

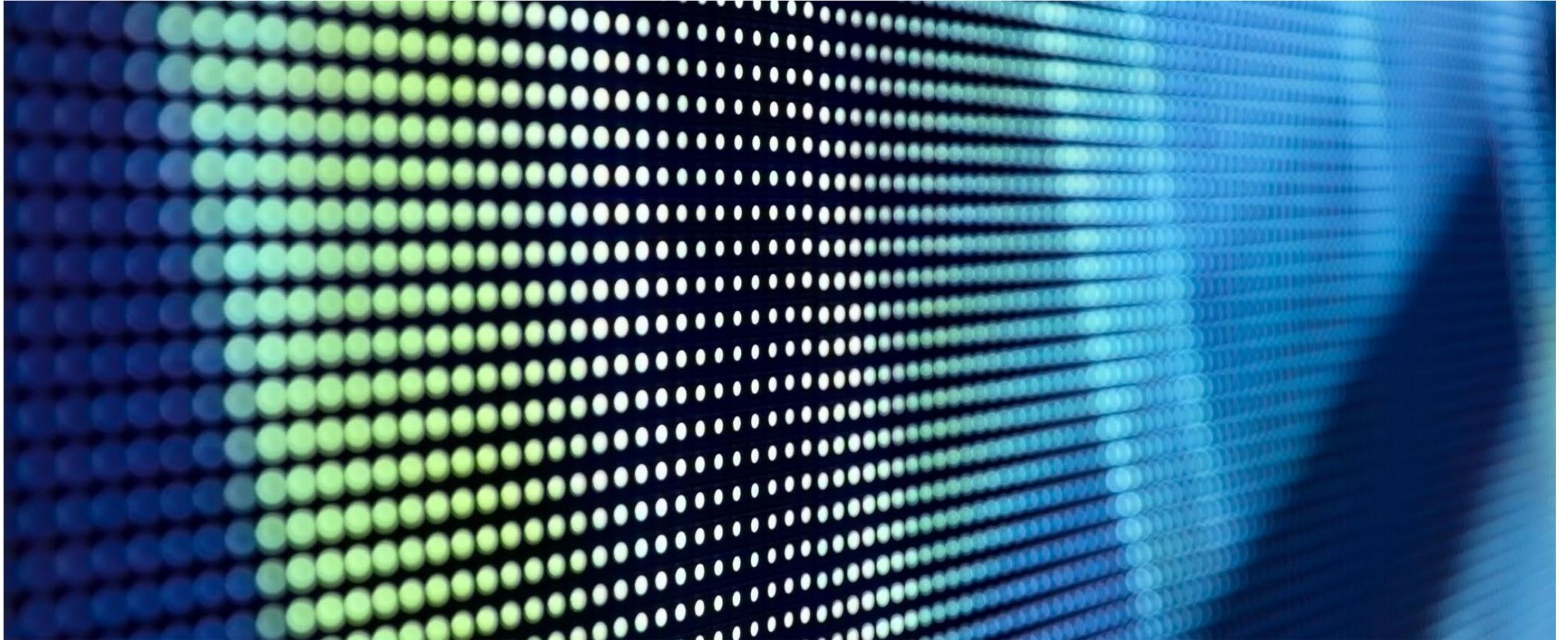


Future trends in IoT

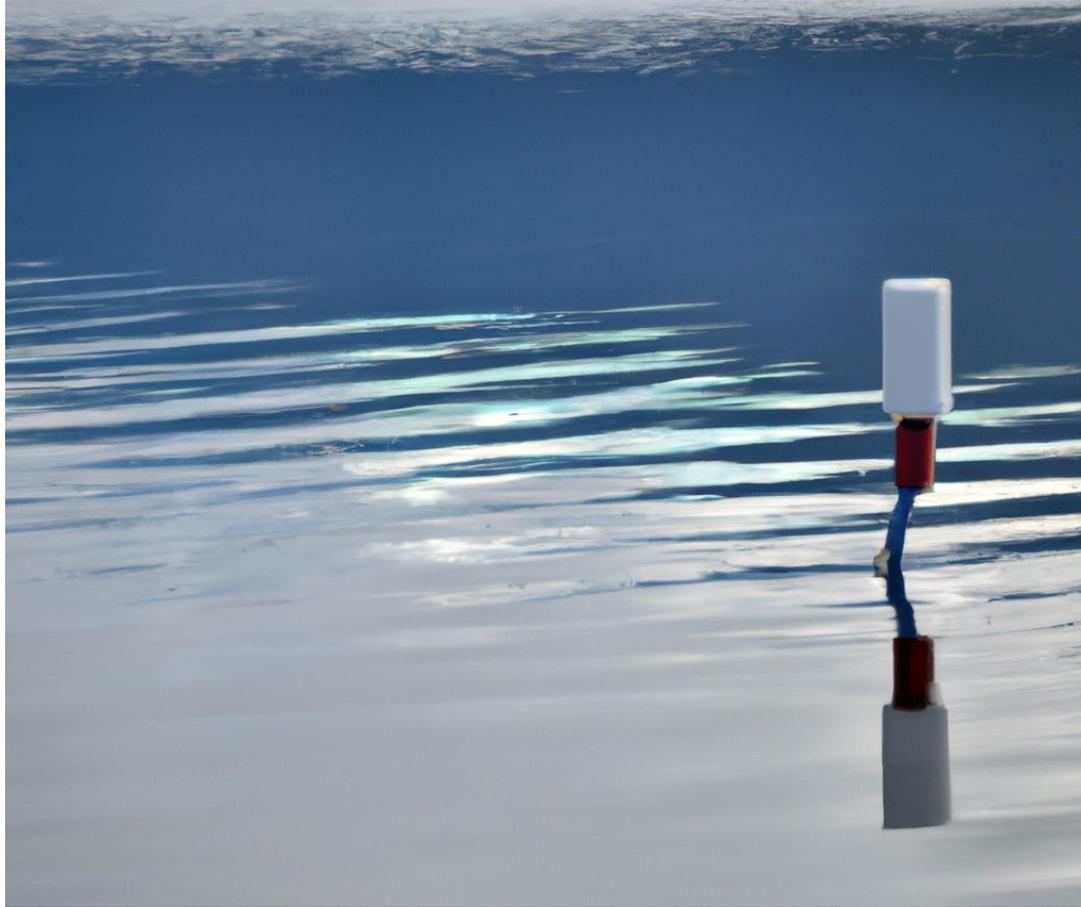
Outline

1. IoT Technology's growth
2. IoT connectivity – 5G/6G, WiFi 6, LPWAN, and Satellites
3. Empowered edge and fog computing in IoT
4. Recent advances and applications of AIoT and Edge AI in cloud-based applications
5. IoT-based smart cities
6. IoT empowered predictive maintenance

IoT Technology's growth



IoT in water sector



- IoT-enabled water meters are expected to reach **5.1 billion USD** by 2026.
- CAGR of **14.2%** from 2021 to 2026
- Demand is expected to accelerate in the near future
- By 2025, it is expected that **75%** of water and wastewater utilities will have deployed IoT solutions for monitoring and control

Key drivers for the surge in IoT devices

- The widespread availability of high-speed internet.
- Reduction in the cost of IoT devices, sensors, and communication hardware.
- Benefits over traditional measuring devices
- An increase in industry-specific applications
- Availability of widely accepted standards in IoT communication protocols.

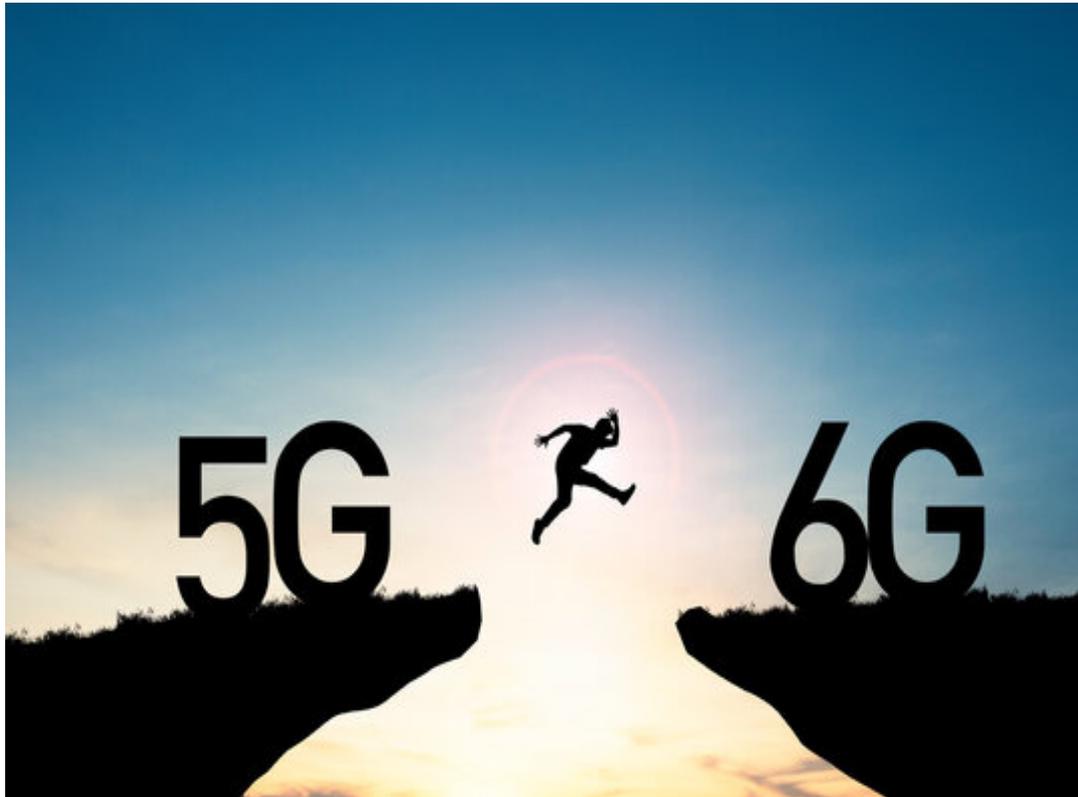


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IoT connectivity



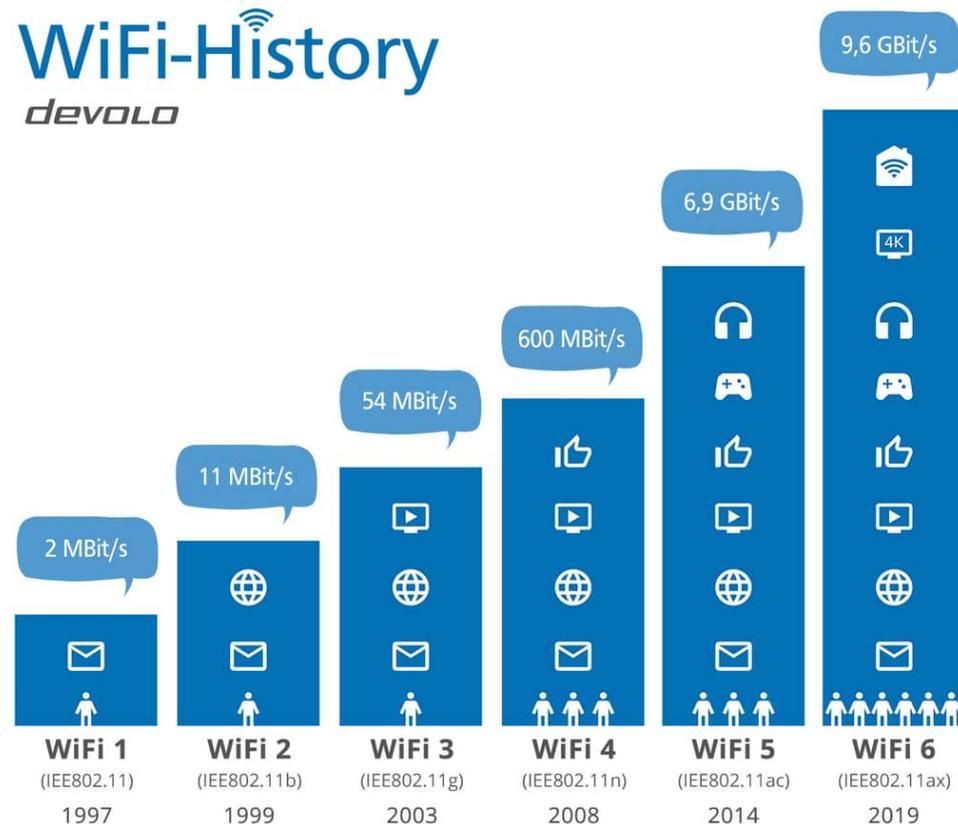
Network protocols of the future 5G/6G



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- While the race to 5G is ongoing. Talks about 6G have already begun.
- Interconnected IoT devices would be the prime focus.
- 5-time increase in data rate compared to 6G.
- Low latency and better performance at peak usage.

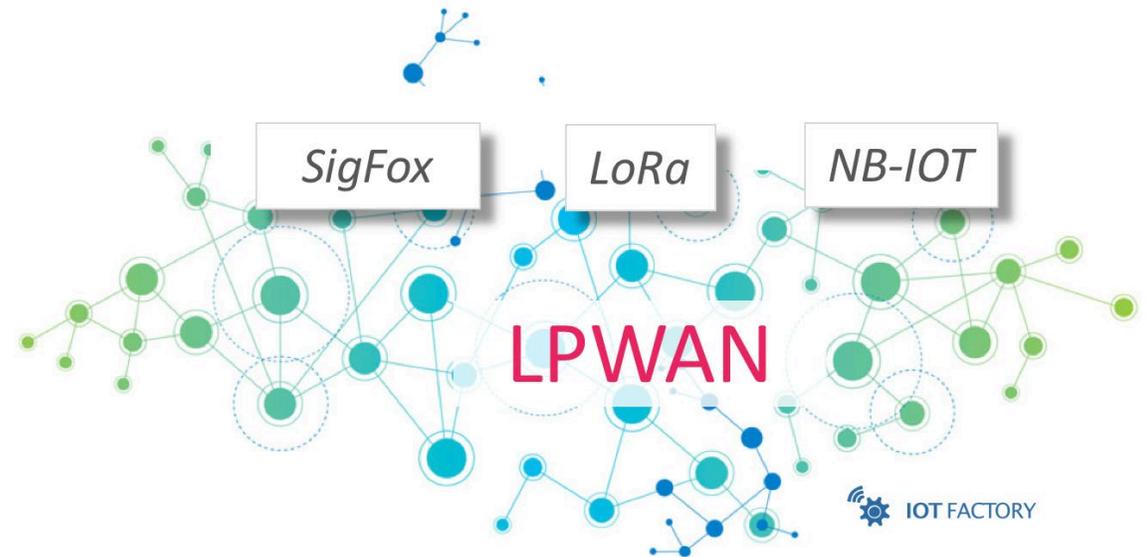
Network protocols of the future WiFi 6



- Supports higher data transfer speeds through improved modulation and coding techniques.
- Orthogonal Frequency Division Multiple Access - A key feature that allows multiple devices to transmit data simultaneously
- Target Wake Time (TWT): A power-saving feature to optimize power consumption
- BSS Coloring –A feature that reduces interference in dense Wi-Fi environments. By allowing devices to differentiate between overlapping Wi-Fi networks

Network protocols of the future LPWAN

- Low Powered Wide Area Network
- Allows devices to communicate over several kilometres or even tens of kilometres.
- Designed to optimise power consumption, allowing extended operation on battery power
- Optimized for transmitting small amounts of data at low data rates.
- Coexistence, and flexible integration with other Wireless Technologies such as Wi-Fi, Bluetooth, and cellular networks



Network protocols of the future Satellites

- Global coverage
- Redundancy and backup connectivity in case of disruptions to terrestrial networks (natural disasters or network failures, etc.)
- Point-to-multipoint communication- single satellite can simultaneously communicate with multiple ground-based terminals.
- Networks can be quickly deployed, reducing the time and infrastructure requirements.

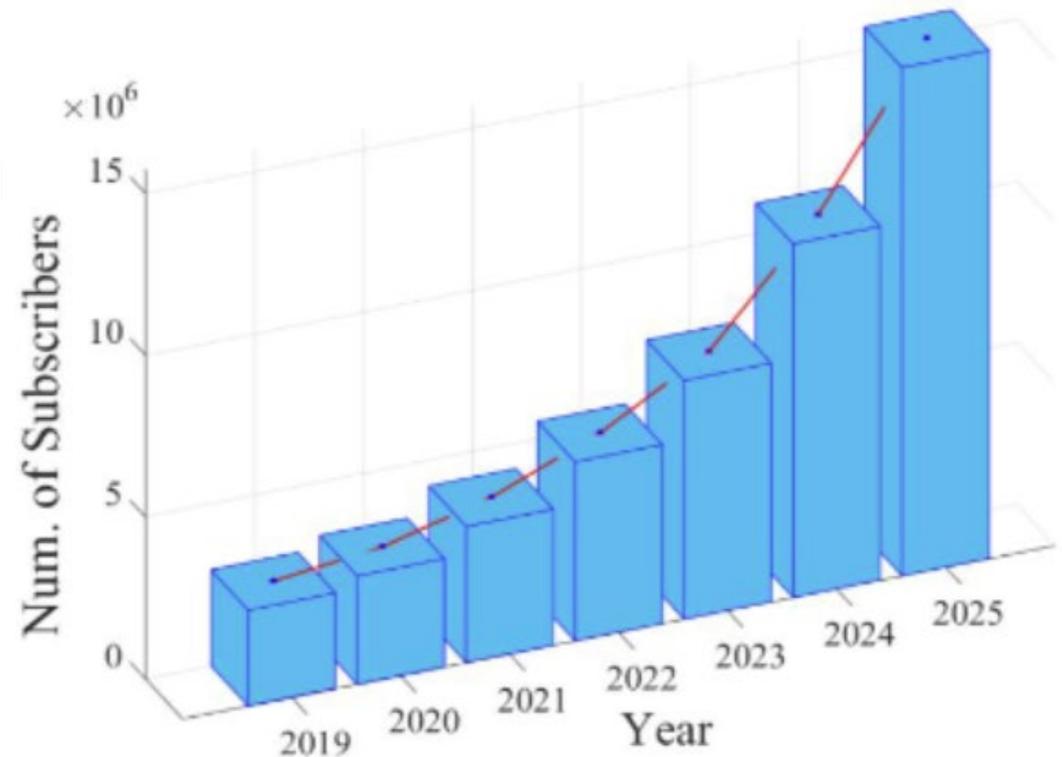
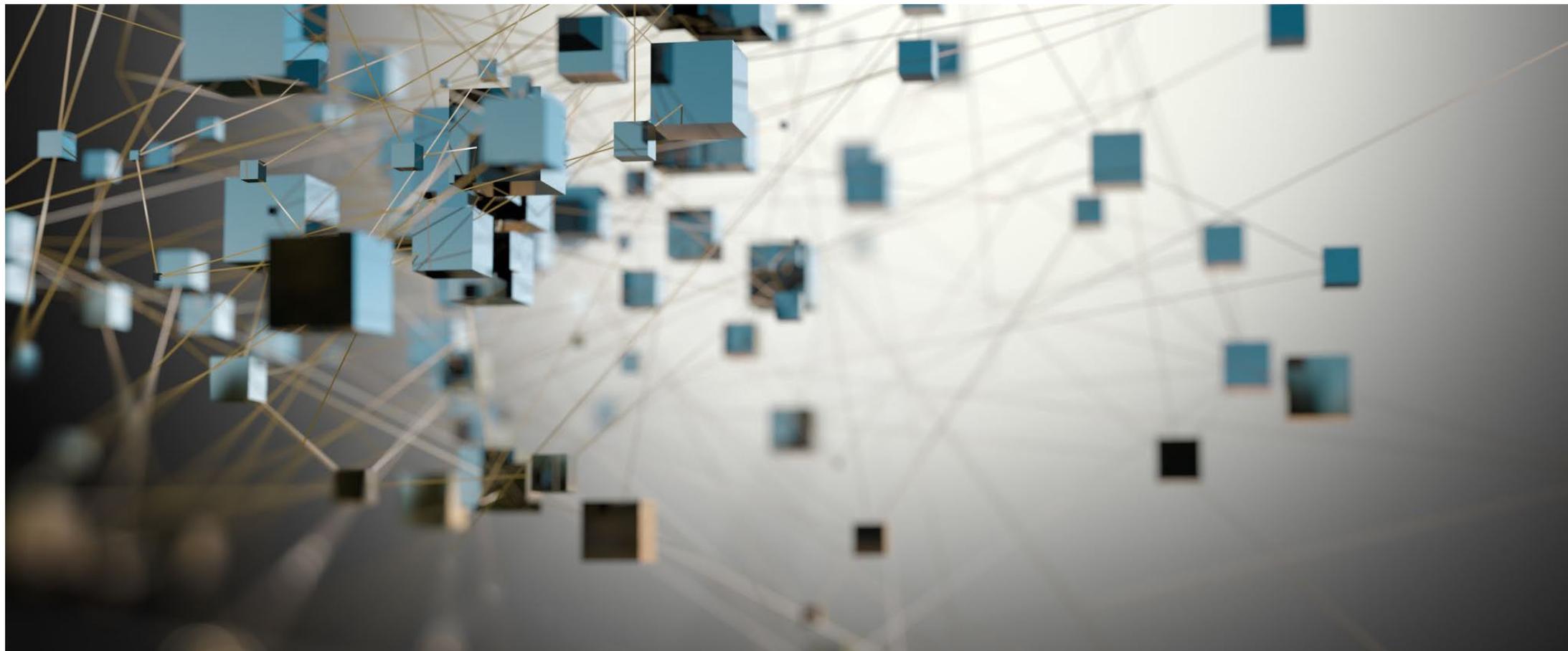


Fig. 12. Global satellite IoT subscribers [2]

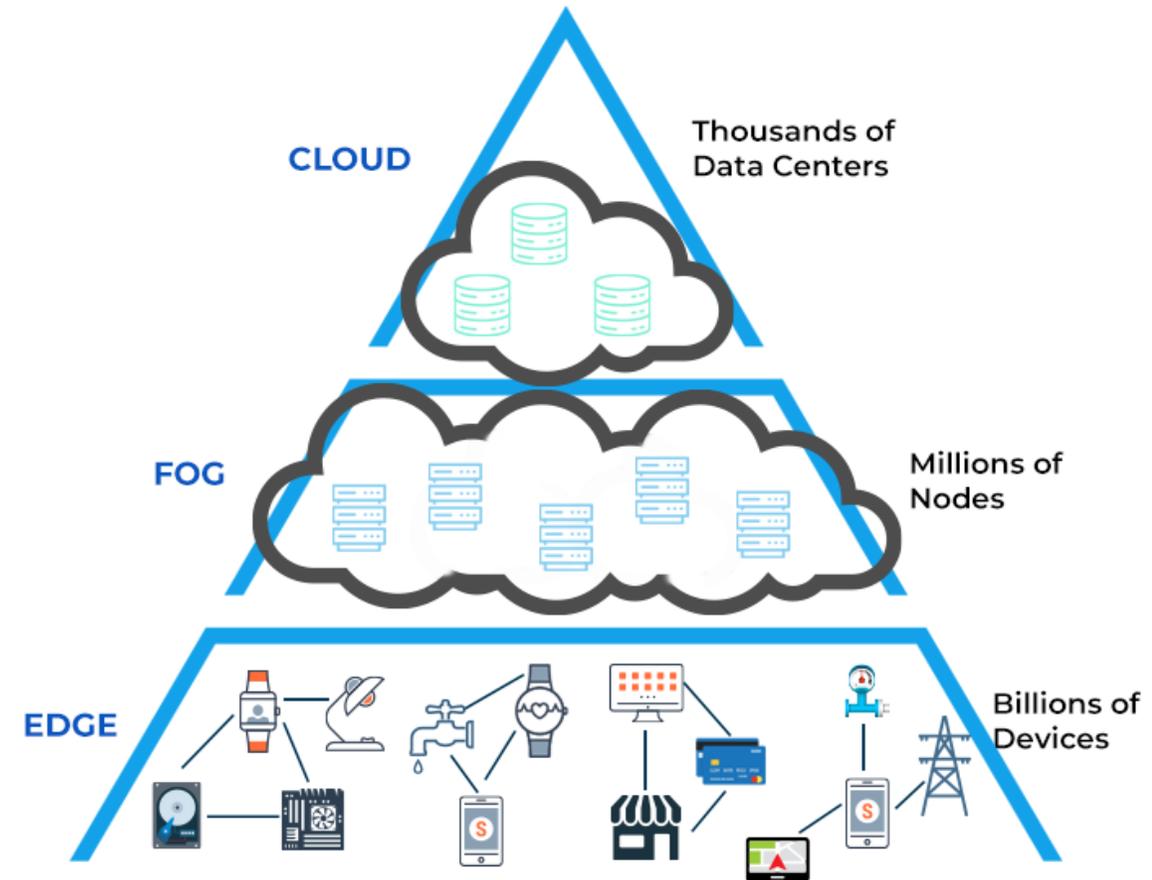
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Empowered edge and fog computing in IoT



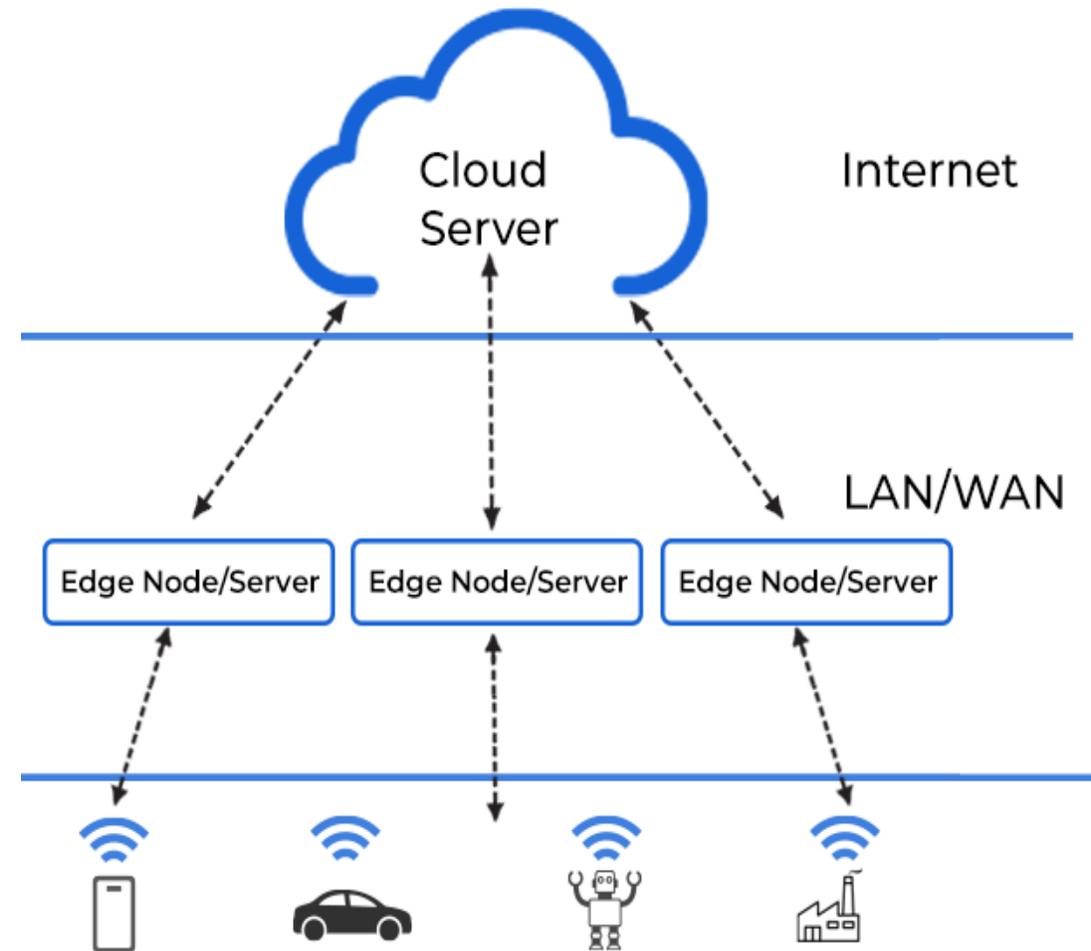
Edge and fog computing

- Brining computing processes closer to where data is generated and collected.
- Enables faster and localised decision-making
- Leverages redundancy and fault tolerance mechanisms to ensure high service reliability
- Reduced Network Congestion, since aggregated or relevant information must be sent to the cloud or central data center.



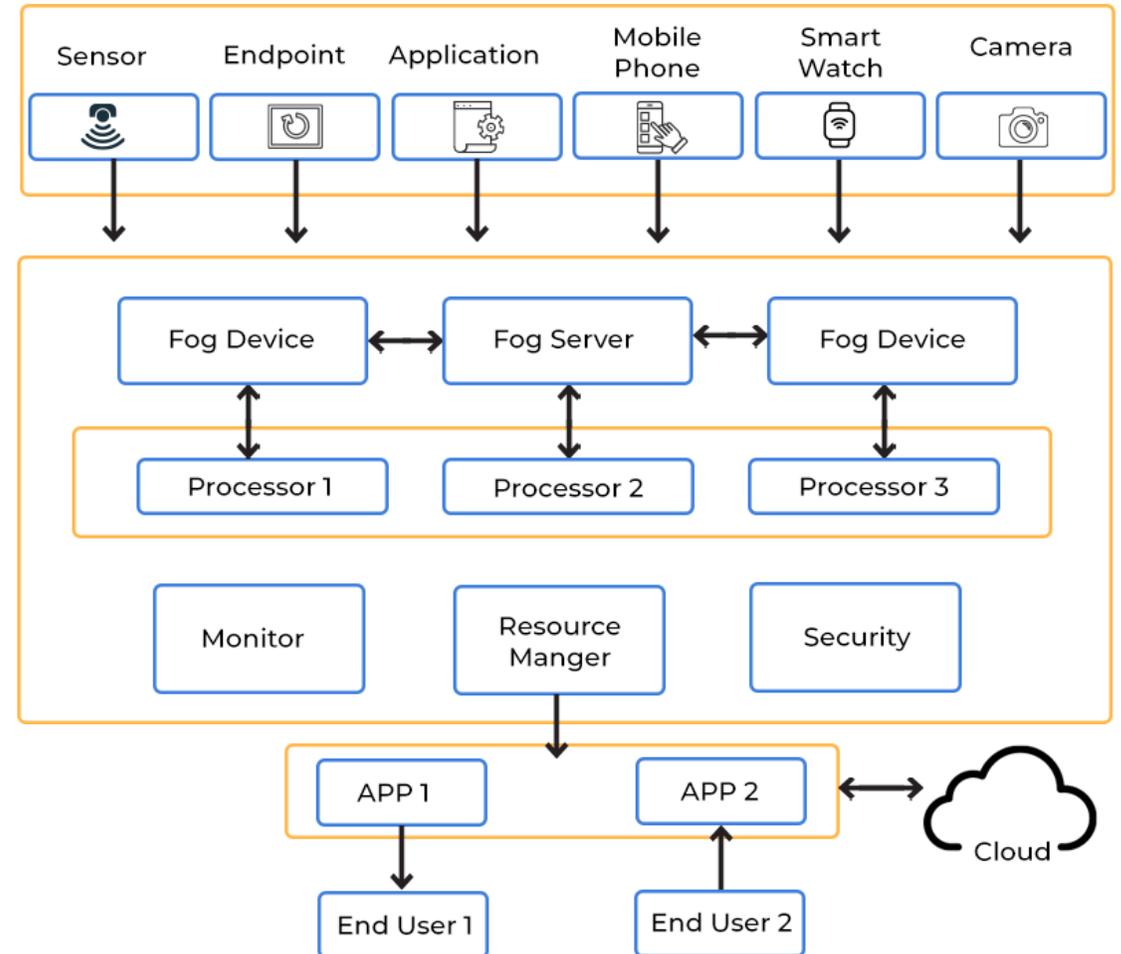
Edge computing architecture

- Cloud Layer
 - Big data processing
 - Data warehousing
- Edge Layer
 - Data processing and reduction
 - Data caching and buffering
 - Control response
 - Virtualization
- Device Layer
 - Sensors and controllers



Fog computing architecture

- Edge Devices - devices located at the edge of the network
- Fog Nodes - intermediate computing devices between edge devices and the cloud.
- Fog Computing Infrastructure - interconnected fog nodes network that shares resources among them
- Fog Orchestrator – a system that manages and coordinates the resources within the fog architecture
- Fog Services and Applications: software components that run on the fog architecture.



Differences between edge and Fog computing

FOG COMPUTING

- *Contains hierarchical architecture with multiple layers of computing resources*
- *Operates on a larger scale and encompasses a broader area.*
- *Fog nodes have higher computing capabilities and storage capacities compared to edge devices*
- *Facilitate communication, data sharing, and orchestration between edge devices, enabling more sophisticated distributed computing scenarios*
- *Establishes a more interconnected network with fog nodes, gateways, and cloud resources*

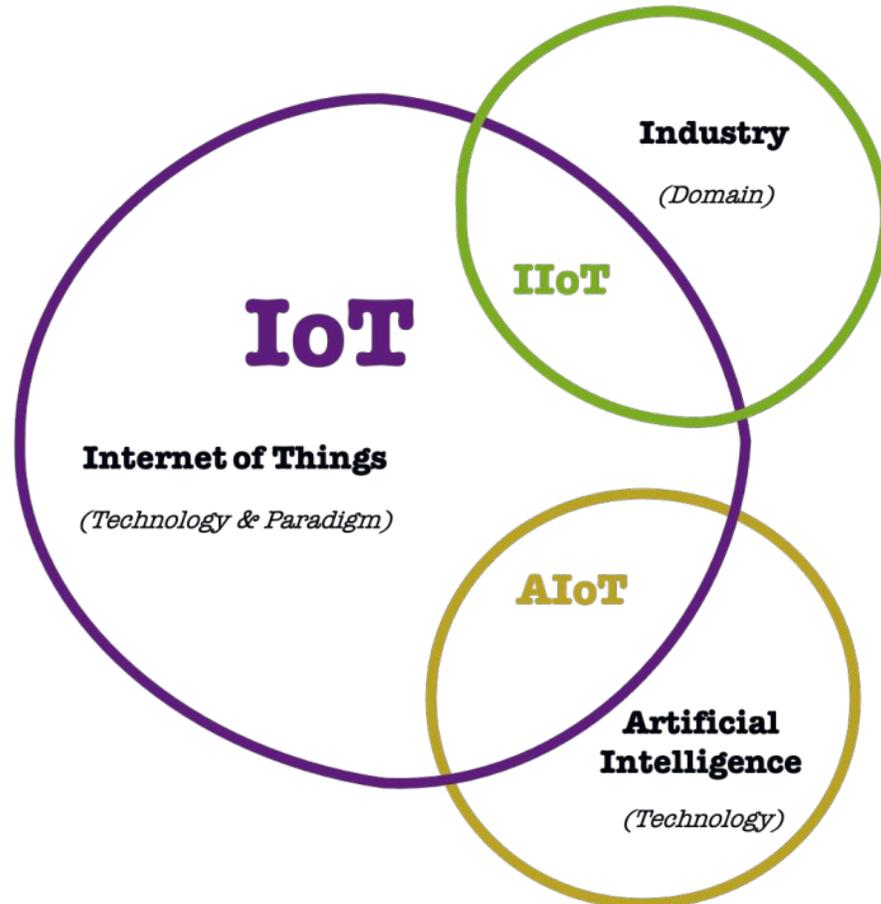
EDGE COMPUTING

- *Computing resources located at the edge of the network*
- *Operates on a smaller scale and focuses on individual device*
- *Devices are often resource-constrained, with limited processing power, storage, and memory*
- *Operates primarily at the device level, with minimal coordination between devices*
- *Typically operate within a local network or near the end-user devices*

Recent advances and applications of AIoT and Edge AI in cloud-based applications



IoT, IIoT, and AIoT/Edge AI



- A technological symbiosis
- AIoT integrates AI technology to find patterns in IoT data
- AIoT can be the most powerful and the most demanding tool in your toolbox .
- AIoT industry projected to reach a total value of 24.9 billion USD by 2028.

Example case I – Driverless car

- Realtime decision-making is critical in driverless car.
- Short reaction time is a vital component.
- Edge AI systems can react faster than cloud-based AI systems.
- Making self-driving care safer.



Example case II – Healthcare

- Monitoring and analysis of health status
- Edge AI can generate alerts in case of abnormality in vital signs.
- Enhanced security and privacy.
- Eliminates risks associated with sending and retrieving data to the cloud.



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Example cases III – Manufacturing



- A step towards Industry 4.0
- Important component in implementing predictive maintenance, lower maintenance downtime.
- Along with faster decision-making, Edge AI also utilises lower network bandwidth
- Enhancing operational resilience

Edge AI in Water sector

- Not too far behind are we compared to other sectors?
- Research underway to use EdgeAI technology for realtime Decision support systems for water and wastewater treatment applications.
- A viable option for critical high-secure water infrastructure that would like to function without constant data connectivity.
- Reduced latency for systems with unreliable internet access.

IoT-based smart cities



Smart cities – The concept

- A place where traditional networks and services are made more efficient with the use of digital solutions for the benefit of its inhabitants and business.
- Primary focus is on
 - smarter urban transport networks
 - upgraded water supply and waste disposal facilities
 - efficient ways to light and heat buildings



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Key objectives of a smart city

- Sustainable city infrastructure with a prime focus on environmental impact.
- Efficient and optimal use of public resources and provide high citizen service.
- Improved mobility, making it easy for citizens, workers and visitors to move around.
- Improved public safety & security in daily life and at special events
- Resilience to disaster and emergency preparedness.
- Growth-oriented economic plan to attract businesses, investors, and visitors.

Water and sewage systems in smart cities

- Preserve CSO's
 - IoT device networks to detect rain events and provide real-time notification on infiltration in sewage networks.
- Monitor pollutant levels
 - water-quality IoT devices to detect variations in household and industrial waste levels in sewage distribution networks.
- Pipeline maintenance
 - Deploy algorithms to trace leakages in pipeline and device maintenance strategies in real time.



Reactive versus predictive

Reactive maintenance takes place after the problem has occurred

Predictive maintenance occurs before the problem presents itself

Predictive maintenance – Pros and cons

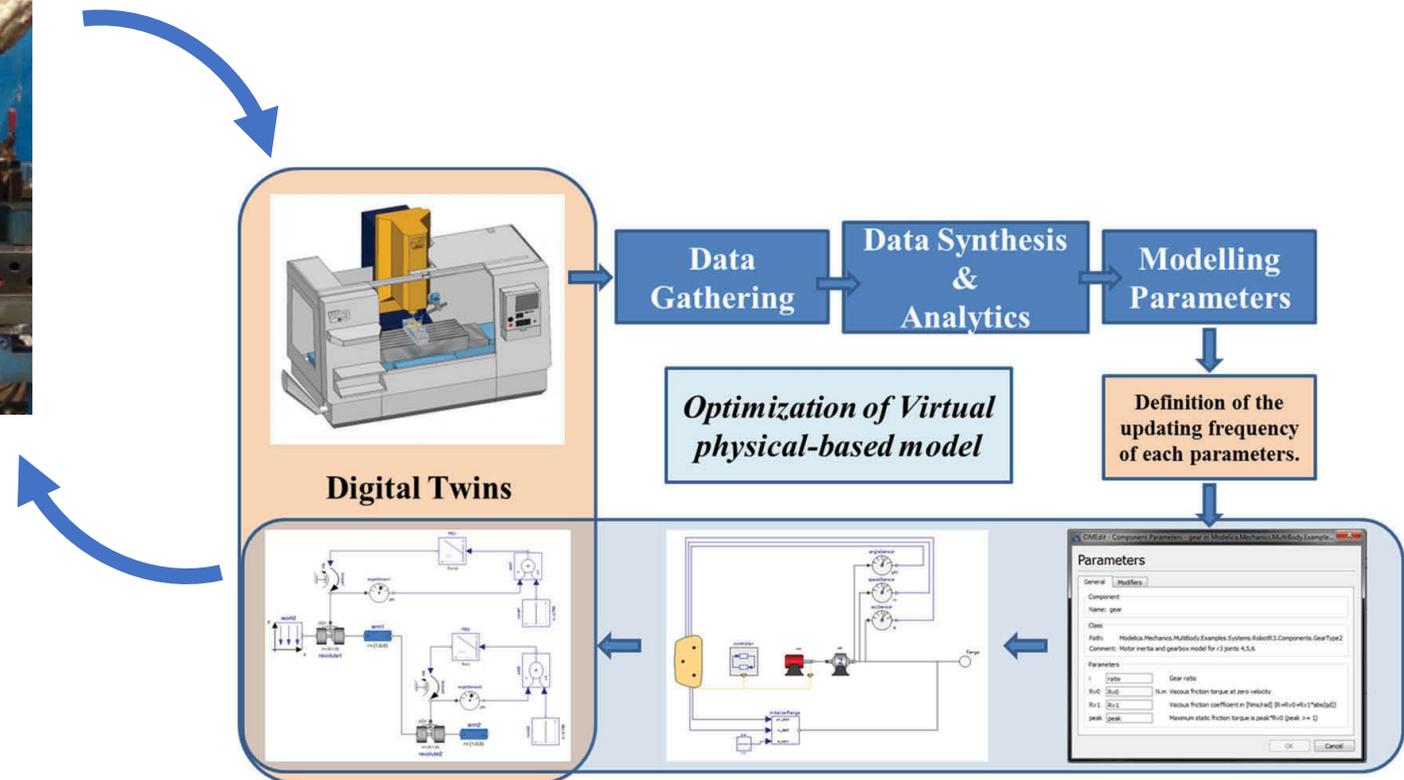
- Low maintenance costs
- Early detection of faults
- Reduced operational downtime
- Increases asset lifespan
- Possible over-maintenance
- Overly dependent on sensors
- Continuous training for technicians
- Higher capital investment

Predictive Maintenance of pumps

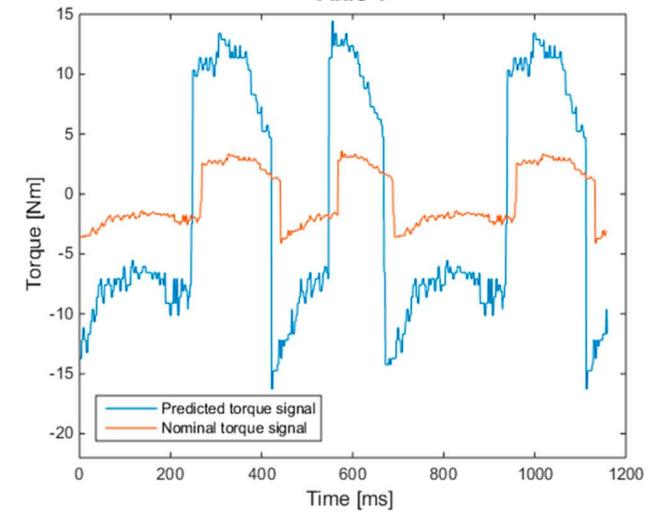
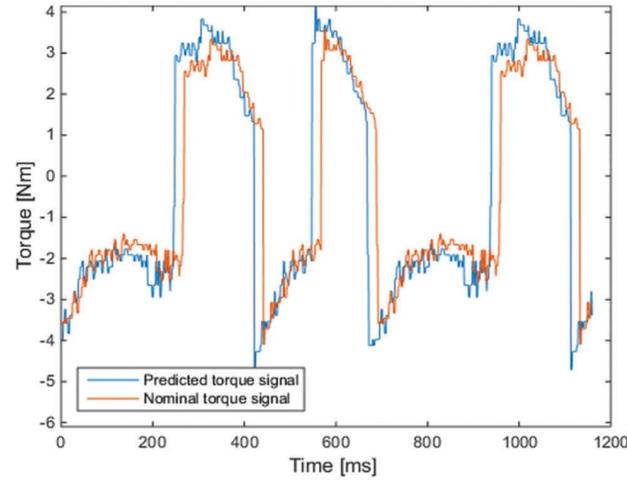
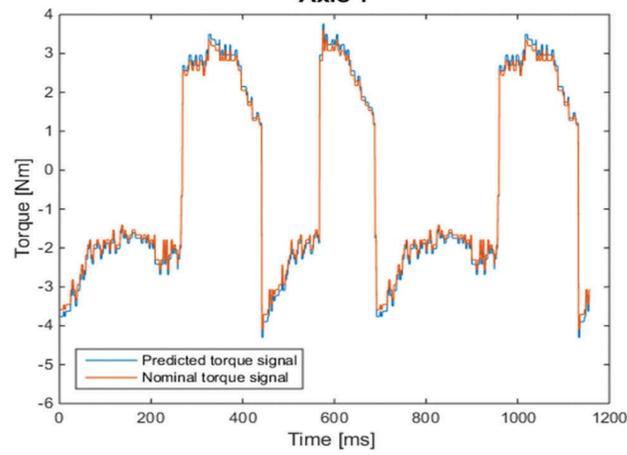


Aivaliotis et al. 2019

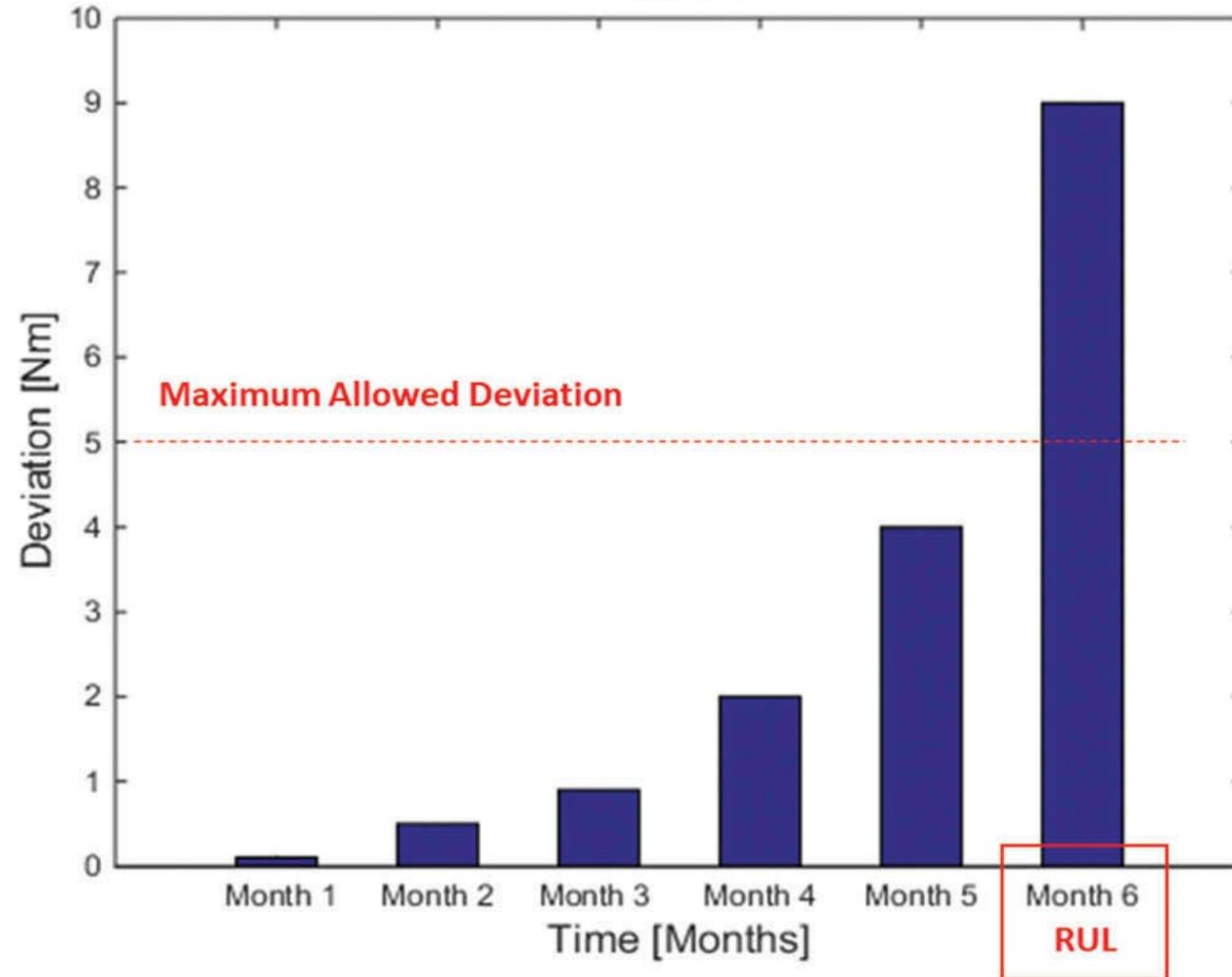
- Pumps and compressors are widely used in WWTP.
- Equipment with moving parts have an operating life.



Detecting deviations in pump operation



Calculating Remaining Useful Life



Thank you