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Roadmapping Telecom Technology

- **The roadmap methodology identifies technology needs and possible solutions.**

- **It also lays out a timetable by which different parts of the ecosystem need to be evaluated**
  - **Firstly by research organizations (~10years)**
  - **Secondly when (~5 years) feasibility of the best solutions needs to be evaluated by development consortia (typically)**
  - **Finally when (1-3 years) actual industry implementation needs to occur.**

Reference:
https://futurenetworks.ieee.org/roadmap

Roadmapping Telecom Technology

- **The pace of the cell phone industry has been mostly characterized by the introduction of new phone models endowed with new features at 6 to 12 months intervals.**

- **Furthermore, the wireless phone industry has transition from one Generation to the next in about 10-year intervals. The technical item that most closely correlates with this time intervals is constituted by the introduction of a new spectrum with any new wireless Generation.**

- **The advent of "5G" is heralded by multiple industries (some already existing and some completely new) each advertising different features of what "5G" is suppose to provide. A merge, or at least a compatibility, of multiple capabilities supported, requested and heralded by completely different industry players that have never cooperated with each other make the deployment of a "5G' network an unprecedented challenge. This has never happened before!**

Reference:

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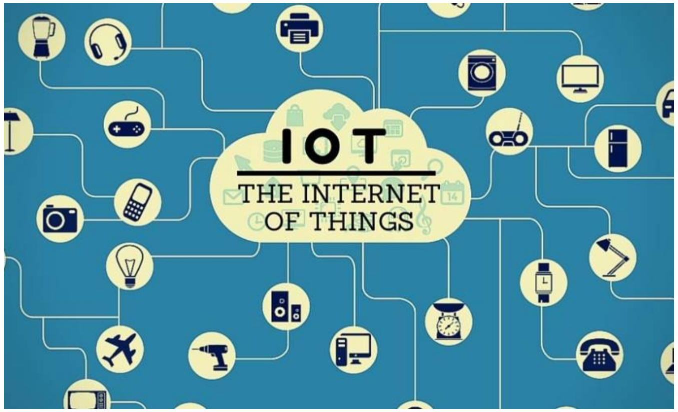
IEEE International Network Generations Roadmap (INGR)

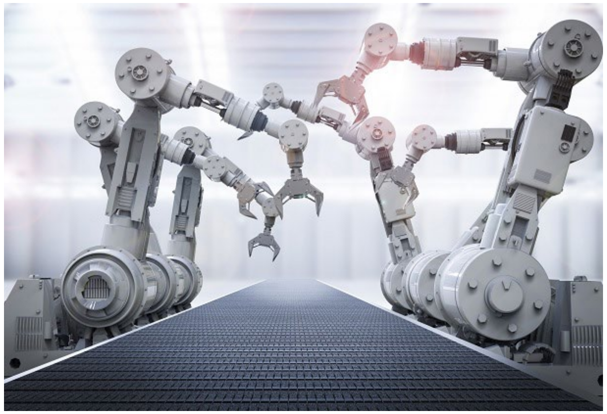
- ✓ Application and Services
- ✓ Deployment
- ✓ Edge Automation Platform
- ✓ Hardware
- ✓ Massive MIMO
- ✓ Millimeter Wave
- ✓ Optics
- ✓ Satellite
- ✓ Security
- ✓ Standardization Building Blocks
- ✓ System Optimization
- ✓ Testbed
- ✓ More to come…

5G Applications

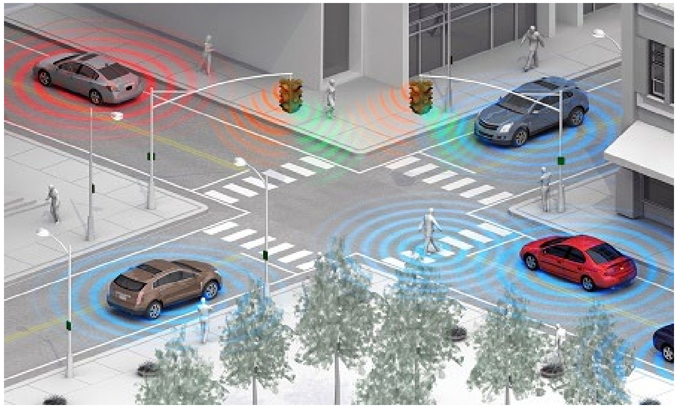
VR/AR Gaming



IoT and Smart City



Critical Control



Autonomous Driving

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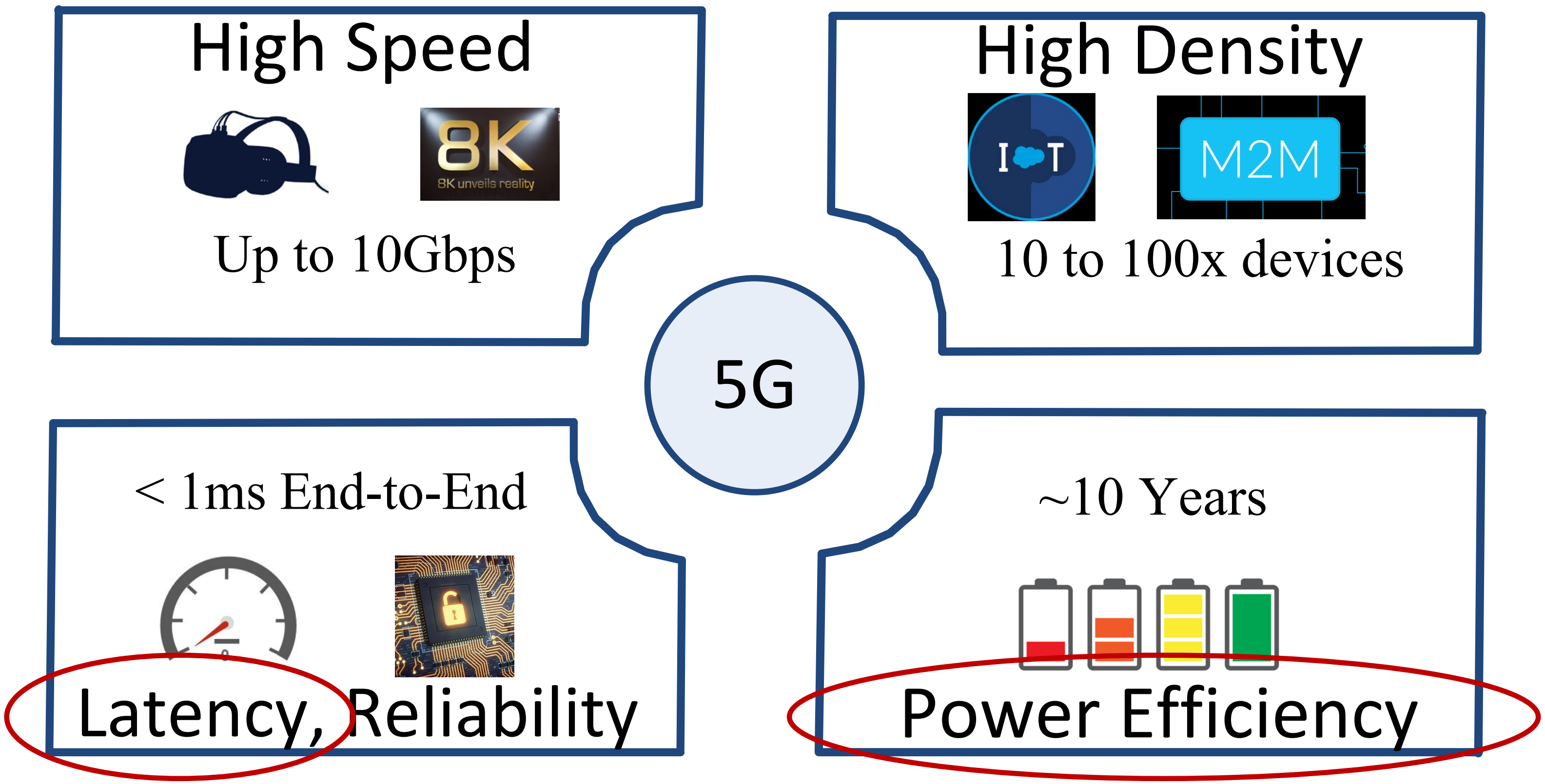
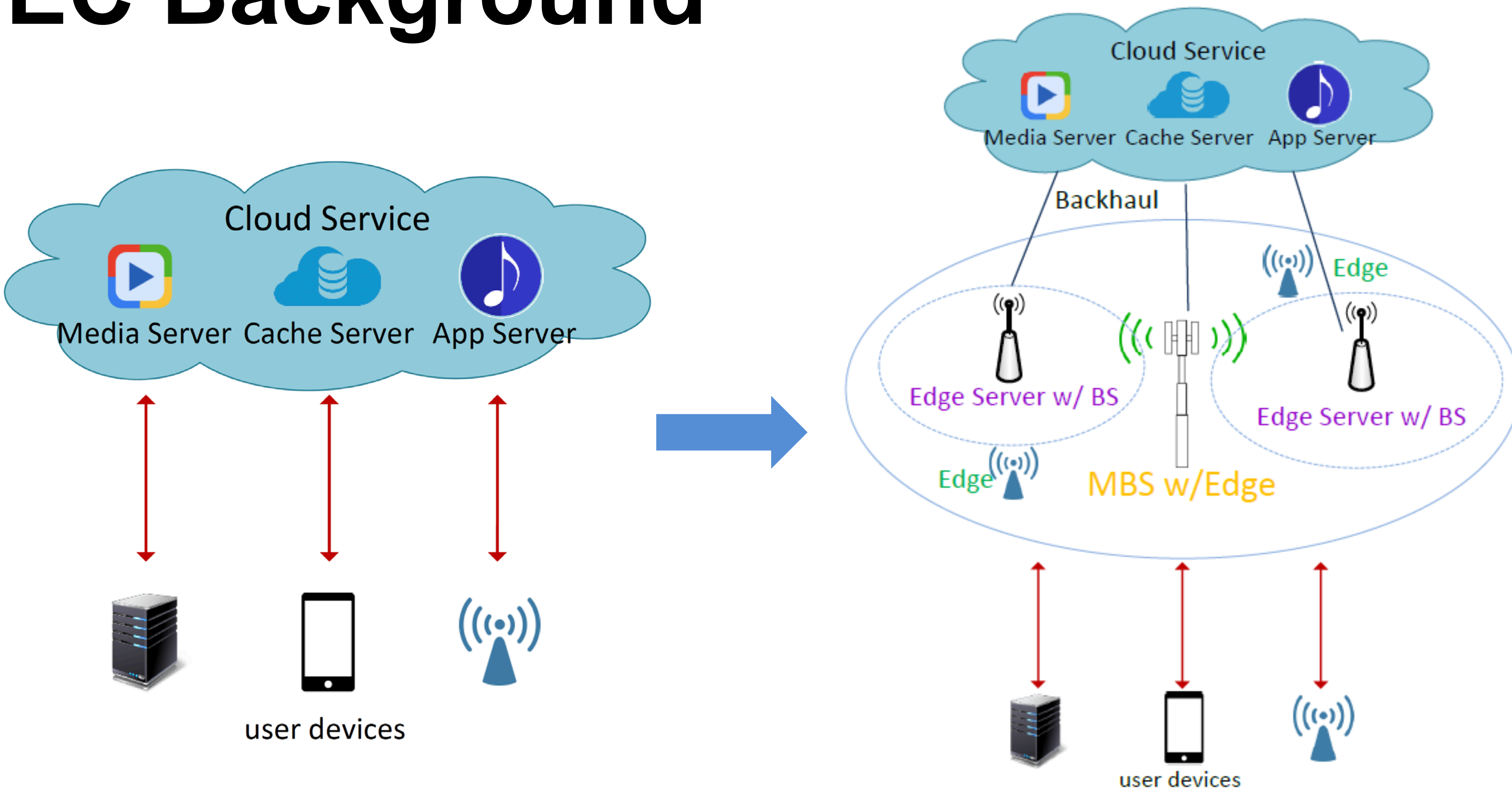
5G Requirements

- High Data Rate
- Low Latency
- High Reliability
- Massive Connectivity
- High Spectrum and Energy Efficient
- …

5G Goals


High Speed
8K
8K unveils reality
Up to 10Gbps
High Density
IoT
M2M
10 to 100x devices
5G
< 1ms End-to-End
Latency, Reliability
~10 Years
Power Efficiency

MEC Background

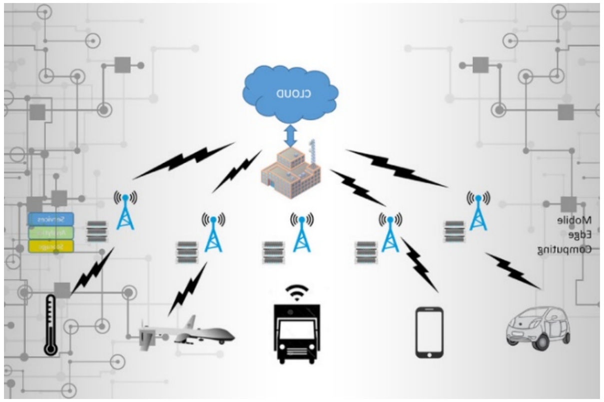


cloud computing

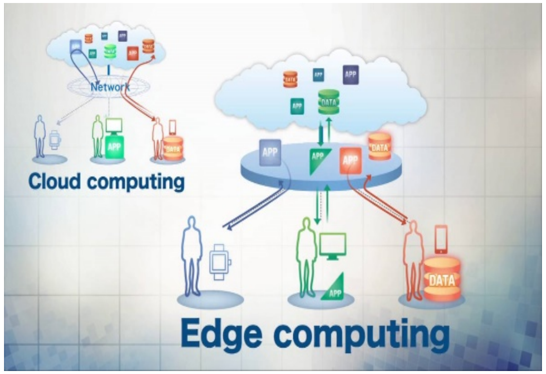
edge computing

- Cloud computing gives feasible solution for low-power devices, by providing centralized computation resources.
- However, cloud servers may locate far from users, induces longer processing delay.
- By placing powerful mobile devices in close proximity, acting as a intermediate layer, edge computing is more flexible and can reduce delay.

MEC Background



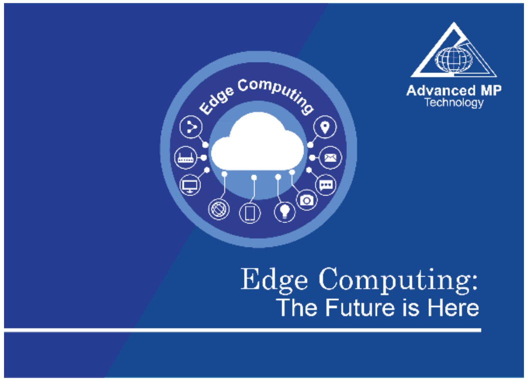
Close to users, **high** uploading efficiency and **low** latency



Medium scale: **flexible** deployment

Mobile edge Computing

Massive existing base stations: **low** cost



Cooperation: **improve** computation capability

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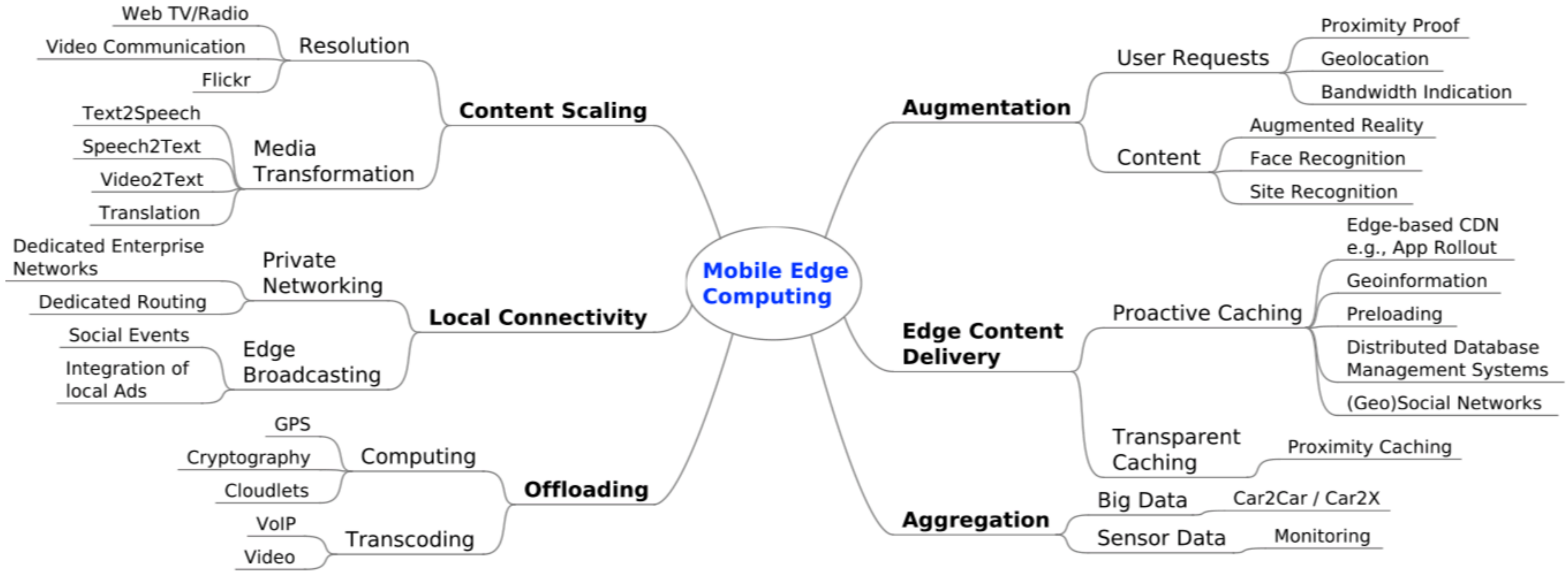
MEC Applications



Use cases for MEC:

1. Content scaling
2. Local connectivity
3. Computation offloading
4. Augmentation
5. Edge content delivery
6. Aggregation

Reference: Michael Till Beck, Martin Werner, Martin, Sebastian Feld, Thomas Schimper , “Mobile Edge

MEC Applications

- Content scaling:
  - downscale user traffic before sending to core network
  - Decrease bandwidth requirement, reduce core network utilization
- Local connectivity:
  - Redirect traffic locally, further reduce latency
  - Ex: Local generated traffic will be broadcast locally.
- Aggregation:
  - Aggregate different UEs' data
  - Increase bandwidth utilization, reduce power consumption

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MEC Applications

- **Augmentation:**
  - **MEC can be customized to provide additional information.**
  - **User-related data can enhance user experience.**
- **Edge content delivery**
  - **ISP and CDN services can shift to the network edge**
  - **Faster and transparent information delivery**
- **Computation offloading:**
  - **MEC offers additional capabilities for low-power users.**
  - **Data can send to MEC servers for joint processing.**

Computation Offloading in MEC

General problem formulation:

1. End UEs have certain amount of data to be processed
2. They can choose to offload or execute locally
3. Task should be finished before a time threshold

Objectives:

1. Max total data bits
2. Or, min total energy consumed.

Variables to be optimized:

1. Local execution CPU frequency
2. Ratio of local/offload data
3. Ratio of local/offload power

Computation Offloading in MEC

Computation efficiency maximization

General problem formulation:

1. **End UEs have certain amount of data to be processed**
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Variables to be optimized:

1. **Local execution CPU frequency**
2. **Ratio of local/offload data**
3. **Ratio of local/offload power**

Existing works focused on computation bits maximization. They cannot guarantee the computation efficiency maximization.

Massive MIMO framework

1. Framework for large number of active users with massive connectivity.
2. Framework for high spectral efficiency and energy efficiency with high user density and emerging applications having the strong need of QoS guarantees.
3. Big Data Management.
4. Cost-effective, reliable, and scalable implementation for Massive MIMO.
5. Machine-type communications and low complexity transceiver design.
6. PHY design for mmWave massive MIMO systems.
7. Analog and digital hybrid precoding design
8. Secure communications for massive MIMO systems

Massive MIMO: *Open Challenges and Directions*

- Massive MIMO in current systems (sub-6G) and mmWave band.
  - Sub-6G for the continuation of current systems
  - mmWave band is critical in 5G
- Implementation and deployment concerns: cost, algorithms, and efficiency.
- Channel state information estimation, complexity reduction, pilot contamination. Beamforming design, comply with antenna structures (from digital/hybrid to fully digital).
- Machine learning aided framework for massive MIMO design. Compressive sensing-based technique for channel state information estimation, pilot contamination, and beamforming design.
- Large intelligence reflective surface (IRS) for beyond 5G

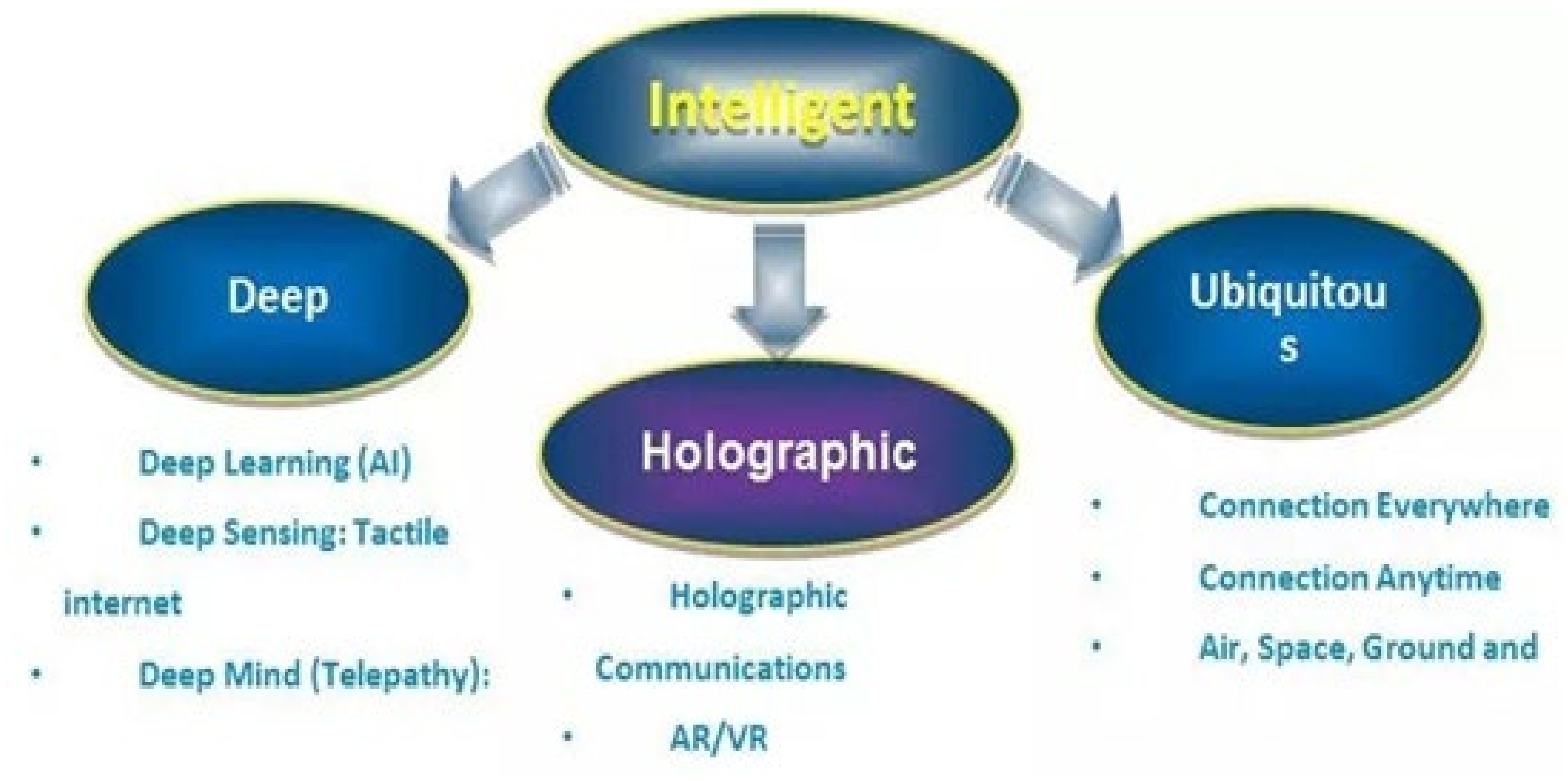
Massive MIMO: Open Challenges and Directions

- Dataset for massive MIMO in machine learning related research
  - Related with geographic information, such as urban, suburban, city, etc.
  - Algorithm processing delay. For massive MIMO application, delay should be small, compared with traditional ML applications in photo and objective recognition
- From hybrid to fully-digital
  - For mmWave band, fully-digital antenna is possible
  - Some prototypes already developed
  - Algorithms need to be adjusted accordingly
- Energy efficiency and thermal issues
  - For a large amount of antenna units, thermal issue might be severe
  - In mmWave band, it is anticipated that energy efficiency is only around 10%, most of eclectic bill goes to AC
- Standardization across various manufactures
  - APIs for different interfaces
  - Manufactures can adopt a common design language for future deployments

More to come…

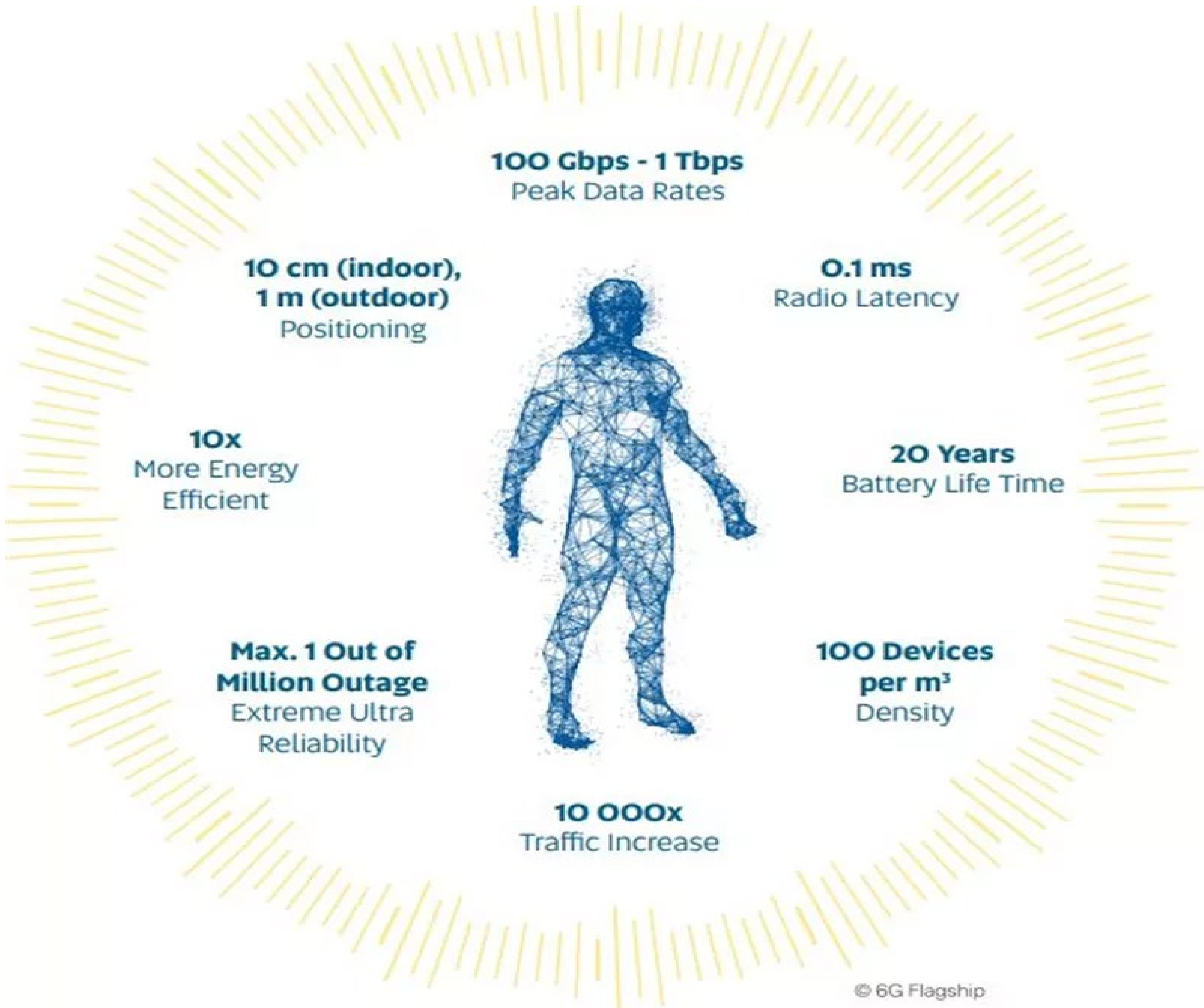
- AI and machine learning, especially distributed AI and machine learning
- How to enable efficient spectrum sharing
- Terahertz communications
- Quantum communications
- Etc

What does 6G possibly want



Reference: https://www.sdnlab.com/23736.html

What does 6G possibly want?



Reference

Thank You!

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