



# Intelligent Transportation Systems Connectivity Perspective & Vision



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# HISTORY OF INTELLIGENT TRANSPORTATION SYSTEMS

2023 Update



U.S. Department of Transportation

[WWW.ITS.DOT.GOV/INDEX.HTM](http://WWW.ITS.DOT.GOV/INDEX.HTM)  
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ITS revolution in the next decade (?)



# CAV: **Connected** and **Autonomous** Vehicles





# CAV: Connected and Autonomous Vehicles



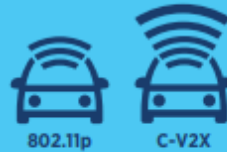


# C-V2X vs. 802.11p

For connecting cars, C-V2X outperforms 802.11p in every aspect

### COVERAGE RANGE

Range improvement of C-V2X vs. 802.11p at 90% PRR



### RANGE IMPROVEMENT ↑



Scenario	Range improvement (m)	Range improvement (%)	Reference
Freeway (70km/h)	88 m	56%	(5)
Highway fast (10 Hz)	260 m	135%	(4)
Urban (15km/h)	30 m	60%	(6)

### RELIABILITY

Ability to deliver Basic Security Message (BSM) in various conditions (90% packet received rate)



In presence of signal attenuation from real-world obstructions, C-V2X is more reliable than 802.11p

- C-V2X + 1.3x-2.9x range advantage
- C-V2X + 1.7x-2.2x LOS advantage

### INTERFERENCE

Ability to deliver BSM when other devices emit RF energy in the V2X channel



### INTERFERENCE IN CLOSE PROXIMITY

- C-V2X vs 802.11p + 1.7x improvement
- C-V2X vs 802.11p + 2.9x improvement (with the adjacent 802.11p interferer)

### EVOLUTION PATH TOWARD 5G

Ability to support 5G use cases

**C-V2X**  
(as part of the 3GPP standards family)

Enhancing of existing 3GPP Release 14 + Additional V2X communication capabilities





# Wi-Fi 7 | In-vehicle Access Point



## Greater Capacity and Improved Link-Reliability

- 6 GHz spectrum availability
- 320 MHz channel availability



## Essential enabler of next-gen applications

- Unprecedented speed
- Wire-like latency



## Transforming Automotive Car-to-Cloud Services

- Faster connectivity







The 5G Infrastructure Public-Private Partnership



## 5G and Vertical Industries (2015)

2G → 3G → 4G: rate

4G → 5G: rate, reliability, latency, density

## 5G Usage scenarios

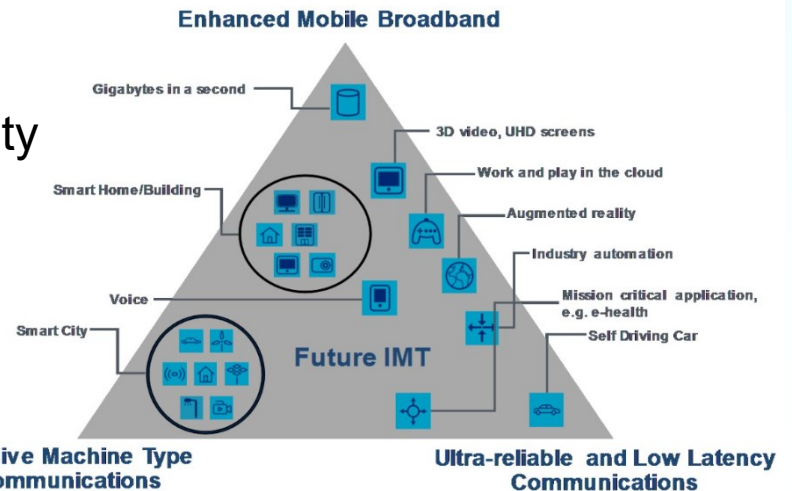


Figure 1. The original 5G triangle, from Recommendation ITU-R M.2083 [ITU-R, IMT Vision—Framework and overall objectives of the future development of IMT for 2020 and beyond]. Recommendation ITU-R M.2083, September 2015, <https://www.itu.int/rec/R-REC-M.2083/en>



The 5G Infrastructure Public-Private Partnership



5G and Vertical Industries (2015)

2G → 3G → 4G: rate

4G → 5G: rate, reliability, latency, density

Failed predictions

- Adoption of vertical paradigms
- Non-ICT related barriers
- Coverage
- Hype

5G Usage scenarios

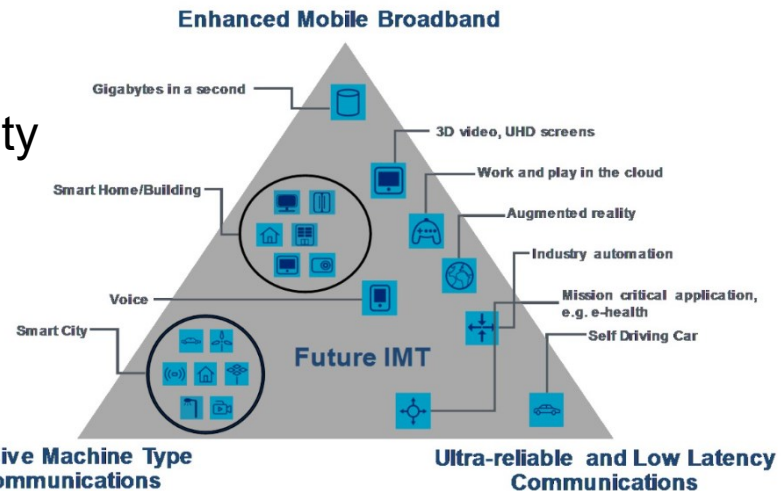
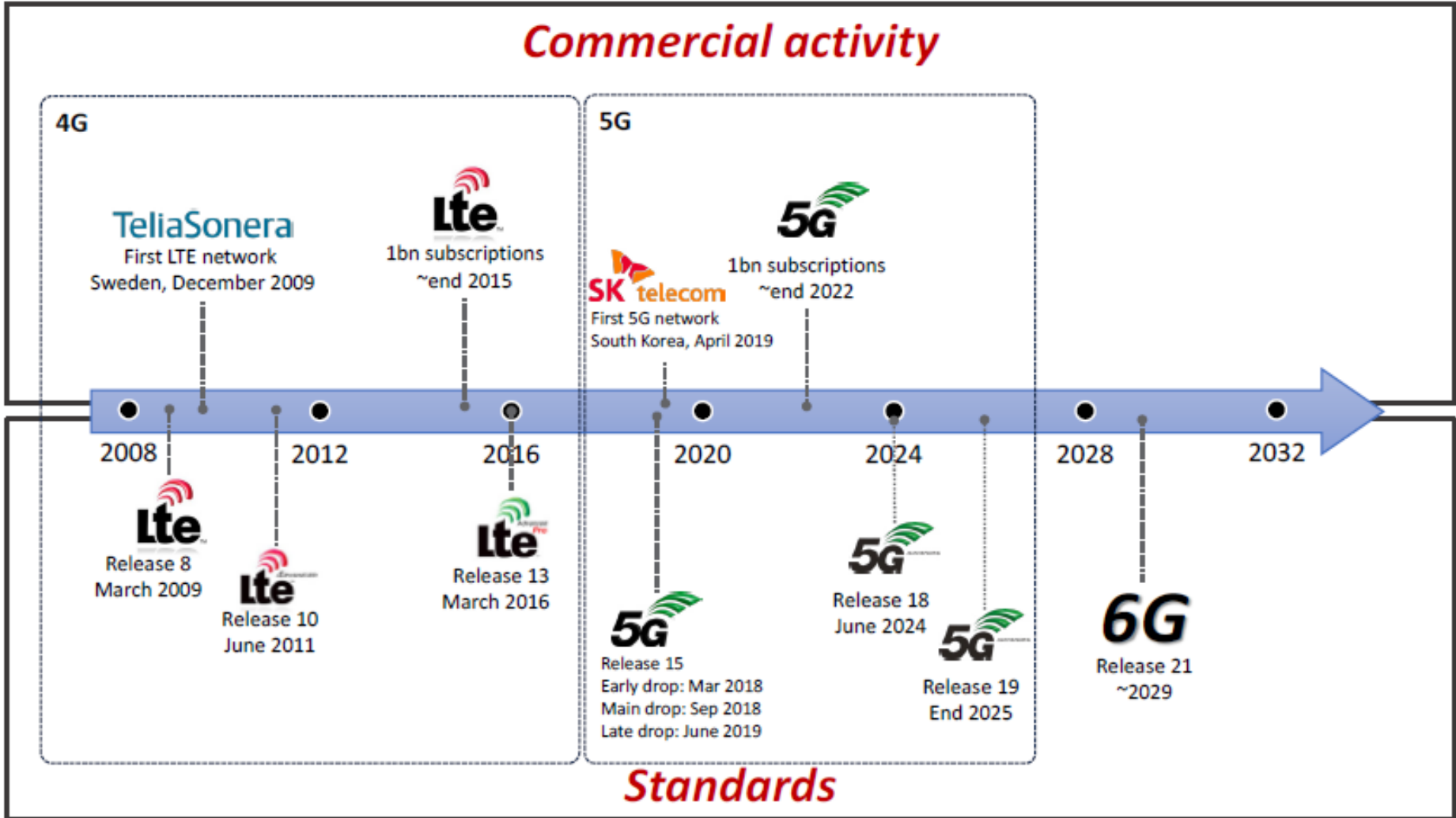


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# 6G Timeline

(Source: ABI Research)





# Usage scenarios

## 6 Usage scenarios

Extension from IMT-2020 (5G)

eMBB → Immersive Communication

mMTC → Massive Communication

URLLC → HURLLC (Hyper Reliable & Low-Latency Communication)

New

Ubiquitous Connectivity

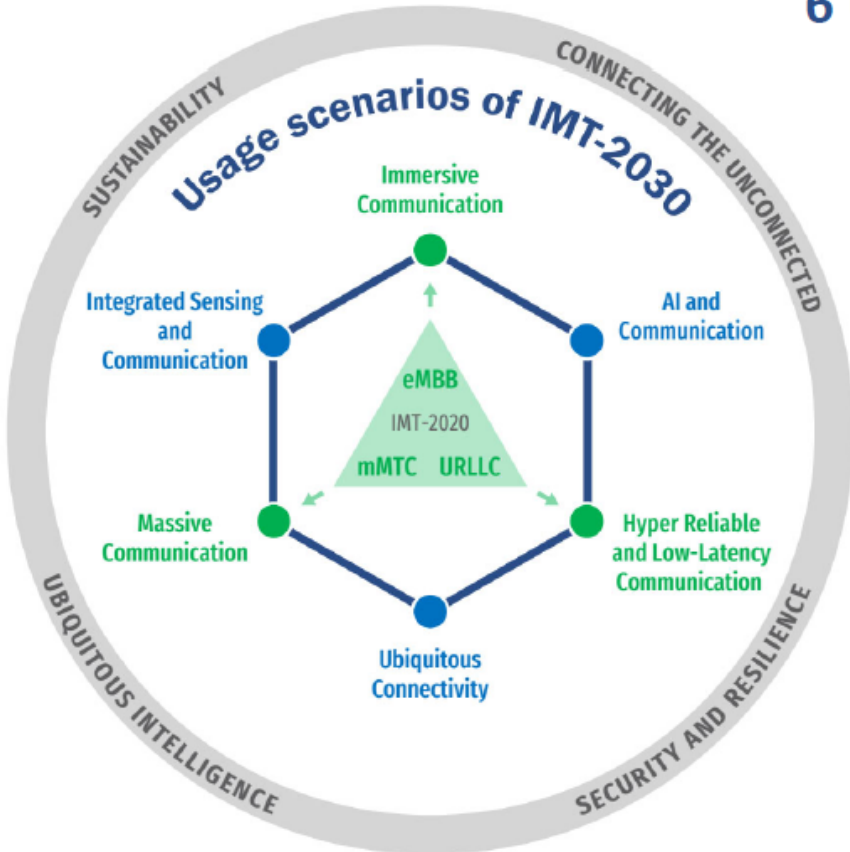
AI and Communication

Integrated Sensing and Communication

4 Overarching aspects:

*act as design principles commonly applicable to all usage scenarios*

Sustainability, Connecting the unconnected, Ubiquitous intelligence, Security/resilience



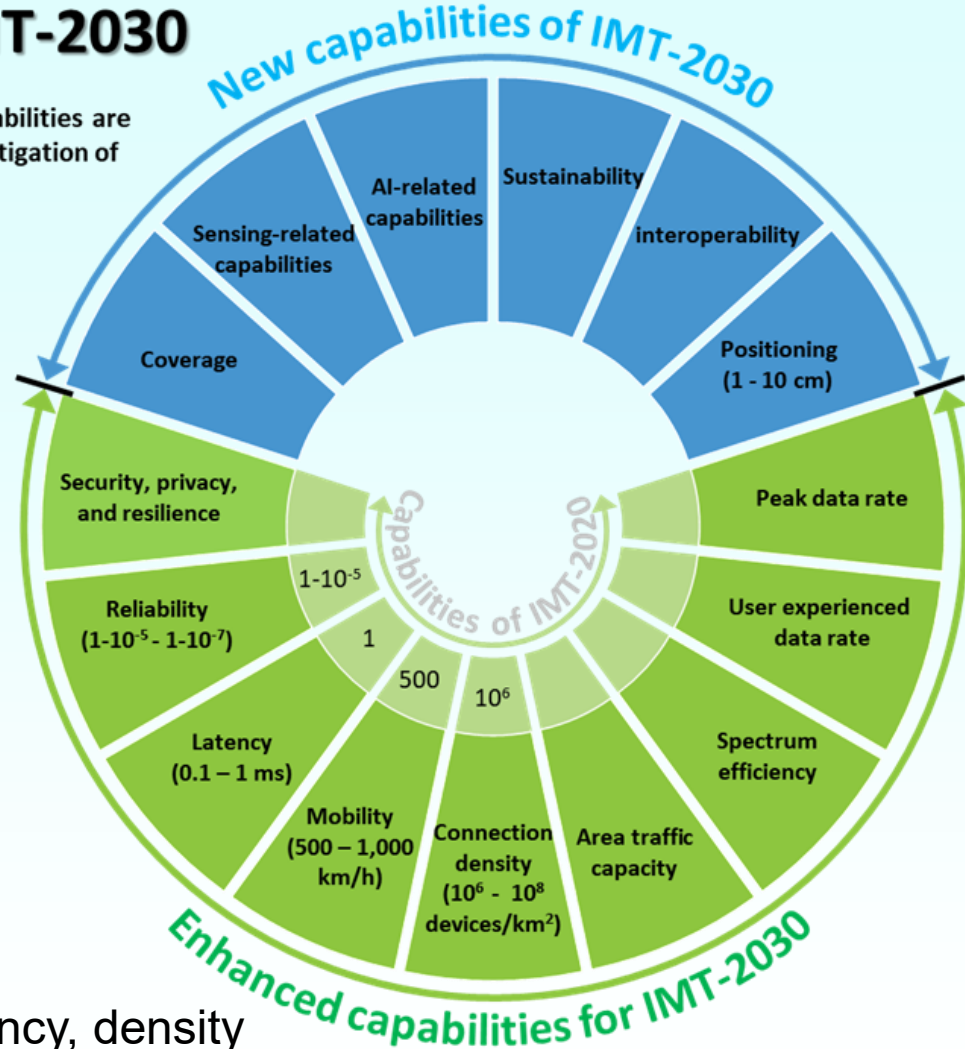
So called "Wheel diagram"

Source: Document 5/131 and edited in SG 5



# Capabilities of IMT-2030

NOTE: The range of values given for capabilities are estimated targets for research and investigation of IMT-2030.



- 2G → 3G → 4G: rate
- 4G → 5G: rate, reliability, latency, density
- 5G → 6G: rate, reliability, latency, density, coverage (NTN), sensing, AI

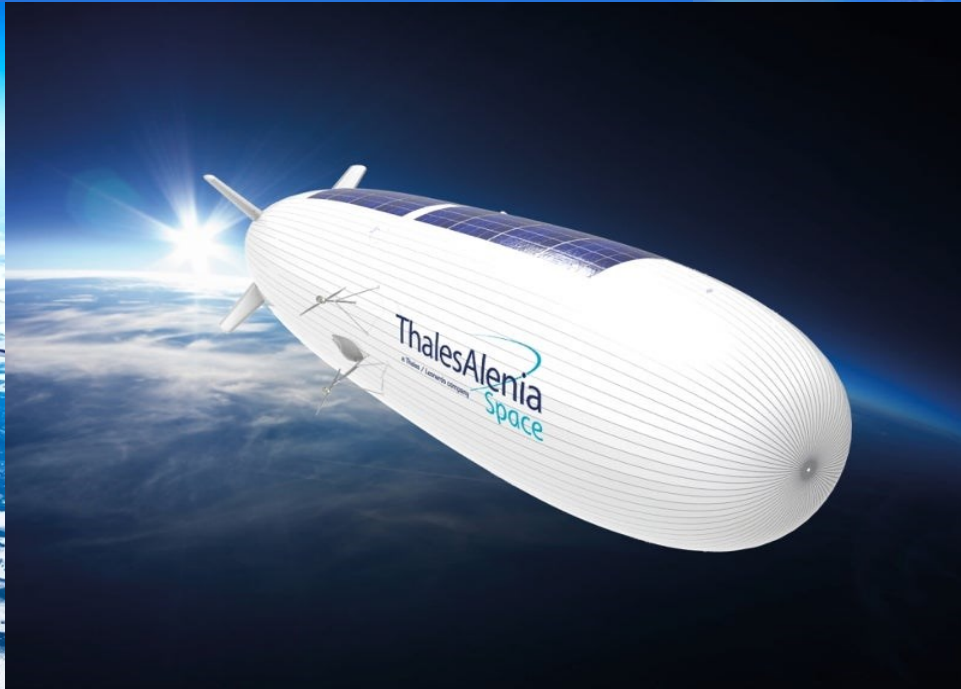


## HAPS: High Altitude Platform Station → HIBS

**HAPS:** “A station on an object at an altitude of 20 to 50 km and at a specified, nominal, **fixed point relative to the Earth**” (ITU Radio Regulations, Article 1.66A).

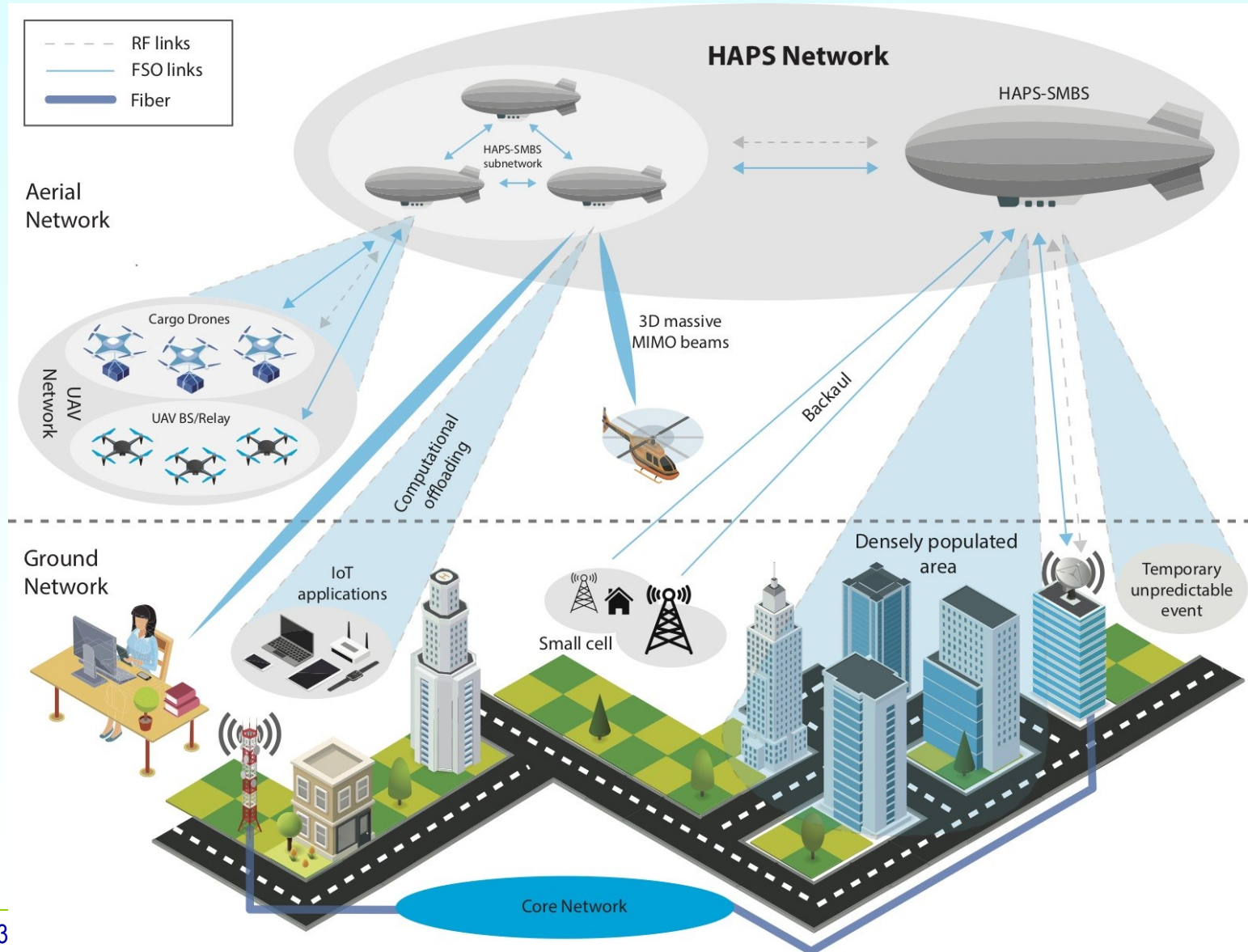
**HIBS:** HAPS as an IMT (International Mobile Telecommunications) Base Station  
HIBS altitude: 18-25 km (WRC-23)







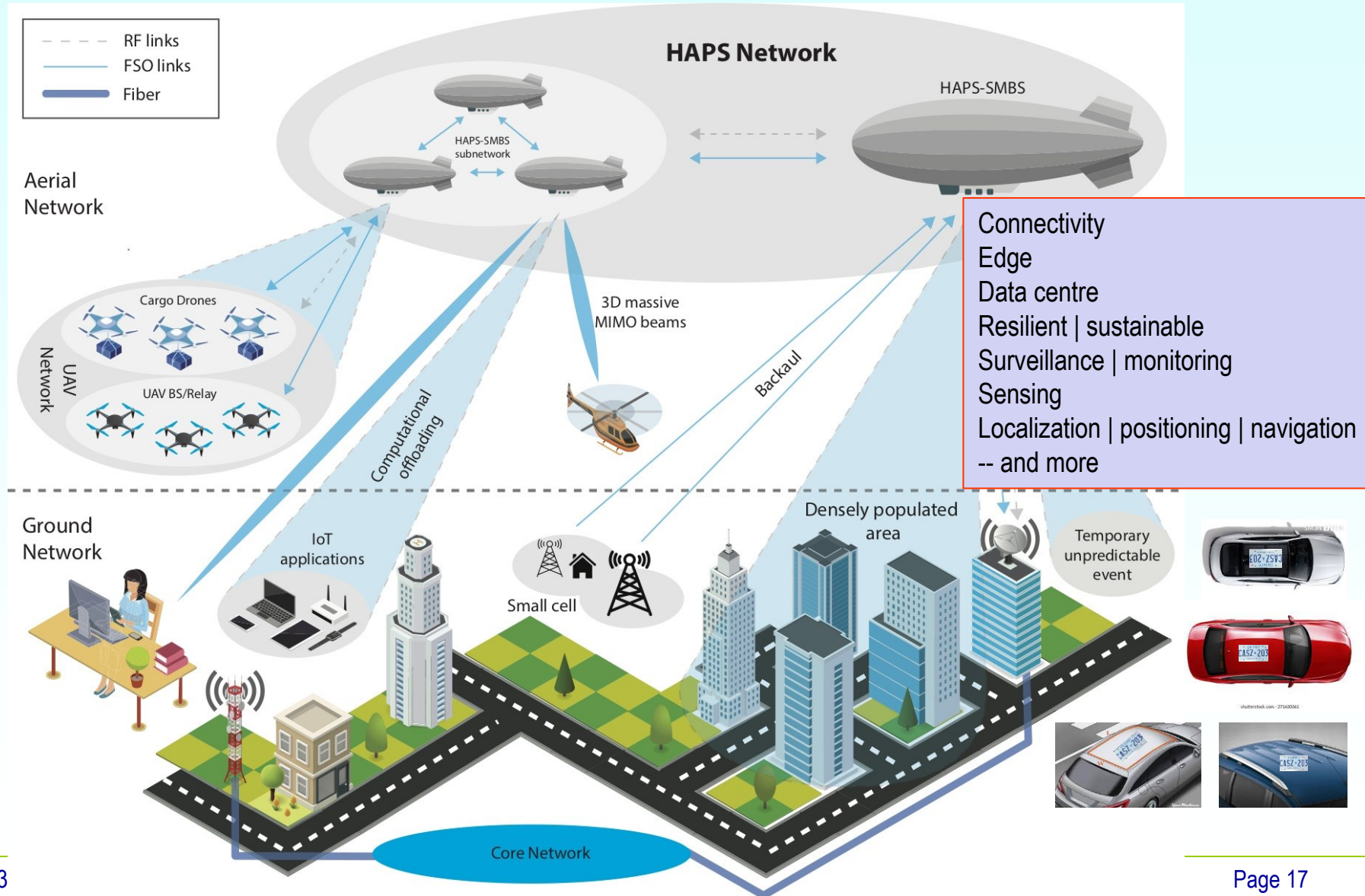
# Terrestrial BSs + HAPS BSs in Urban/Suburban Areas







# Terrestrial BSs + HAPS BSs in Urban/Suburban Areas



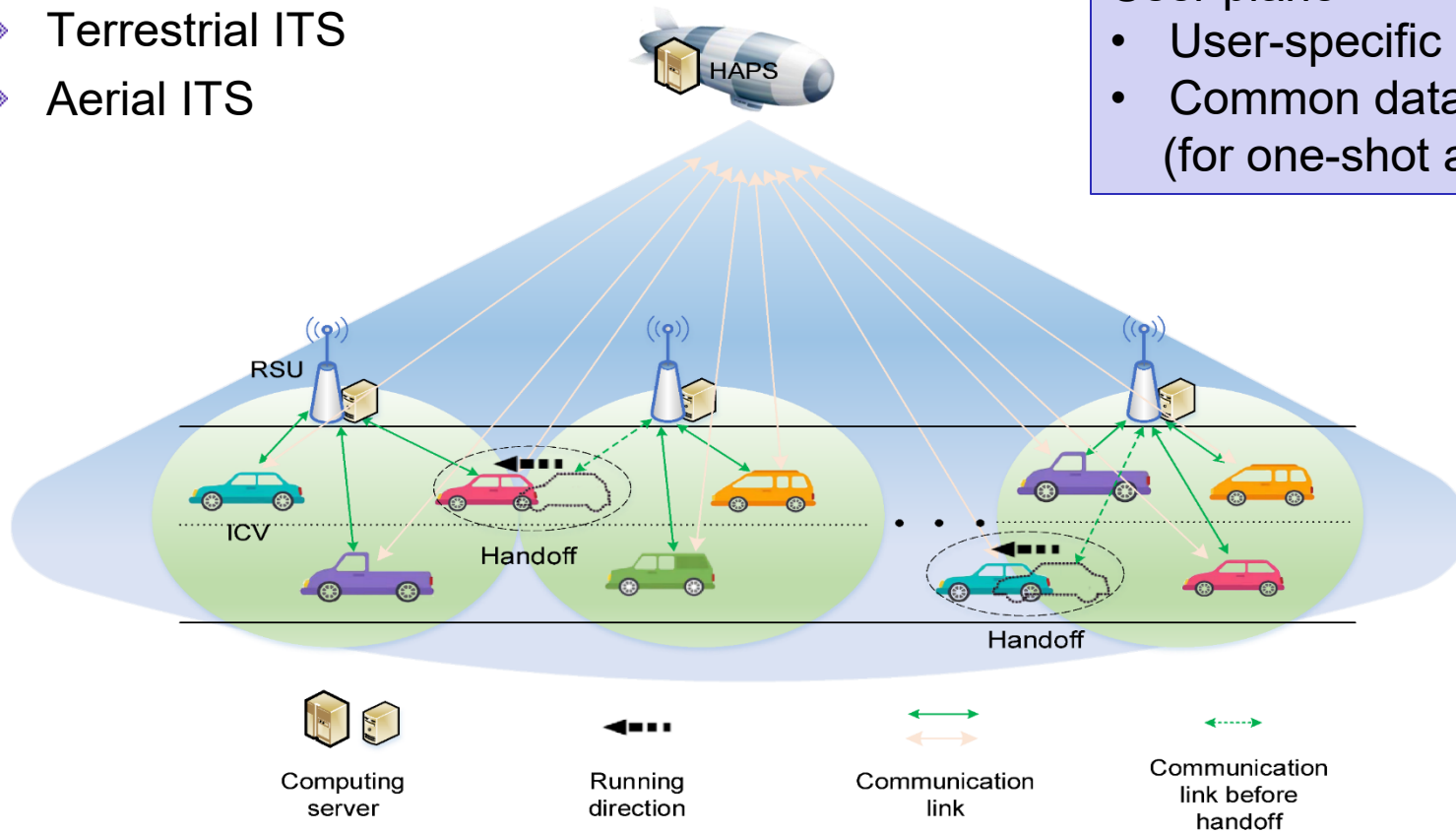


# Edge Computing @ HAPS

- ◆ Terrestrial ITS
- ◆ Aerial ITS

Control plane → HAPS  
 User plane

- User-specific data → RSU
- Common data → HAPS (for one-shot aggregation)



Q. Ren, O. Abbasi, G. Karabulut Kurt, H. Yanikomeroglu, J. Chen, “Caching and computation offloading in high altitude platform station (HAPS) assisted intelligent transportation systems”, *IEEE Transactions on Wireless Communications*, Nov. 2022.

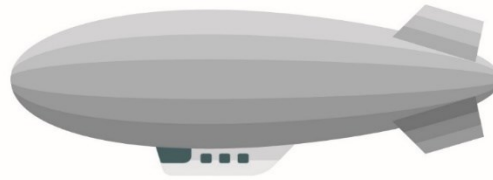
Q. Ren, O. Abbasi, G. Karabulut Kurt, H. Yanikomeroglu, J. Chen, “Handoff-aware distributed computing in high altitude platform station (HAPS)-assisted vehicular networks”, *IEEE Transactions on Wireless Communications*, Dec. 2023. [YouTube]



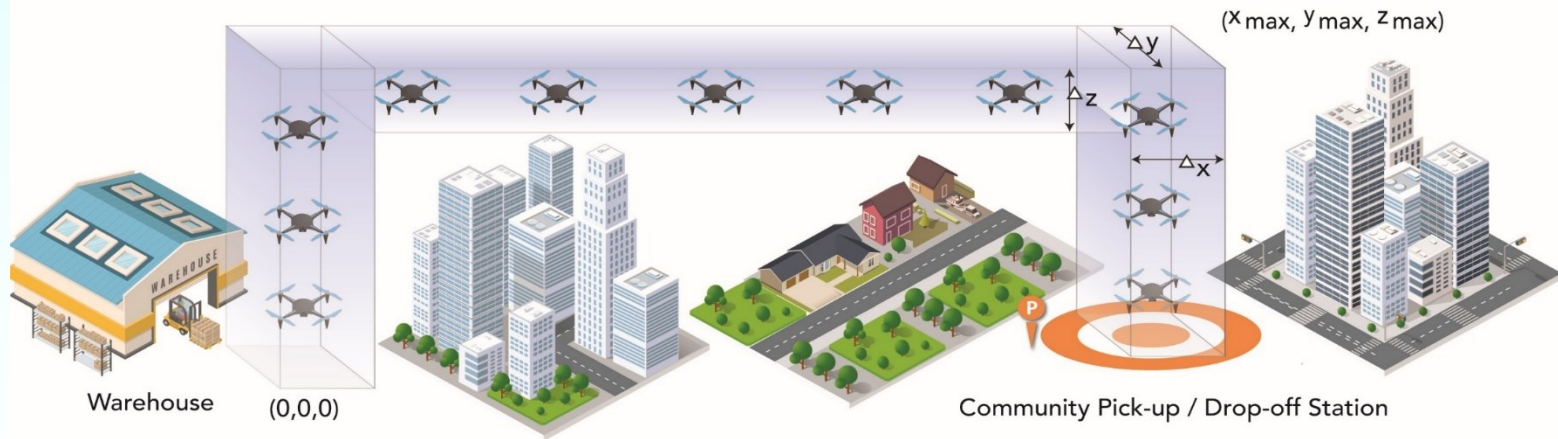
# HAPS for 3D Aerial Highways

## HAPS Services

UAV Traffic Management  
(UTM)



- Communication
- Computing
- Caching

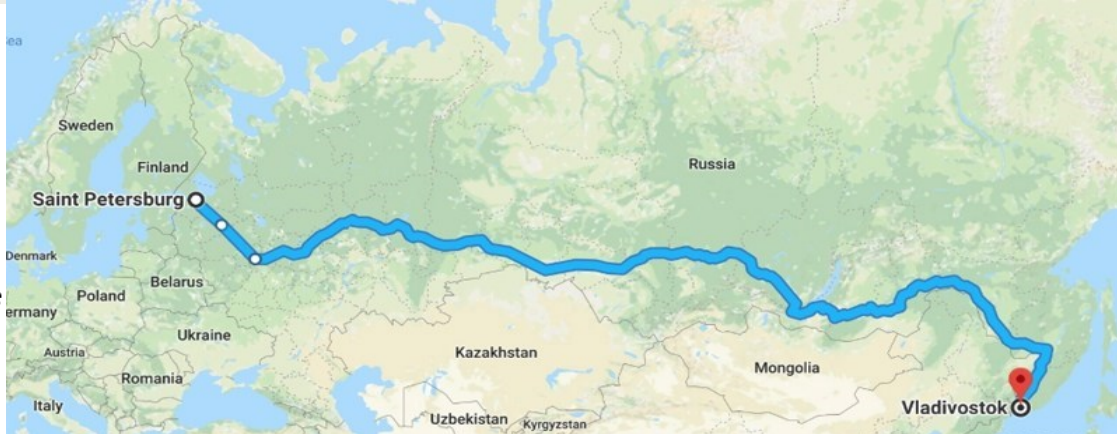


N. Cherif, W. Jaafar, H. Yanikomeroglu, A. Yongacoglu, “3D Aerial highways: The key enabler of the retail industry transformation”, *IEEE Communications Magazine*, Sep 2021.

G. Karabulut Kurt, H. Yanikomeroglu, “Communication, computing, caching, and sensing for next generation aerial delivery networks: Using a high-altitude platform station as an enabling technology”, *IEEE Vehicular Technology Magazine*, Sep 2021.



# HAPS Constellation for Intelligent Transportation Systems



W. Jaafar, H. Yanikomeroglu, "HAPS-ITS: Enabling future ITS services in trans-continental highways", *IEEE Communications Magazine*, Oct 2022.



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