

6G



6G Mobile Wireless Communications Vision, Roadmap, Technologies & Use Cases *Course Summary & Conclusion*

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Course Outline: An Introduction to 6G Wireless

- Part 1: Introduction
- Part 2: 6G Vision
- Part 3: 6G Use Cases & Applications
- Part 4: 6G Timeline
- Part 5: 6G Requirements
- Part 6: 6G Groups
- Part 7: 6G Technologies
- Part 8: 6G Devices
- **Part 9: Course Summary and Conclusion**

Part 1: Introduction

- What exactly is 6G?
- When is 6G coming?
- If 5G is being launched just now, why are we talking about 6G already?
- Who is standardising 6G?
- Will 6G be called 6G?

4G	IMT-Advanced	LTE-Advanced	E-UTRAN	Evolved Packet Core (EPC)	Evolved Packet System (EPS)
5G	IMT-2020	5G	New Radio (NR)	5G Core (5GC)	5G System (5GS)
6G	IMT-2030	6G	?	?	?

Red text indicates that the names have not been confirmed.

Part 2: 6G Vision

NTT Docomo's 6G Vision

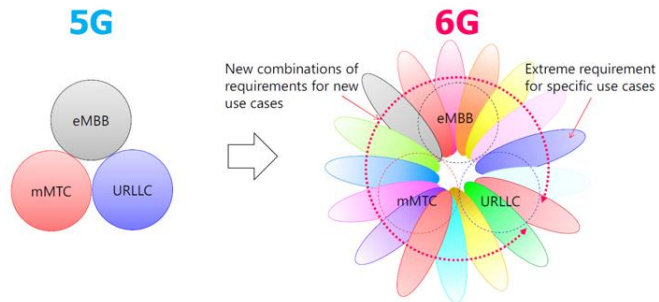
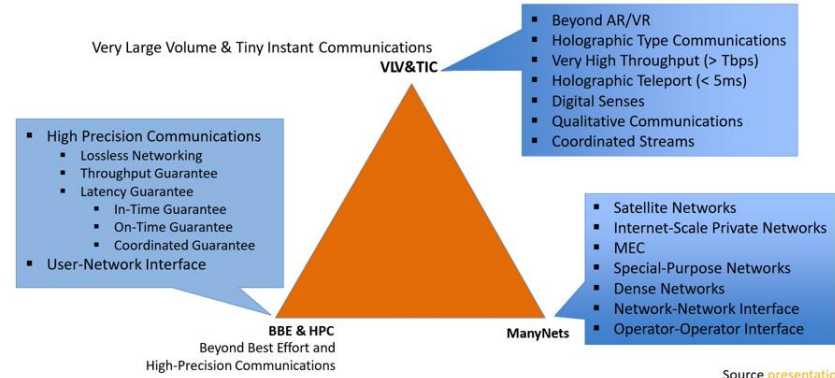


Figure 2-5. Image of technological development toward 6G

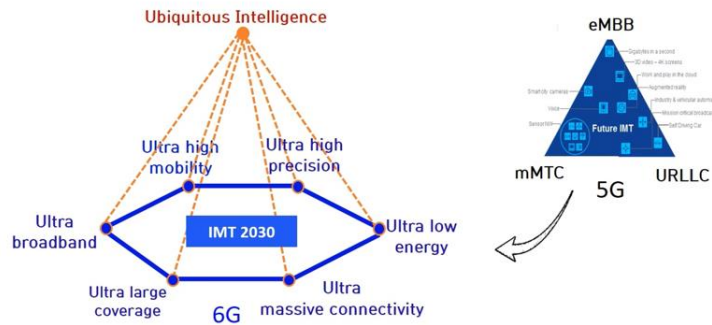
NTT Docomo 6G
whitepaper

ITU FG NET-2030 Vision



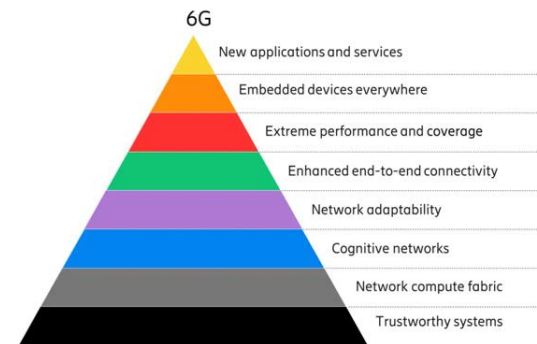
Source: presentation

ETRI: 6G Usage Elements and Scenarios



Source: ETRI, South Korea ([link](#))

Ericsson's 6G Vision



Source: [Free 6G Training](#)

Part 3: 6G Use Cases & Applications

XR will impact everyone and everything

Transform how children learn and play



Children chasing virtual characters/immersive gaming, students using VR aids

Tourists exploring historical sites



Exploring historical sites through VR seeing them in their original state

Families communicating



Families brought together with life-like communication

Working Professionals



Engineers collaborating on shared design to improve efficiency

Health and Fitness



Virtual trainers to motivate fitness groups

People with disabilities



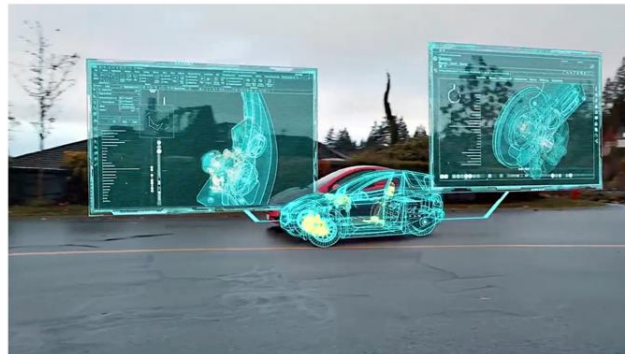
Experiences that might be impossible or unsafe for them in real life. They can run, ski, ride bikes, and climb mountains.

Holoportation / 'Holographic Telepresence'



Holoportation example from movie Kingsman: The Secret Service (see [video](#))

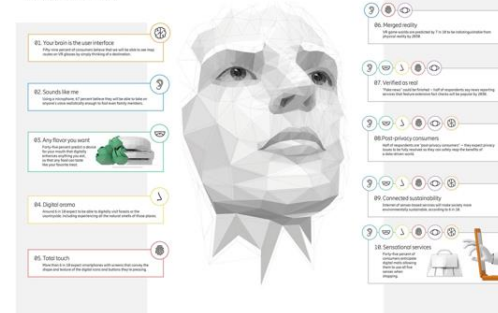
Digital Twins



Source: [Siemens](#)

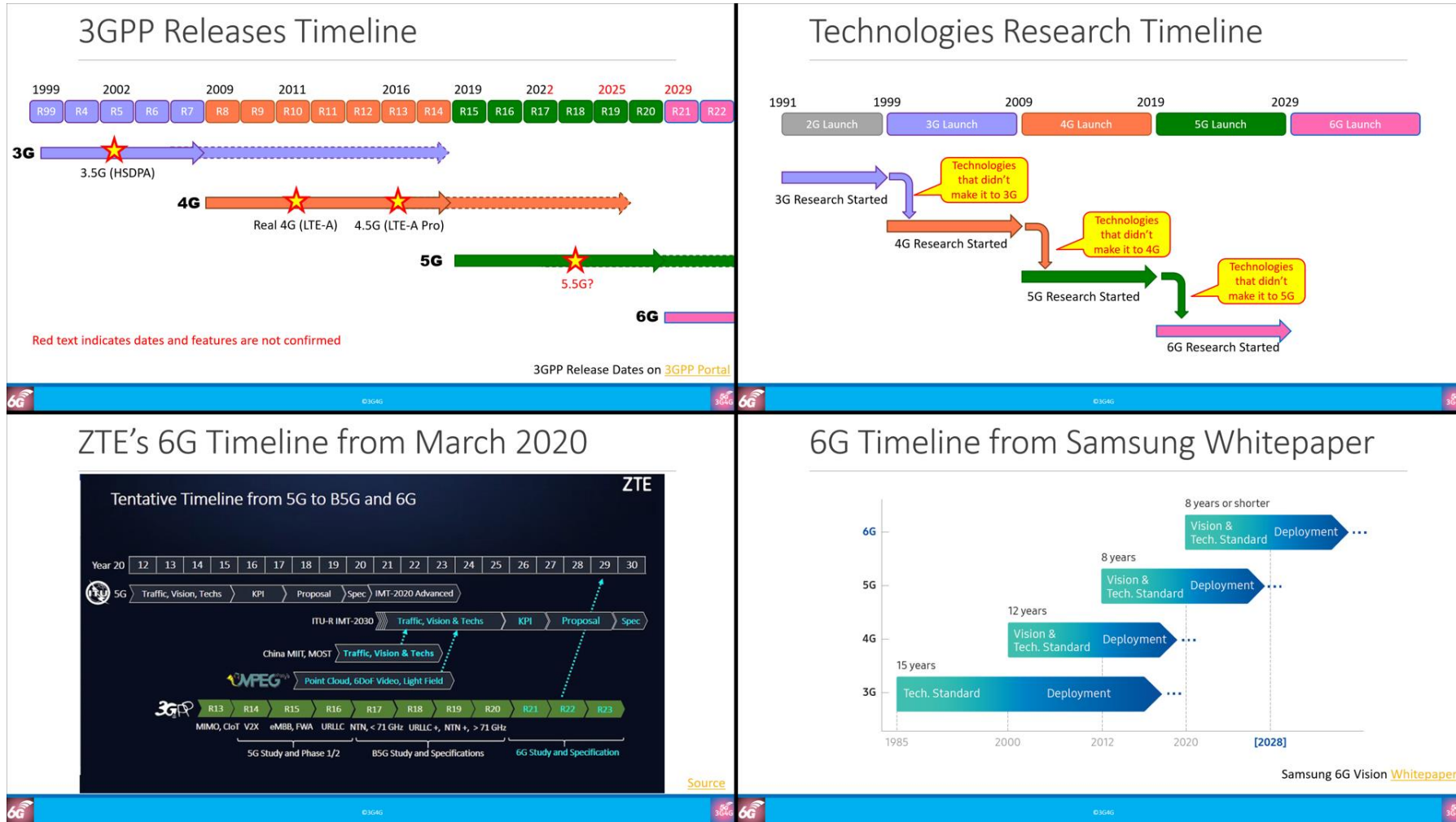
Ericsson's 2030 Trends: Internet of Senses

10 Hot Consumer Trends 2030
Welcome to the internet of the senses.



Watch the 'Internet of senses' video [here](#)

Part 4: 6G Timeline



Part 5: 6G Requirements

NTT Docomo 6G Requirements

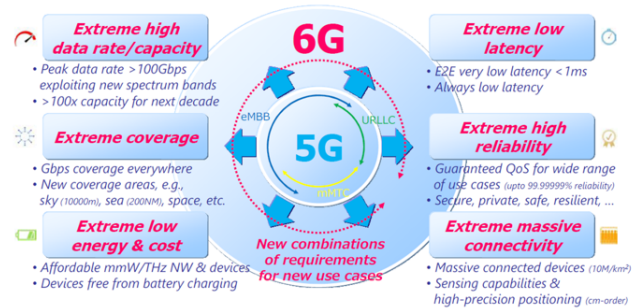


Figure 3-1. Requirements for 6G wireless technology

Source: NTT Docomo 6G Whitepaper, Jan 2020

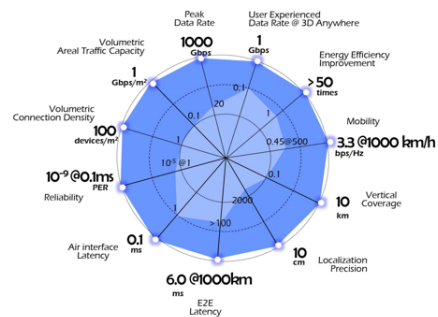
6G Research Visions, 5G & 6G KPIs Comparison

KPI	5G	6G
Peak data rate	20 Gb/s	1 Tb/s
Experienced data rate	0.1 Gb/s	1 Gb/s
Peak spectral efficiency	30 b/s/Hz	60 b/s/Hz
Experienced spectral efficiency	0.3 b/s/Hz	3 b/s/Hz
Maximum bandwidth	1 GHz	100 GHz
Area traffic capacity	10 Mb/s/m ²	1 Gb/s/m ²
Connection density	10 ⁶ devices/km ²	10 ⁷ devices/km ²
Energy efficiency	not specified	1 Tb/J
Latency	1 ms	100 μs
Reliability	1-10 ⁻⁴	1-10 ⁻⁹
Jitter	not specified	1 μs
Mobility	500 km/h	1000 km/h

Table 1: A comparison of 5G and 6G KPIs [4-6,9].

6G Research Visions: White Paper 10 on Broadband Connectivity in 6G

ETRI: 6G KPIs



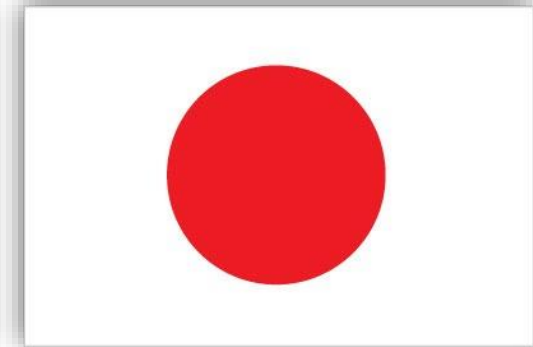
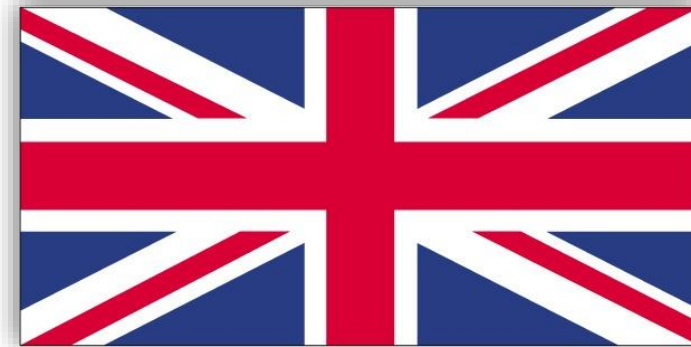
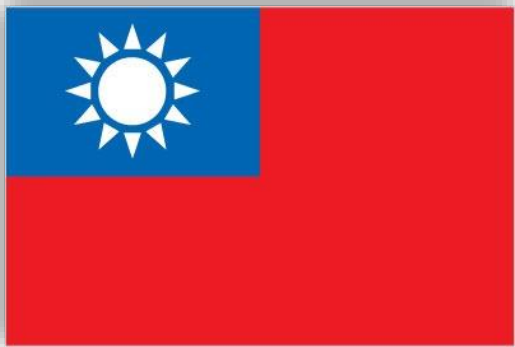
Source: ETRI, South Korea ([link](#))

Comparison* of different Technology Generations

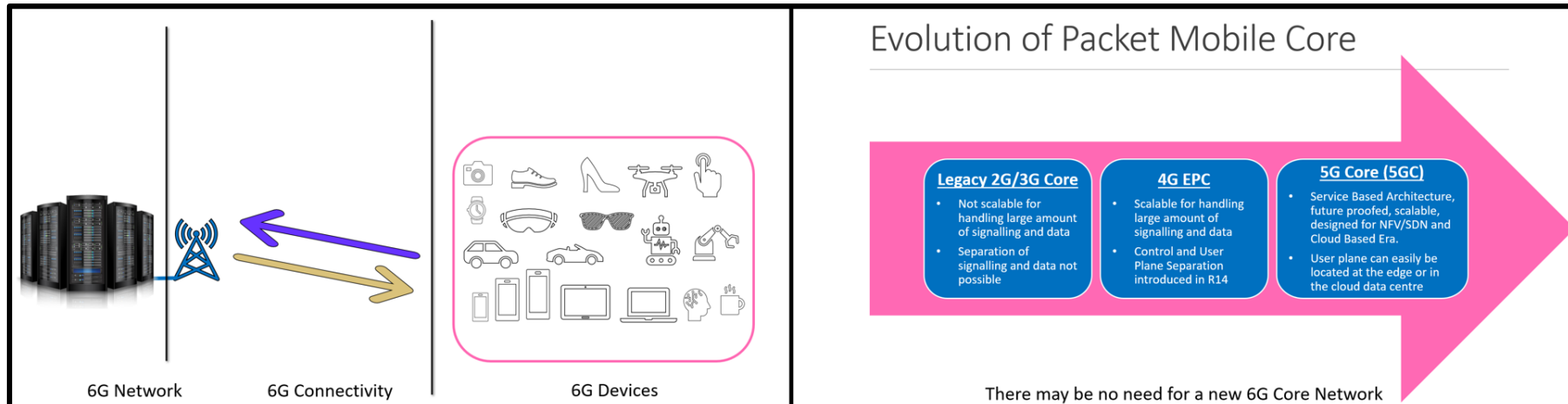
	2G	3G (HSPA+)	4G	5G	6G**
Year	1990	2000	2010	2020	2030
Max DL Speed (theoretical)	473.6 Kbps	42 Mbps	3 Gbps	20 Gbps	1 Tbps
Avg DL Speed (practical)	50 Kbps	8 Mbps	100 Mbps	300 Mbps	1 Gbps
Max UL Speed (theoretical)	473.6 Kbps	11.5 Mbps	1.5 Gbps	10 Gbps	10 Gbps
Avg UL Speed (practical)	50 Kbps	2 Mbps	50 Mbps	100 Mbps	1 Gbps
E2E Latency (practical)	600 ms	120 ms	30 ms	10 ms	1 ms
Reliability	99%	99.9%	99.99%	99.999%	99.99999%
Connection Density	N/a	N/a	10 ⁵ devices/km ²	10 ⁶ devices/km ²	10 ⁷ devices/km ²
Mobility	150 km/h	300 km/h	350 km/h	500 km/h	1000 km/h

* Approximate values to show comparisons. ** Subject to change when standards process starts.

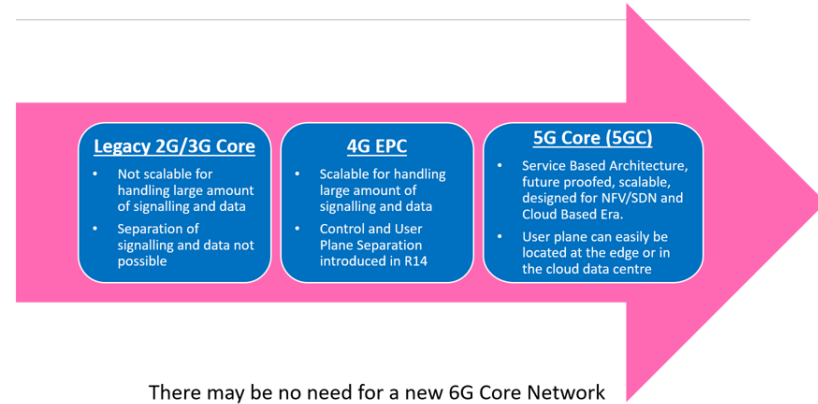
Part 6: 6G Groups



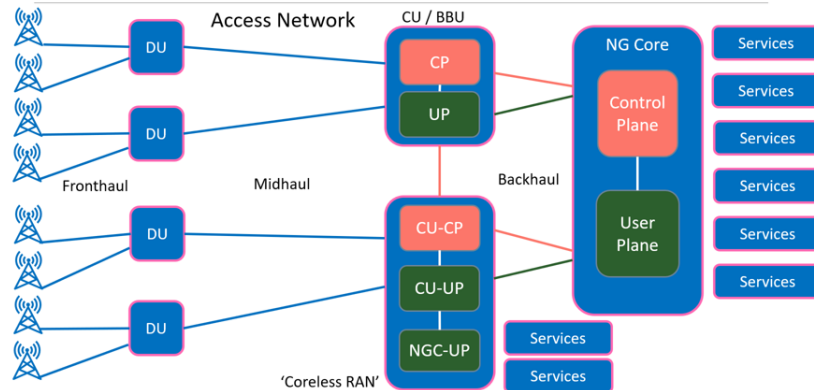
Part 7: 6G Technologies



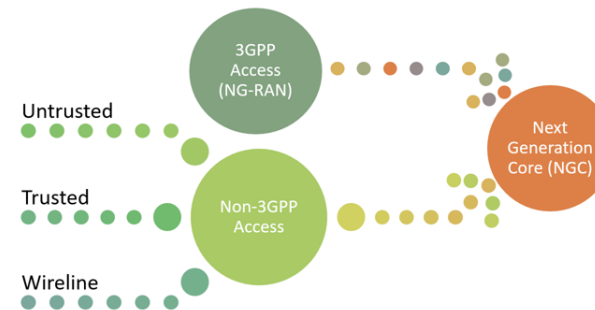
Evolution of Packet Mobile Core



RAN-Core convergence



Support of non-3GPP access



Complete Tutorial [here](#)

Part 7: 6G Technologies

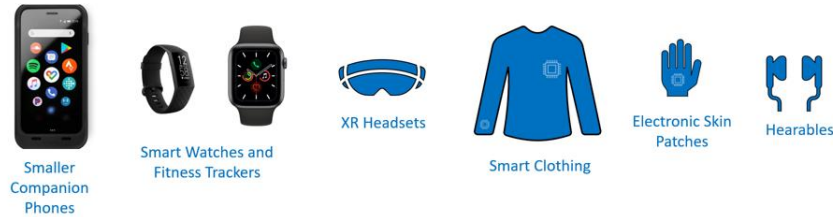
List of Probable 6G Technologies

Spectrum	THz	mmWave	
Spectrum Sharing			
Antenna Technologies	OAM	RIS	Metamaterials
Evolution of Duplex	Half Duplex FDD	In-band Full Duplex (IBFD)	
Evolution of Network Topology	HAPS, Satellites, NTN	Wireless Wireline Convergence	
Comprehensive AI/ML	AI/ML Air Interface	AI/ML at Edge	AI/ML in RAN
Split Computing			
High Precision Network			
Communications & Sensing			
Extreme Connectivity/Networking	Extreme URLLC		
Industrial IoT	Sub-Networks		
Localization & Sensing			
Security & Trust			
Fully Service Based, Cloud Native Networking and RAN-Core Convergence			
Expanded integration of variable wireless technologies			
Open Platforms			

Presentations on these topics coming soon

Part 8: 6G Devices

Example of Companion Devices



© 3G4G

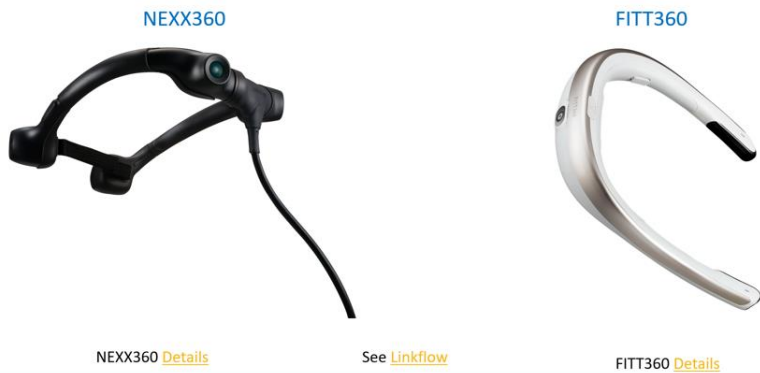


Source: Qualcomm

A glimpse into the future — everyday AR glasses



Wearable 360° Cameras



© 3G4G



Wearables – TESLASUIT ([link](#))



Teslasuit relies on 2.4GHz Wi-Fi for connectivity today. Could it be using 5G/6G in future?

© 3G4G



An Update from ITU

MyITU > News > [5G: IMT-2020 update](#)

Beyond 5G: What's next for IMT?

5G

NETWORK MANAGEMENT

POLICY AND REGULATION

STANDARDS

02/02/2021 | ITU News



The ITU Radiocommunication Sector (ITU-R) has recently published Recommendation ITU-R M.2150 titled 'Detailed specifications of the radio interfaces of IMT-2020'.

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Further Reading – Our Websites

- Free 6G Training ([link](#))
- 3G4G: 6G and Beyond-5G Wireless Technology ([link](#))

Not directly relevant to 6G but may be useful

- The 3G4G Blog ([link](#))
- Telecoms Infrastructure Blog ([link](#))
- Operator Watch Blog ([link](#))
- Connectivity Technology Blog ([link](#))
- 3G4G YouTube ([link](#))
- Free 5G Training ([link](#))

Further Reading – 6G Whitepapers

- 6G Research Visions: White paper 1 on Key drivers and research challenges for 6G ubiquitous wireless intelligence, Sep 2019 ([link](#))
- 6G Research Visions: White paper 2 on 6G Drivers and The UN SDGs, June 2020 ([link](#))
- 6G Research Visions: White Paper 3 on Business of 6G, June 2020 ([link](#))
- 6G Research Visions: White Paper 4 on Validation and Trials for Verticals towards 2030's, June 2020 ([link](#))
- 6G Research Visions: White Paper 5 on Connectivity for Remote Areas, June 2020 ([link](#))
- 6G Research Visions: White Paper 6 on 6G Networking, June 2020 ([link](#))
- 6G Research Visions: White Paper 7 on Machine Learning in 6G Wireless Communication Networks, June 2020 ([link](#))
- 6G Research Visions: White Paper 8 on Edge Intelligence, June 2020 ([link](#))
- 6G Research Visions: White Paper 9 on Research Challenges for Trust, Security and Privacy, June 2020 ([link](#))
- 6G Research Visions: White Paper 10 on Broadband Connectivity in 6G, June 2020 ([link](#))
- 6G Research Visions: White Paper 11 on Critical and Massive Machine Type Communication towards 6G, June 2020 ([link](#))
- 6G Research Visions: White Paper 12 on Localization and Sensing, June 2020 ([link](#))

Further Reading – 6G Whitepapers

- ITU FG NET-2030: Focus Group on Technologies for Network 2030 ([link](#))
- 5G Americas: Mobile Communications Beyond 2020 – The Evolution of 5G Towards Next G, Dec 2020 ([link](#))
- NTT Docomo white paper: 5G Evolution and 6G, January 2020 ([link](#))
- University of Surrey, 6GIC – 6G Wireless: A New Strategic Vision ([link](#))
- Samsung 6G Vision Whitepaper, July 2020 ([link](#))
- Nokia Bell Labs: Communications in the 6G Era Whitepaper, Sep 2020 ([link](#))
- Ericsson: Ever-present intelligent communication - A research outlook towards 6G, Nov 2020 ([link](#))
- University of Surrey, 6GIC – 6G Wireless: A New Strategic Vision ([link](#))

Further Reading – 6G Research Papers

- Z. Zhang et al., "6G Wireless Networks: Vision, Requirements, Architecture, and Key Technologies," in IEEE Vehicular Technology Magazine, 28-41, Sept. 2019 ([link](#))
- Virtual Reality Book by Steven M. LaValle ([link](#))

Further Reading – Others

- Free 6G Training: 6G Usage Elements and Scenarios ([link](#))
- Free 6G Training: '6G Vision for 2030+' from 6th Generation Innovation Centre (6GIC) ([link](#))
- Free 6G Training: Huawei talks about Beyond 5G, 5.5G and 6G ([link](#))
- NTT announces new R&D projects of Digital Twin Computing, Nov 2020 ([link](#))
- Free 6G Training: 6G may just make Teleportation a Reality ([link](#))
- Ericsson: 10 Hot Consumer Trends 2030 ([link](#))
- Enabling holographic media for future applications: Missing pieces and limitations in networks, SIGCOMM, Aug 2019 ([link](#))
- Holographic Type Communication, Kiran Makhijani, Future Networks, Futurewei, Oct 2019 ([link](#))

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