WWRF-45

Evolution of URLLC toward 6G

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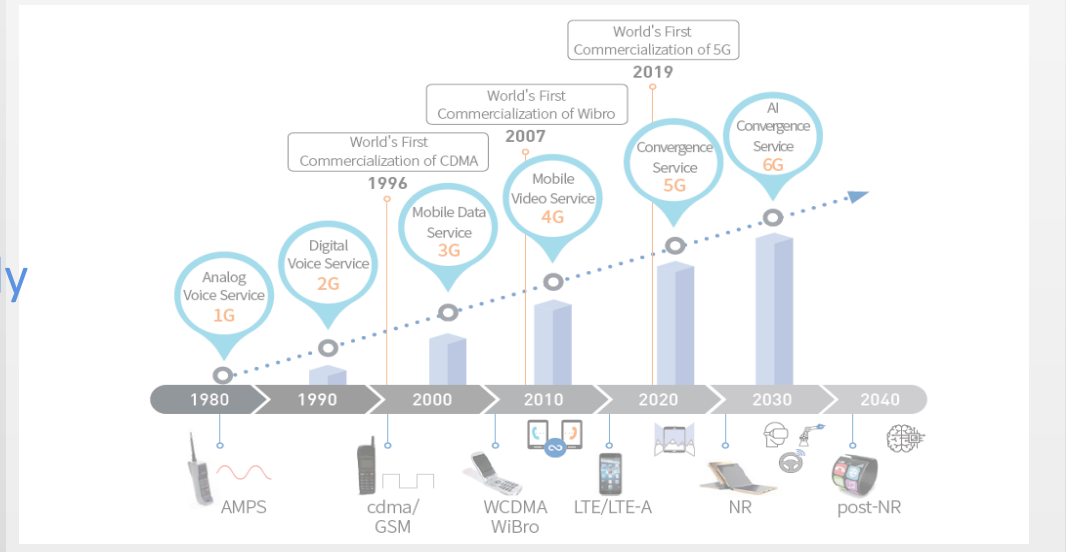
ETRI
Electronics and Telecommunications Research Institute
UNIVERSITY OF OULU
6G FLAGSHIP UNIVERSITY OF OULU

- Overview of B5G/6G
- Introduction of Global Collaborative Project
- Evolution of URLLC

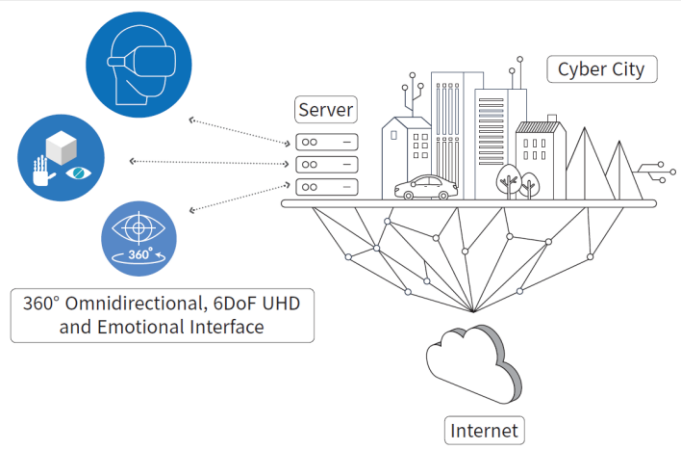
Global Background on 6G Activities

- Finland - 6G Flagship programme, 2018
  - First 6G Wireless Summit in Levi, Finland 2019
- ITU-T Focus Group on Technologies for Network 2030, 2018-2020
- ITU-R WP5D 'Future Technology Trends for the evolution of IMT towards 2030 and beyond', 2020-2022
- US FCC opened 95 GHz to 3 THz spectrum for 6G research, 2019
- WWRF 6G WG, 2020
- Next G Alliance, 2020

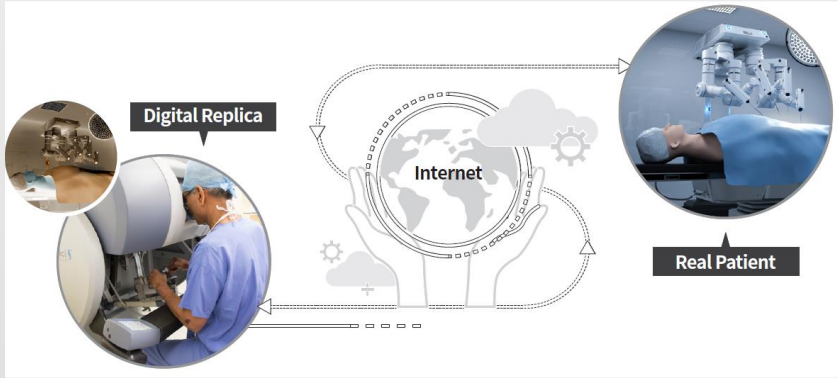
- Korea: 6G R&D strategy announced, 2020
- ETRI and Samsung released white papers on 6G, respectively in 2020
- China: IMT-2030 promotion group, 2019
- Japan: Beyond 5G promotion strategy published, 2020



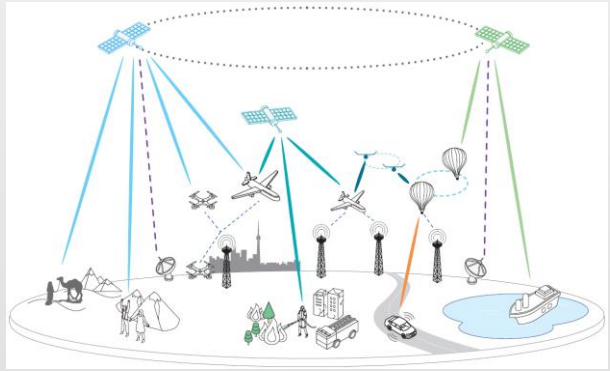
- Diversification of data consumers
- Digital representation of everything
- Real-time interaction between physical and digital worlds
- Expansion of service coverage
- Emergence and Convergence of new verticals



Future immersive internet

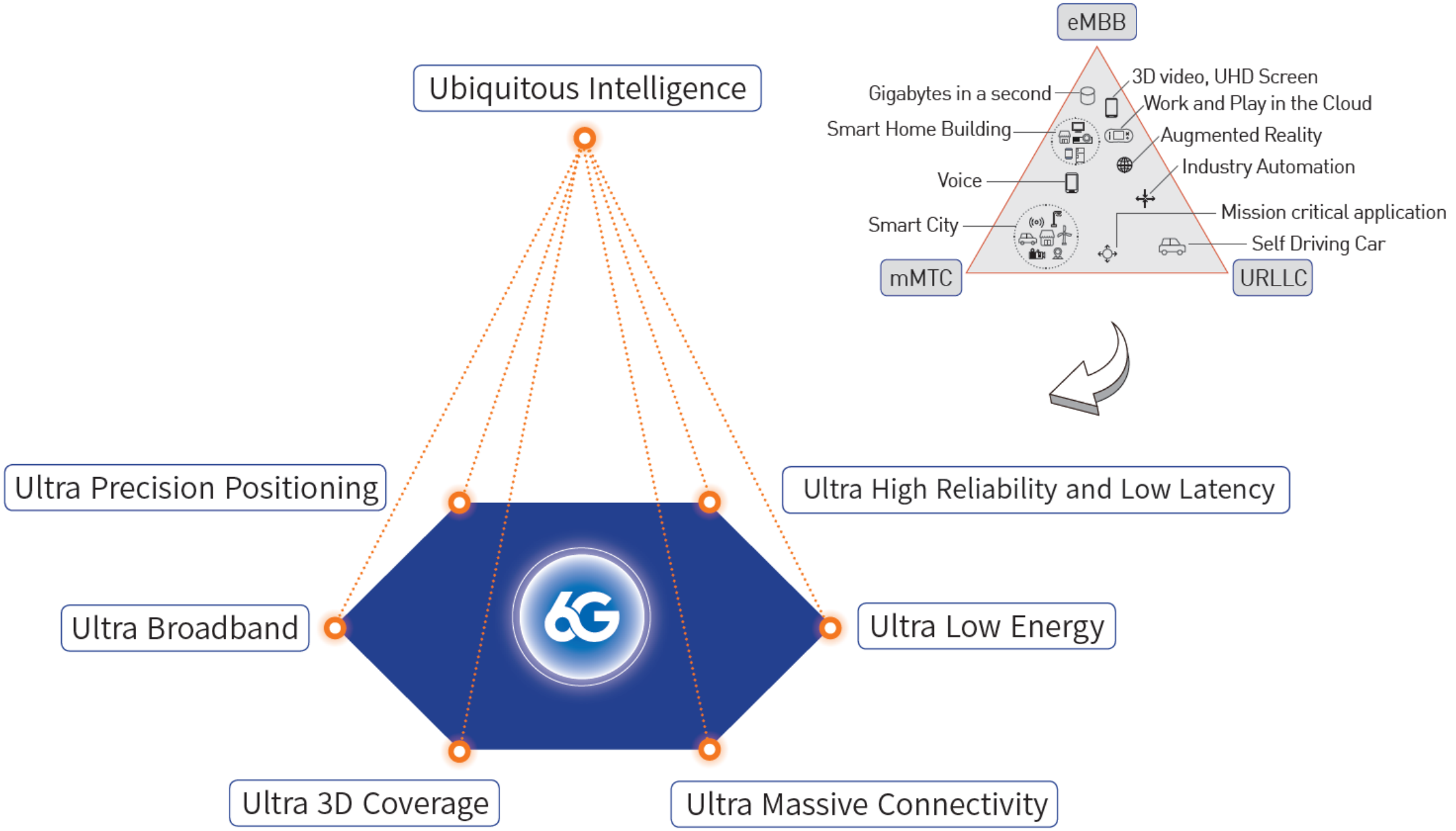


CPS-based broadband tactile interent

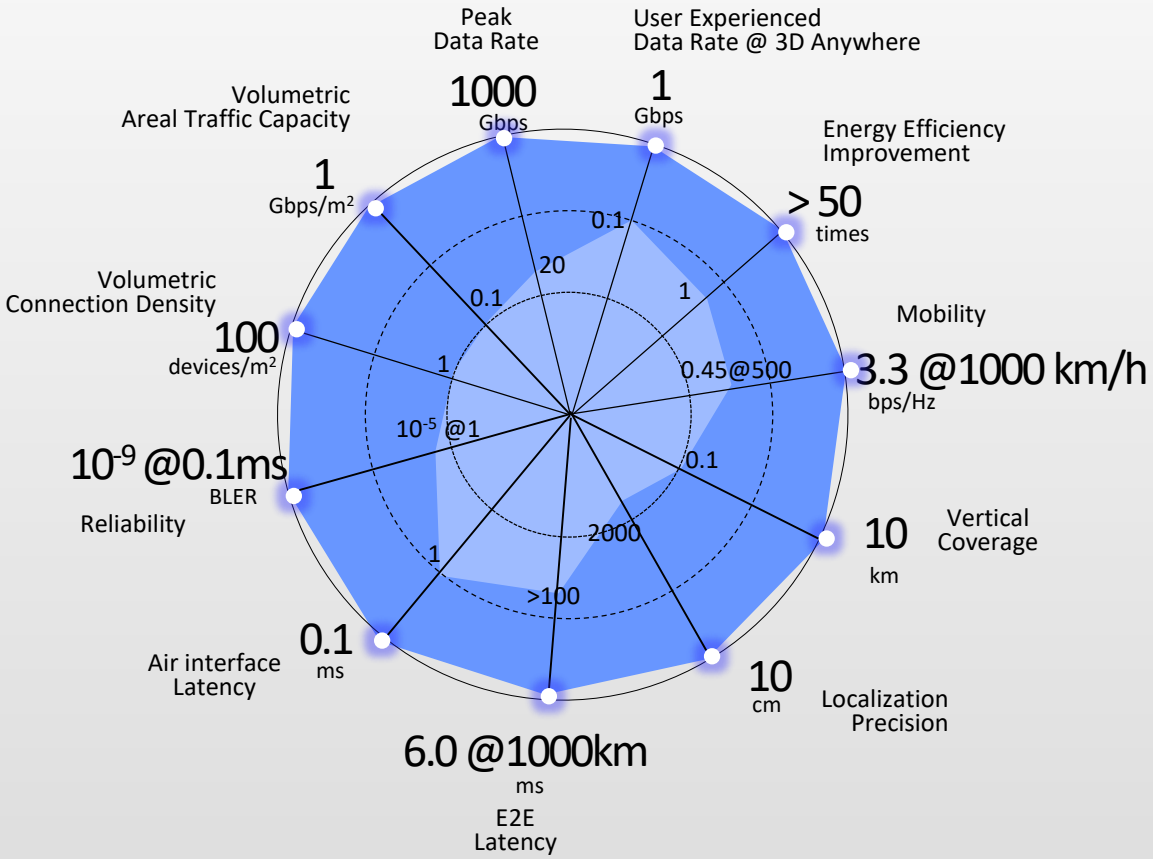


3D spatial communication

ETRI's 6G Vision & KPIs (1/2)



ETRI's 6G Vision & KPIs (2/2)

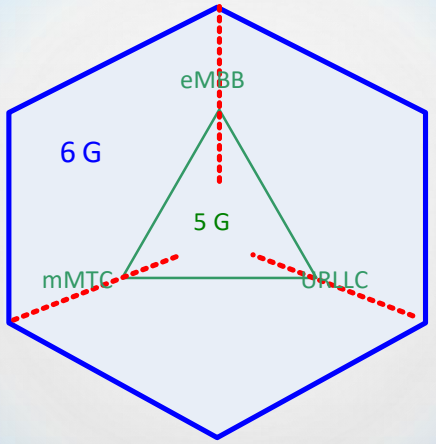


Peak data rate
User experienced data rate
Areal traffic capacity
Spectral efficiency
Spectral efficiency @ mobility

Ultra broadband

Ultra 3D coverage
Horizontal coverage
Vertical coverage

Ultra precision positioning
Positioning accuracy



Ultra massive connectivity
Volumetric connection density

Ultra high reliability -low latency
Reliability & Latency
Clock synchronicity

Ultra low energy
Energy efficiency

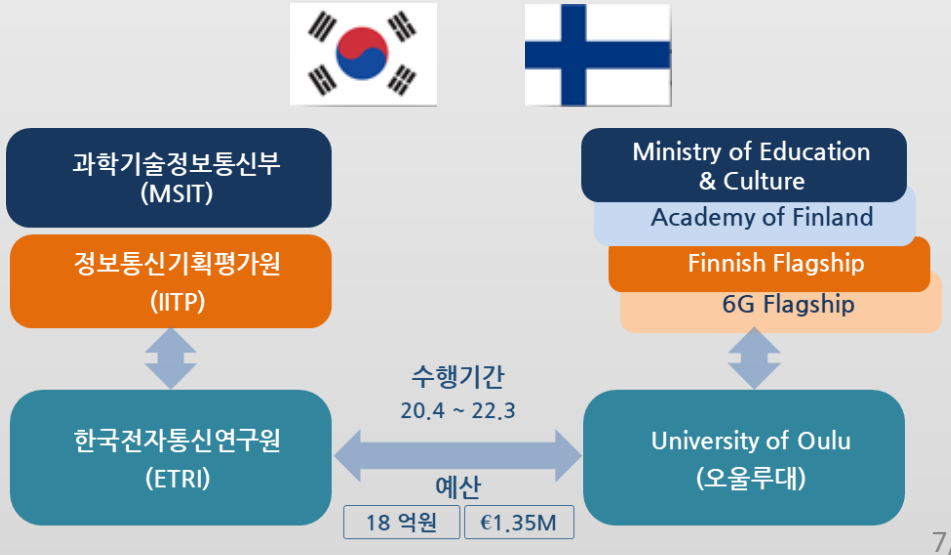
Ubiquitous Intelligence

- Title
  - R&D on the Evolution of URLLC for Beyond 5G Mobile Communication

- Goal
  - Key tech. development on 5G+ URLLC
  - Demo. On IIoT remote control service across continent

- Participants
  - KR: ETRI, Dankook Univ.
  - FI: Univ. of Oulu, 6G Flagship, 5GTN(5G Test Network)

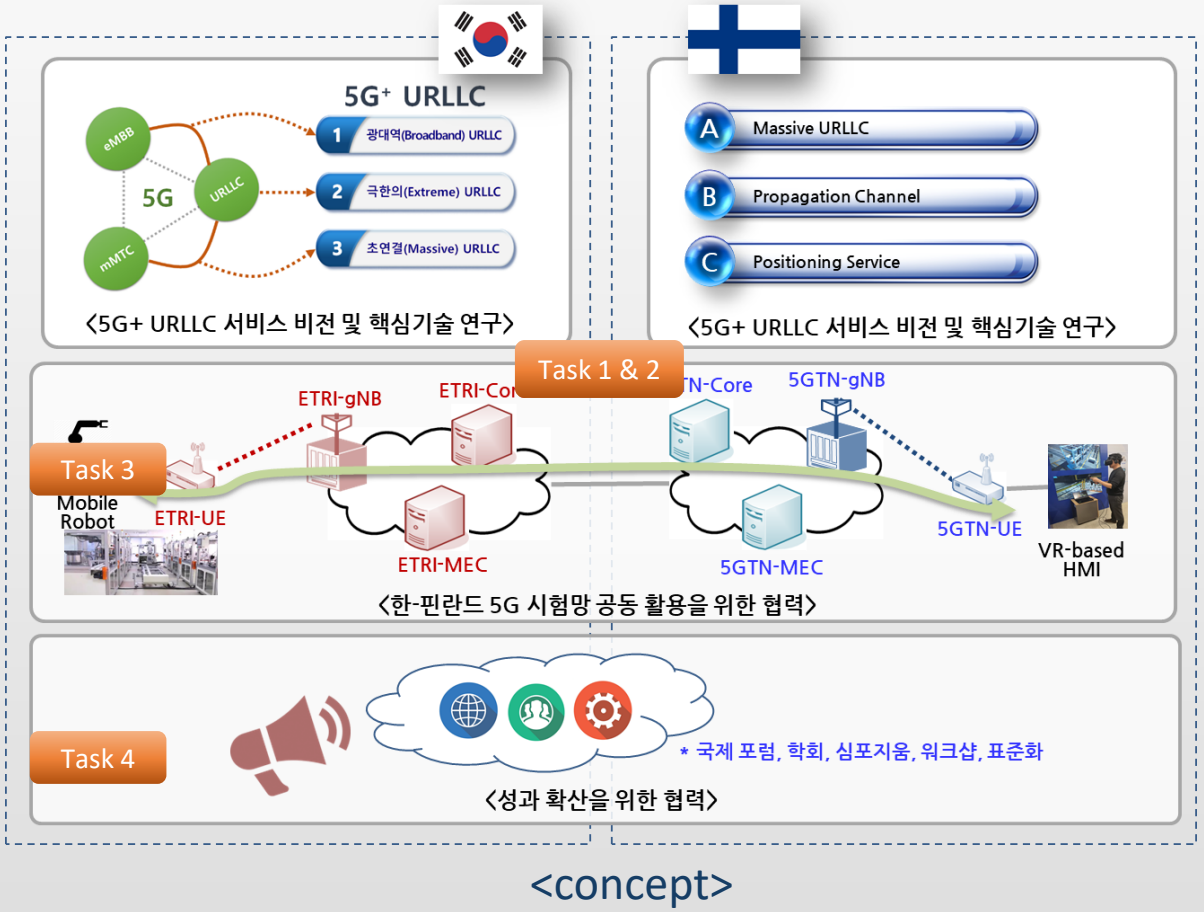
- Period
  - 04.01.2020 ~ 03.31.2020 (2 years)



Project Details

Tasks

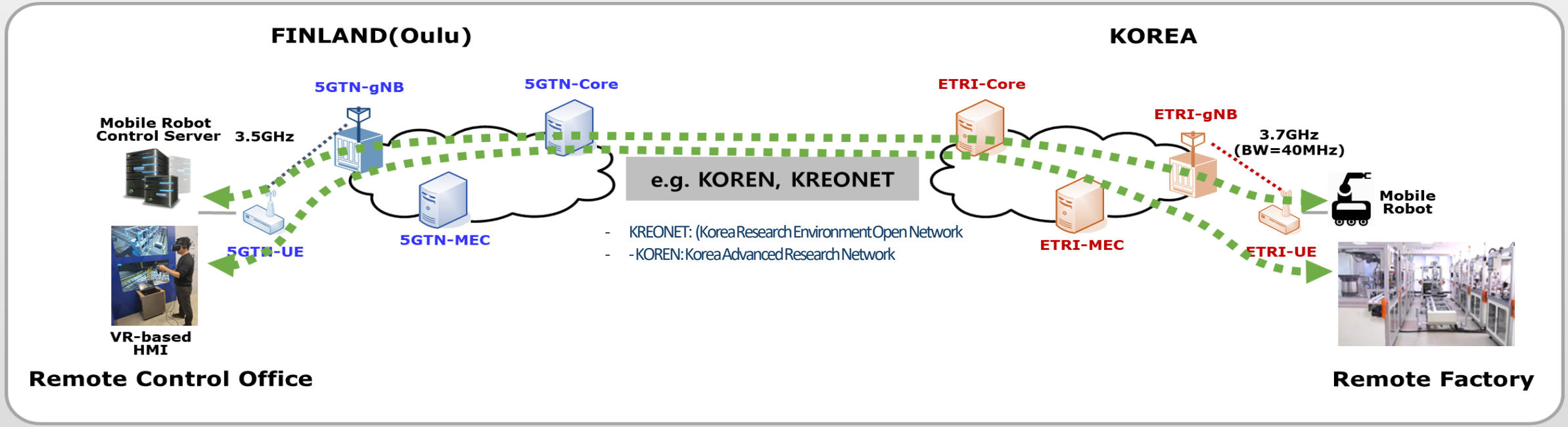
- (Task 1) 5G+ URLLC Service Vision
  - Development of Use cases
- (Task 2) 5G+ URLLC Tech. enabler
  - Research on the evolution of URLLC
- (Task 3) Demonstration
  - Inter-continental Service Test for Industrial Automation
- (Task 4) Dissemination
  - Global Collaboration for Open R&D



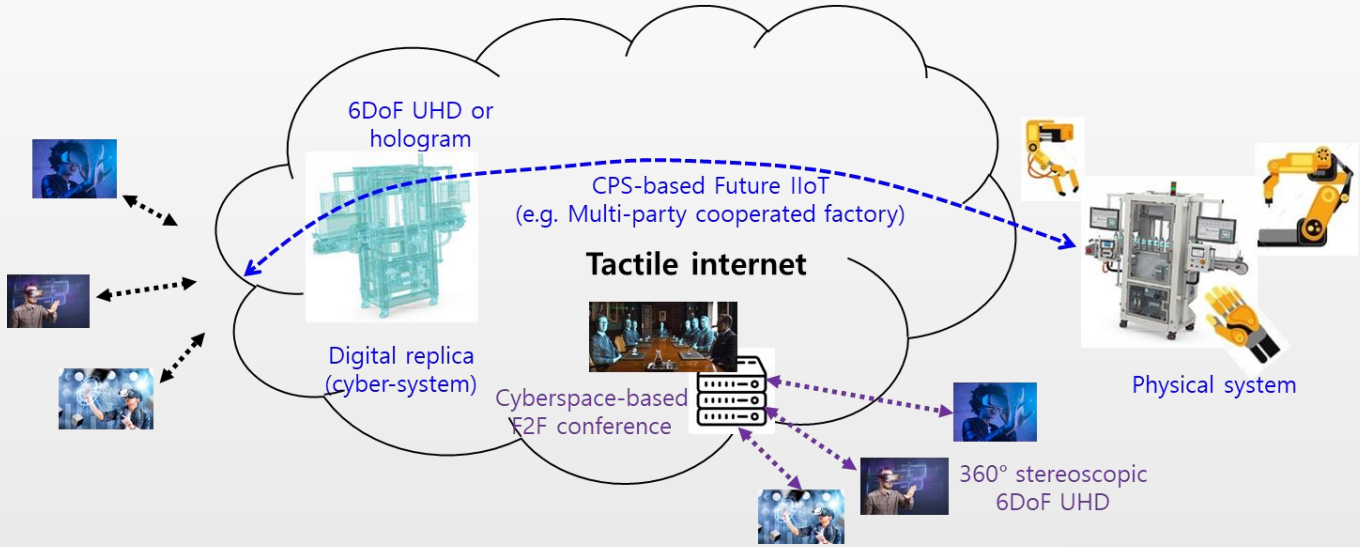
<concept>

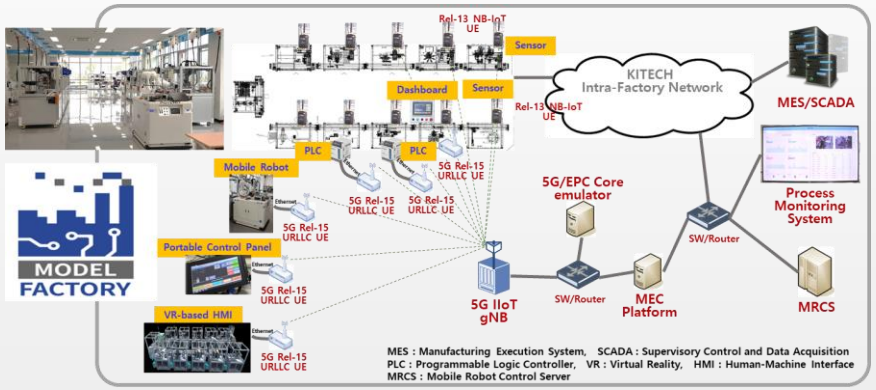
Plan for Demonstration

- Remote control service between countries: Remote/VF(KR), Remote CO(FI)
- Scenario:
  - Remote monitoring in real time at Oulu office through VR-based HMI
  - Mobile Robot control using Robot Controller at Oulu office

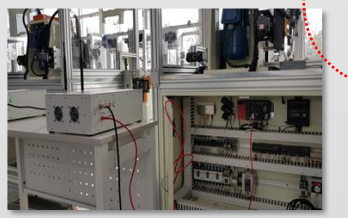


Use Cases

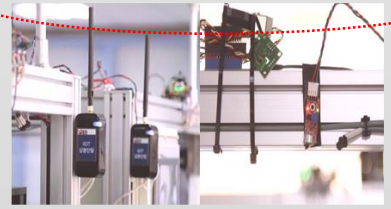




Mobile Robot



Wireless PLC Communications

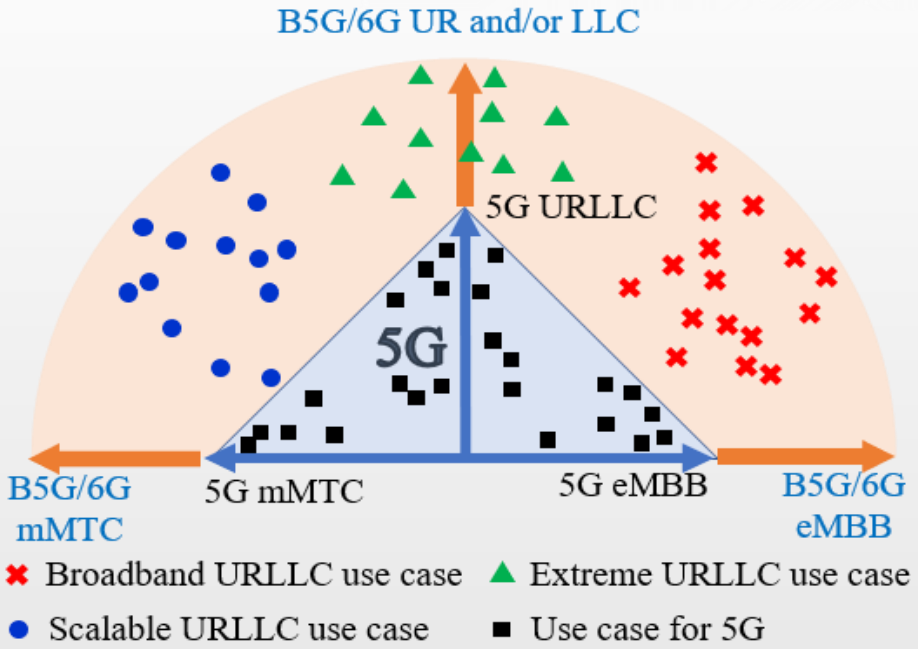


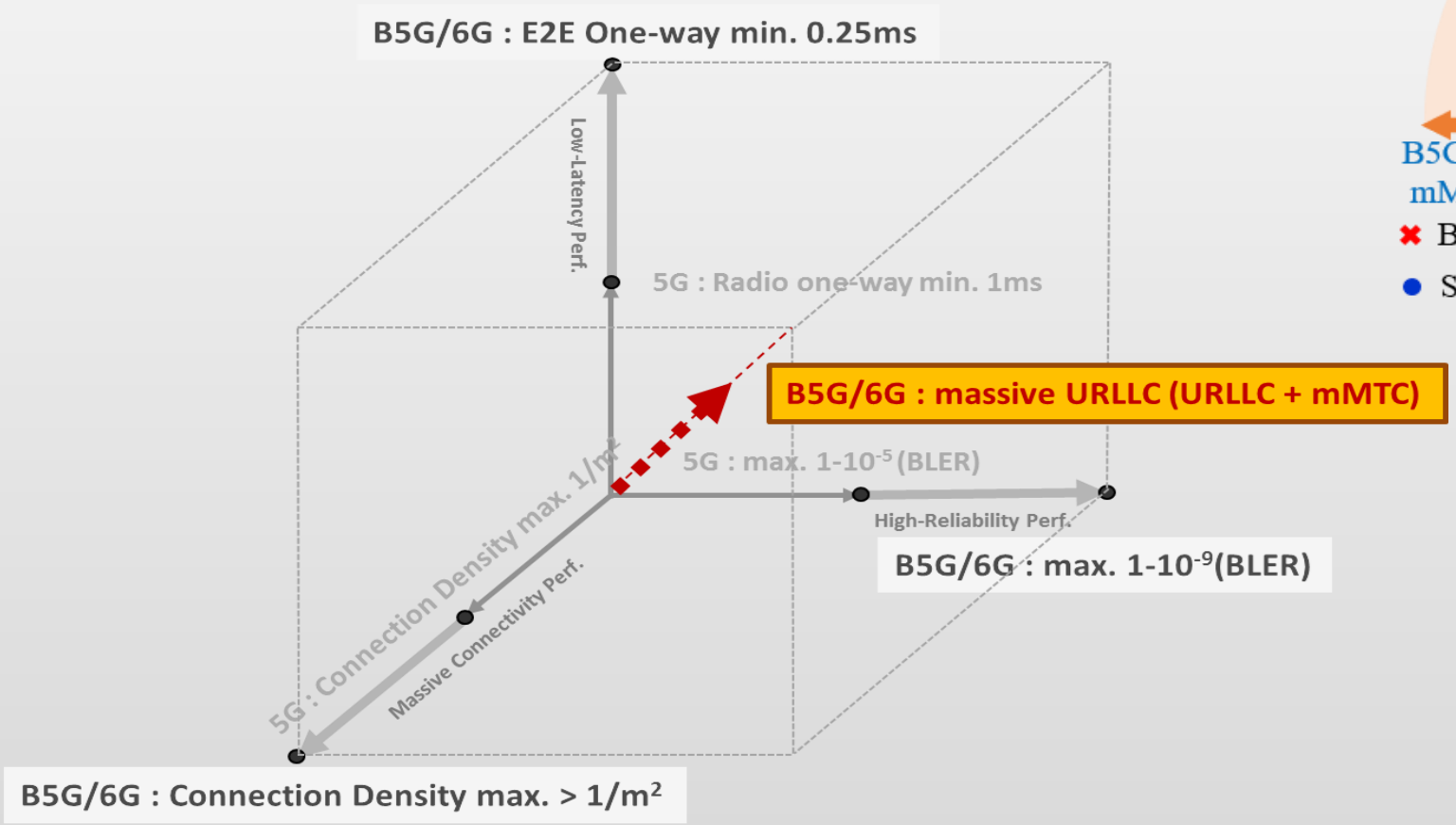
Process Monitoring with Massive Sensors

VR-based HMI

Portable Control Panel

- Broadband URLLC (eMBB + URLLC)
- Extreme URLLC (Advanced URLLC)
- Scalable URLLC (mMTC + URLLC)





B5G use cases and KPIs for each service class

Applications		Use Cases	KPIs	Class
Broadband tactile internet with haptic feedback	CPS-based	Tele-surgery, remote driving	E2E RTL ≤ 20 ms BLER 10^{-9} Data rate > 10 Gbps	Broadband URLLC
		Holographic tele-surgery	E2E RTL ≤ 20 ms BLER 10^{-9} Data rate < 4.6 Tbps	
	Cyber-space based	Digital real estate, eCommerce, eTourism, eConference, eEducation, eGames	E2E RTL ≤ 20 ms BLER 10^{-5} - 10^{-6} Data rate > 10 Gbps	
		Holographic education/training	E2E RTL ≤ 20 ms BLER 10^{-5} - 10^{-6} Data rate < 4.6 Tbps	
Narrowband tactile internet with haptic feedback	CPS-based	Cooperative factory automation	E2E RTL ≤ 20 ms BLER 10^{-5} - 10^{-6}	Scalable URLLC
	Others	Wearables/exoskeletons for healthcare, heavy-labor, and mission critical		
Future ITS	Fusion	Autonomous driving	E2E 5-10 ms BLER 10^{-5}	
	V2X	Smart highway, smart road, smart intersection		
Future factory	Factory automation	Motion control	Cycle time < 0.5 ms Payload <50 bytes	Extreme URLLC

KPIs in 3GPP

3GPP Rel.	Service (Use Cases)	URLLC KPIs		eMBB KPIs	mMTC KPIs	New KPIs
		Reliability(%)	Max E2E Latency(ms)	Data rate (Mbit/s)	Connection density(UEs/km^2)	Clock synchronicity(µs)
Release 15 (5G Phase 1)	Discrete/Process automation (remote-control)	1 - 10^{-5}	10 / 60	10 / 1-100	100,000 / 1,000	Not defined
	Electricity distribution automation (medium/high voltage)	1 - 10^{-5}	40 / 5	10	1,000	
	Entertainment (AR/VR)	1 - 10^{-5}	7 - 15	250	-	
Release16 (5G Phase 2)	Factory automation (motion control)	1 - 10^{-6}	0.5 - 2	1	100	0.9
	Electricity distribution automation (grid fault – automated switching)	1 - 10^{-6}	5	1.5	20	-
	Central power generation automation (wind power plant – control traffic)	1 - 10^{-9} (wired)	16	-	1,000	-
Release 17 (5G evolution)	Wired to wireless 1Gbps link replacement in factory	1 - 10^{-6}	1	250	2 - 5	-
	UHD video for robotic aided surgery/telesurgery	1 - 10^{-6}	1/20	50,000 / 6,000	1 / 2	50
	Audio streaming live performance/outside broadcast contribution - uncompressed UHD video	1-10^{-6} / UL:1-10^{-10}, DL:1–10^{-7}	0.75/400	UL: 0.5, DL: 1 / UL: 12,000, DL: 20	100 – 200 / 1	1

Broadband URLLC

- Use case
  - Multiple HD video streaming
- Target
  - To maximize spectral efficiency with URLLC requirements
- Enabling technologies
  - Intelligent modulation and coding
    - AI-driven approaches find an optimal code for the effective SNR.
    - Nonbinary codes are beneficial to the lossless reception of coded symbols.
  - Terahertz
    - Ultra-massive MIMO provides coverage extension and spectral efficiency improvements.
    - Wider subcarrier spacing or single carrier modulation in THz band

Scalable URLLC

- Use case
  - Production line in Indoor Factory
- Target
  - To maximize connection density with URLLC requirements
- Enabling technologies
  - Positioning based on fingerprint mapping
    - For massive URLLC links, we consider geometrical characteristics as well as the instantaneous minimum required SINR in resource allocation.
    - CSI can be acquired in the fingerprint map according to the location of a device without frequent RS transmission and measurement reports.
  - Advanced random access
    - Grant free access based on NOMA
    - Adaptive preamble allocation based on temporal traffic dynamics

Extreme URLLC

- Use case
  - Motion control in Indoor Factory
- Target
  - To achieve higher reliability or lower latency
- Enabling technologies
  - Location awareness
    - Location information as well as sensing information can improve RRM, and mitigate interference, control signalling overhead, and beam management overhead.
  - Ubiquitous diversity
    - For higher reliability, signal mapping design of massive transmit diversity with wide bandwidth resource allocation
    - For lower latency, low rate channel coding with wide bandwidth and without the feedback of channel state information

Summary

- 6G Vision, use cases, requirements, technical solutions considered
  - Current URLLC, which is one of the key features in 5G, has inherent limitations to fully support future services
- URLLC will continue its evolutionary path to extend the service scenarios and features and finally converging to 6G technologies in 2030
- Three URLLC variants proposed
  - Broadband, Scalable and Extreme URLLC
- Research directions
  - Broadband URLLC: coding & modulation and large bandwidths toward THz
  - Scalable URLLC: random access and positioning based fingerprint mapping
  - Extreme URLLC: location awareness for RRM and ubiquitous diversity
- Open R&D shall help shaping what 6G will be

  (i.e. Collaboration between ETRI and Univ of Oulu in 6G Flagship)

Thank you!

Making a Better Tomorrow

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