



# 6G how to do it ?

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# Outline

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- I. Service Trends
- II. 6G Vision – Direction & Usage Scenarios
- III. 6G Enabling Technologies

# Service Trends (1/3)

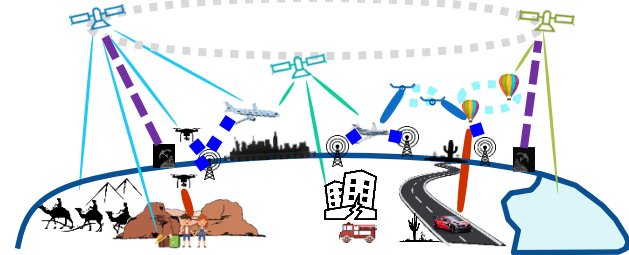
## Autonomous vehicles

- Self-driving and flying vehicles
- Initiation in 5G → full realization in 6G



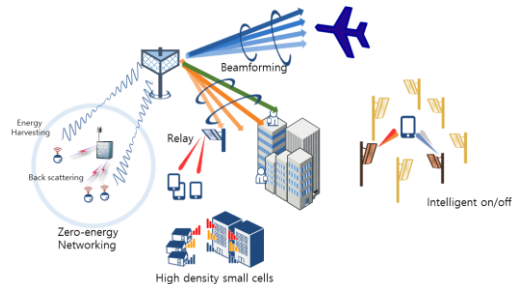
## Coverage extension

- Towards broadband service anywhere on earth including airspace, sea, remote areas, deserts etc



## Energy consumption reduction

- User terminals with no battery charging
- Energy-efficient RAN and core networks



## Factory automation

- Remote control & collaboration
- Replacing wirelines with wireless connection



# Service Trends (2/3)

## XR (eXtended Reality)

- Create a real and virtual combined environment, where human-machine interaction (through e.g., BCI and HCI) generates a realistic experience



## 4<sup>th</sup> Industrial Revolution

- Fusion of all new technologies: AI, robotics, nano, bio, Industrial IoT, 3D printing etc
- Cyber Physical System (CPS): control of factory processes using a cyber representation



## Digital twin

- Virtual entity: digital replica of a physical entity
- Interaction between virtual-and-physical entities through communication networks



## Tele-presence

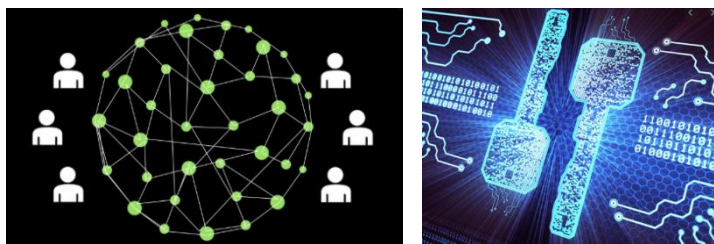
- People feel as if he is present at a place other than his true location
- Conference, tourism, education, sports/concert



# Service Trends (3/3)

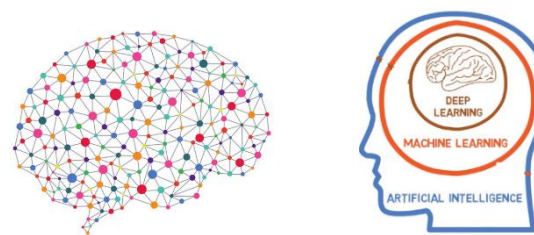
## Privacy & Security

- DLT for data integrity & against cyber-attacks
- Quantum and/or homographic cryptography  
→ neutralizing eavesdropping



## Artificial intelligence

- User-centric QoS management
- Self-optimization for RAN and core networks
- New radio interface design by AI



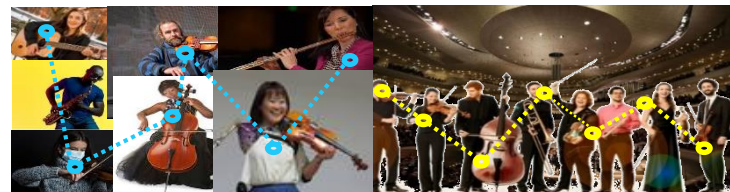
## Intelligent Robots

- Robots that can obtain and handle information on behalf of humans
- Robots that can engage in human life as friend, secretary, and life-partner



## Real-time Interactive SNS

- From: texts, pictures, and video clips in Facebook, Tweeter, Youtube, and Twitch
- To: more vivid & live video with tactile internet for instantaneous group-sharing



# Service Trends: Key aspects

## Emergence of variety of new verticals

### XR (eXtended Reality)

- All real and virtual combined environments
- Human-machine interactions generated by AR/VR/MR, BCI, and HCI



### Digital twin

- Virtual entity: digital replica of a physical entity
- Interaction between virtual-and-physical entities through communication networks



## AI playing an increasingly important role

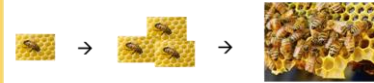
### Tele-presence

- A person feels as if he is present at a place other than his true location
- Conference, tourism, education, sports/concert



### Social Networking Service

- From: texts, pictures, and video clips in Facebook, Tweeter, Youtube, and Twitch
- To: more vivid and live video contents with tactile internet for instantaneous group-sharing



## Digital representation of everything

## Fusion of physical and digital worlds

## Increasing data consumption by machines

## Broadband connectivity anywhere

### Robots

- Robots that can obtain and handle information on behalf of humans
- Robots that can engage in human life



### Autonomous vehicles

- Use of autonomous driving and flying
- 5G (initiation) → 6G (full realization)



### 4<sup>th</sup> Industrial Revolution

- Fusion of all new technologies: AI, robot, nano, quantum computing, bio, Industrial IoT, communication, 3D printing, autonomous vehicle
- Cyber Physical System (CPS)



### Coverage and connectivity extension

- Non-terrestrial areas such as airspace and ocean
- From low-rate connection to broadband service



# 6G Vision: Direction

- Overcoming the limitations of the current technology & Creating new paradigms of communication for AI

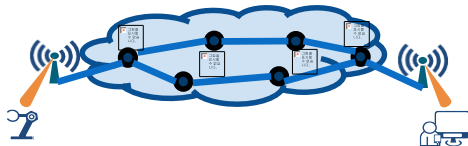
## Limitations of 5G

### E2D Latency

- 5 Limited to radio interface latency improvement  
**E2E including wireline networking not considered**

5G Latency:  
Wireless: 10ms → 1ms  
Wireline: > tens of ms

**Not fulfilling high real-time interaction requirements**



### Realization of Verticals

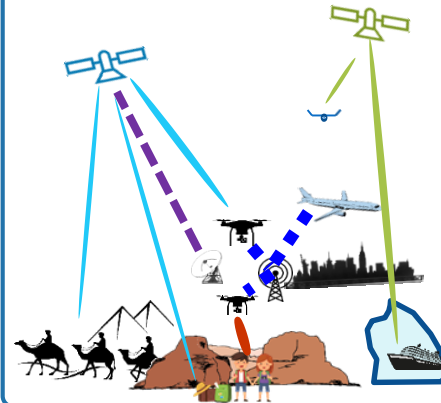
- 5 Limited Capacity & Precision  
User Experienced Rate: ~100Mbps  
URLLC: 5 nines@1ms  
Positioning Accuracy: ~ a few meters

**Difficult for full realization of Self-driving/Industrial IoT**



### Spatial Coverage

- 5 Limited Service Coverage  
**Ground-centered coverage extension**



# 6G Vision: Direction

- Overcoming the limitations of the current technology & Creating new paradigms of communication for AI

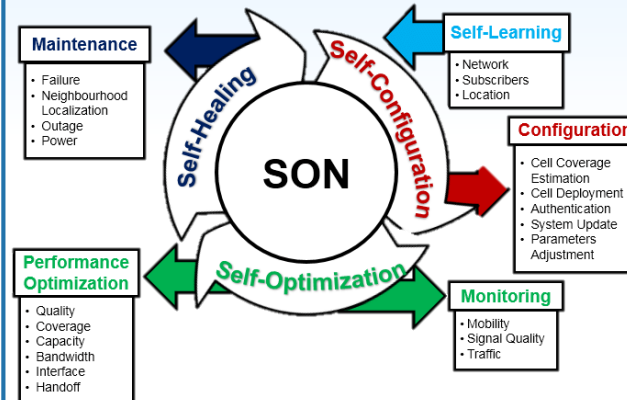
## New Communication Paradigm

### Communication for AI Reinforcement



- Distributed Infra for AI & Mobile Core for AI
- Low latency· Ultra broadband· Absolute Synchronization for AI

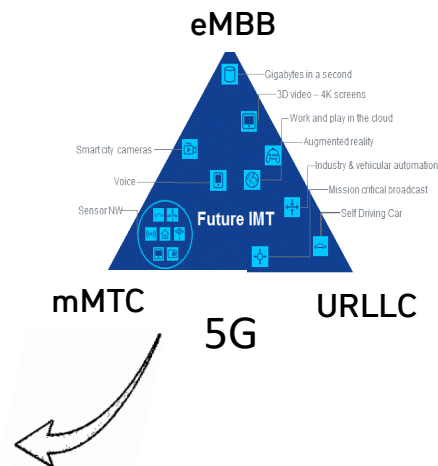
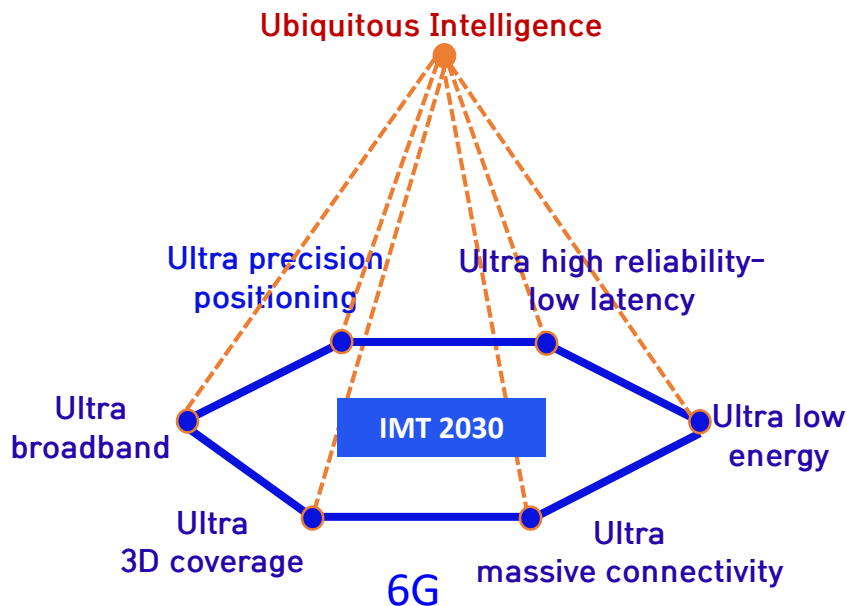
### AI-Native Networking



- Intelligent radio access
- Full automation/autonomy in networking

# 6G Vision: Usage Elements & Scenarios

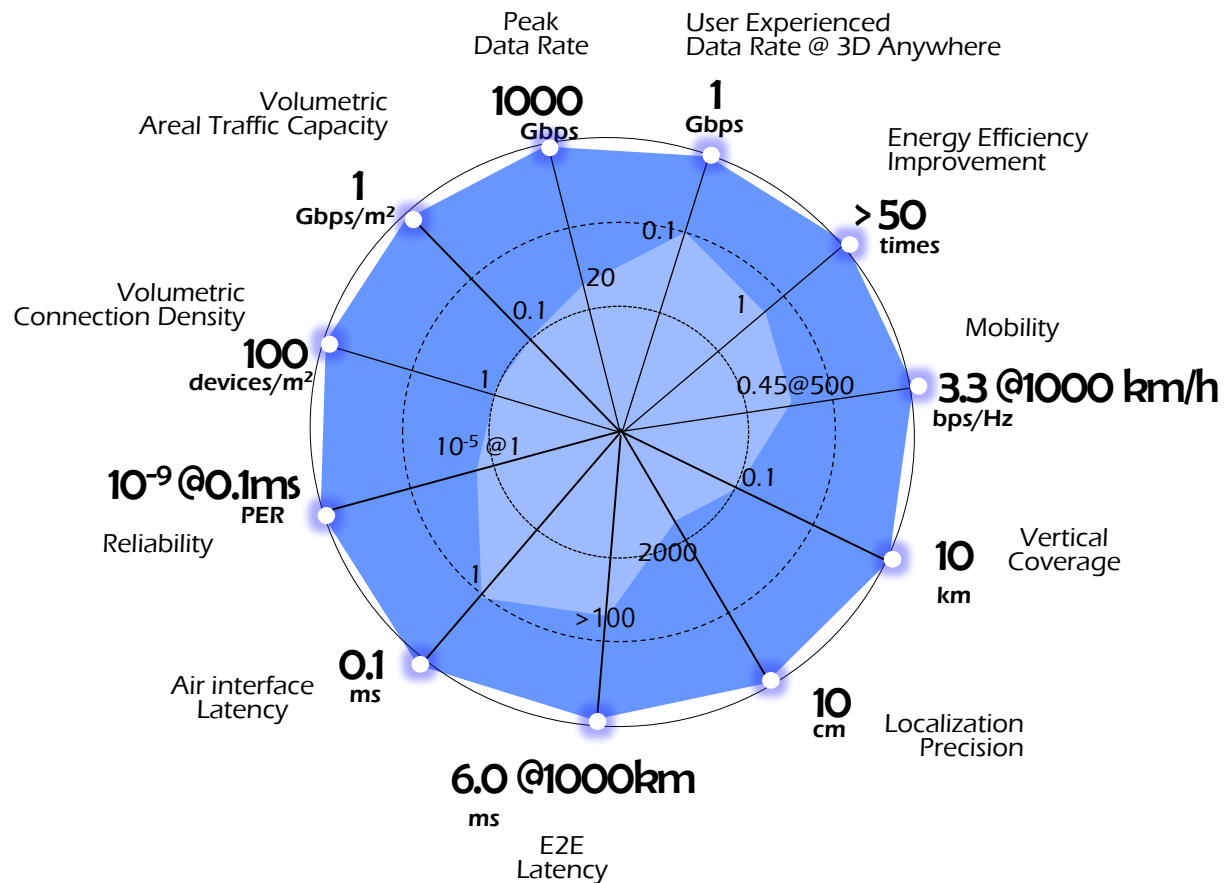
- 6 Usage Elements
  - ✓ Ultra broadband, Ultra precision positioning, Ultra high reliability-low latency
  - ✓ Ultra 3D coverage, Ultra low energy, Ultra massive connectivity
- Ubiquitous Intelligence: Intelligence everywhere
- Expansion and enhancements of 5G usage scenarios, i.e., eMBB, mMTC, and URLLC
- New usage scenarios provided as a combination of one or more usage elements



# Examples of 6G Use Case

Use Cases	6G Usage Elements					
	uBroadband	uPosition	uMC	uHRLLC	u3DCov	uEnergy
Live sports/concert broadcasting	√	√	√			√
6 DoF XR, Hologram, Perceptual Illusion	√					√
In-flight broadband internet	√				√	
Gbps for high-speed trains				√		
Digital twin (tourism, gaming, automotive)	√	√				√
Digital twin (4IR)	√	√				
Self-driving car/PAV		√		√	√	
Smart factory		√	√			
Smart city			√			√
Tele-presence	√	√				

# 6G KPIs



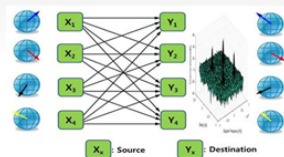
# 6G Enabling Technologies

- Ultra Broadband

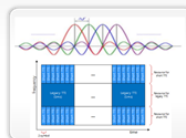
## Terahertz radio access

New radio access technology, using a THz band in the frequency range of 100GHz ~ 1 THz, to achieve high-speed, low-latency, low power-consumption by overcoming the limiting factors such as short propagation range and RF impairments in THz communication

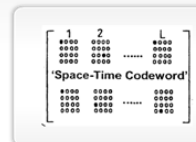
- Max Bandwidth: ~40 GHz
- Peak rate: DL 1 Tbps, UL 100 Gbps
- User experience data rate: > 1 Gbps



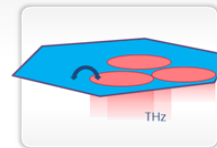
Channel Modeling  
RF impairment



New Waveform



Channel Coding  
& Modulation



Synchronization  
& Signaling

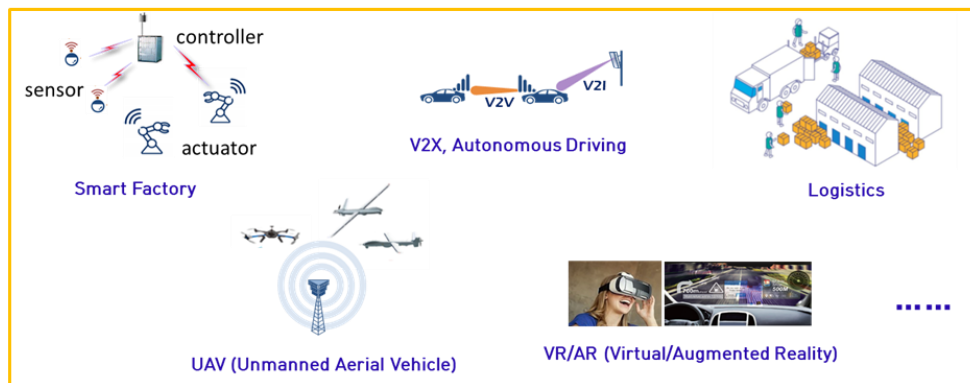
New RAT for THz

# 6G Enabling Technologies

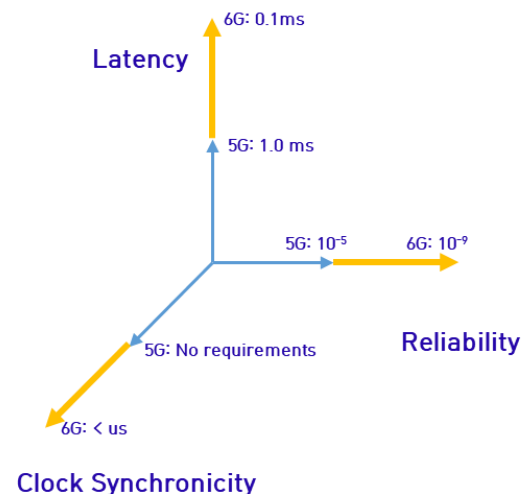
- Ultra High Reliability-Low Latency

## URLLC & Mobile TSN Enhancements

- Higher reliability  $\sim (1 - 10^{-9})$
- Lower latency  $\sim 0.1$  ms
- Clock synchronicity  $< \mu s$



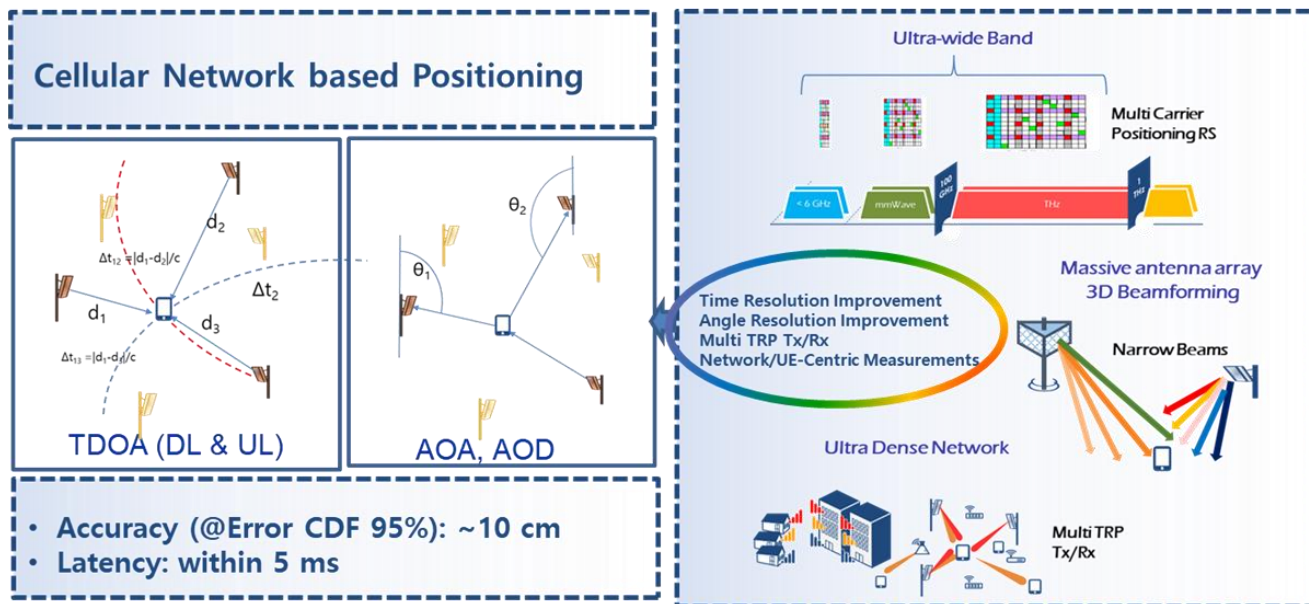
\*TSN: Time Sensitive Networking



# 6G Enabling Technologies

- Ultra Precision Positioning

## Real-Time High-Precision Positioning

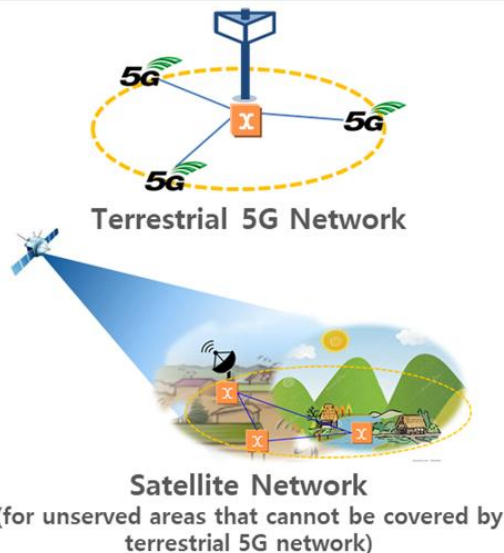


# 6G Enabling Technologies

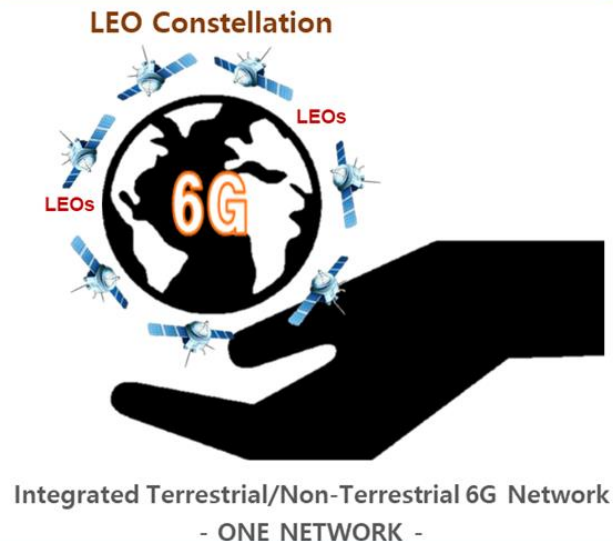
- Ultra 3D coverage

## Integration of satellite and terrestrial networks

Separated Satellite and Terrestrial Networks



Integrated Satellite and Terrestrial Network

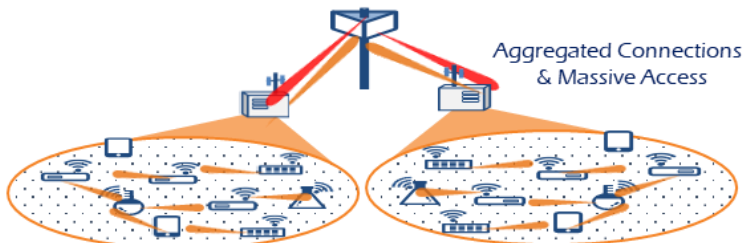


# 6G Enabling Technologies

- Ultra Massive Connectivity

## Ultra low power and low cost massive IoT

- Ultra low power, low cost narrowband radio access technology
- Signaling overhead reduction
  - ✓ Advanced Grant Free Access
  - ✓ Advanced NOMA
- Deep coverage provisioning
- Massive connectivity based on D2D



## Massive connectivity for Ultra high precision and Aerial devices

- Massive URLLC
  - ✓ URLLC for massive high-precision devices (e.g. large factory automation)
- Massive Aerial IoT
  - ✓ Non-terrestrial / terrestrial cooperation based service coverage extension for massive aerial devices



# 6G Enabling Technologies

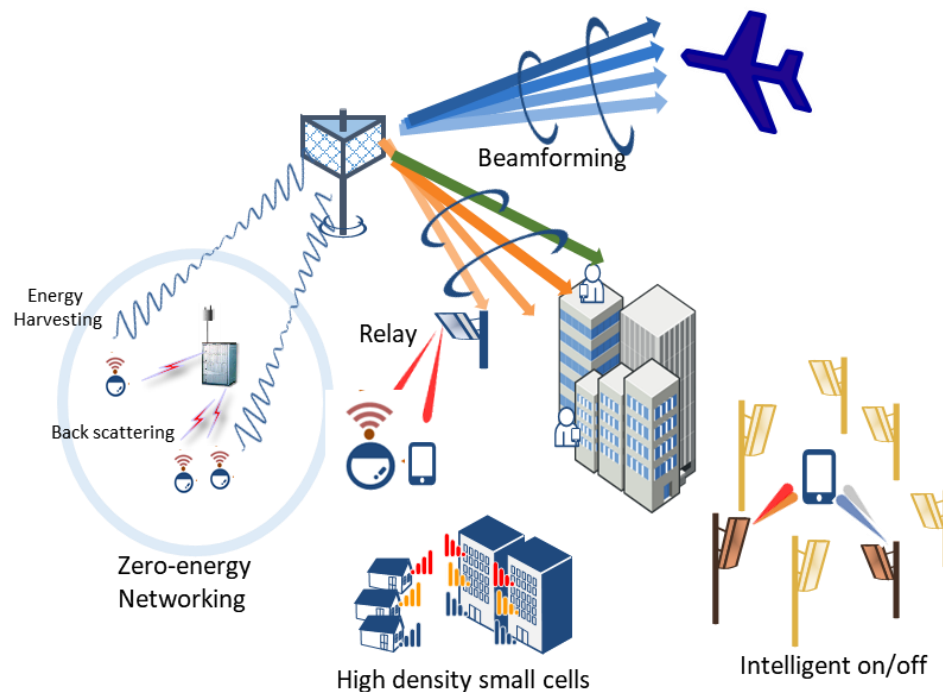
- Ultra Low Energy

- Zero-energy networking

- Ambient RF energy harvesting
    - Backscatter communication
    - Short-range zero-energy IoT networking

- Energy-efficient radio access

- 3D beamforming
    - High-density small cells
    - Relaying
    - Intelligent node/device on-off



**Thank You!**

