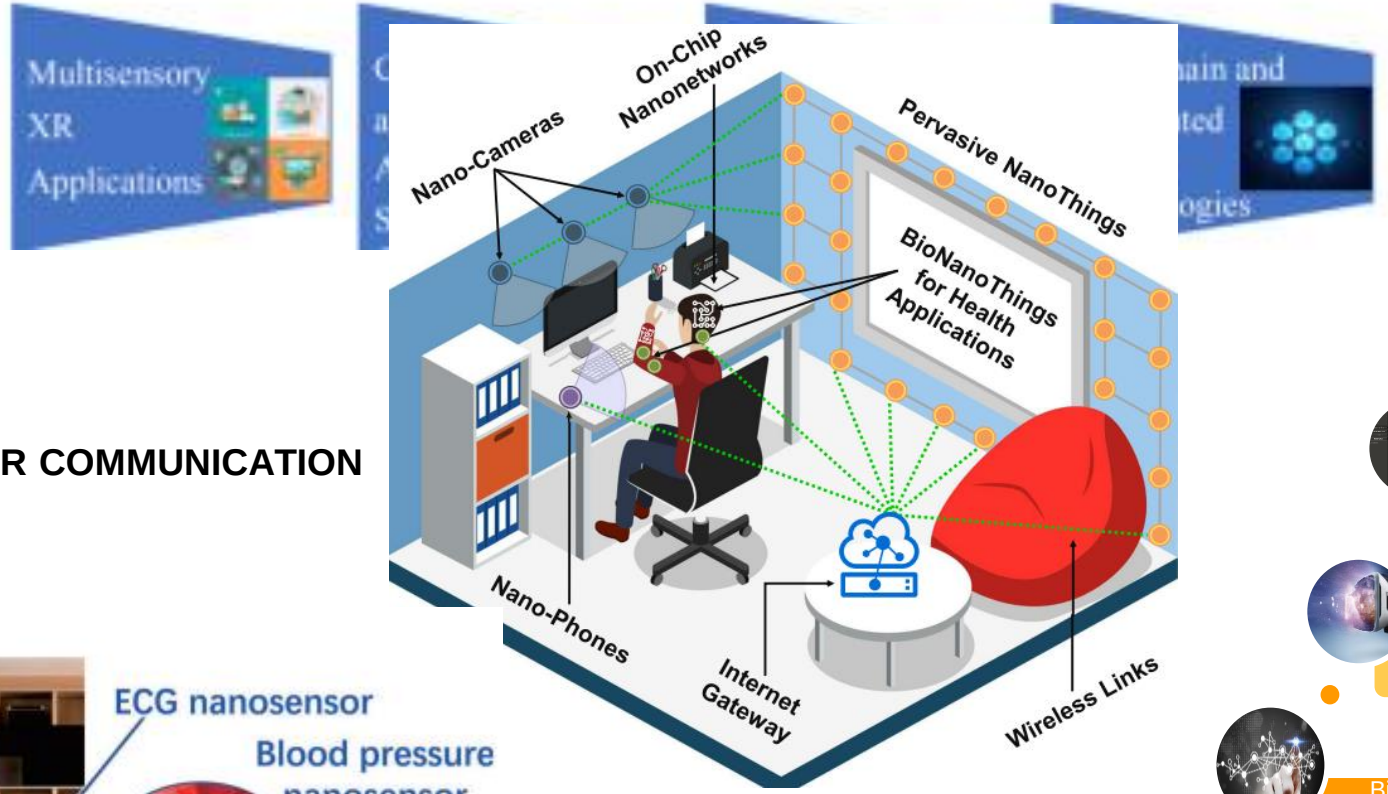
Av/VR multisensory applications

Bio-Nano Internet of things Molecular Communication

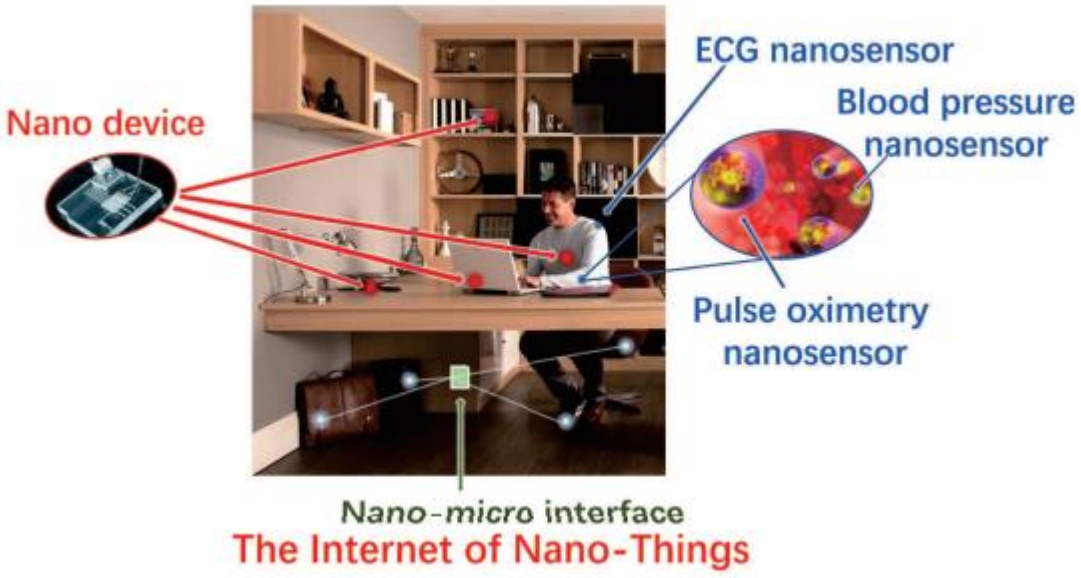
Tangible internet

Holographic communication

6G: Driving Applications

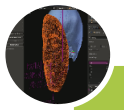


MOLECULAR COMMUNICATION



Digital Agriculture and Industrial

Smart hydro power vehicles



Digital Replica

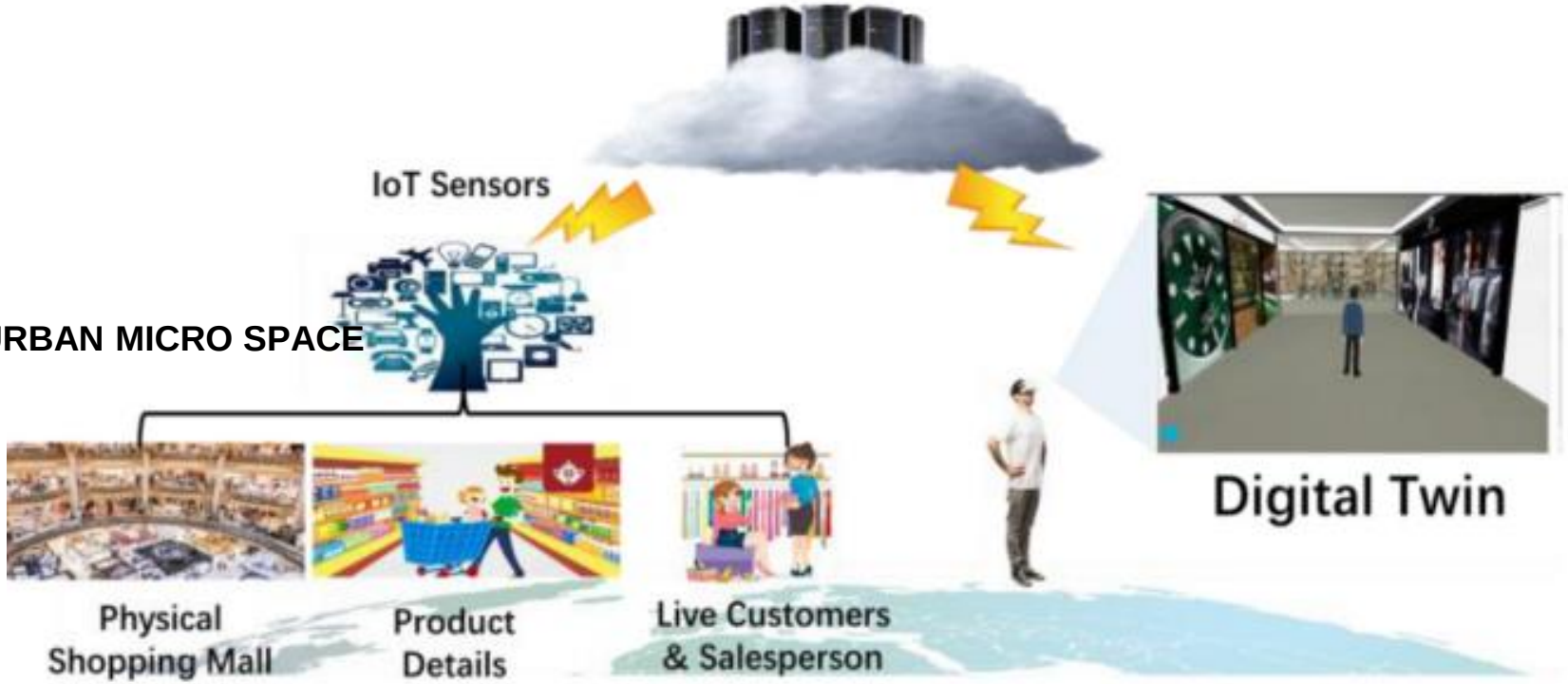
Av/VR multisensory applications

Bio-Nano Internet of things Molecular Communication

Tangible internet

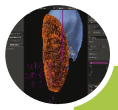
Holographic communication
Health etc

6G: Driving Applications



Digital Agriculture and industrial

Smart hydro power vehicles



Digital Replica

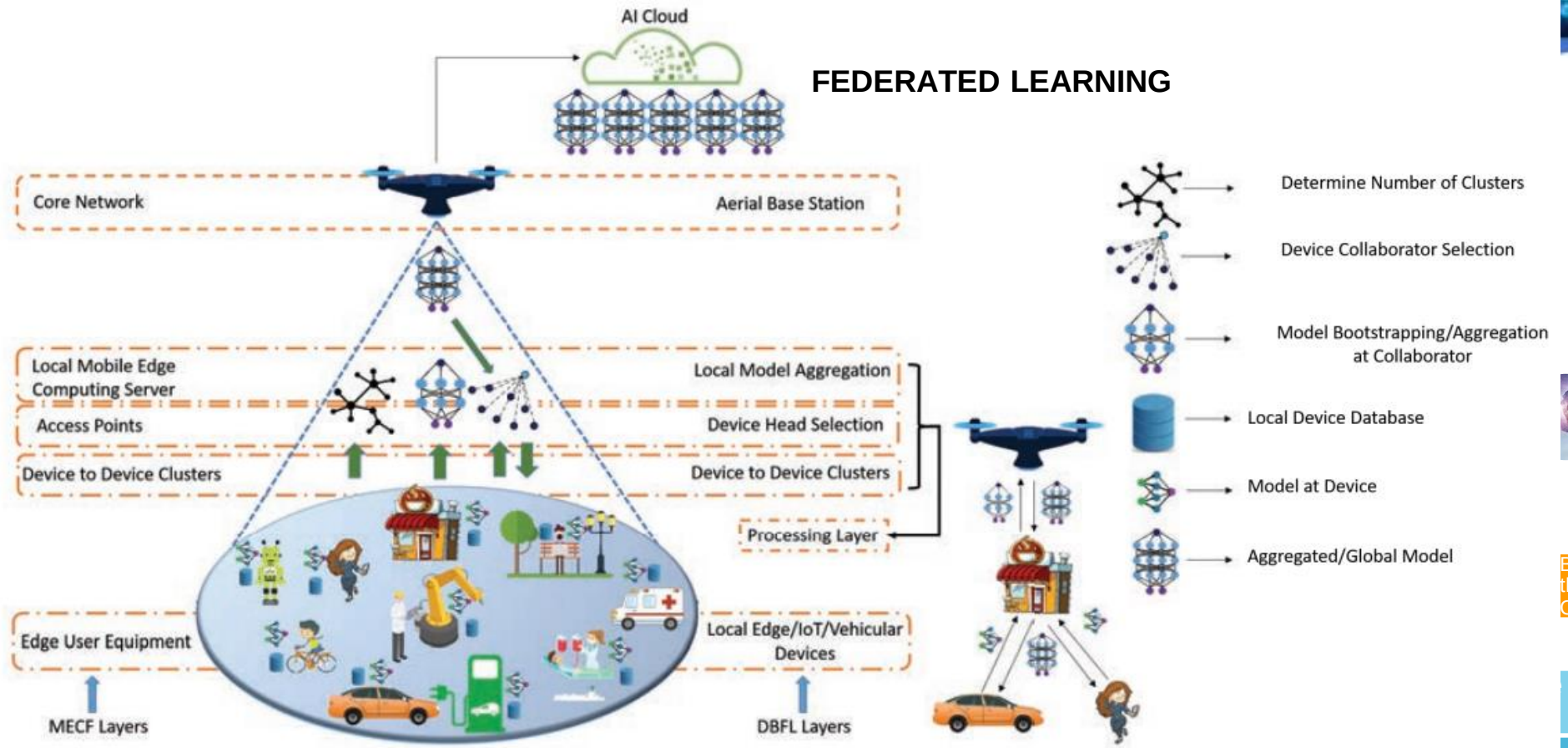
Av/VR multisensory applications

Bio-Nano Internet of things Molecular Communication

Tangible internet

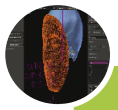
Holographic communication

6G: Driving Applications



Digital Agriculture and industrial

Smart hydro power vehicles



Digital Replica

Av/VR multisensory applications

Bio-Nano Internet of things Molecular Communication

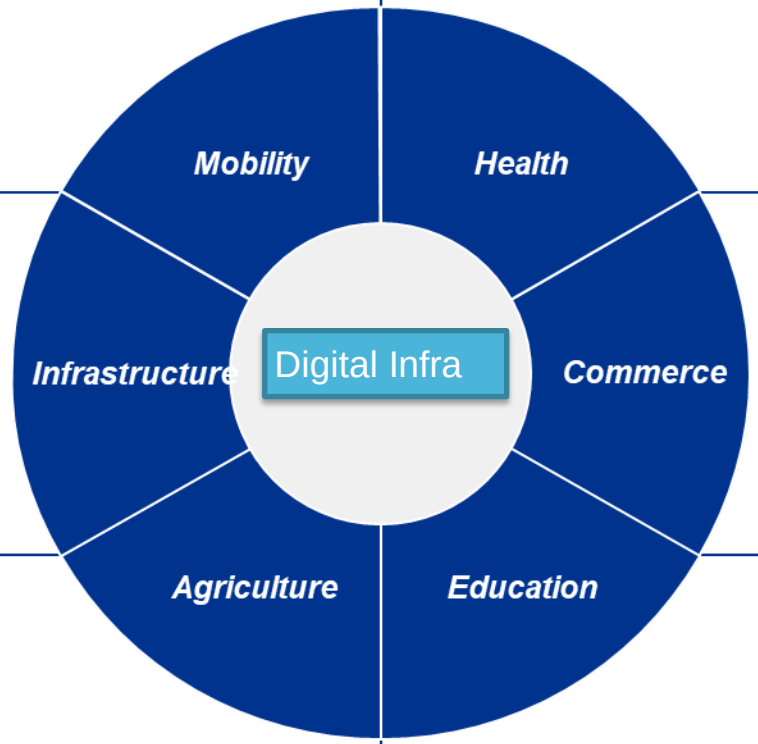
Holographic communication

Digital Infrastructure

Mobility
- Roads data
- Vehicles
- Traffic Data

Health
- Personal Heath
- Hospital Stats
- Medicine Sales
- Insurance Stats

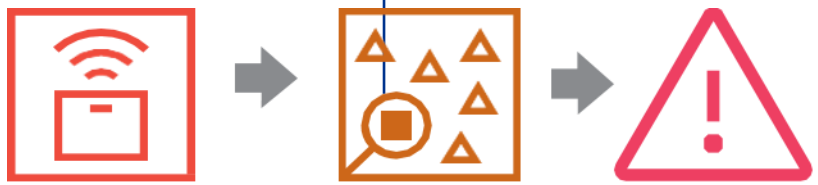
Infrastructure
- Buildings
- Airports
- Ports



Commerce
- Payments
- Taxes & Sales
- Inventory
- Logistics

Agriculture
- Farm data
- Subsidies
- Sales

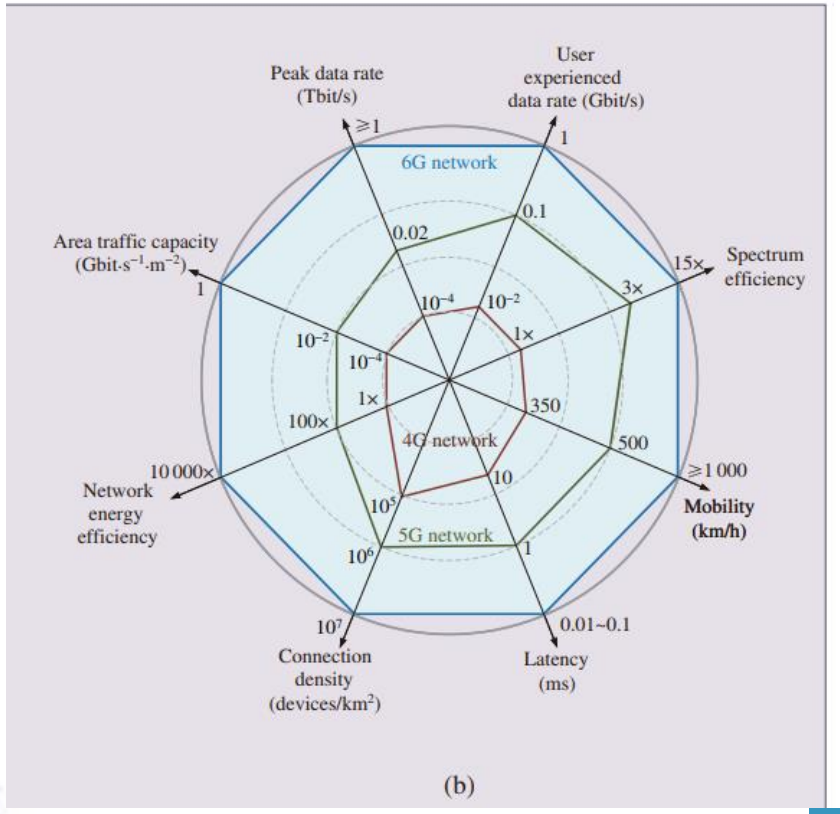
Education
- Personal Education Records
- Competitive Exams



Place sensors around the city

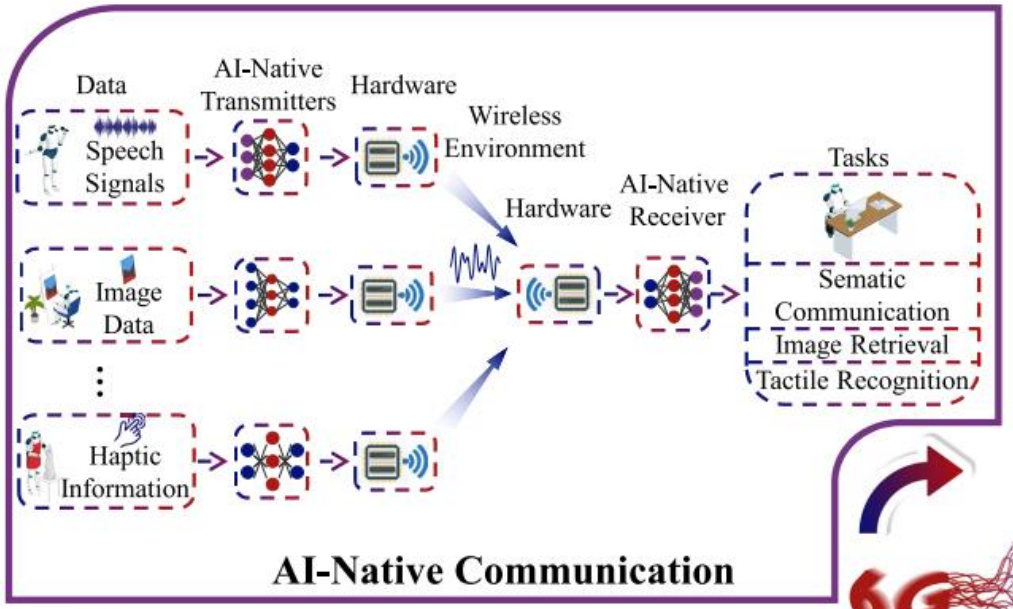
Build a simulation model

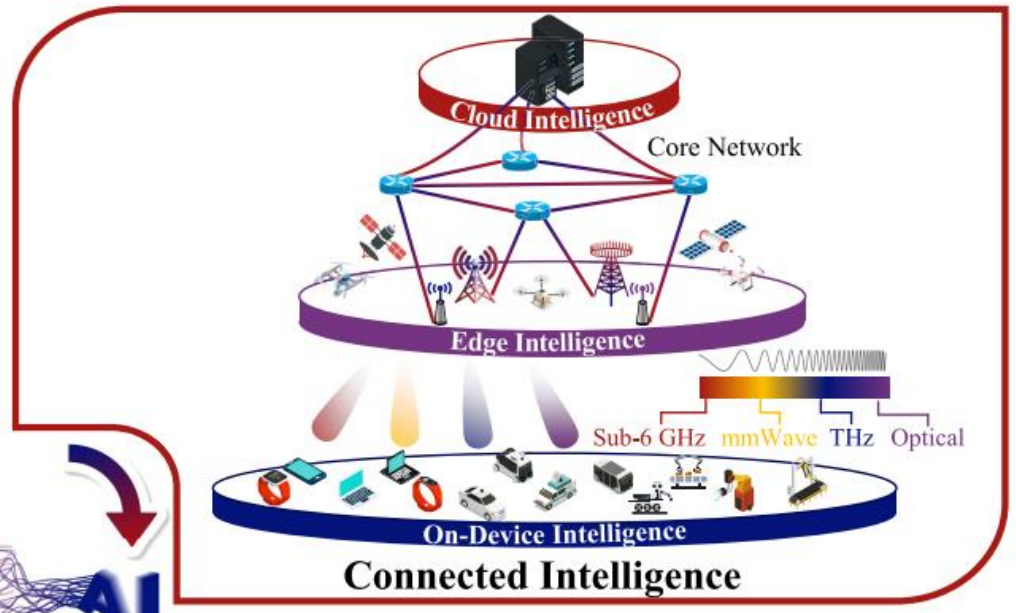
Provide a disaster risk map and disaster alert service;
Weather pattern;
Crime Analysis etc

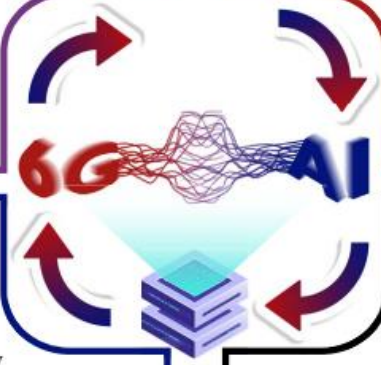


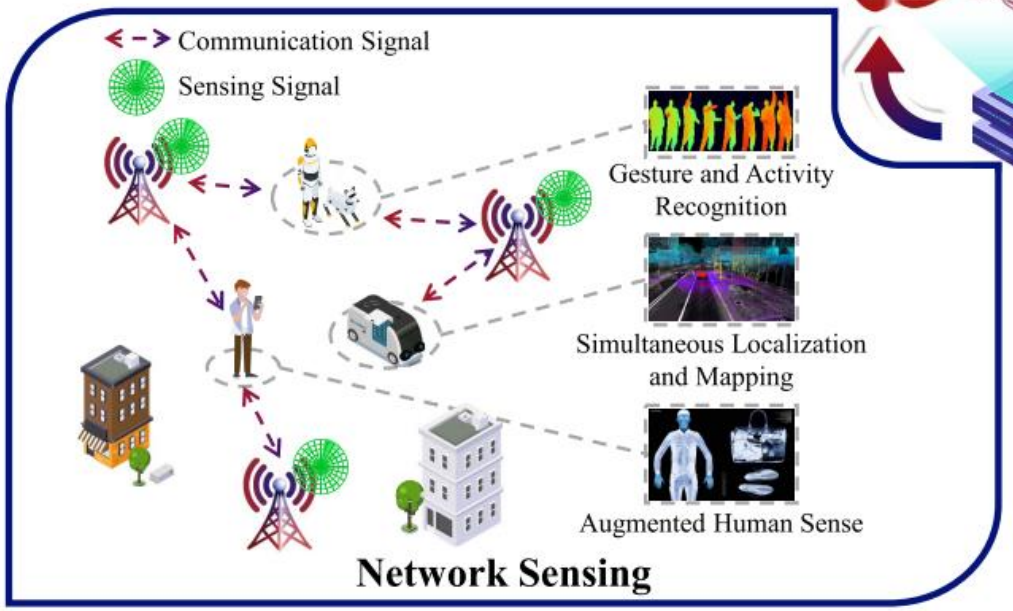
6G: Driving Trends

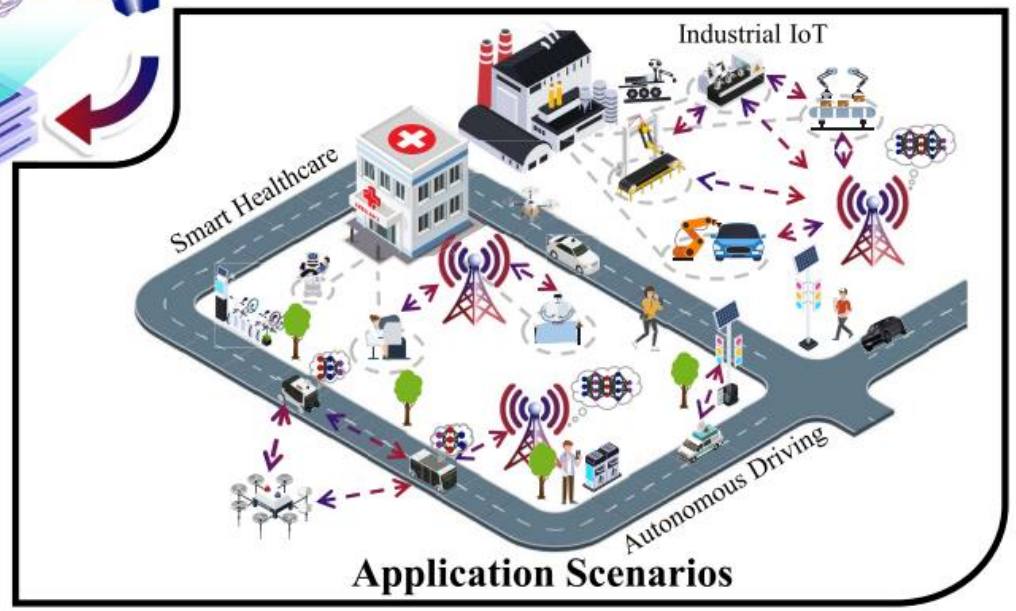
Edge AI empowered 6G networks

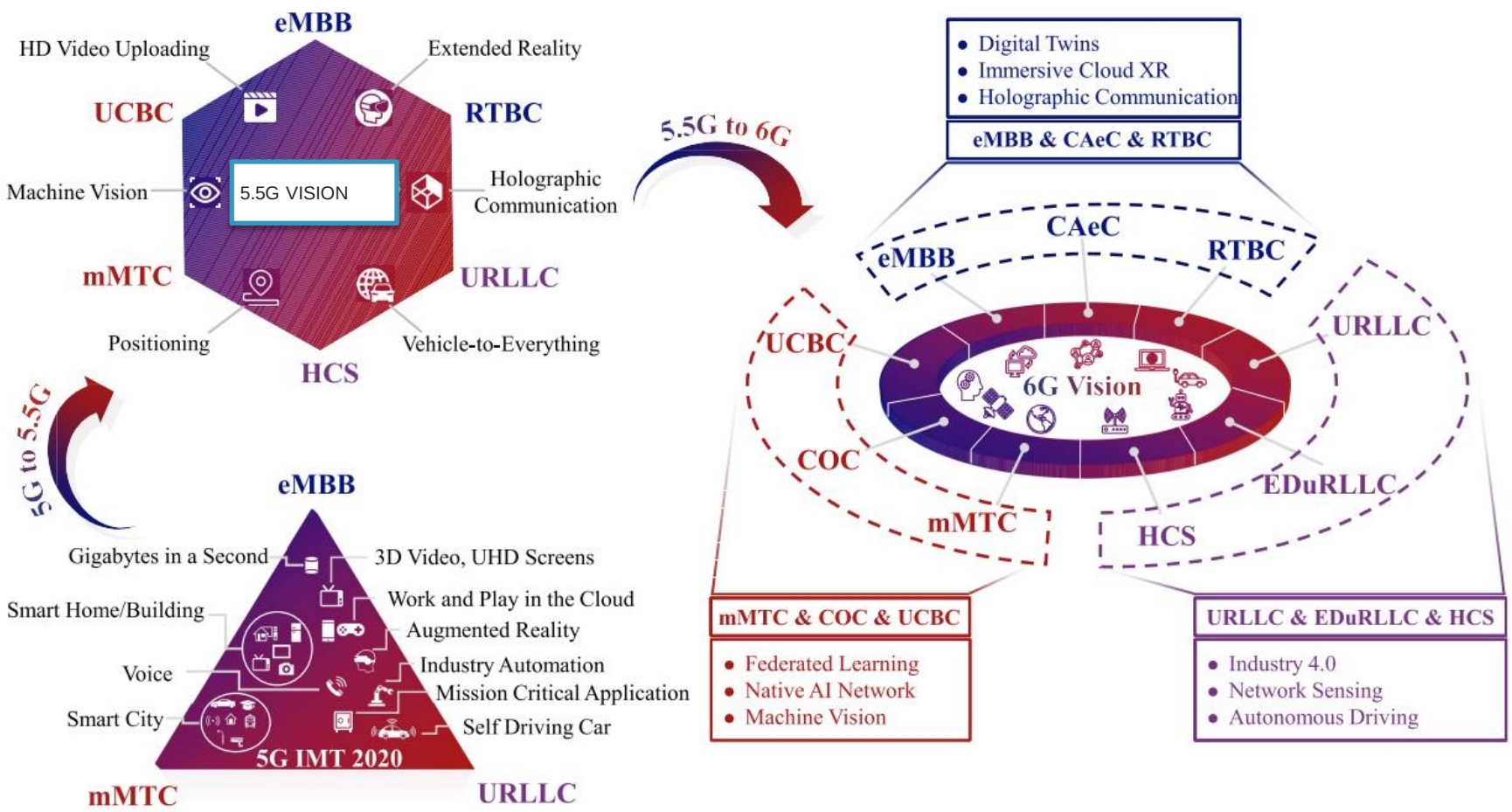


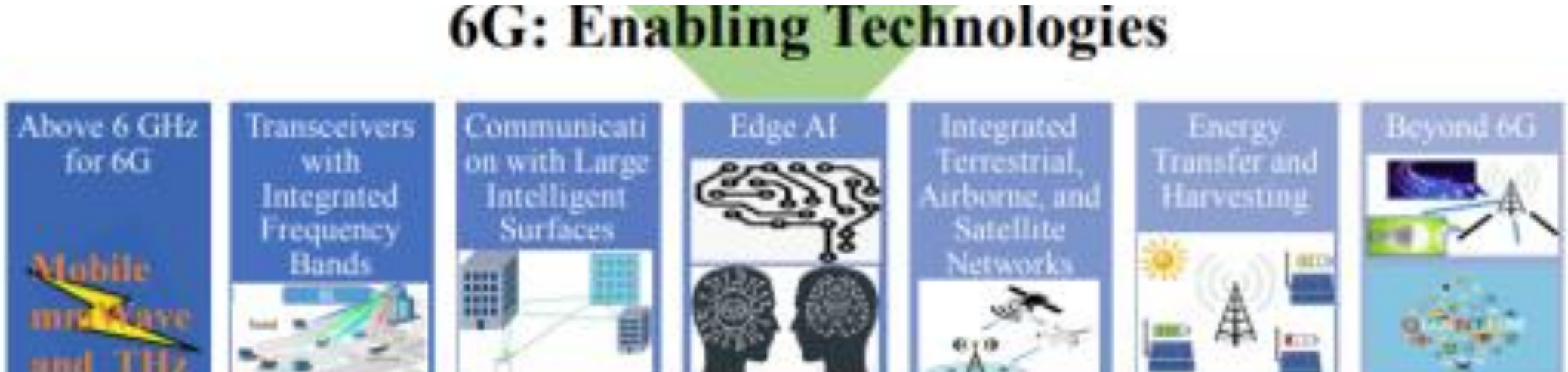


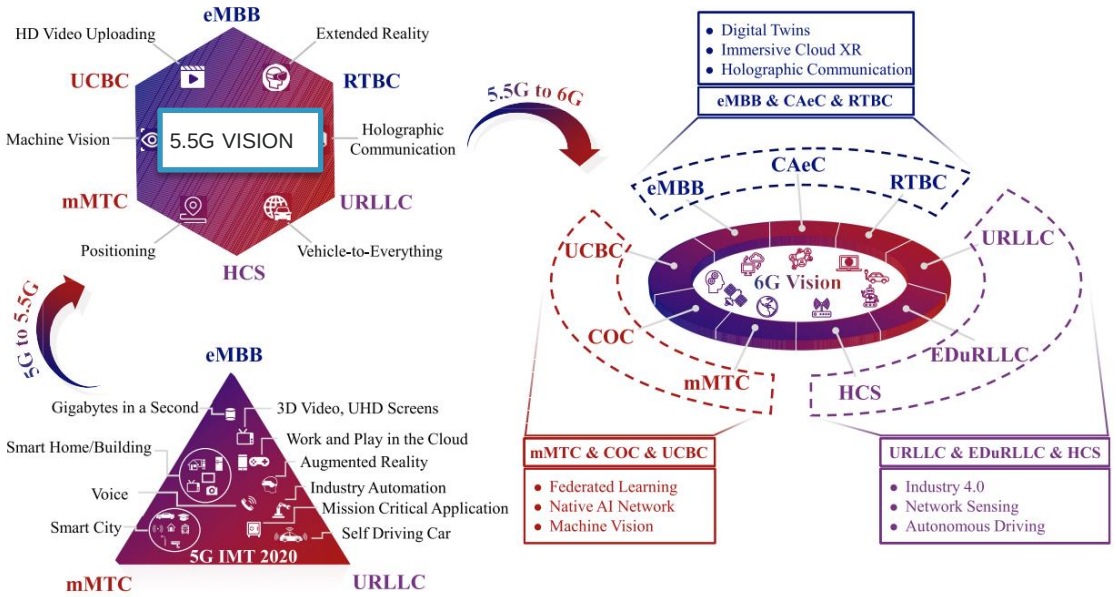


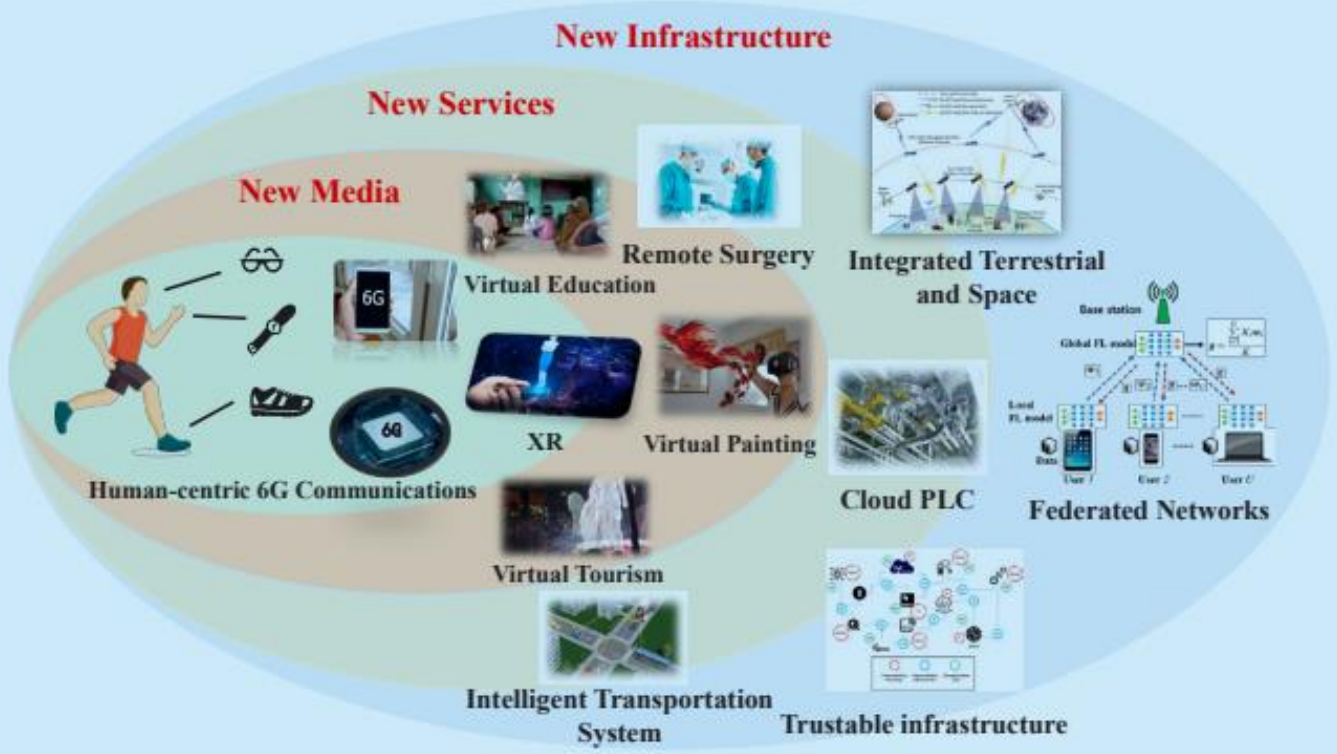


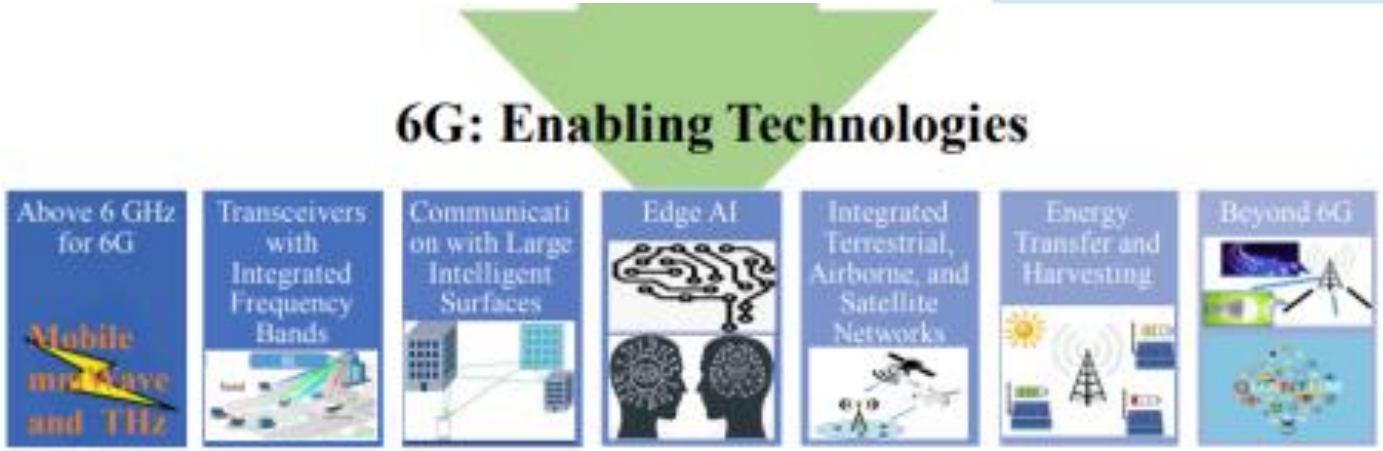


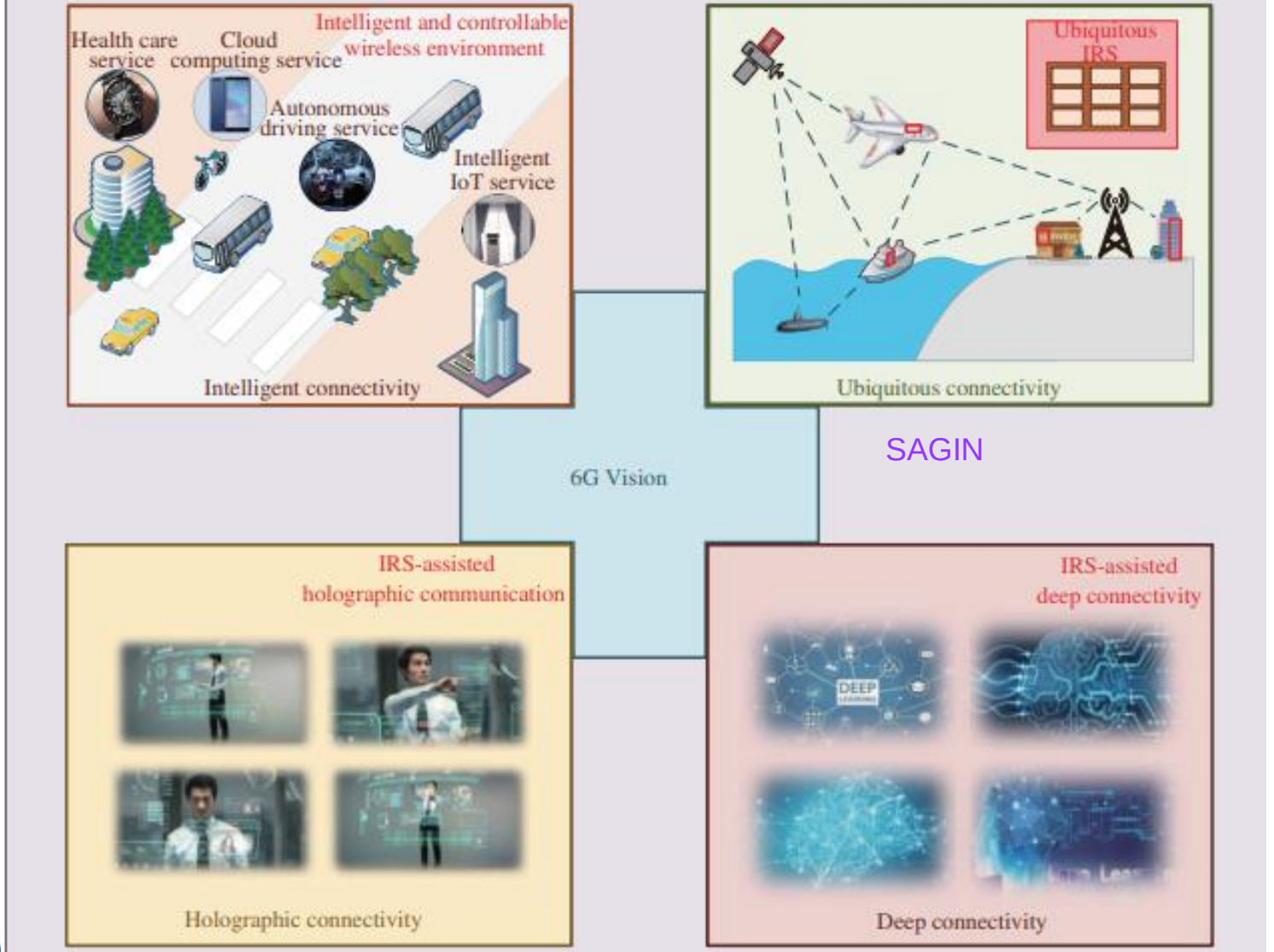

eMBB
HD Video Uploading
Extended Reality
UCBC
RTBC
Machine Vision
5.5G VISION
Holographic Communication
mMTC
URLLC
Positioning
Vehicle-to-Everything
HCS
5.5G to 6G
• Digital Twins
• Immersive Cloud XR
• Holographic Communication
eMBB & CAeC & RTBC
CAeC
eMBB
RTBC
UCBC
URLLC
6G Vision
COC
EDuRLLC
mMTC
HCS
mMTC & COC & UCBC
• Federated Learning
• Native AI Network
• Machine Vision
URLLC & EDuRLLC & HCS
• Industry 4.0
• Network Sensing
• Autonomous Driving
5G to 5.5G
eMBB
Gigabytes in a Second
3D Video, UHD Screens
Work and Play in the Cloud
Smart Home/Building
Augmented Reality
Industry Automation
Voice
Mission Critical Application
Smart City
Self Driving Car
5G IMT 2020
mMTC
URLLC


6G: Enabling Technologies
Above 6 GHz for 6G
Transceivers with Integrated Frequency Bands
Communicati on with Large Intelligent Surfaces
Edge AI
Integrated Terrestrial, Airborne, and Satellite Networks
Energy Transfer and Harvesting
Beyond 6G

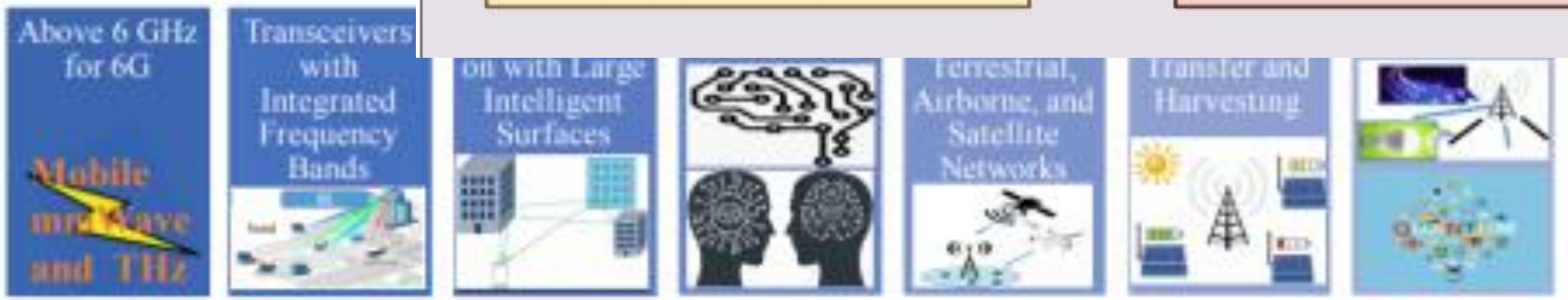

eMBB
HD Video Uploading
Extended Reality
UCBC
RTBC
Machine Vision
5.5G VISION
Holographic Communication
mMTC
URLLC
Positioning
Vehicle-to-Everything
HCS
5.5G to 6G
4G to 5.5G
eMBB
Gigabytes in a Second
3D Video, UHD Screens
Work and Play in the Cloud
Smart Home/Building
Augmented Reality
Industry Automation
Voice
Mission Critical Application
Smart City
Self Driving Car
5G IMT 2020
mMTC
URLLC
Digital Twins
Immersive Cloud XR
Holographic Communication
eMBB & CAeC & RTBC
CAeC
eMBB
RTBC
UCBC
URLLC
6G Vision
COC
EDuRLLC
mMTC
HCS
mMTC & COC & UCBC
Federated Learning
Native AI Network
Machine Vision
URLLC & EDuRLLC & HCS
Industry 4.0
Network Sensing
Autonomous Driving


New Infrastructure
New Services
New Media
Remote Surgery
Integrated Terrestrial and Space
Virtual Education
6G
XR
Virtual Painting
Human-centric 6G Communications
Cloud PLC
Federated Networks
Virtual Tourism
Intelligent Transportation System
Trustable infrastructure


6G: Enabling Technologies
Above 6 GHz for 6G
Mobile mmWave and THz
Transceivers with Integrated Frequency Bands
Communicati on with Large Intelligent Surfaces
Edge AI
Integrated Terrestrial, Airborne, and Satellite Networks
Energy Transfer and Harvesting
Beyond 6G


Health care service
Cloud computing service
Intelligent and controllable wireless environment
Autonomous driving service
Intelligent IoT service
Intelligent connectivity
Ubiquitous IRS
Ubiquitous connectivity
6G Vision
IRS-assisted holographic communication
Holographic connectivity
IRS-assisted deep connectivity
DEEP
Deep connectivity

SAGIN


Above 6 GHz for 6G
Mobile mmWave and THz
Transceivers with Integrated Frequency Bands
Intelligent Surfaces
Terrestrial, Airborne, and Satellite Networks
Harvesting

concepts of everything-connected-to-the-network and everything-as-a-service

Semantic communications

ARTIFICIAL NEURAL NETWORKS FOR COMMUNICATIONS

3D call

quantum teleportation

Augumentation of Human Intelligence

GENETIC PROGRAMMING

Back scatter communication

HC2WA framework

QUANTUM AND QC-ASSISTED COMMUNICATIONS

DEEP LEARNING FOR COMMUNICATIONS

Model Acoustic Meta Learning

Federated Learning

Spectrum Sensing - Blind detection/Eigen Value detection/ cyclco-stationary

QUANTUM TECHNOLOGY AND QML-ASSISTED COMMUNICATIONS

Quantum-assisted SatCom systems

Time Convergence

QUANTUM SVMS AND ANNS

Six Sense Communication Network

Hybrid front-end for all spectrum sensing end to end THz com system

Multi-hop transmission system

A complete AI solution for intelligent cognitive and self-sustaining networks

Endogenous security technology

Visible Light Communications

Over The Air - Computation

Edge AI for Metaverse

New infra; info-structure; fusion-infrastructure ; innovation infra – integrates ground; UAV, satellite for global coverage

QoL. /. Generative Adversarial Networks

HOLISTIC SECURITY SOLUTION

Liquid Ionization System, and fluid-antennas

end-to-end auto-encoding, *learning at user-side, multiple access for massive connectivity,*

Cell free Macro MIMO

Nano scale applications


6G: Driving Applications
Multisensory XR Applications
Connected robotics and Autonomous Systems
Wireless Brain-Computer Interactions
Blockchain and Distributed Ledger Technologies
6G: Driving Trends
More Bits, Spectrum, Reliability
From Areal to Volumetric Spectral and Energy Efficiency
bps/Hz/ Joules/m³
Emergence of Smart Surfaces and Environments
Massive Availability of Small Data
From SON to Self-Sustaining Networks
Convergence of Communication, Sensing, Control, Localization, and Computing
End of the Smartphone Era
6G: Enabling Technologies
Above 6 GHz for 6G
Mobile mm-Wave and THz
Transceivers with Integrated Frequency Bands
Communication with Large Intelligent Surfaces
Edge AI
Integrated Terrestrial, Airborne, and Satellite Networks
Energy Transfer and Harvesting
Beyond 6G

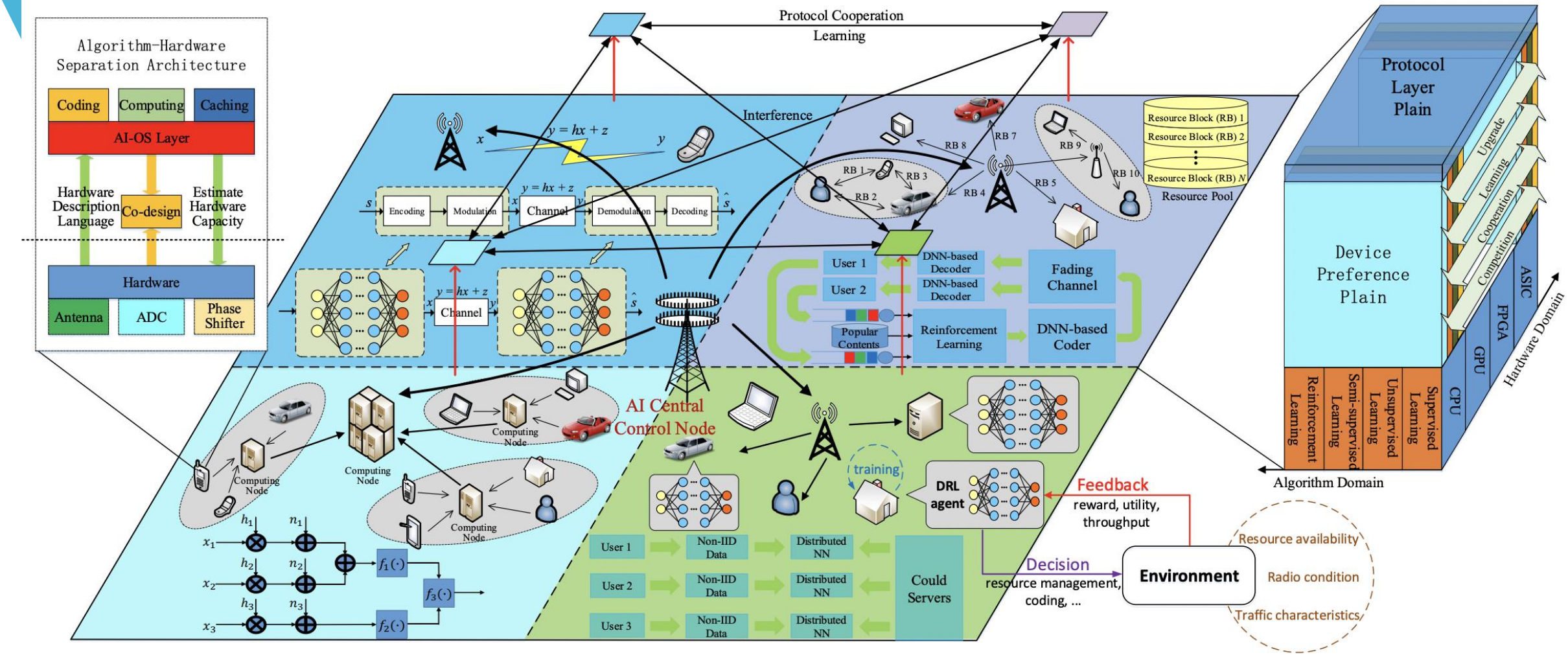
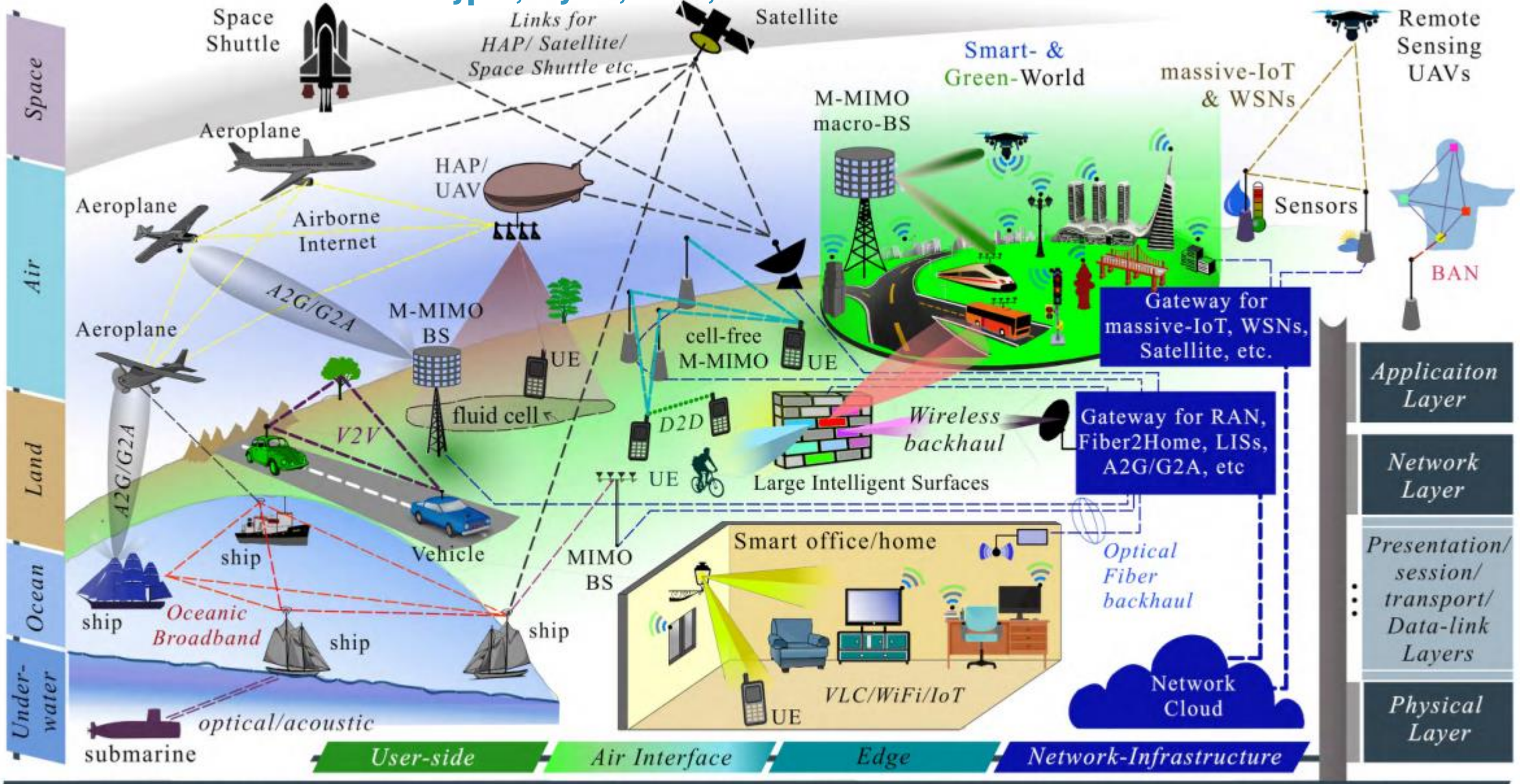

Algorithm-Hardware Separation Architecture
Coding
Computing
Caching
AI-OS Layer
Hardware Description Language
Co-design
Estimate Hardware Capacity
Hardware
Antenna
ADC
Phase Shifter
Protocol Cooperation Learning
Interference
Encoding
Modulation
Channel
Demodulation
Decoding
Resource Block (RB) 1
Resource Block (RB) 2
Resource Block (RB) N
Resource Pool
User 1
User 2
DNN-based Decoder
Fading Channel
Popular Contents
Reinforcement Learning
DNN-based Coder
AI Central Control Node
Computing Node
training
DRL agent
User 1
User 2
User 3
Non-IID Data
Distributed NN
Could Servers
Feedback
reward, utility, throughput
Decision
resource management, coding, ...
Environment
Resource availability
Radio condition
Traffic characteristics
Protocol Layer Plain
Device Preference Plain
Upgrade
Learning
Cooperation
Competition
ASIC
FPGA
GPU
CPU
Supervised Learning
Unsupervised Learning
Semi-supervised Learning
Reinforcement Learning
Hardware Domain
Algorithm Domain

Illustration of different types, layers, sides, and levels of B5G communication networks



M-IoT, M-MIMO, tiny-cells, cell-free, fluid cells, mmWave, multiteraHertz, VLC, SD fluid antennas, LISs, V2X, D2D, mMTC, MEC, NOMA, intelligent caching, energy harvesting, wireless backhaul, UAVs/satellites/airborne/underwater/oceanic, etc

Key Enabling Technology	Open Problems for further Study
THz Band Communication	▪ Fabrication and testing of antenna arrays. ▪ Real-time control algorithms in transceivers. ▪ Communication protocol for coordination between transmitter, receiver and reflect arrays. ▪ Routing protocol design.
Intelligent Communication Environments	▪ Trade-off between dimensions and energy consumption ▪ Compatibility with existing solutions. ▪ Standardization ▪ Inclusion of advanced application scenarios ▪ Smart resource allocation solution ▪ AI-driven and optimization
Pervasive Artificial Intelligence	▪ Generalized algorithms for broad use-cases ▪ Effective comparison metrics ▪ Absence of high quality data sets
Network Automation	▪ Accurate intent definition ▪ Automated real-time inference ▪ In-band telemetry
Reconfigurable Transceiver Front-ends	▪ Novel device designs for all-spectrum communication ▪ Re-programmable circuitry, interconnects and antennas ▪ Novel integration and packaging techniques
Ambient Backscatter Communication	▪ Spectral and energy efficiency ▪ Protocol design

Key Enabling Technology	Open Problems for further study
The Internet of Space Things	▪ Multi-band transceiver design ▪ Low-latency, low-overhead routing techniques ▪ Optimized handover techniques with smart gateway diversity
Cell-free Massive MIMO	▪ User Scheduling ▪ Location optimization of APs
The Internet of Nano Things	▪ Power efficiency optimization ▪ Interference control ▪ Network protocol design
The Internet of BioNano Things	▪ Experiment validation ▪ Data storage and validation
Quantum Communication	▪ Quantum error correction ▪ Entanglement distribution ▪ At-scale deployments

THANKS!

Any questions?