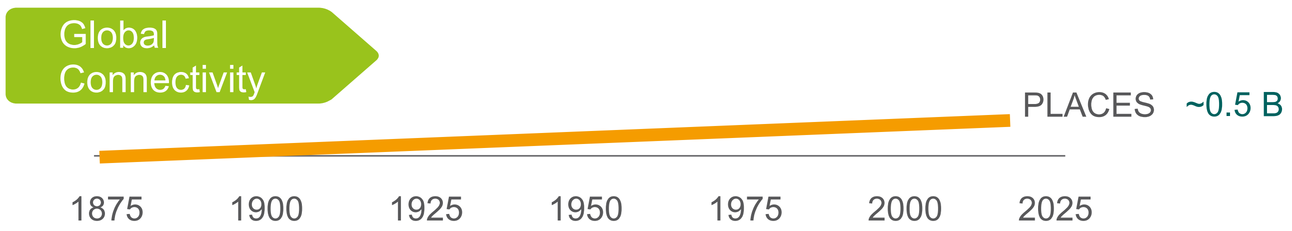
POTENTIAL OF LTE FOR MACHINE-TO-MACHINE COMMUNICATION

Dr. Joachim Sachs
Ericsson Research

OUTLINE

- Trend towards M2M communication
- What is the role of cellular communication
- 5G - the next generation of cellular communication
- Cellular M2M communication
  - Sensors and meters
  - Intelligent Transport Systems (ITS)
  - Distributed embedded control
- Conclusion

TELECOMMUNICATION TODAY



Source: Ericsson

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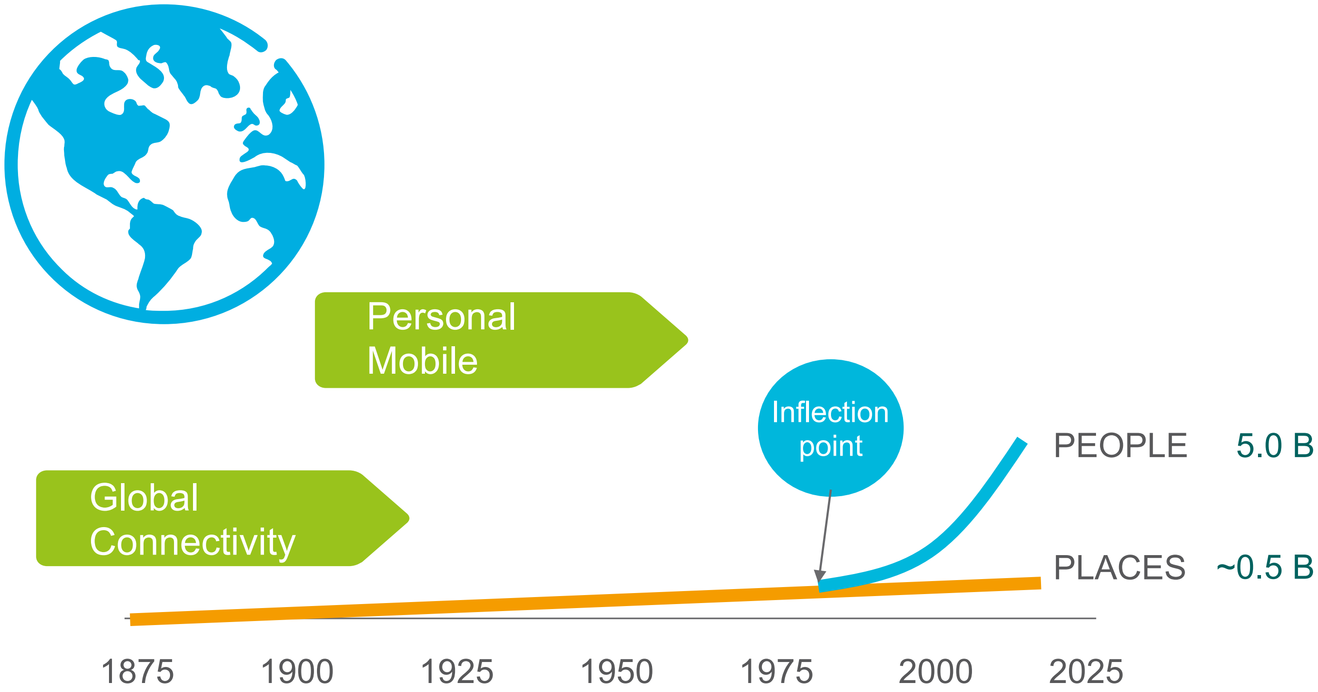

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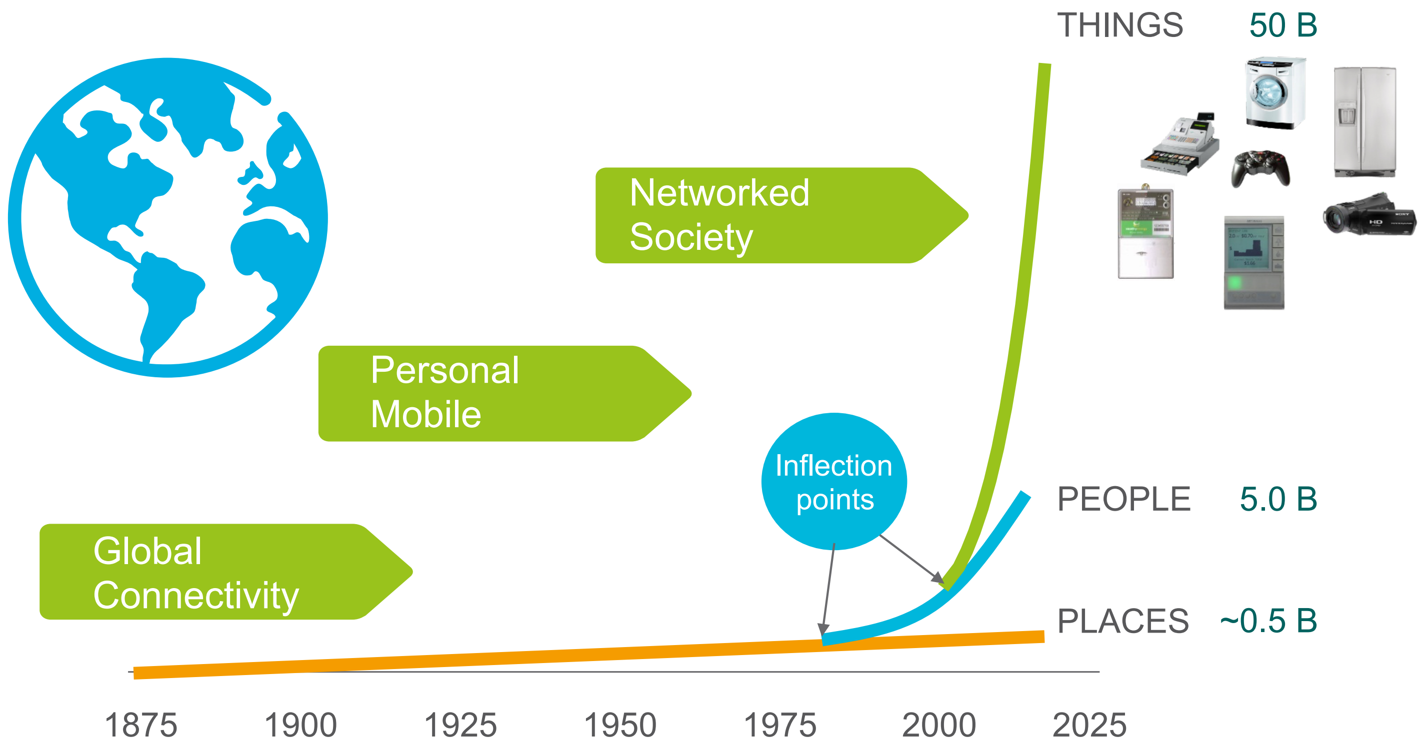
TELECOMMUNICATION TOMORROW



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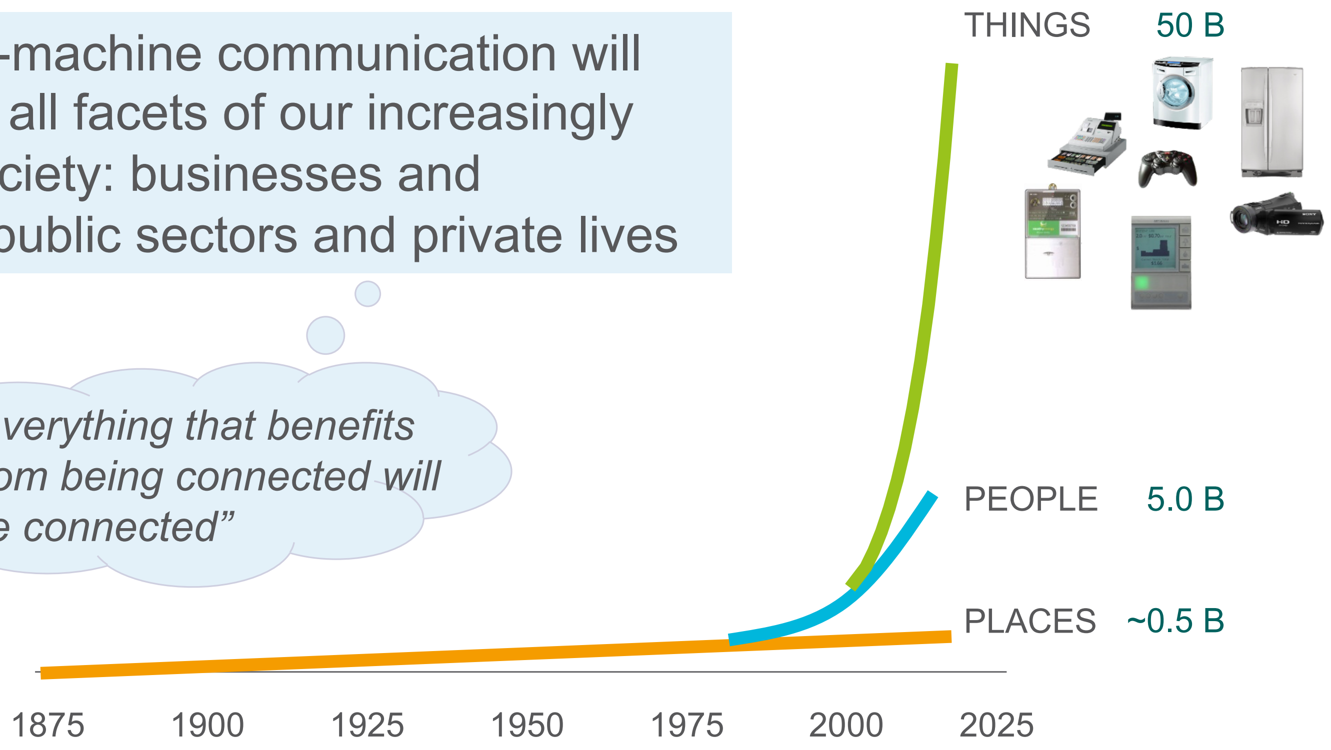
THE NETWORKED SOCIETY

Machine-to-machine communication will spread into all facets of our increasingly digitized society: businesses and industries, public sectors and private lives

“everything that benefits from being connected will be connected”



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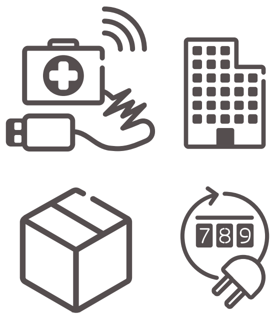
CONNECTED DEVICES

Meters and Sensors

- Sensor, actuators, meters, connected devices and things
- Small, simple, low-cost
- Low energy consumption
- Long-range coverage

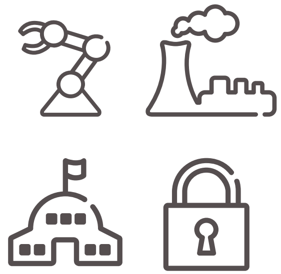


Intelligent Transport Systems

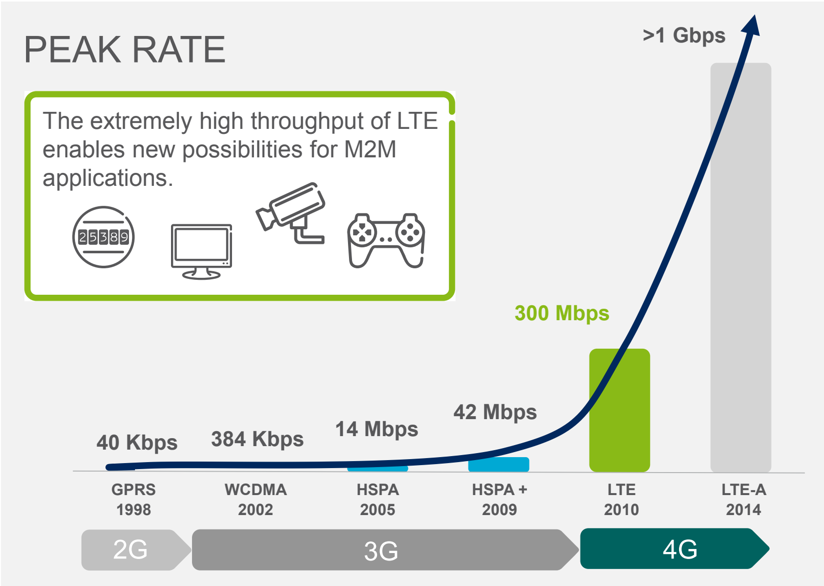
- Connecting vehicles, transport infrastructure and transport management
- Incl. safety-related services
- Low delay
- High mobility

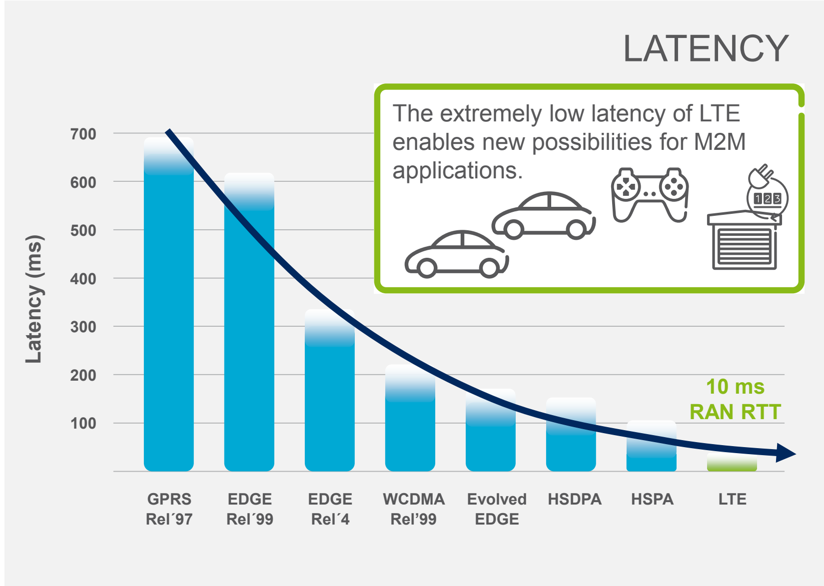
Critical Communication

- Distributed embedded control & cyber-physical systems
- High reliability and availability
- Low delay
- Autonomous operation



Role of cellular communication

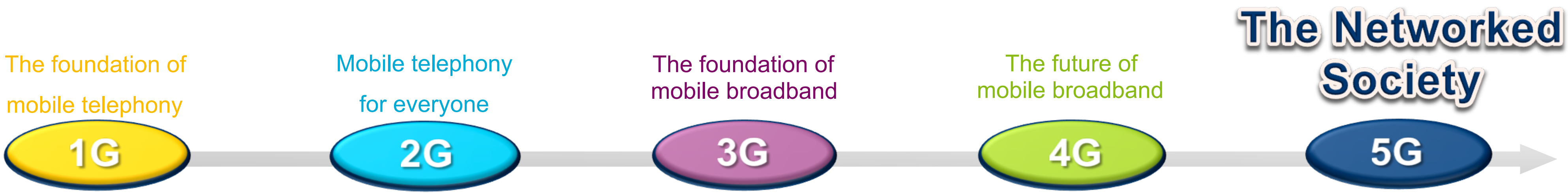




Capabilities to fulfill demanding requirements,

not limited to personal communication

WIRELESS ACCESS GENERATIONS

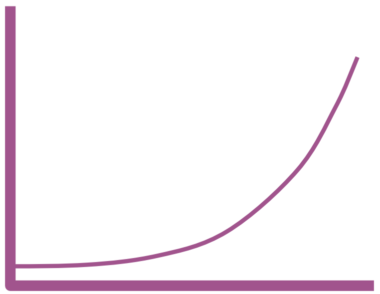


Unlimited access to information and sharing of data available anywhere and anytime to anyone and anything

KEY CHALLENGES ON 5G

Massive growth in

Traffic Volume



Massive growth in

Connected Devices

Wide range of

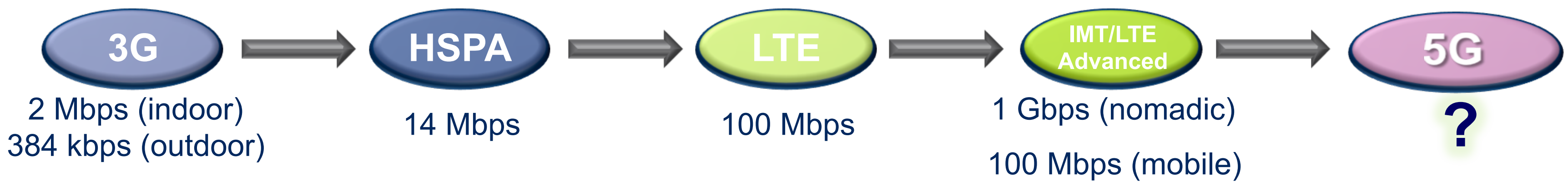
Requirements & Characteristics

- **Data rates**
- **Latency**
- **Reliability/availability**
- **Device cost and energy consumption**
- **Security**
- **.....**

Affordable and sustainable

DATA RATES FOR 5G

Higher rata rates has been the “flying flag” for each technology step!



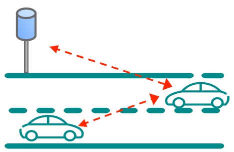
Target for the future

- 10 Gbps in specific scenarios
- 100 Mbps generally available in urban/suburban scenarios
- High-quality (Mbps) connectivity essentially everywhere

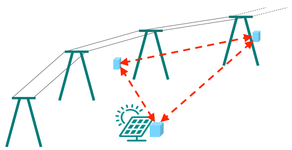
LATENCY / RELIABILITY FOR 5G

LTE radio-interface latency sufficient in most cases

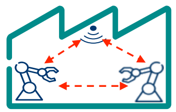
Very low latency may be required by some ”new applications”



Traffic safety/control



Smart grid



Industrial application

“Tactile Internet”

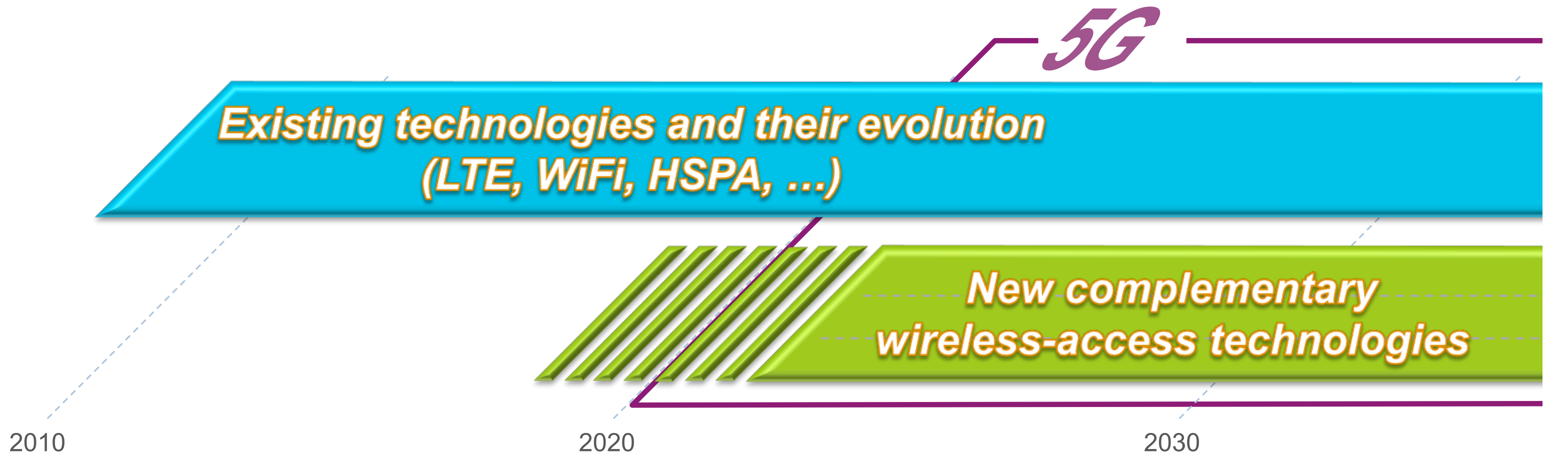
…

Target for the future

Possibility for sub-ms latency with very high reliability

FUTURE WIRELESS ACCESS – 5G

A set of integrated radio-access technologies
jointly enabling the long-term Networked Society



- Evolution of existing radio-access technologies
- New *complementary* radio-access technologies

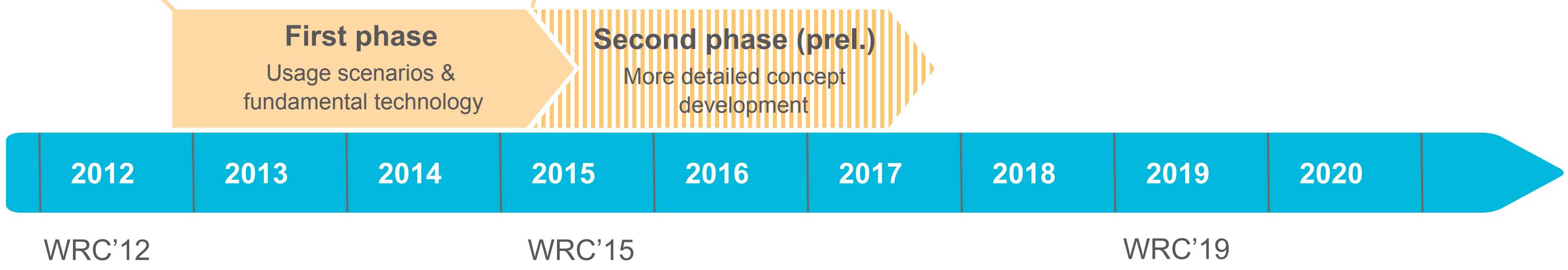
New technology components in both cases

METIS PROJECT

Universities and research institutes

EU-funded research project on future wireless communication

29 partners / ≈2500 man-month / 29 M€



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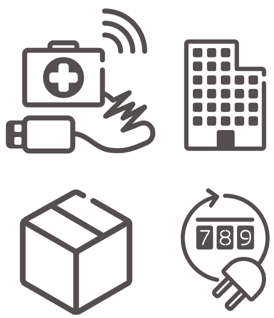

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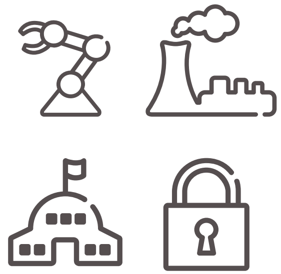

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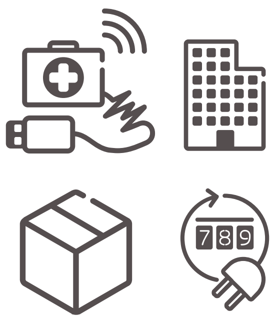

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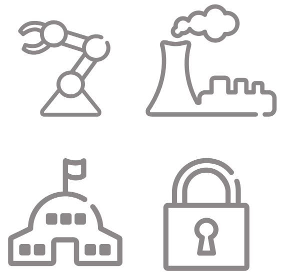

SENSORS & METERS
USE CASES

- **Building automation** (temperature, light, doors, heating, …)
- **Ambient Assisted Living** personal monitor (blood pressure, pulse, …)
- Sensors and **smart meters** in the smart grid (e.g. distributed weather sensors)
- **Goods / fleet tracking** in logistics
- **Agriculture / aquaculture** sensors (irrigation, fertilization, cattle tracking, …)
- **Smart city infrastructure** monitoring (availability of parking lots, full dustbins, …)

SENSORS & METERS
CHARACTERISTICS

- Typically **infrequent** measurements of **limited size**
- Traffic mainly in **uplink** (measurement reports), but **downlink** also possible (configuration, SW update, control)
- **Delay-tolerant** in **downlink** and / or **uplink**
- **Stationary** or **mobile** devices
- **Long lasting battery operation** or **with power supply**
- **Constrained** (cost/processing) or **complex** devices
- Potentially dense accumulation of **many** devices

SENSORS & METERS CHARACTERISTICS

Theme

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REQUIREMENT #1: LOW COST

Example LTE

- Cost reduction of up to 80% possible
  - (3GPP TR 36.888) by reduced UE features and performance
- 3GPP Rel-12 WI targeting 50% cost reduction
  - one receive antenna
  - data rates limited to 1 Mb/s
  - data transmission in 1.4 MHz only
- Beyond Rel-12 features e.g.
  - half-duplex FDD, reduced RF bandwidth

Low-end UE category 1

Downlink
- up to 10 Mb/s (64 QAM)
- up to 10296 bits transport block size
- 2 receiver antennas and reception from up to 4 antenna ports
- single stream transmission

Uplink
- up to 5 Mb/s (16 QAM)
- up to 5160 bits transport block size
- two transmit antennas

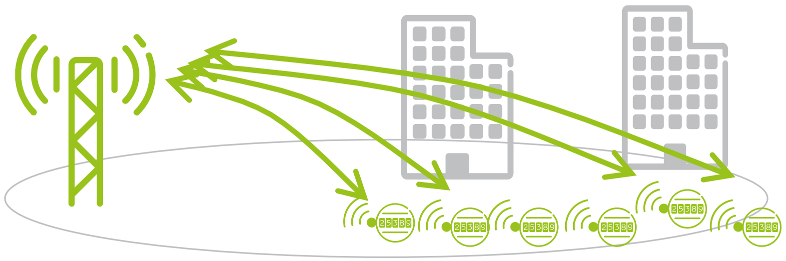
Layer 2 buffer size 150 kB

Source: 3GPP TS 36.306 and Dahlman et al. 2011

REQUIREMENT #2: EXTENDED COVERAGE

<u>Example LTE</u>

› 3GPP TR 36.888 lists coverage improvement options for low-rate MTC devices
  – repetition with energy accumulation
  – power/PSD boosting
  – relaxed performance requirements
  – simplification/elimination of physical control channel functionality or design of new channels/signals

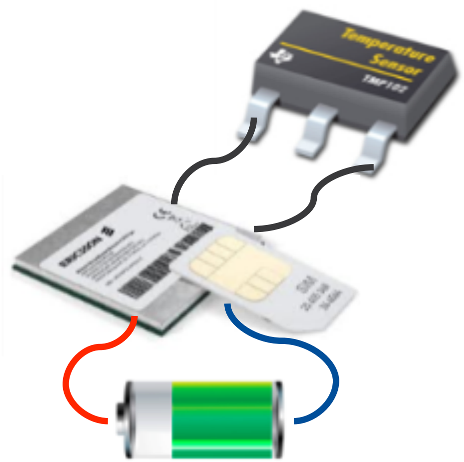


› 3GPP Rel-12 work item targeting 15dB coverage extensions for MTC UEs
› More aggressive improvement imaginable beyond Rel-12

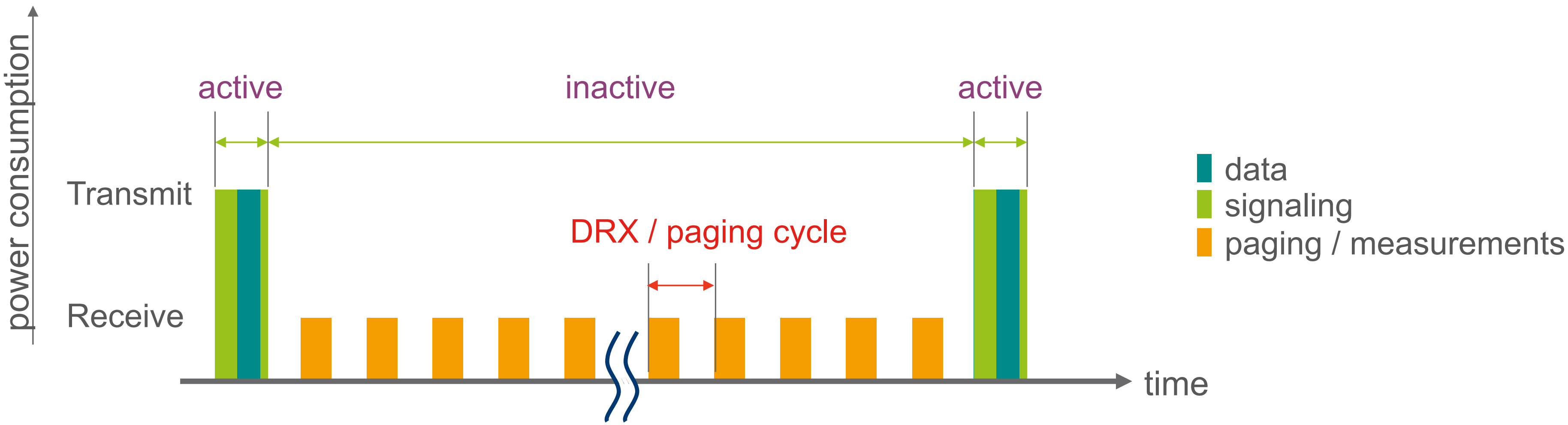
MTC – Machine-type communication

REQUIREMENT #3: LOW ENERGY CONSUMPTION

› Operate devices for years on a single battery

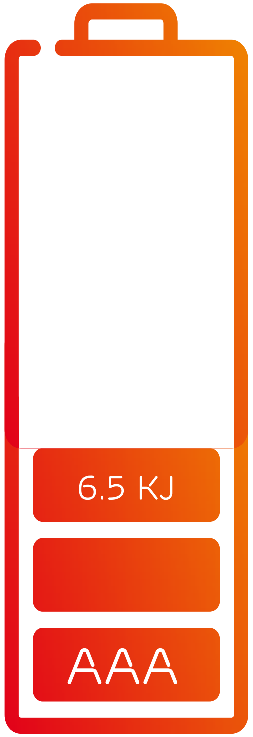


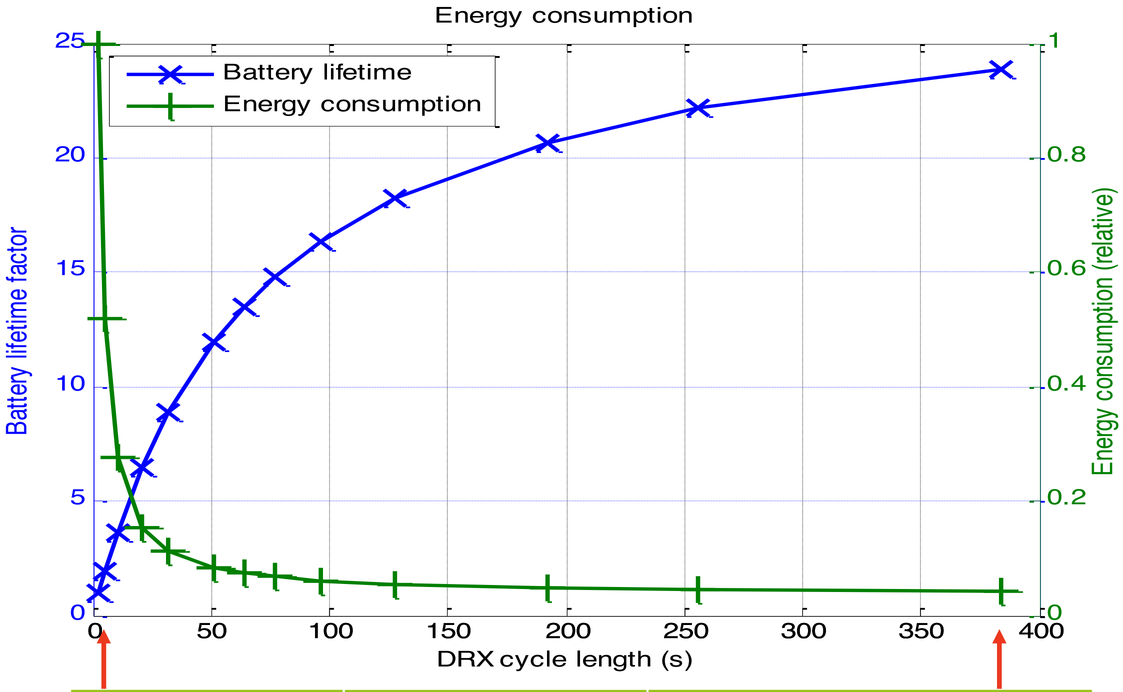
WHAT CONSUMES ENERGY IN LTE?



DRX active times dominate UE energy consumption

LTE: LOW-ENERGY UE TRANSMISSION





DRX cycle	Battery life	Average DL response
2.56s	2.8 months	1.28s
384s	67 months	~3 min

Assumptions

No downlink transmission

Uplink transmission
- 1000 bytes every 12 min
- 10 ms synchronization
- 50 ms data transmission

DRX active periods
- 10 ms synchronization
- 10 ms reading control channel

Source: Tirronen et al. 2012 & 2013

LTE: LOW-ENERGY UE TRANSMISSION (2)

- Currently maximum DRX (&paging) cycles of 2.56 s
- Longer DRX can reduce UE energy consumption

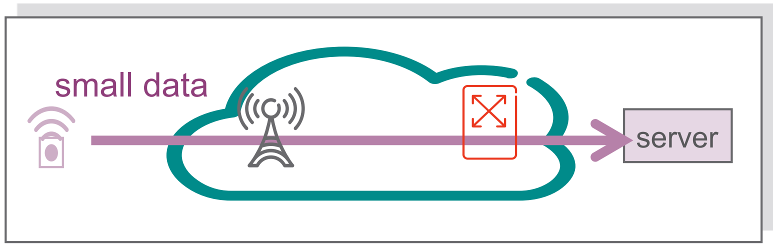
- Energy saving vs. delay trade-off for downlink data
  - Long DRX cycle reduce the UE responsiveness to network triggers e.g. with 2.56 s DRX cycle a UE can respond on average within 1.28 s
  - If UE is delay tolerant for downlink data, long DRX cycles can be used

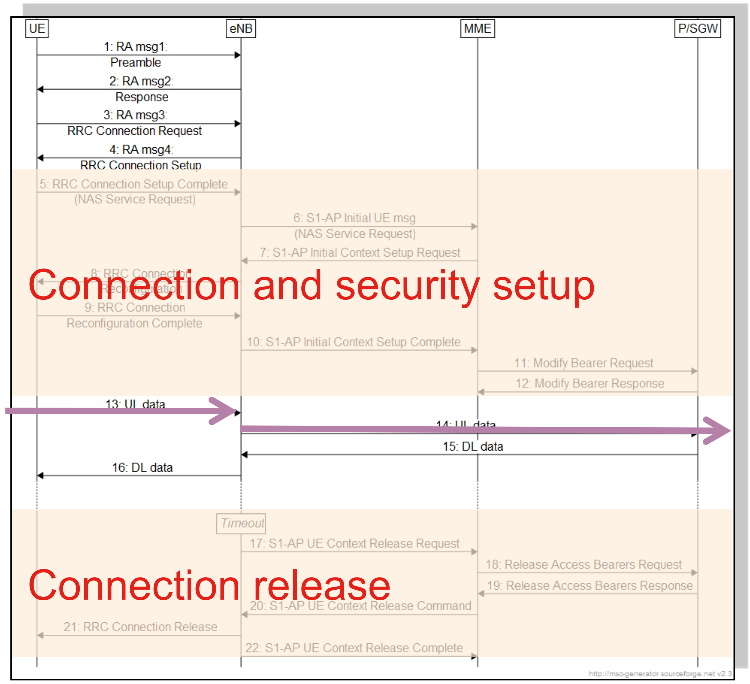
- In uplink a UE can transmit whenever it desires
  - no delay impact

REQUIREMENT #4: LITTLE OVERHEAD FOR SMALL DATA

› Can we simplify the transmission procedures for small data transmission?

– Connection / bearer setup and tear-down for every data transfer



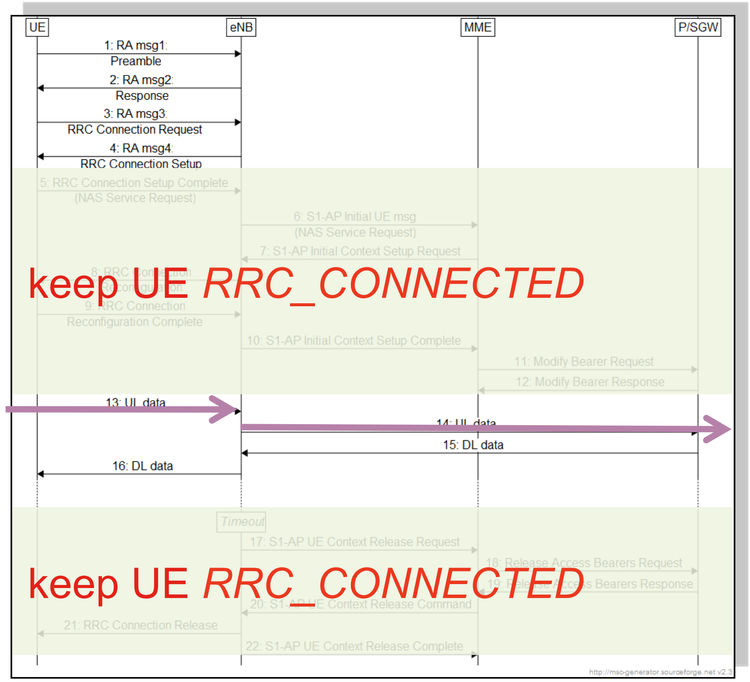


REQUIREMENT #4: LITTLE OVERHEAD FOR SMALL DATA

› Investigation on optimizations is currently ongoing in 3GPP

– E.g. keep UE in *RRC_CONNECTED* state with long sleep (DRX) cycles

– E.g. simplified bearer handling and lightweight connection setup



5G RESEARCH
METIS – MASSIVE MACHINE COMMUNICATION

- Different test cases on massive machine communication:
  - Shopping mall (dense sensor deployment)
  - Massive deployment of sensors and actuators
- MTC scalability and performance
  - supporting 10-100 times more devices
    - 80% protocol efficiency for 300 000 devices per access point
    - efficient random access, protocol overhead
  - 10 times better battery lifetime
    - improved UE sleep modes
  - 99.9% coverage
    - long-range coverage features

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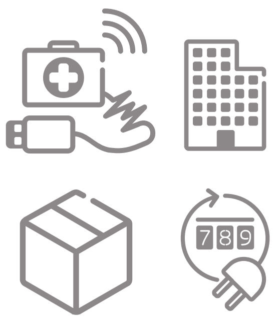

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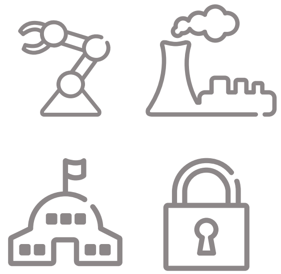
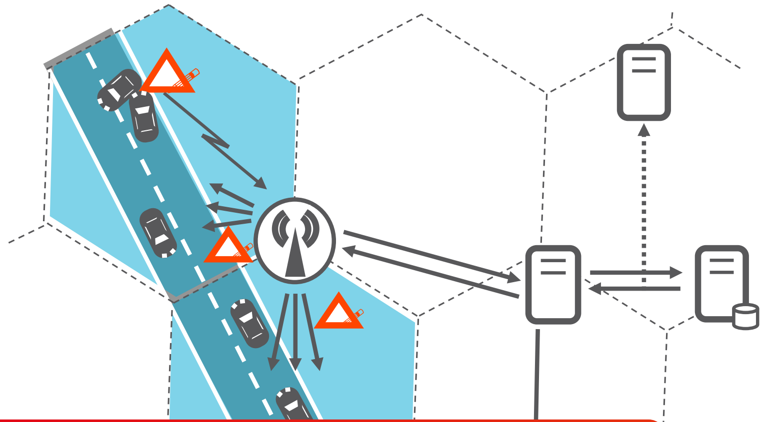


INTELLIGENT TRANSPORT SYSTEMS
EARLIER RESEARCH

- Mobile networking for ITS has been demonstrated
- ETSI ITS has endorsed cellular networks as communication technology for Cooperative Intelligent Transport Systems



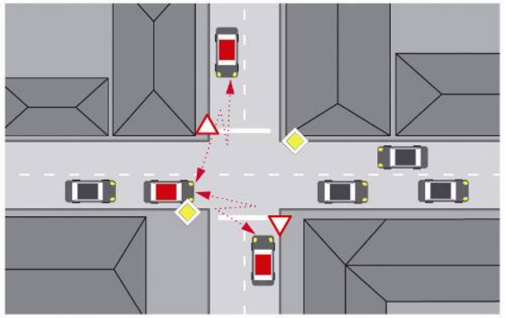
- **Cooperative Cars (CoCar, 2006-2009)**
  - Basic research on cellular car-to-car communication using UMTS and HSPA
  - Reference case: Road Hazard Warnings

- **Cooperative Cars eXtended (CoCarX, 2009-2011)**
  - LTE, session and lifecycle management, heterogeneous approach

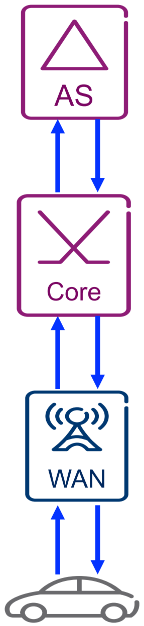
ETSI STANDARDIZATION

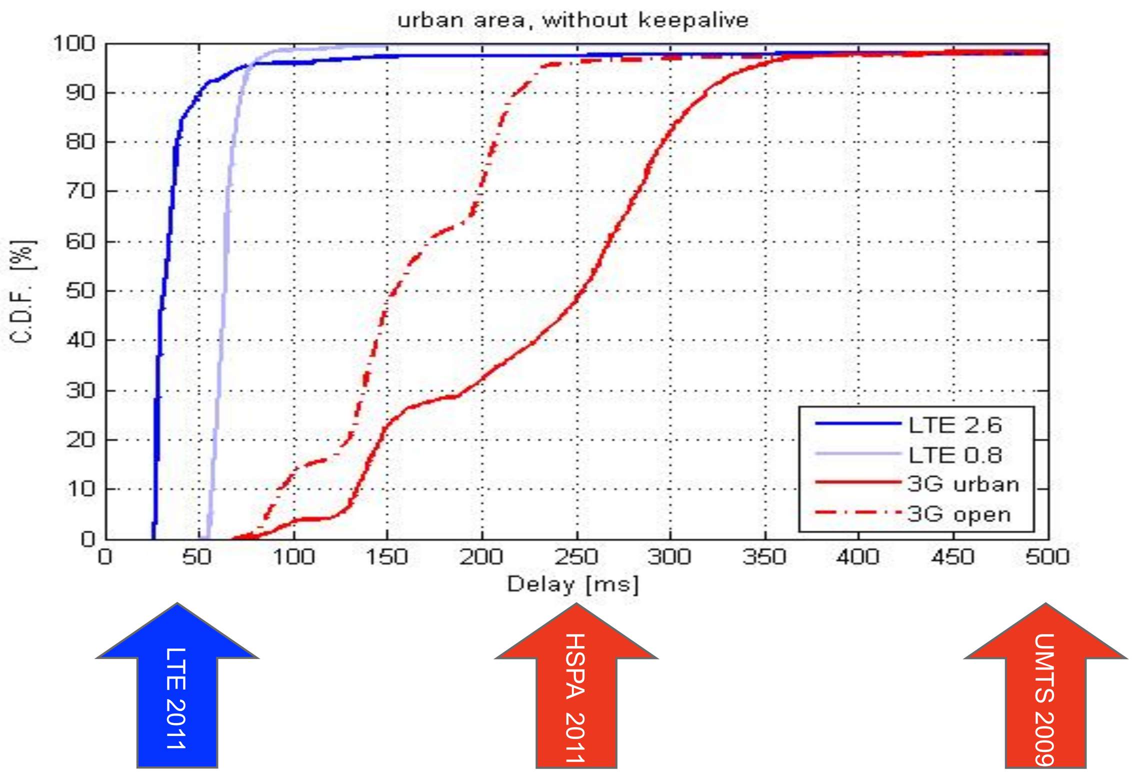
- C-ITS – Cooperative Intelligent Transport Systems
  - Goals, e.g.:
    - Improved traffic efficiency
    - Increased road safety
- Automotive Messaging Types
  - CAM – Cooperative Awareness Message
    - Continuous notification for ambient awareness
  - DEN – Decentralized Environmental Notification
    - Event based notifications

Intersection assistance



CELLULAR CAR-TO-CAR DELAY





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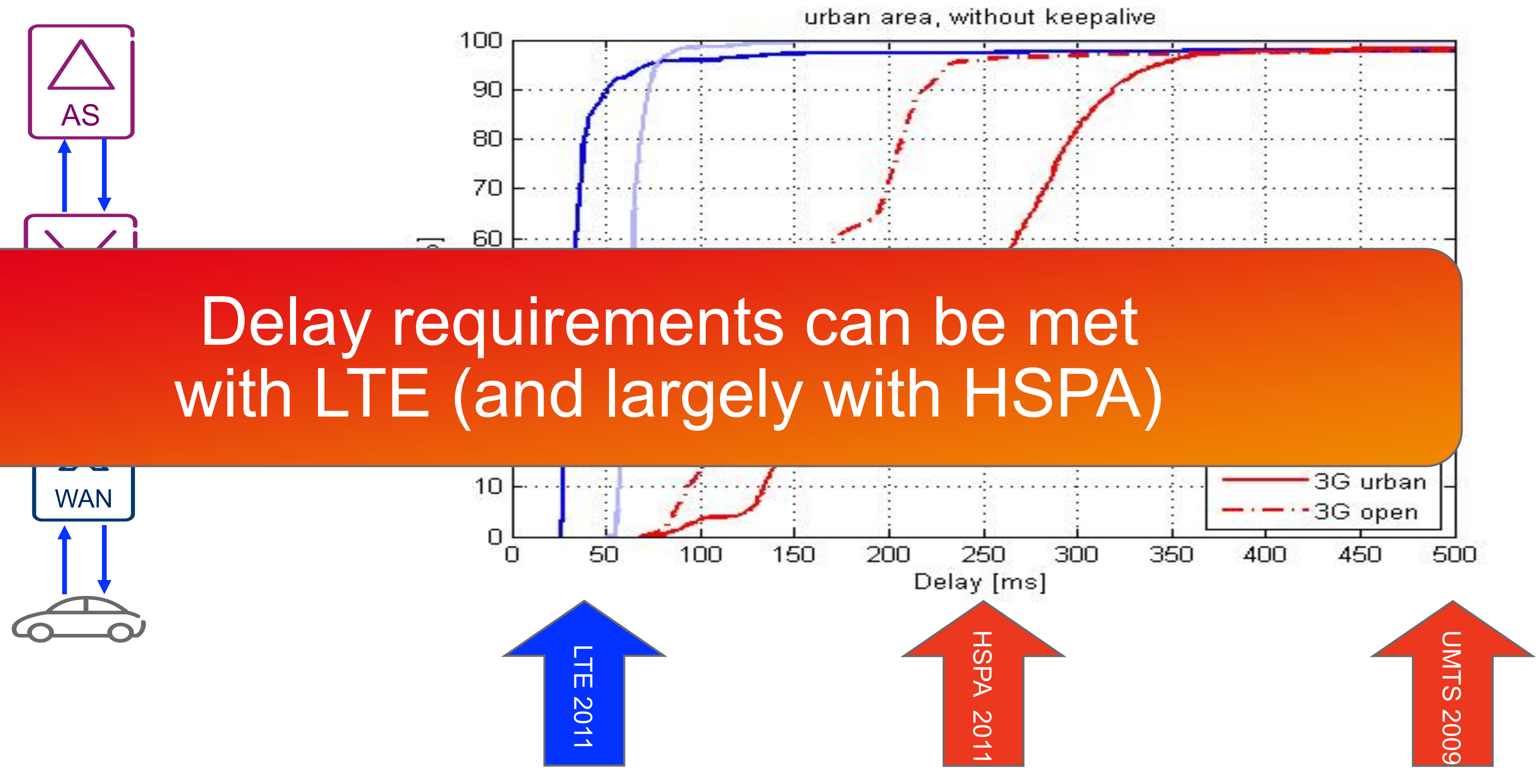

Delay requirements can be met
with LTE (and largely with HSPA)

HOW ABOUT SYSTEM CAPACITY ?

Evaluated
in simulation study

ITS SUMMARY

- CAM could in theory be supported by LTE networks
  - High traffic load and radio resource usage for little new information
- DEN can efficiently be supported by LTE networks
  - Warning essential to increase road safety
  - Delay requirements can be met
- Possible capacity improvements
  - Solution using Multimedia Broadcast Multicast Service or Device-to-Device communication
- Other vehicular communication use cases have more relaxed requirements
  - Remote diagnostics, road traffic management, …

M. Phan, R. Rembarz, S. Sories: 'A Capacity Analysis for the Transmission of Event and Cooperative Awareness Messages in LTE Networks', ITS World Congress, Orlando, Florida, October 2011.

INTELLIGENT TRANSPORT SYSTEMS
CURRENT RESEARCH

Converge (2012-2015)

› Concepts and prototypes of
  - data and content exchange network (for ITS safety & efficiency data)
  - a multi-operator & multi-technology wireless access solution

5G / METIS (2012-2015)

› Test Case: “Traffic Safety and Efficiency”
  - road platooning (vehicle-2-vehicle)
  - traffic safety, including pedestrians & cyclists (vehicle-2-vehicle, vehicle-2-infrastructure, vehicle-2-device)
  - integration of wide-area connectivity with D2D and DSRC
  - guaranteed e2e delay of 5ms
  - transmission reliability of 99.999%
  - relative velocities up to 500 km/h

› Driver:

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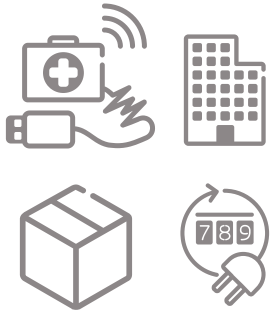

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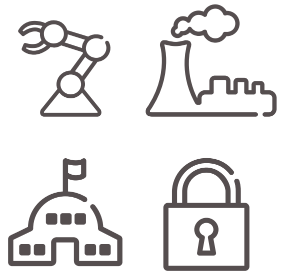
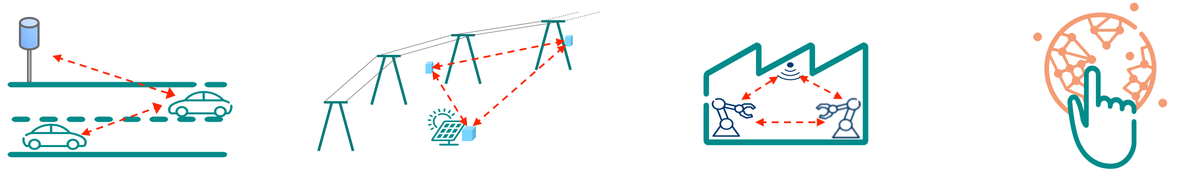


5G LATENCY / RELIABILITY

New MTC use cases drive 5G to address demanding requirements

Very low latency may be required by some ”new applications”



Traffic safety/control *Smart grid* *Industrial application* *“Tactile Internet”* …

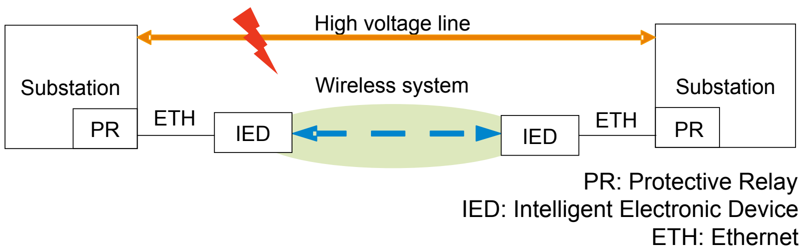
Target for the future

Possibility for sub-ms latency with very high reliability

5G RESEARCH
METIS – ULTRA-RELIABLE COMMUNICATION

- Super real-time with guaranteed ultra-low delays
- Reliable connections
- Relevant for industrial automation and distributed embedded control

- Test case: Teleprotection in smart grid network
  - based on IEC 61850 substation automation
  - guaranteed 8ms one-way, end-to-end delay
  - 99.999% service availability



SUMMARY

- Machine-to-machine communication is a major part in enabling the Network Society
- Cellular communication will play a strong role
  - Capabilities, availability, global market
- Optimization of cellular communication is possible for M2M
  - Several activities ongoing in 3GPP
- 5G addresses novel and demanding use cases (e.g. in METIS)

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