5G – ENABLING RELIABLE LOW LATENCY COMMUNICATION FOR CONNECTED INDUSTRIES

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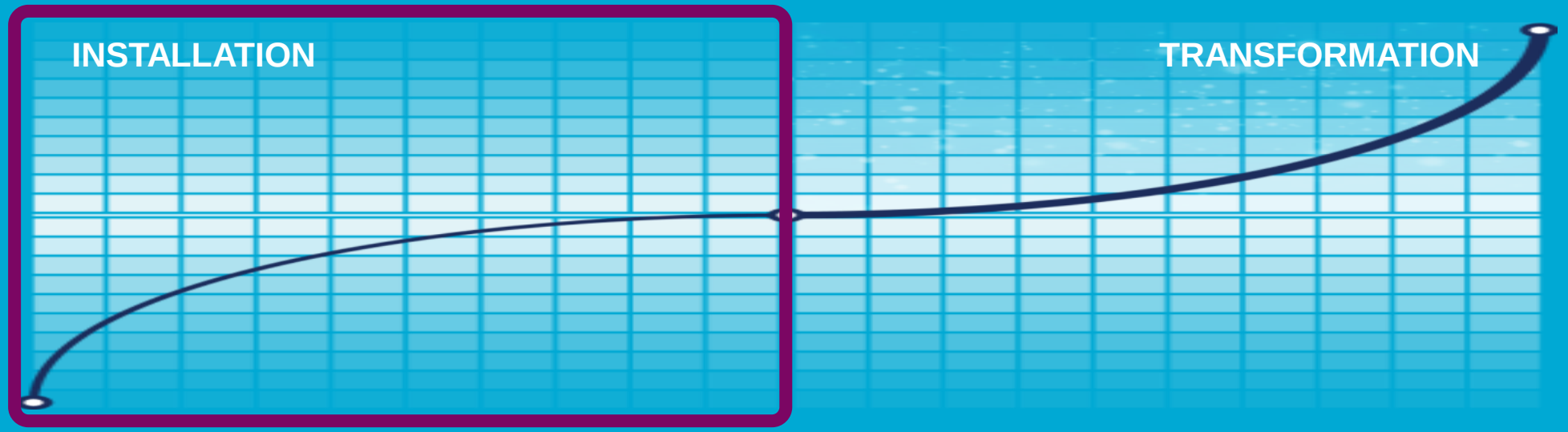
THE POWER OF TRANSFORMATION

EXAMPLE: HOUSEHOLD ELECTRIFICATION



1880-1940s electrification of households from centralized power stations

- Replace gas/oil lighting with electric lighting
  - ✓ brighter light
  - ✓ reduced fire risk
  - ✓ cleaner

THE POWER OF TRANSFORMATION

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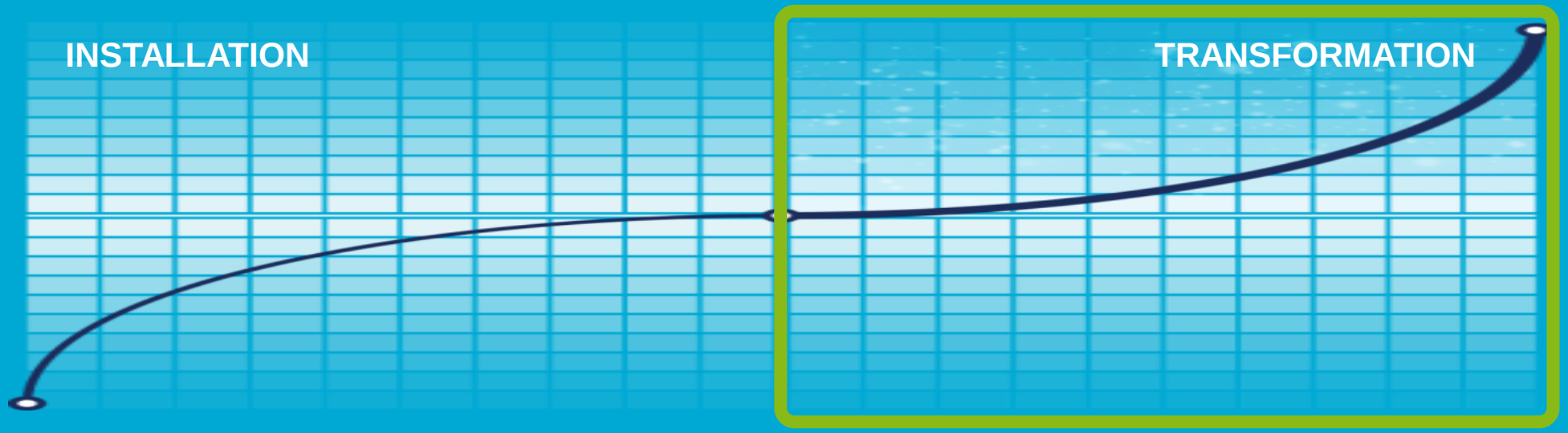
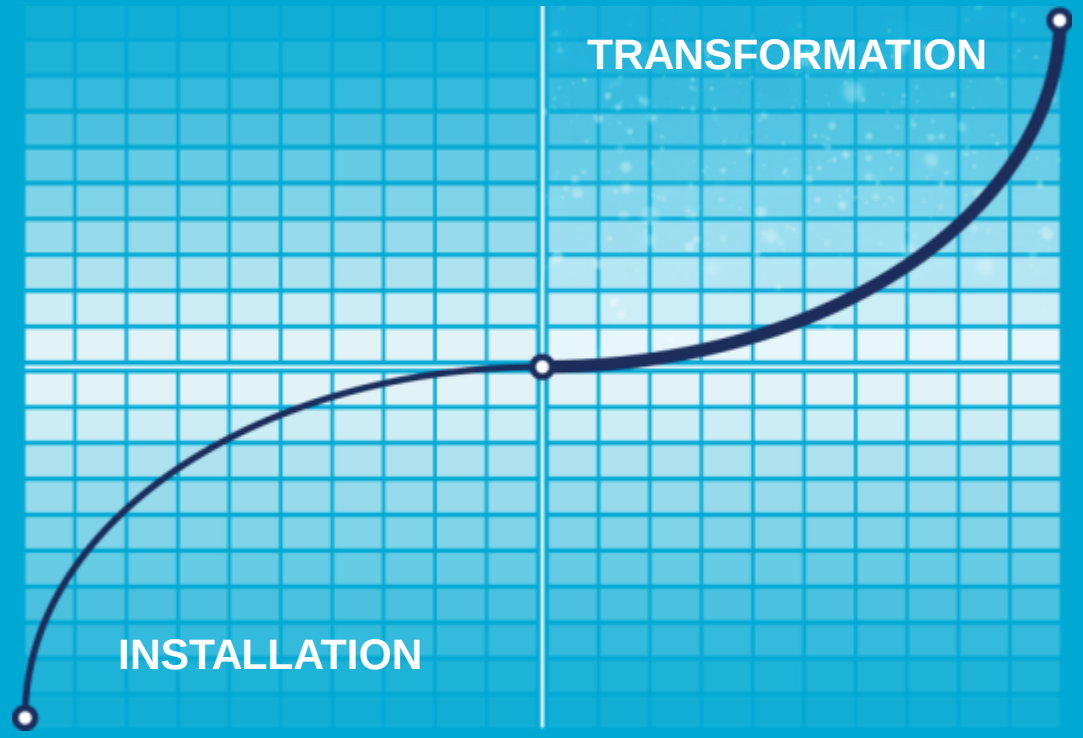


- Home appliances
  - Refrigerator, Freezer 1920/30s-
  - Stove 1930s-
  - Heating, ventilation, air conditioning
  - Washing machine 1940s-
  - Dishwasher 1950s-
  - …

- Home electronics
  - Broadcasting (radio, TV) 1920s- 1930s-
  - Personal computers 1970s-
  - Audio, phones, tablets, gaming, …
  - Electric vehicles
  - Smart homes / buildings,
  - …

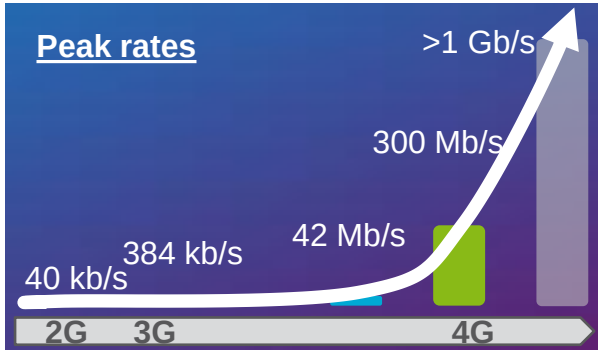
ICT BEYOND THE INFLECTION POINT

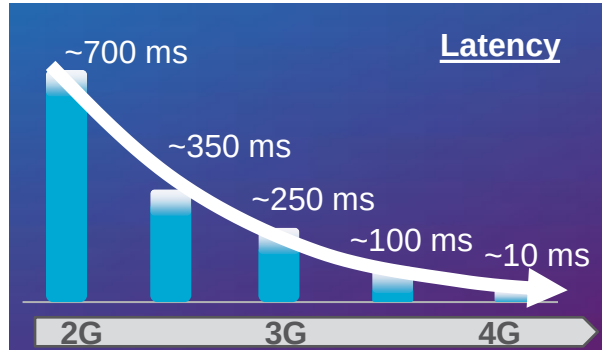


MOBILITY - BROADBAND - CLOUD

› Mobile communication has revolutionized personal communication

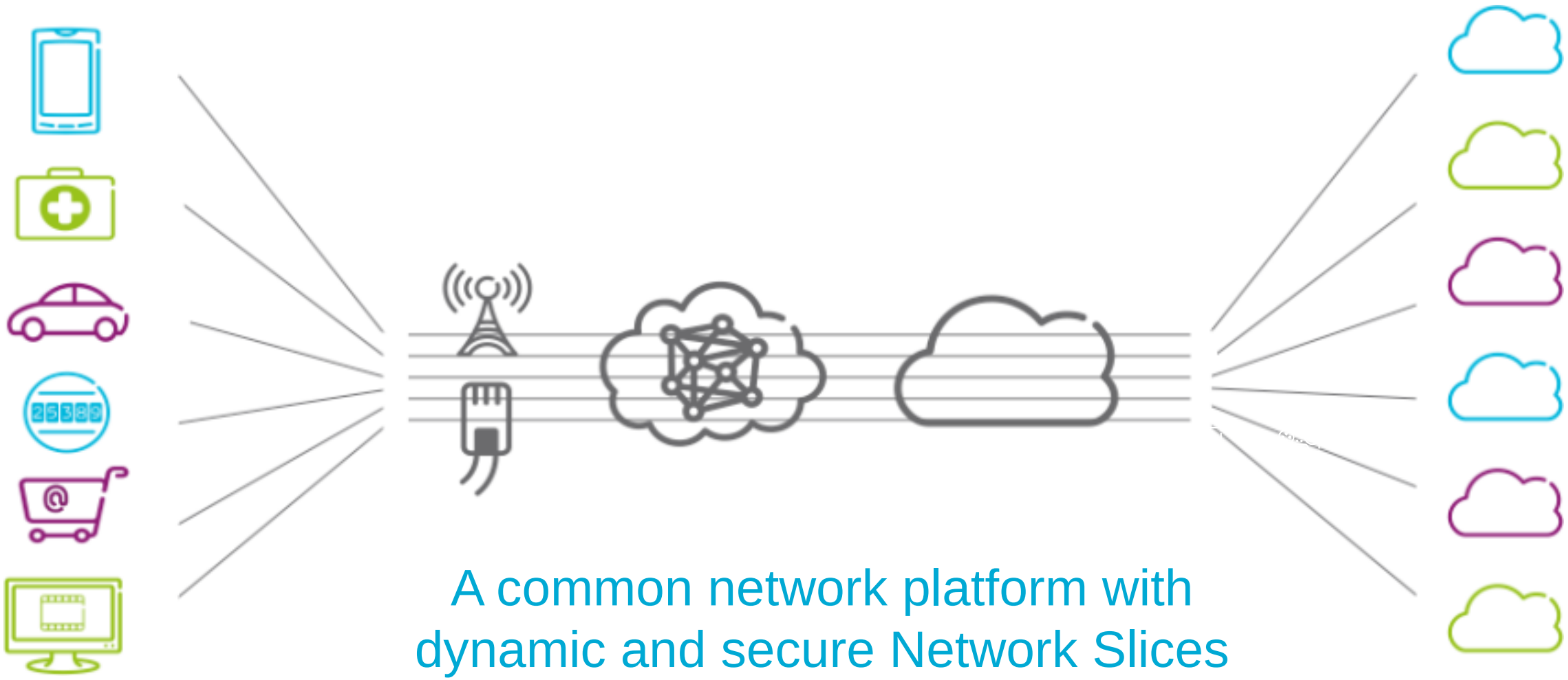
› Installed communication infrastructure
  › Ubiquitous availability at marginal costs
  › Broad capabilities and evolving





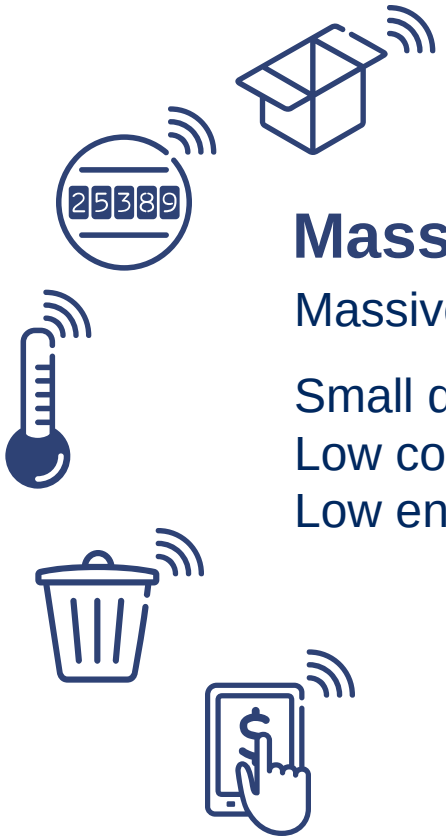
› Enabler for industry transformation with digitized processes

ONE NETWORK – MULTIPLE INDUSTRIES



A common network platform with
dynamic and secure Network Slices

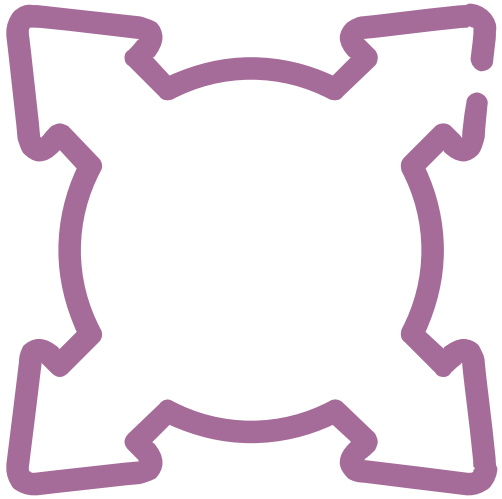
MACHINE-TYPE COMMUNICATION

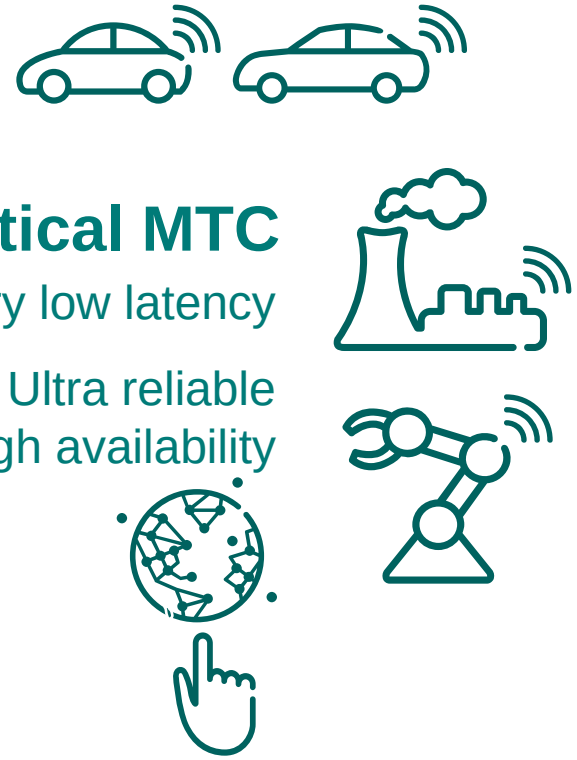


Massive MTC

Massive numbers

Small data volumes
Low cost
Low energy





Critical MTC

Very low latency

Ultra reliable
Very high availability

Cellular networks addressing new requirements

MACHINE-TYPE COMMUNICATION

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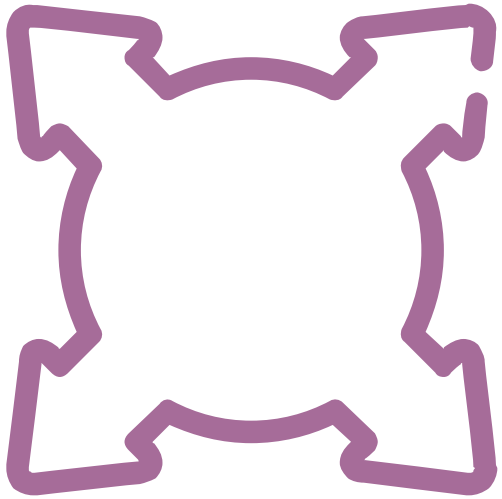

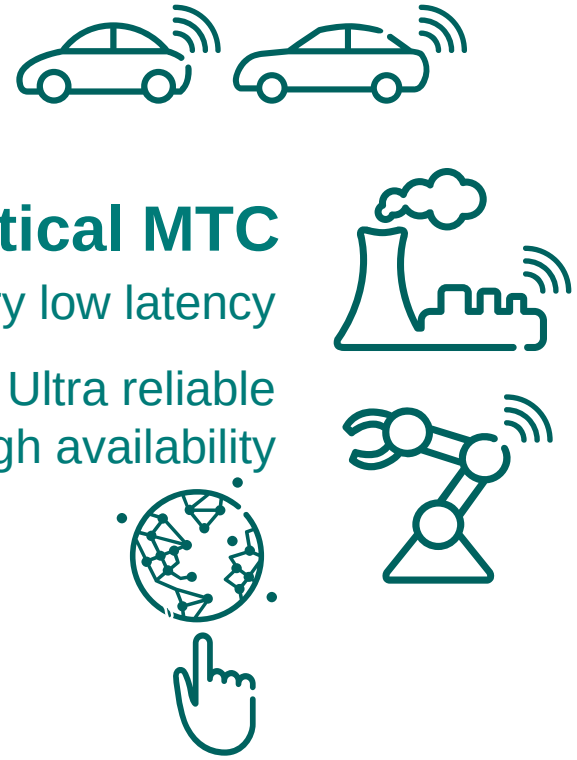

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CRITICAL MACHINE-TYPE COMMUNICATION: GUARANTEED IN-TIME DELIVERY

Factory Automation
≤ 1 ms

Motion Control
≤ 1 ms

Remote Control
5-100 ms

Intelligent Transportation Systems
5 ms

Smart Grid
3-5 ms

Tactile Internet
1 ms

Process Automation
100 ms

Automated Guided Vehicle
15-20 ms

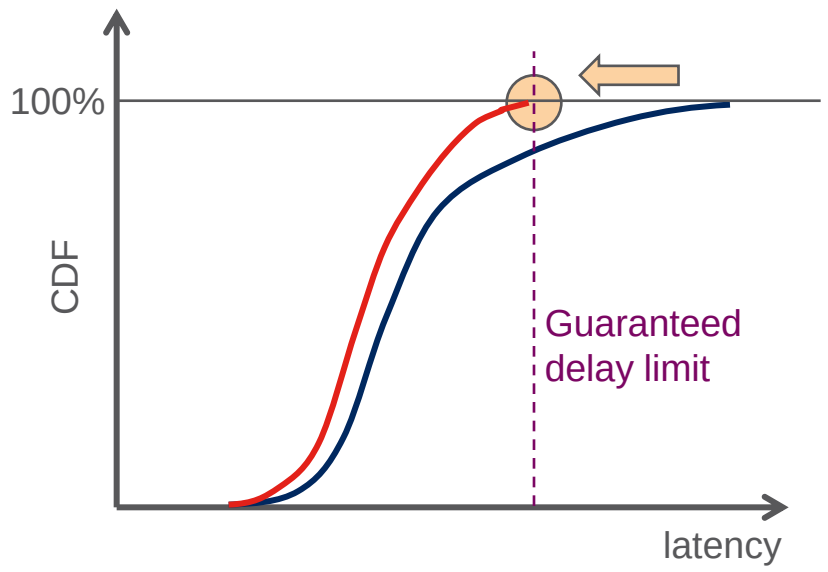
Numbers are examples, requirements vary within one application area

DESIGN OBJECTIVE

Ultra-reliable low latency communication

- Metric: 99.9999…-percentile

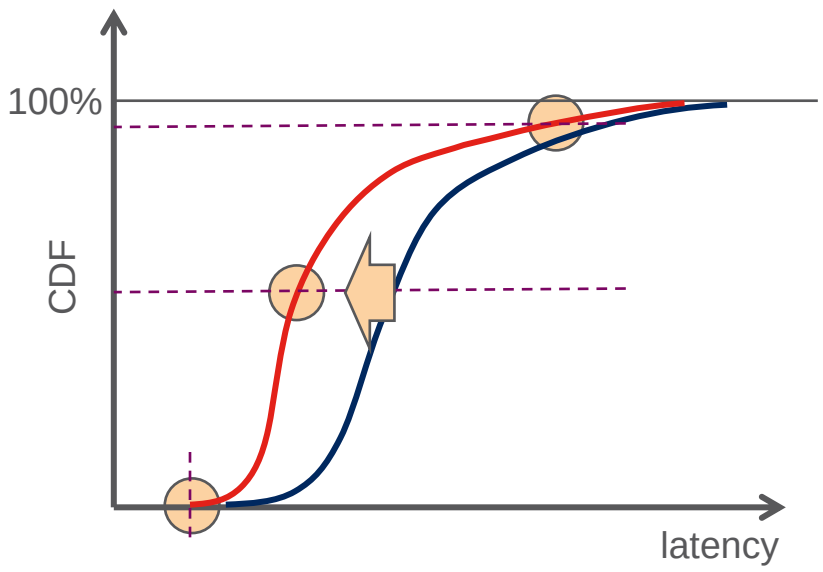
Focus on worst-case



“Normal” reliability (e.g. mobile Internet)

- Metrics: peak, median, 95-percentile

Exploit opportunities of favorable conditions



RELIABLE REAL-TIME : EXAMPLE FACTORY AUTOMATION

› Manufacturing cell with central controller communicating with sensors and actuators

Wireless communication enables more flexible configuration of manufacturing cells and communication with moving parts

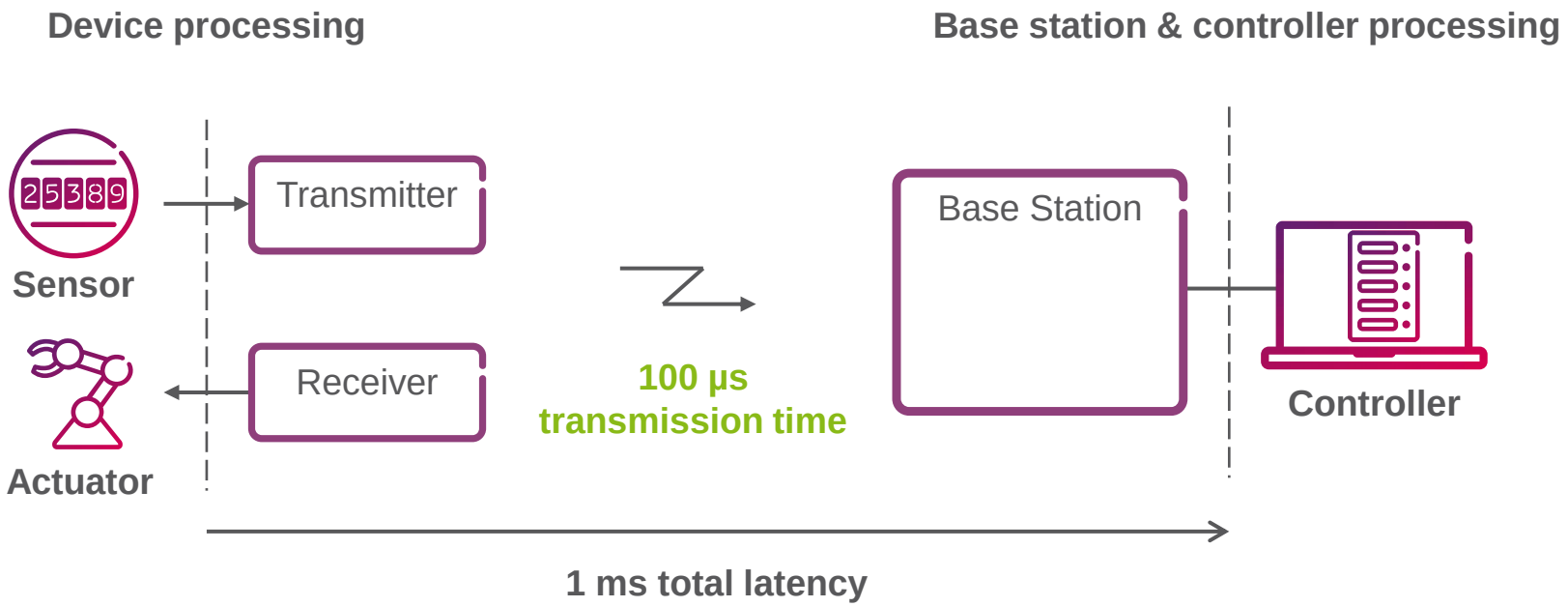
Combination of high reliability and low latency not achievable with current wireless standards

Characteristics	Motion control	Alarms
Maximum end-to-end latency [ms]	0.5 to 1	1
Jitter [us]	<1	–
Packet size [bytes]	10 to 16	2 to 10
Packet loss rate	10^{-9}	10^{-9}
Application availability	99,999 %	

based on fixed links

› Small message sizes
› Periodic traffic
  – Time-triggered data generation (e.g. real time motion control)
› Sporadic traffic and alarms
  – Event-triggered data generation

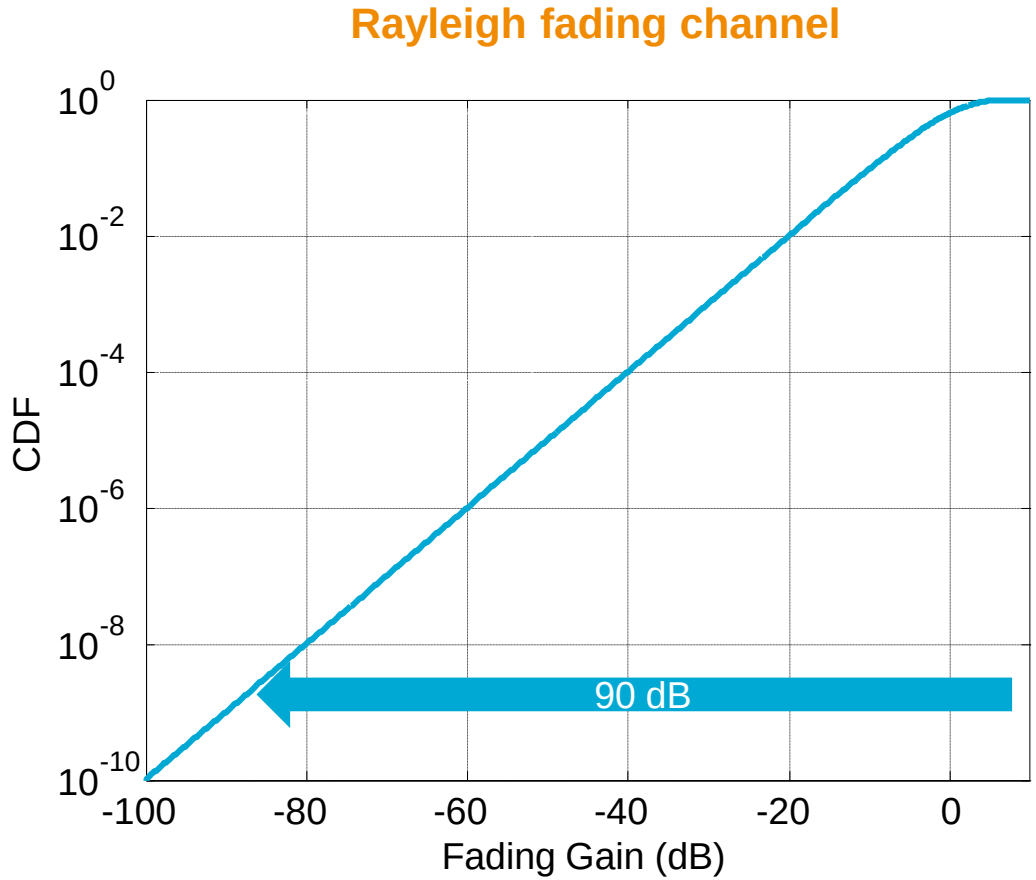
LATENCY BUDGET



- **100 µs transmission time** (i.e. 10th of the end-to-end delay budget)
- **Guarantee for successful in-time delivery** (reliability)

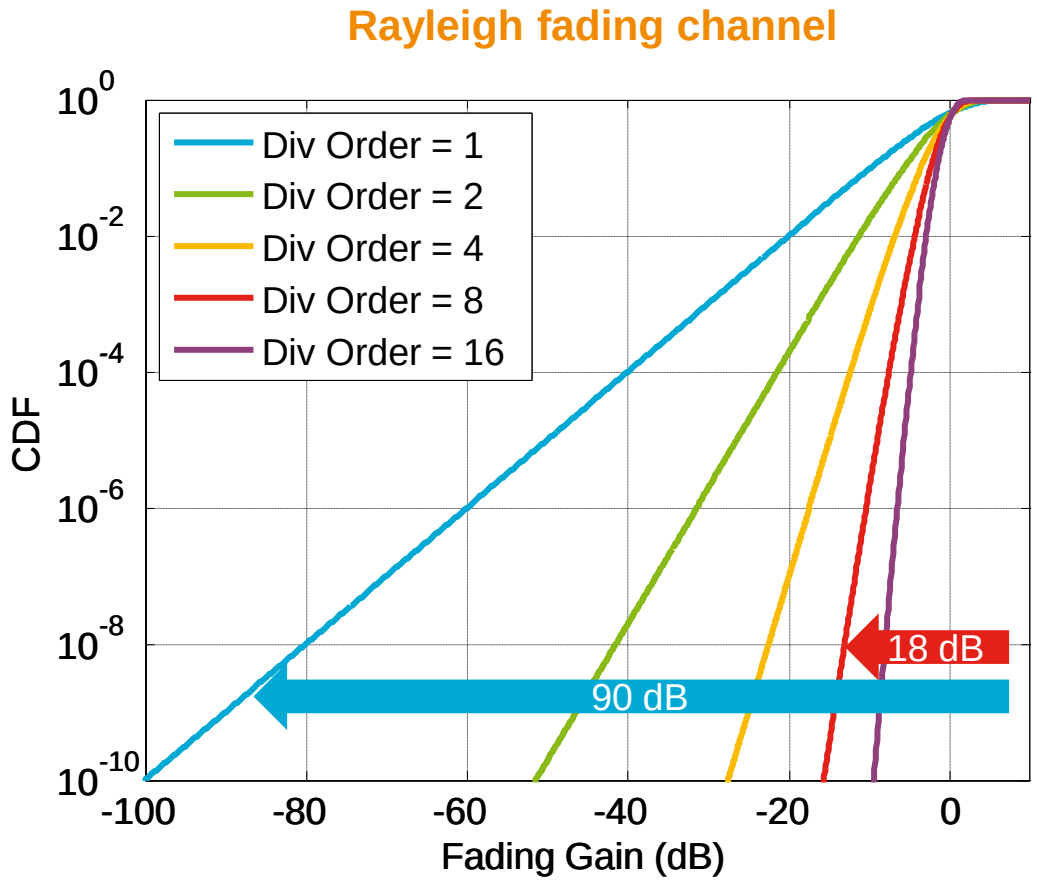
COST OF GUARANTEEING HIGH RELIABILITY

- High reliability (e.g. 10^{-5} – 10^{-9})
  - 50-90 dB fading marging



REDUNDANCY THROUGH DIVERSITY

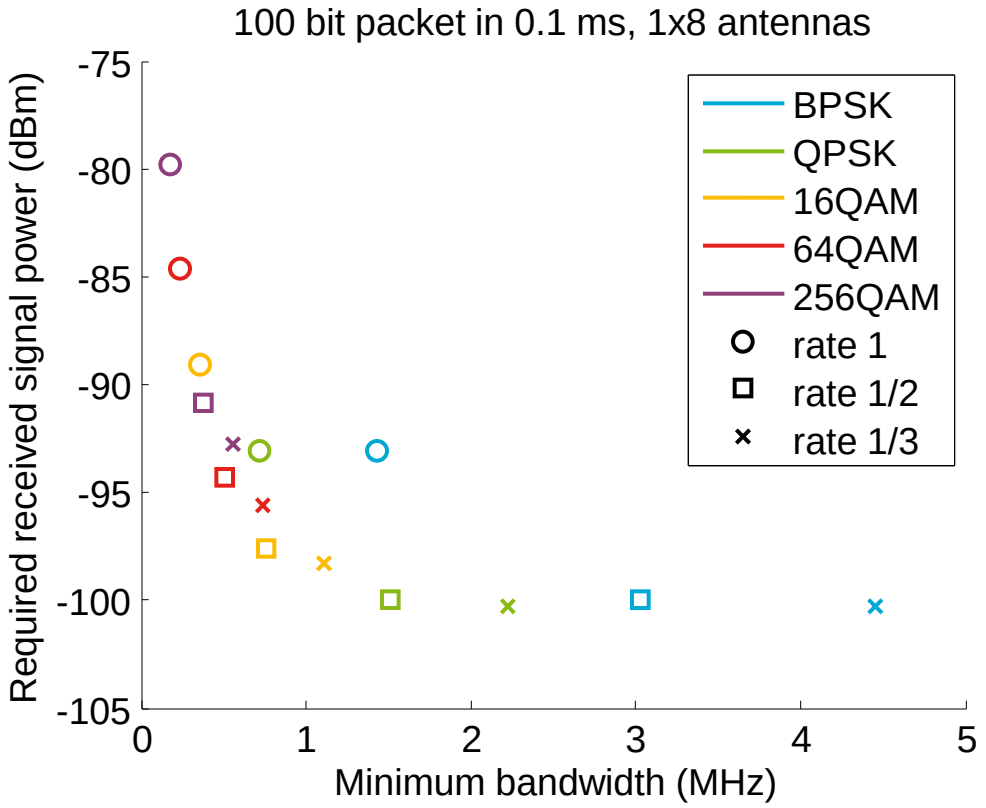
- Diversity may be obtained through
  - spatial diversity, and
  - frequency diversity
- Time diversity difficult due to latency constraint
- Coding needed to fully exploit frequency and transmit diversity



Diversity is key for ultra-reliable communications

CODING & MODULATION

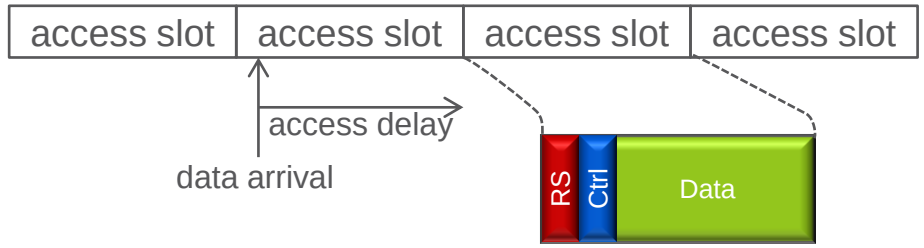
- Coding scheme
  - Block code for packets < 10 bits
  - Convolutional code for packets up to a few hundred bits
- Code rate
  - Rate 1/2 – 1/3 good for performance-bandwidth tradeoff
  - Minimum distance need to be greater than diversity order
- Higher order modulation
  - For devices with good SNR for bandwidth efficiency
  - To keep code rate low for reliability
  - Maximum order limited by transmitter and receiver impairments (EVM)



WAVEFORM & FRAME STRUCTURE

- High reliability
  - Avoid own-cell interference, preserve interference margin towards uncoordinated interference sources
  - Synchronized (slotted) access helps maintain user orthogonality
  - OFDM as baseline

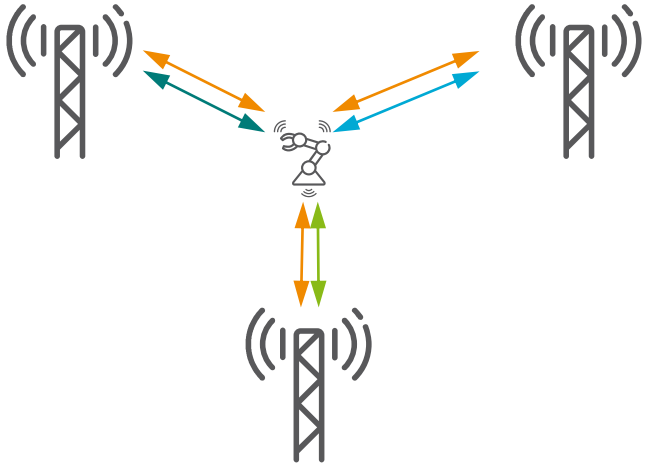
- Latency: access slots ≤0.1 ms
  - Frame structure enabling low scheduling latency
  - Slot formatting enabling low processing delay and on-the-fly decoding
  - No computationally intensive receiver operation



- Traffic handling: support both periodic and sporadic traffic types
  - Persistent scheduling for periodic traffic
  - Dynamic scheduling or contention-based access for sporadic traffic
  - All with high reliability and low latency

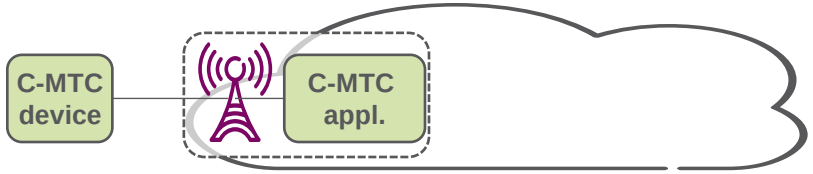
MULTI-CONNECTIVITY FOR HIGH RELIABILITY

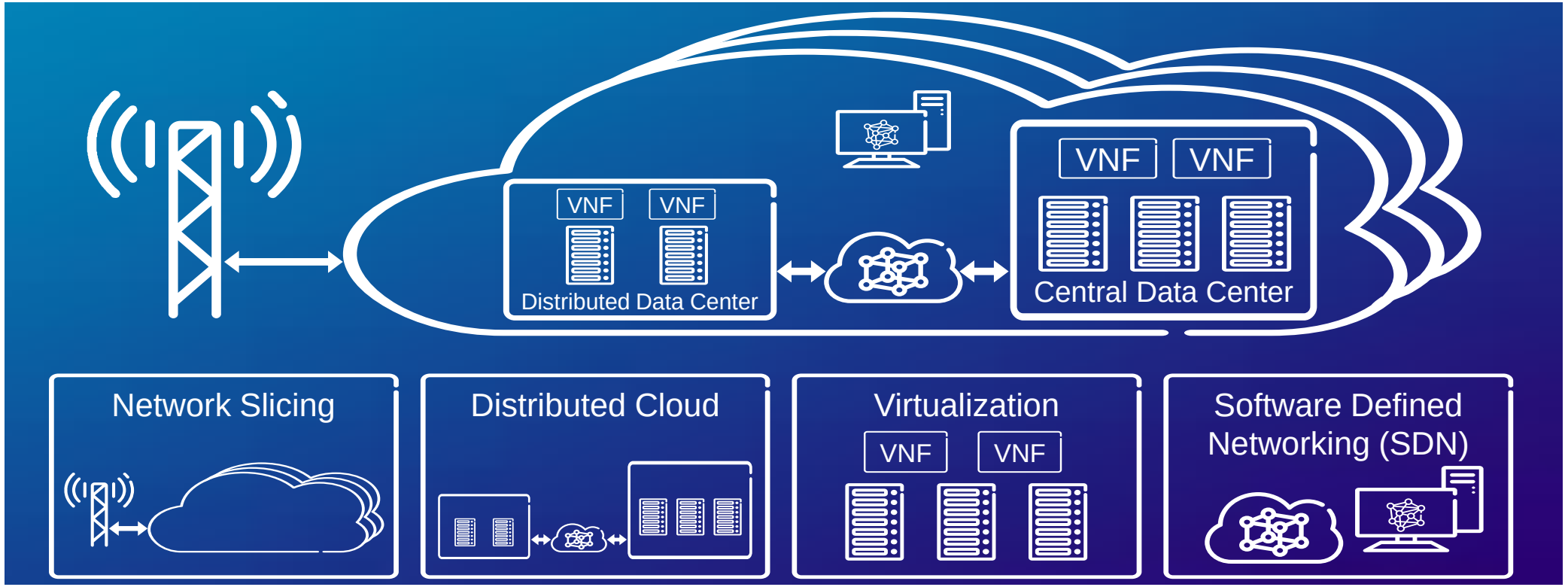
- Robust connectivity via coordinated multipoint communication
  - via multiple sites
  - across multiple frequency layers
- Fallback to other RATs (e.g. LTE)



FLEXIBLE NETWORK ARCHITECTURE

- Network layout for optimized service performance
  - E.g. local functionality for delay optimization





SUMMARY

- ICT is an enabler for industry transformation based on digitized processes
  - Cellular communications provides ubiquitous connectivity and broad capabilities
- 5G is addressing requirements of new use cases including ultra-reliable low latency communication
  - Diversity via coordinated multi-point communication and robust coding for reliability
  - Frame format for short delay and on-the-fly processing
  - Flexible network architecture for service-optimized network design and deployment
  - Ultra-reliable wireless transmission within 1ms latency is possible

ERICSSON