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**5G and Tactile Internet. Network and Services
Decentralization**

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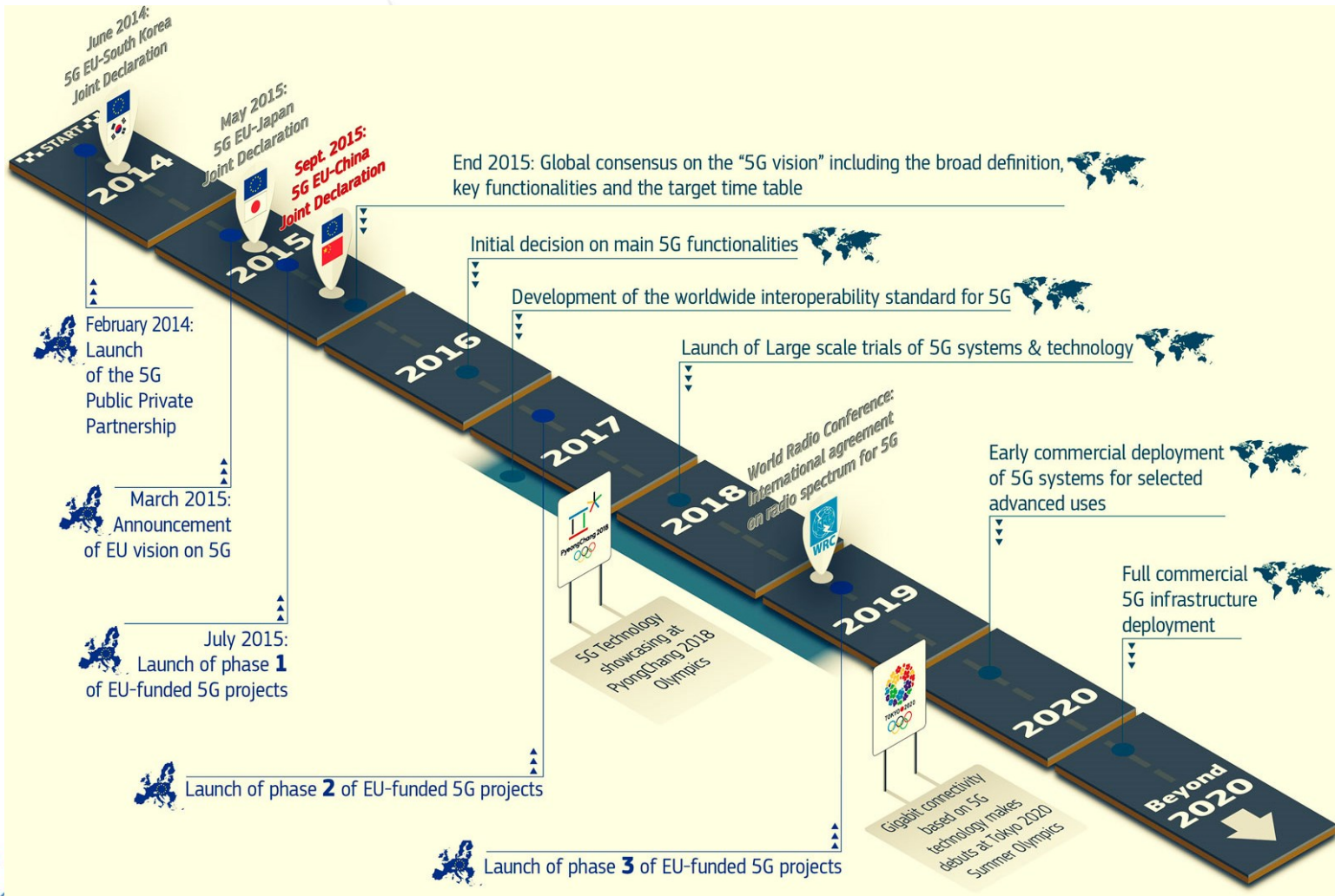
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Fifth-Generation networks

- 5G or IMT-2020 - a new generation of telecommunication standards
- In June 2015, the ITU has developed a roadmap of IMT-2020
- The full implementation of IMT-2020 is expected by 2020 at the latest

Roadmap of «IMT-2020»



<https://ec.europa.eu/digital-agenda/en/towards-5g>

Vision of IMT-2020 (5G)



<https://ec.europa.eu/digital-agenda/en/towards-5g>

Potential technologies of IMT-2020/5G

- Multiple MIMO antennas
- Using the centimeter and millimeter frequency ranges
- UDN - Ultra-Dense networking
- D2D (Device-to-Device) Communications
- SDN (Software-Defined Network)
- NFV (Network Functions Virtualization)
- The convergence of all existing legacy technologies

Estimated parameters of 5G networks

- Data rate:
10-50 Gb/s (Download); 100 Mb/1 Gb/s (Upload)
- Delay - 1 millisecond
- Frequency range (in July 2016):
28 GHz (27,5-28,35 GHz)
37 GHz (37-38,6 GHz)
39 GHz (38,6-40 GHz)
64-71 GHz
95 GHz (in future)
- Number of subscriber's units in the cell - up to 300K
- Failure probability is less than 10^{-7} (layup 3.17 s/year)

Network architecture of 5G networks

5G network will be based on three subsystems (clouds):

- Access Cloud
- Control Cloud
- Core cloud

“On demand” architecture

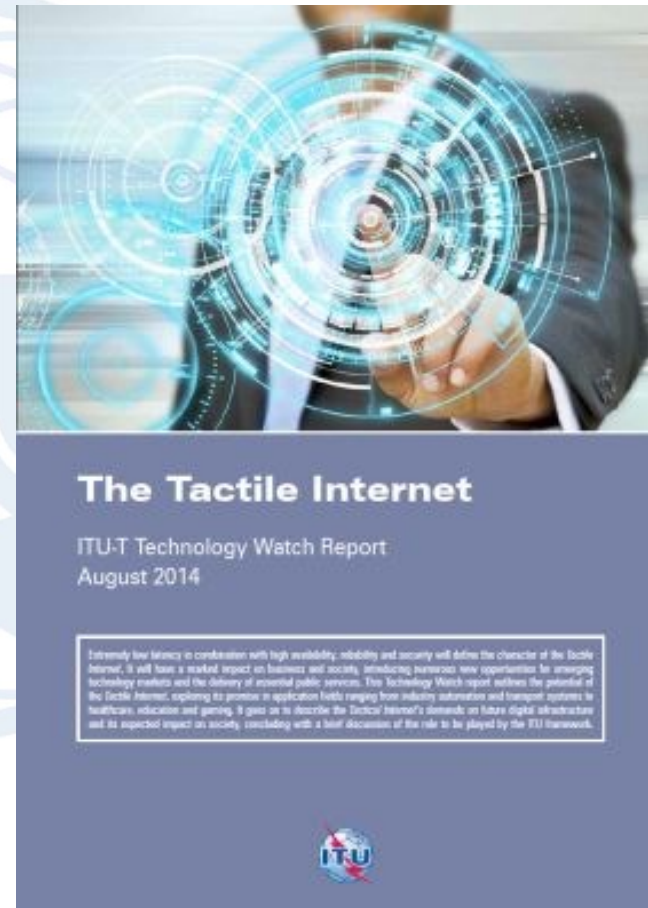
Key issues of the implementation of 5G

- Current wireless technologies, which are available at the access level, cannot achieve the data rate ~ 10 Gb/s
- Standardization and implementation of new technologies are needed:
 - MU-MIMO
 - SCMA, MUSA,...
 - F-OFDM, FB-OFDM,...
 - Polar Code
 - WiGig and etc.

New application of IoT - Tactile Internet



2005



2014

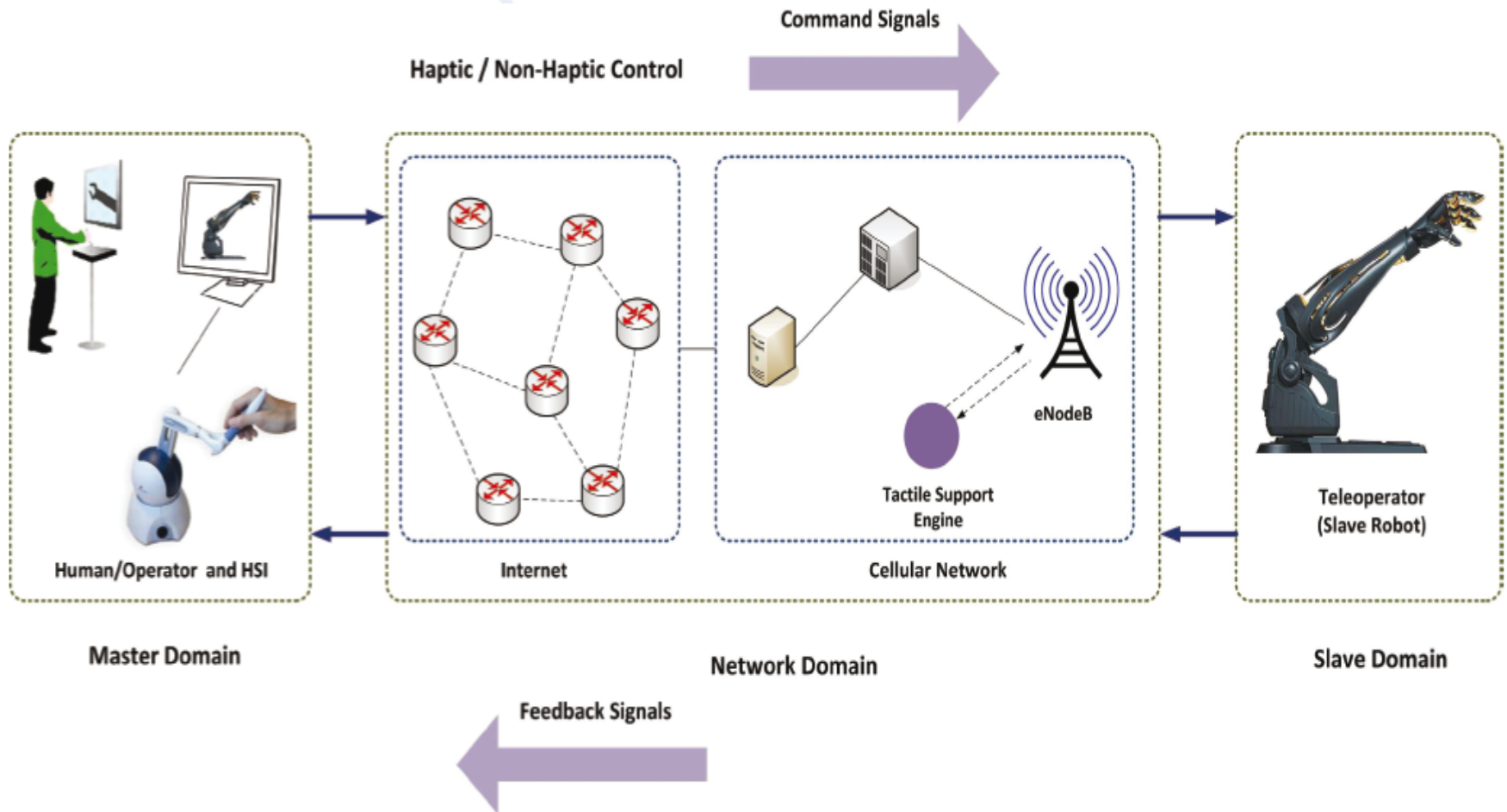
Evolution of delays

Network	Delay value
NGN	100 ms
Telemedicine network	10 ms
Tactile Internet	1 ms

Evolution of data rate

Network	The data rate at the access layer	The data rate at the core
NGN	MB/s	GB/s
Communication networks with the low latency	GB/s	TB/s
Tactile Internet	TB/s	PB/s

Architecture of Tactile Internet

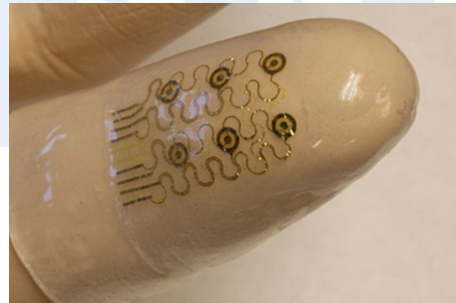


Applications of Tactile Internet

1. Augmented reality
2. Telemedicine network
3. Emergencies



Gloves which transmit feelings



Electronic skin



Tactile mattress for babies

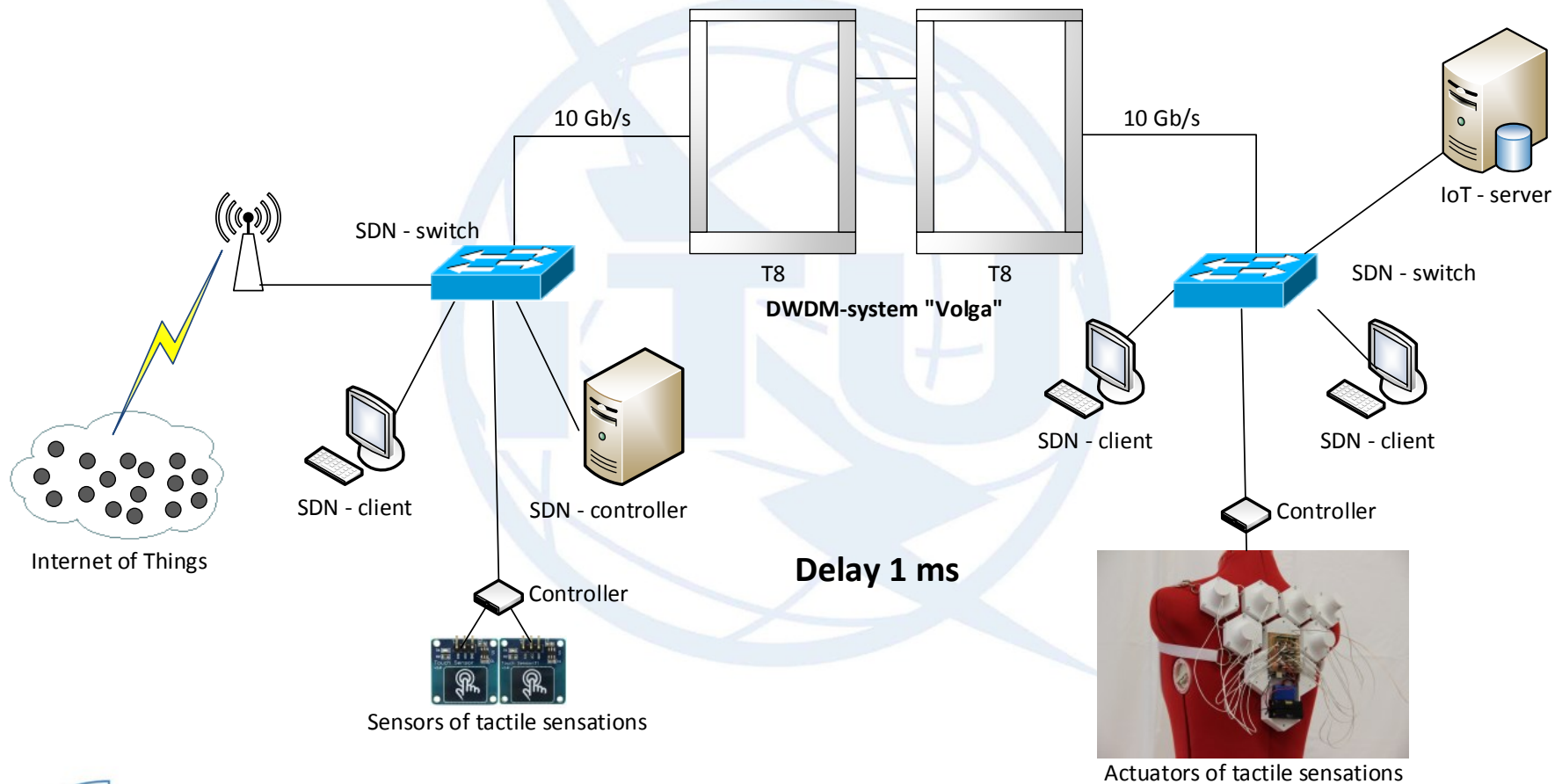
Virtual Reality
Augmented Reality



Existing Cellular Technologies are not ready for Tactile Internet

Technology	The data rate	Delay
GPRS	114 kbps	~ 500 ms
EDGE	236.8 kbps	~ 250 ms
W-CDMA	384 kbps	~ 200 ms
HSPA	2 Mbps	~ 150 ms
HSPA	42 Mbps	~ 70 ms
LTE	300 Mbps	~ 30 ms
LTE-A	1 Gbps	~ 20 ms

The model network for testing Tactile Internet applications



Decentralized networks

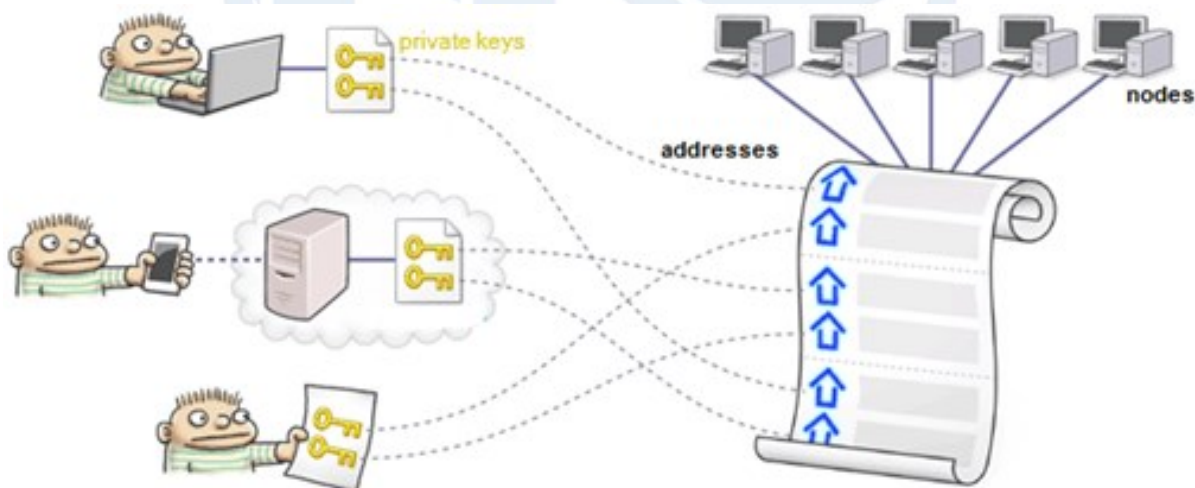
- Computer networks which are based on the equality of participants
- In such networks, there are no dedicated servers. Every node (peer) is client/server
- In spite of a client/server-based architecture, this architecture is robust and can function with any number of available nodes

Hybrid networks (partially decentralized)

- There are servers which are used for coordinating, searching and providing information about existing network equipment and their status (on-line, off-line, etc.)
- Hybrid networks are rapid, as centralized networks, and reliable as they are based on the independent indexing servers which synchronize information between themselves
- Network will continue functioning even though one or more servers are broken

Services of decentralized networks

- Data storage
- Security of information
- Bank transfers



Clouds are located closer to the consumer

To reduce network latency, it is advised to place a cloud closer to the user:

- Home-based cloud (e.g. for IoT-devices of smart home)
- Cloud for augmented reality applications
- Cloud for nanonetworks to be used in telemedicine



Conclusions (1)

1. 5G networks become a platform for different applications of the Internet of Things. The main traffic will be consumed by devices, not people
2. The basic architecture of the 5G networks is determined – new standards and guidelines for the implementation of 5G are needed
3. Due to the high data rates and low latency in the future networks, a new application of IoT “Tactile Internet” can be made available

Conclusions (2)

4. Model Network needs to be set up for simulating interconnection scenarios for Tactile Internet
5. Network decentralization can be used for delivering new services, such as distributed data storage, information security, banking, to name a few

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