WHAT DOES A VEHICLE NEED FROM 5G?

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AGENDA

- **Why do we need connectivity in a vehicle?**
- **5G axis of improvements**
- **Focus on vehicular communications**
  - Overview
  - Metric of interest
  - Example of breakdown of latency.
- **Conclusions**

Autonomous Driving (Assistence)
HD Maps, road safety + Platooning, Cooperative collision avoidance, extended sensors

Emergency service
eCall, crash info

Software Updates

Infotainment
Advertisement, personal information management, connected media, audio and video streaming etc..

Remote sensing and control
Remote control of the car, warm up/down, remote monitoring for maintenance etc..

Vehicle Apps
vehicle related apps (parking, meteo), traffic efficiency, etc..

Road Safety
Road hazard warning, traffic jam ahead warning emergency vehicle approaching etc..

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HD Maps, road safety + Platooning, Cooperative collision avoidance, extended sensors

Emergency service
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Vehicle Communication

Communicating vehicle

Remote sensing and control
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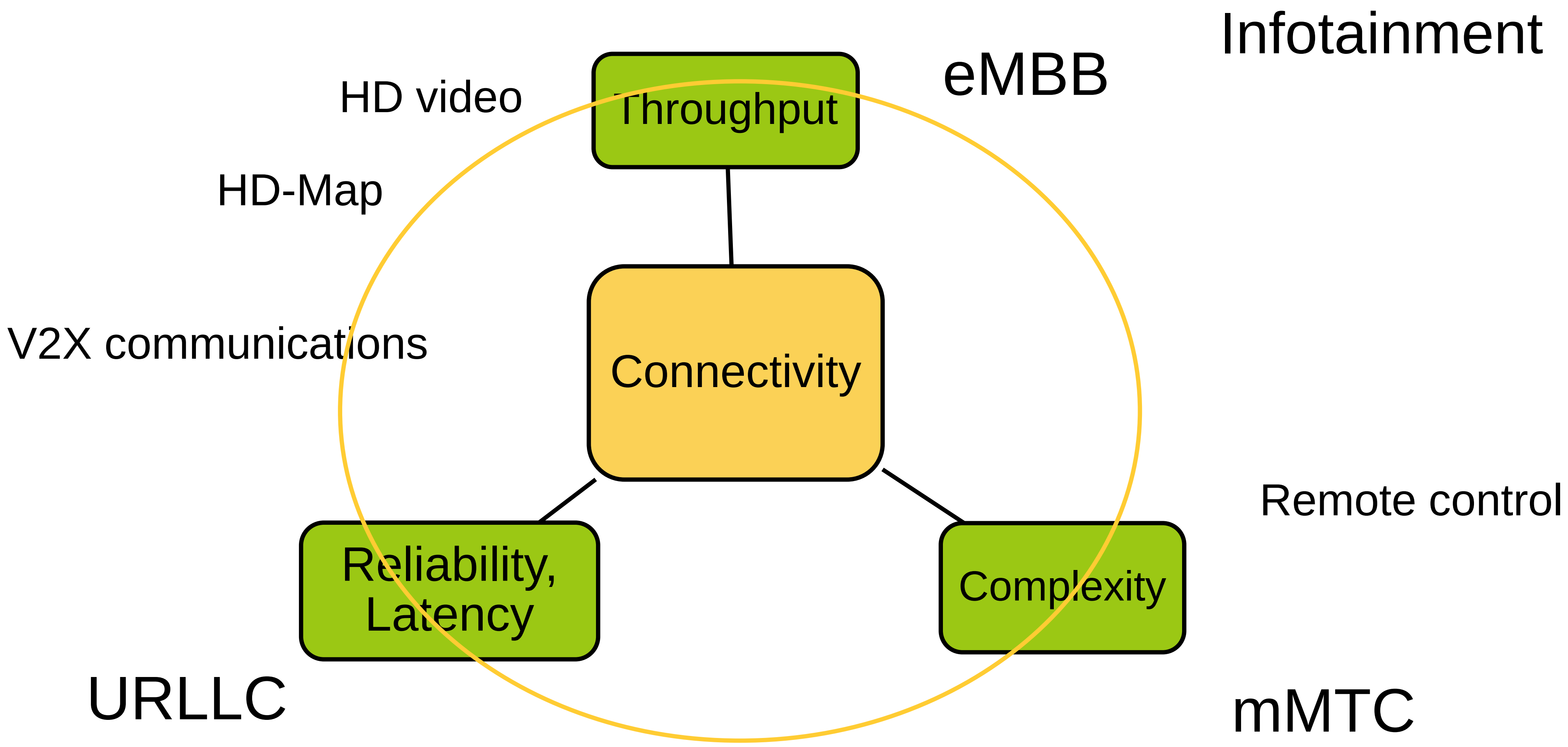
Vehicle Apps
vehicle related apps (parking, meteo), traffic efficiency, etc..

Road Safety
Road hazard warning, traffic jam ahead warning emergency vehicle approaching etc..

WHICH TECHNOLOGIES TODAY



4G TO 5G EVOLUTIONS

5G eMBB targets
- High data rate with uniform user experience
- High traffic density
- Improved power efficiency

Techniques such as
- Scalable numerology
- Massive MIMO/BF/CoMP
- Large BW
- Aggregation
- Non Standalone and Standalone

5G mMTC targets
- 5x device density (wrt NB-IOT)
- +10dB coverage (wrt NB-IOT i.e. 175dB MCL)
- Extended battery life (wrt 10ys target for NB-IOT)

5G mMTC > Rel15

MBB

MTC, IoT

4G

Side Link, Vehicular Comm

New spectrum

5G URLLC
- Reliability of 1-10^{-5} for 32 bytes with a U-plane latency of 1ms
- Latency x 1/10 wrt LTE

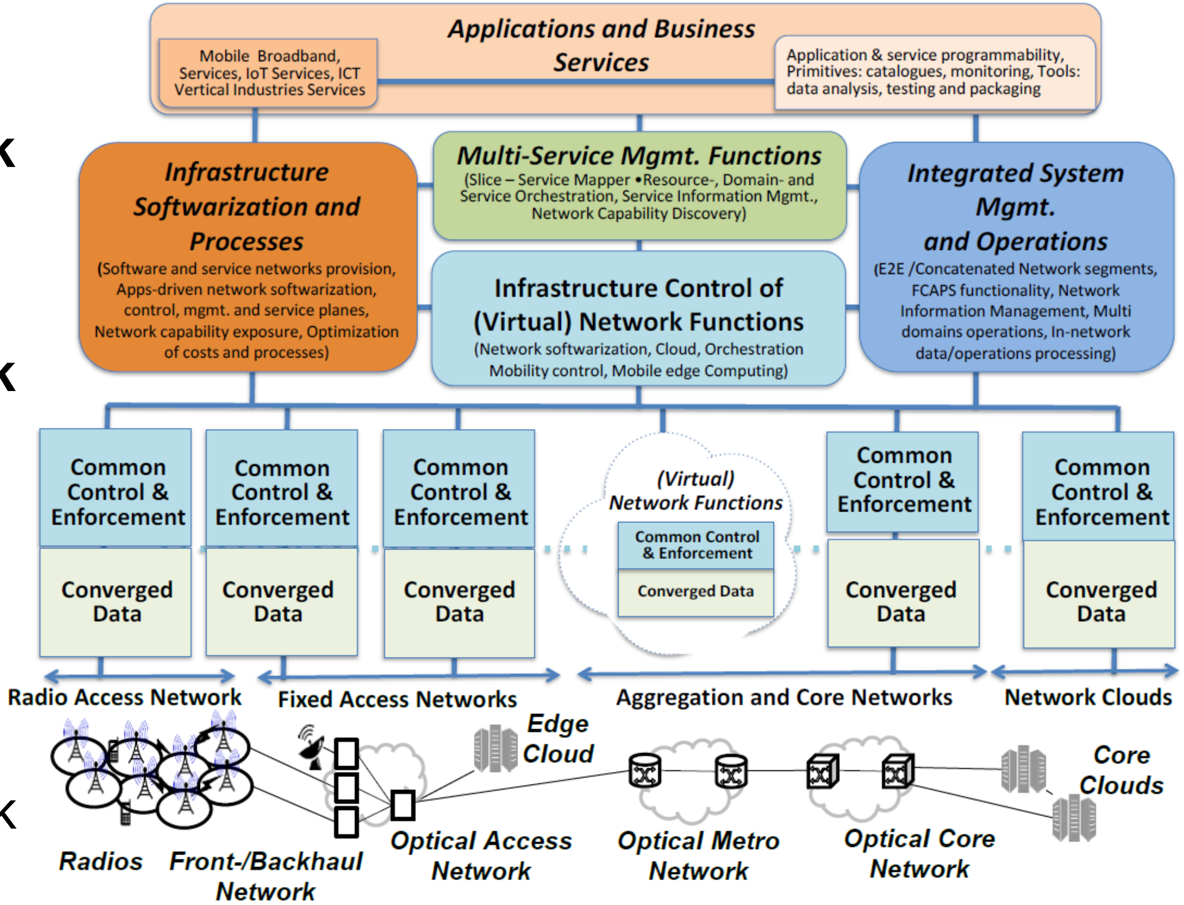
5G flexible spectrum usage
- First design for <6GHz and >6GHz but <39GHz
- New RAT for >39GHz
- CA <6GHz for coverage and mmwave for throughput booster
- New deployment types

5G V2X
- Reliability of 1-10^{-5}
- V2V latency <5ms
- V2X latency up to 5ms
- Increased data rate for up to 250Km/h
- Lateral and longitudinal cm-level accuracy

5G Side Link > Rel15

NETWORK EVOLUTION

- **Softwarization and programmability framework**
  - Software Defined Network
  - Network function virtualization
- **Cloudification and edge-fication of the network**
  - Data center for max of resource usage
  - Distributed computing between UE, local servers and centralized servers
- **E2E slicing**
  - provides logically separated virtualized network slices for diversified services, which significantly simplifies network construction for dedicated services
- **Control and user plane separation**



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(*) “View of 5G architecture”, 5G PPP Architecture WG, July 16.

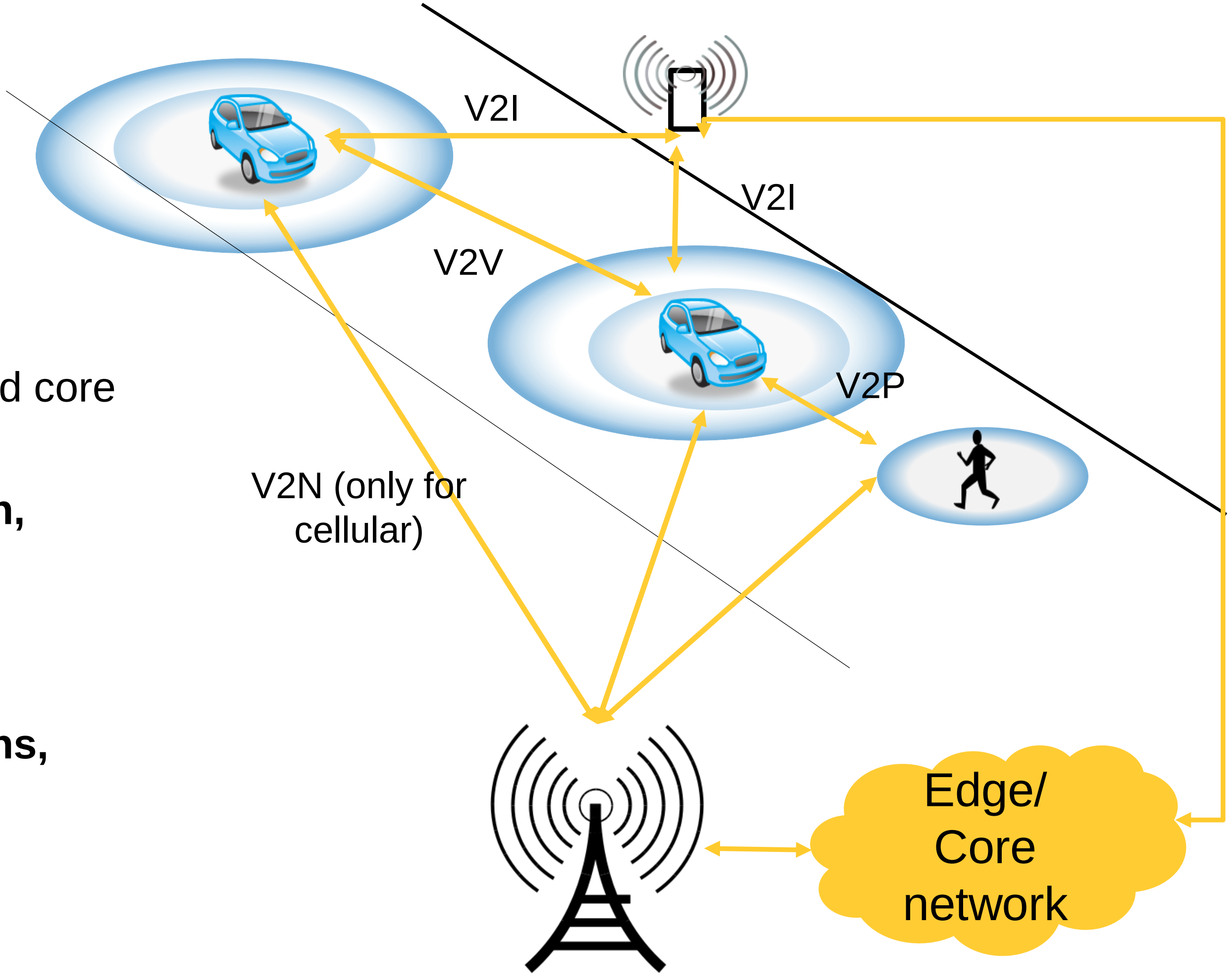
VEHICLE COMMUNICATIONS – V2X

DIRECTION/REDACTOR | DATE

GROUPE RENAULT

OVERVIEW OF V2X

- V2V and V2I (and V2P) via short range communication
  - 802.11p or C-V2X PC5
  - Low latency, ad hoc network
  - **Use of dedicated spectrum but with no guaranteed performance**
- V2N via long range communication
  - LTE Uu or NR Uu interface and LTE based or NR based core
  - Longer range, centralized approach based on eNB
  - **Best effort bearers, unicast link with retransmission, scheduled resources**
- Indirect links V2N2X
  - LTE Uu or NR Uu and LTE based or NR based core
  - **Best effort bearers, unicast link with retransmissions, scheduled resources**

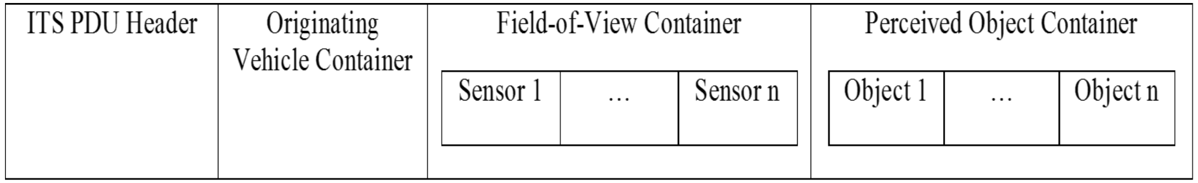


DATA TRANSMITTED VIA V2X

- **CAM, Basis vehicle status information** periodic 1Hz and 10Hz depending on the dynamic behaviour of the vehicle (speed, steering, acceleration, path history..). Size: 400Bytes - 700Bytes depending on the data content
- **DENM:** a periodic msg, triggered by an event, sent only during a specific period of time, typical size is 800Bytes
- Normally the ratio between CAM and DENM is 80%, 20%
- **IVI:** in vehicle Information (example of size ~600Bytes)
- **SPAT**: phase of traffic light (~500Bytes)
- **MAP:** informs about the Map topology (e.g. intersections) (~750Bytes)

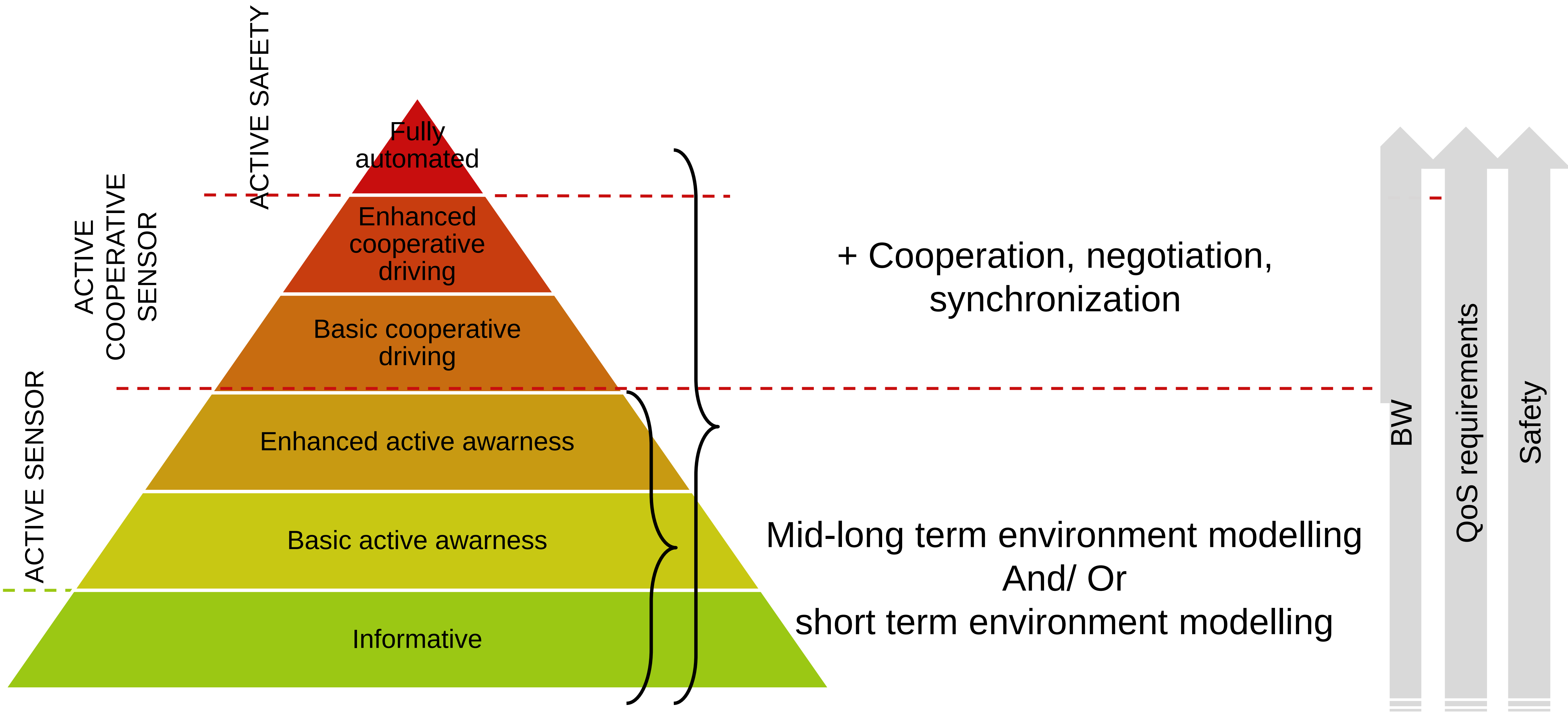
- Small packets
- Density depends on % penetration
- More or less delay sensitive depending on use cases

- **More reach content is planned**
  - Collective Perception Message → sharing the local perception
    - From 0.5 to 50Mbps depending on the amount of data sent
  - Maneuver Coordination Message → providing guidance in terms of trajectories
  - + others for platooning, tolling etc..



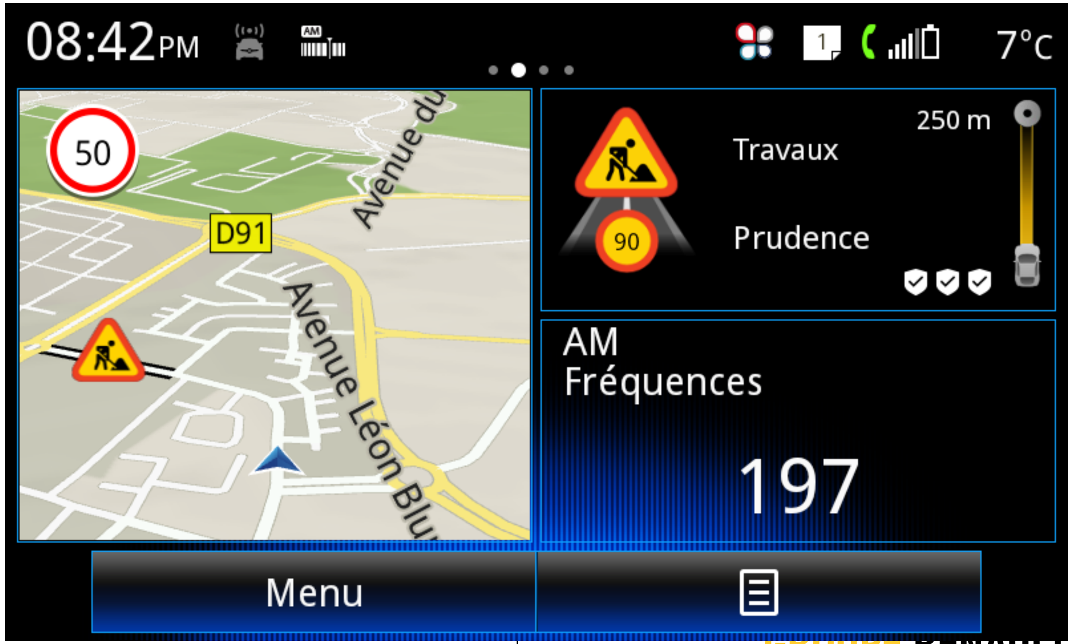
- Larger payload
- Density depends on % penetration
- Delay and reliability sensitive

HOW TO USE V2X

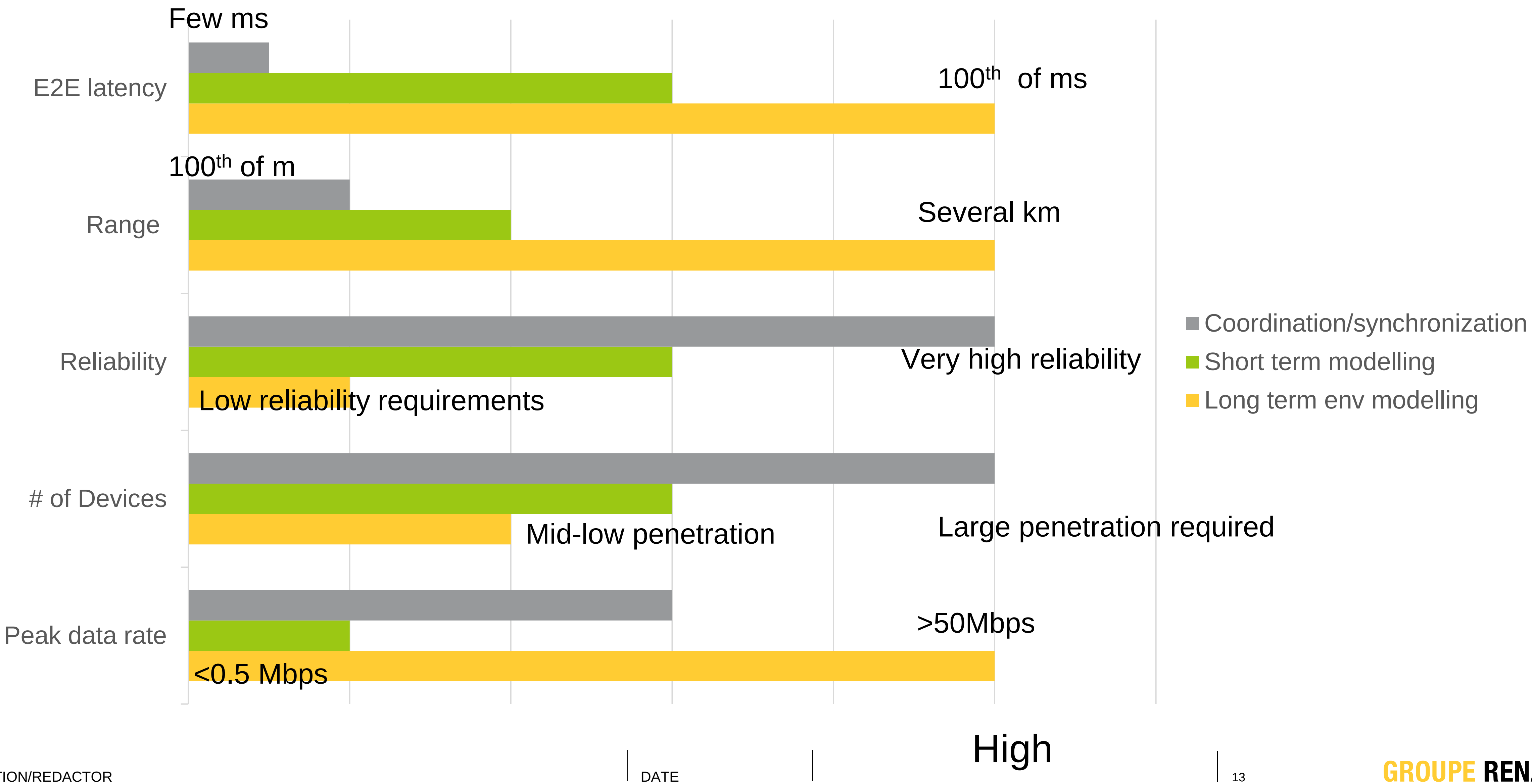


HOW TO USE V2X

- Large set of applications have been developed (C-Roads, C2C Consortium and ETSI and later 5GAA) and many to come
- Initial use of V2X → informative as warning system
- V2X is evolving towards becoming a sensor among the others
- Sensor →
  - To enrich the MAP, To optimize the traffic management for road operators → **mid-long term environment modelling**
    - Packet forwarding via shor range technologies or
    - **LTE and later 5G**
  - To enhance the local perception with dynamic information, improve the vehicle energy consumption
    - **Short term environment modelling**
      - **11p or PC5 and later 5G sidelink**



BASIC KPI


Few ms
E2E latency
100th of ms
100th of m
Range
Several km
Reliability
Very high reliability
Low reliability requirements
# of Devices
Mid-low penetration
Large penetration required
Peak data rate
>50Mbps
<0.5 Mbps
Coordination/synchronization
Short term modelling
Long term env modelling
High

MAIN KPI FOR AUTOMOTIVE INDUSTRY

- **Peak and average data rate, Bandwidth, spectral efficiency, Capacity**
  - #Bits/s, Bits/s/Hz, # of served users/s
- **Quality of Service → JOINT METRICS reliability and latency join metrics**
  - **Guaranteed QoS:**
    - **Short term env modelling:** Q = Prob (latency <=Target Latency L_t | service is available) > 1-ε
    - **Long term env modelling:** latency can be relaxed but
      - E.g. Precision of position could be more important
      - Range could be more important
  - **Availability of the service**:
    - For short term env modelling
      - Prob (E2E latency ≤ Max Latency L_{MAX}, and packet rx correctly) = Q* (1-PER)
    - tradeoff, Guaranteed QoS but accepting some Outage
- **Range:**
  - Maximum Coupling Loss → MCL = P_{TX} – REFSENS
    - Better range characterization in LOS and NLOS at a target QoS (not only PER) and load

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What do we need ?

- Configurable metrics, configurable parametrization wrt service
- Guaranteed QoS
- Predicive QoS,

- **Range:**
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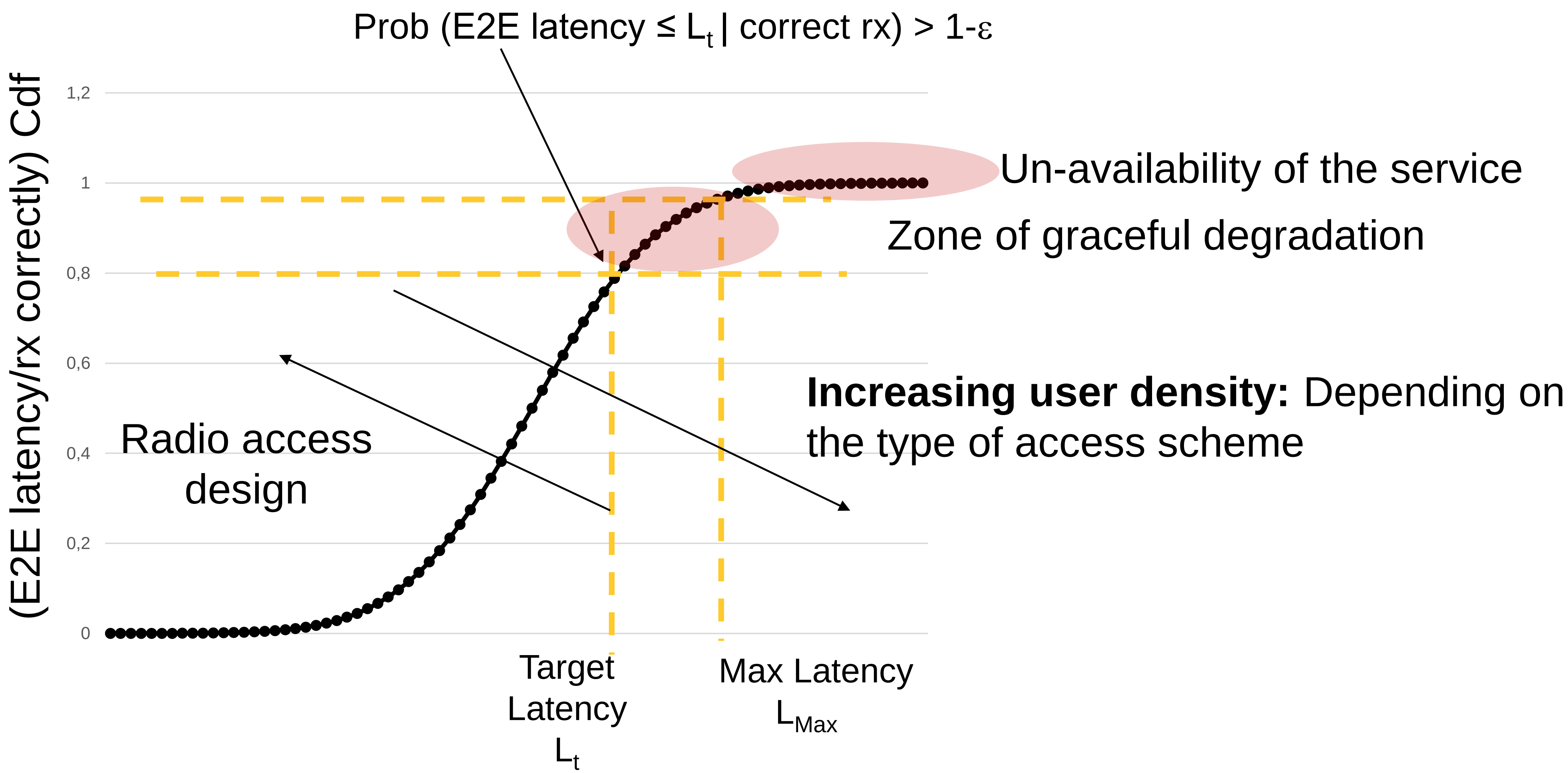
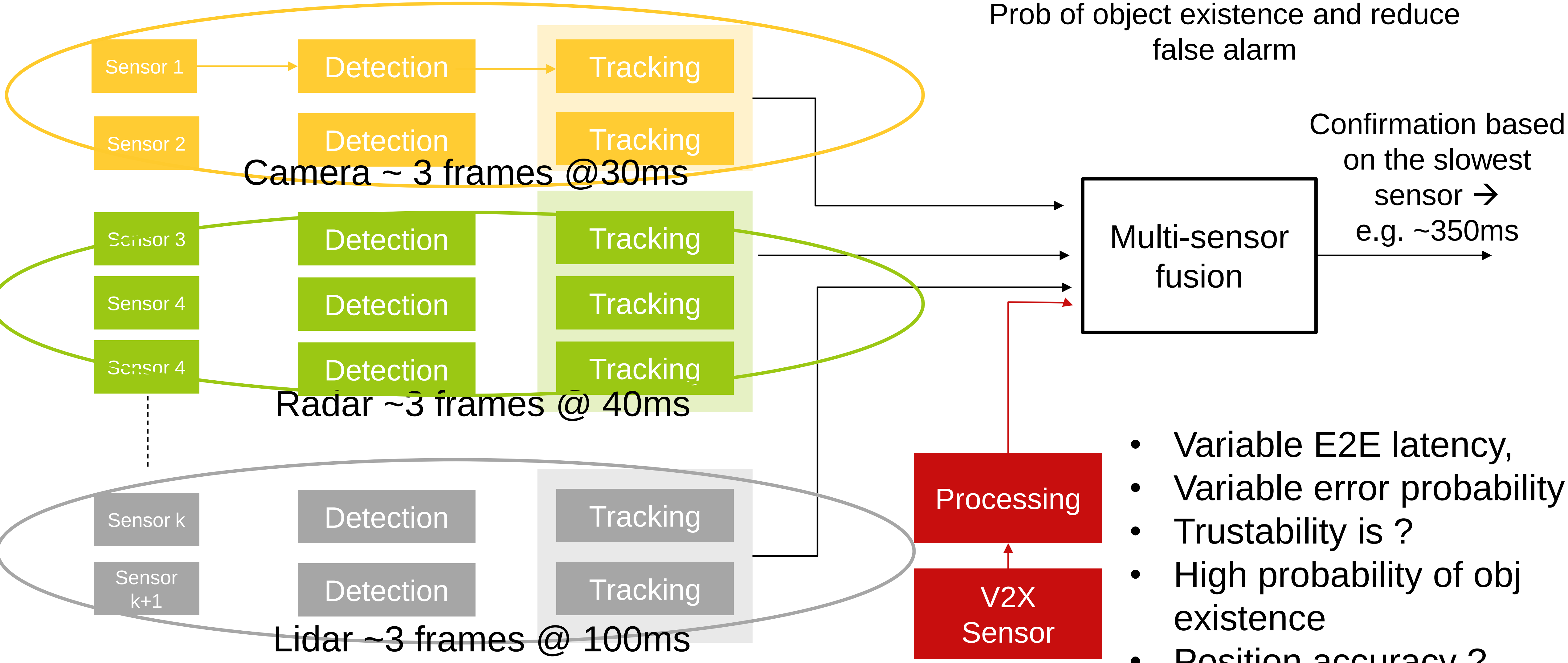
EXAMPLE



Prob (E2E latency ≤ L_t | correct rx) > 1-ε
(E2E latency/rx correctly) Cdf
1,2
1
0,8
0,6
0,4
0,2
0
Un-availability of the service
Zone of graceful degradation
Increasing user density: Depending on the type of access scheme
Radio access design
Target Latency L_t
Max Latency L_{Max}

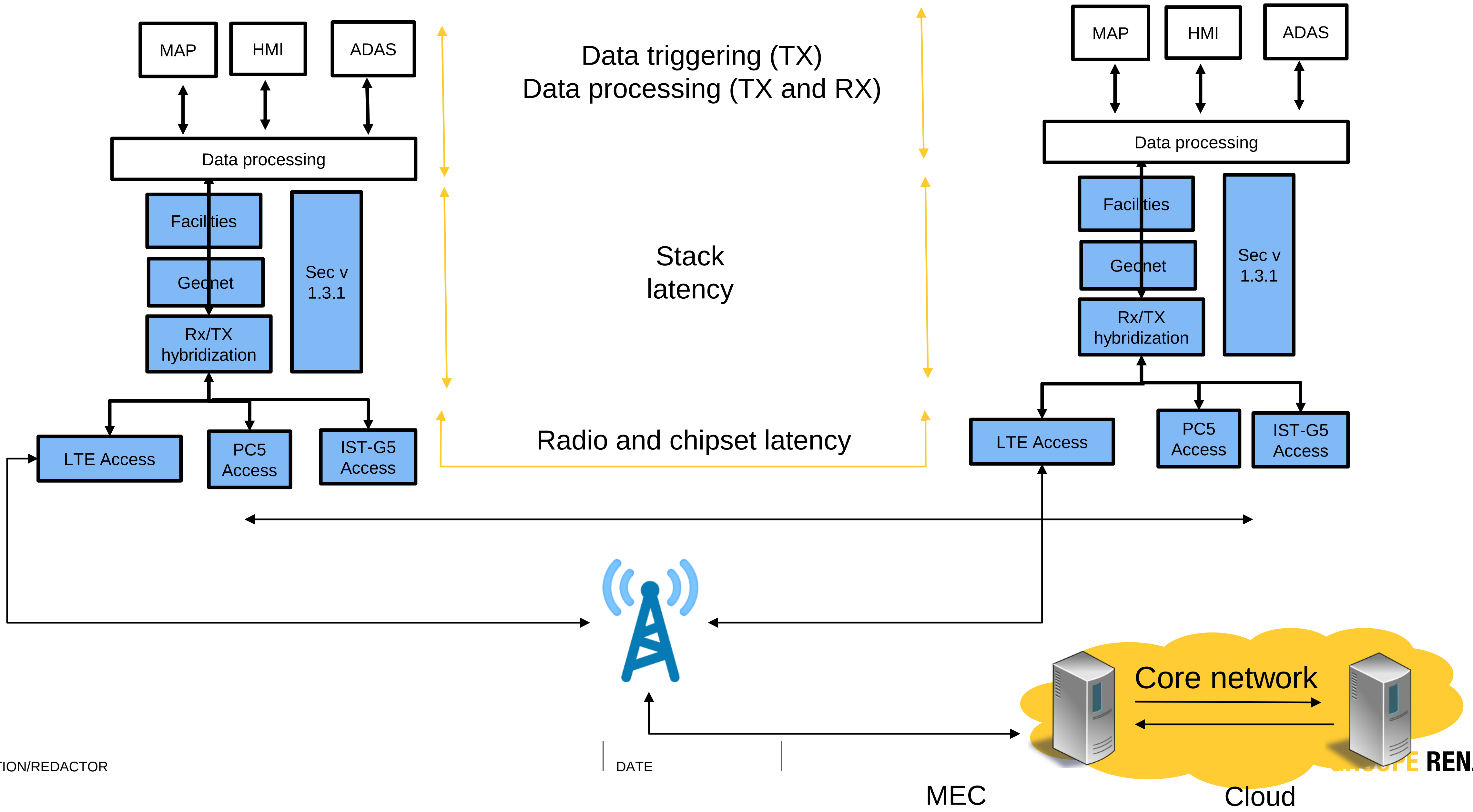
V2X AS A SENSOR (SHORT ENV MODELLING)

Fusion: Exploiting the diversity of sensors to improve
Prob of object existence and reduce false alarm



- Variable E2E latency,
- Variable error probability
- Trustability is ?
- High probability of obj existence
- Position accuracy ?

EXAMPLE OF LATENCY BREAKDOWN

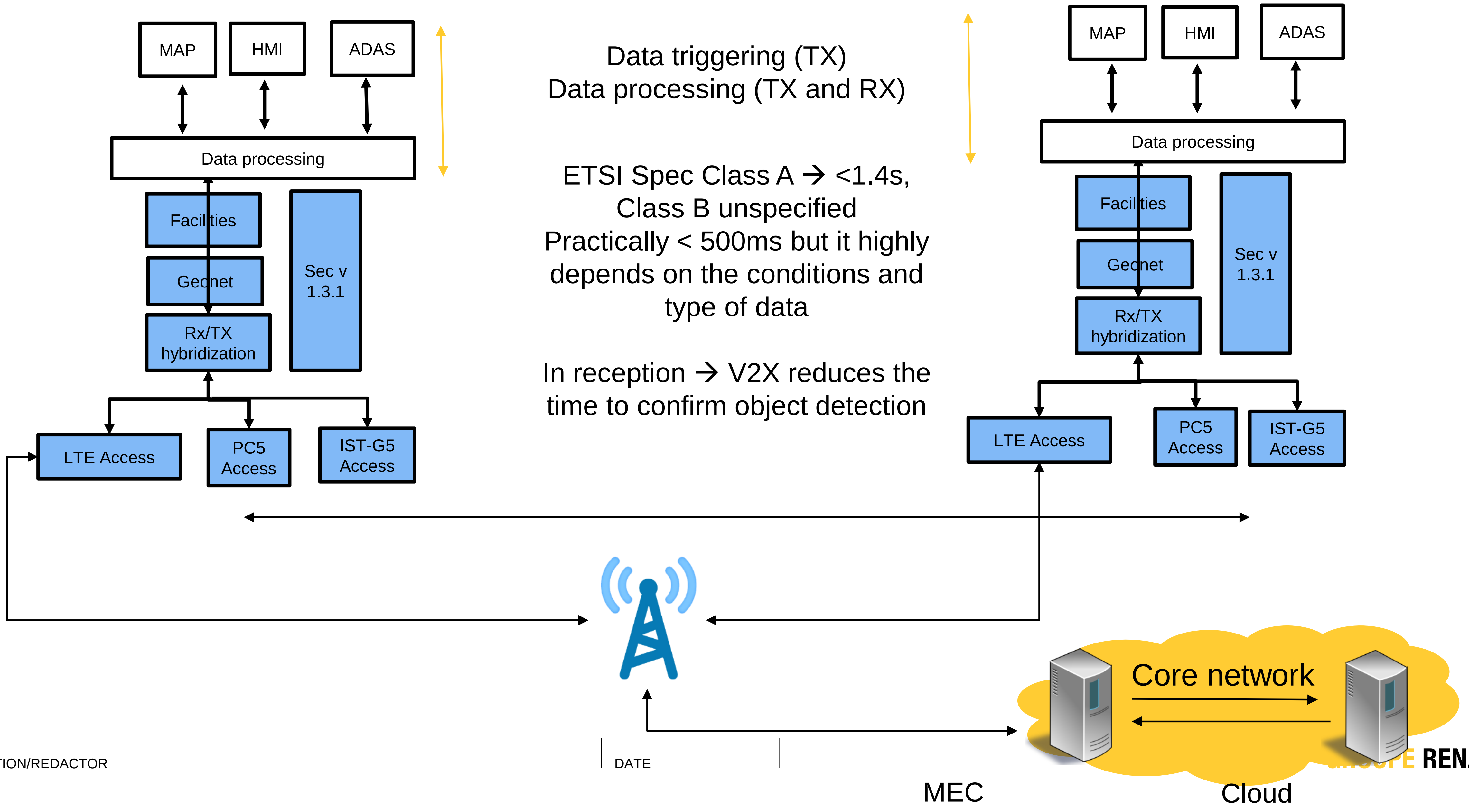


EXAMPLE OF LATENCY BREAKDOWN

Data triggering (TX)
Data processing (TX and RX)

ETSI Spec Class A → <1.4s,
Class B unspecified
Practically < 500ms but it highly depends on the conditions and type of data

In reception → V2X reduces the time to confirm object detection



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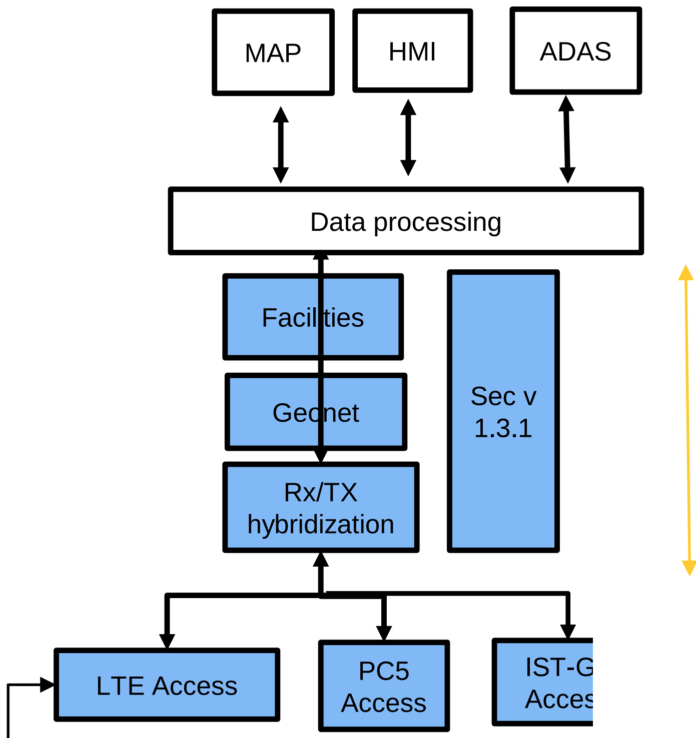
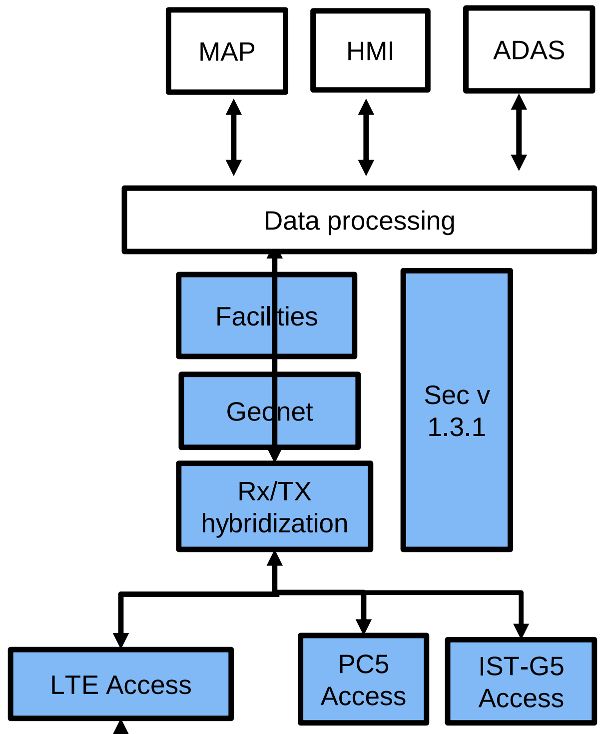


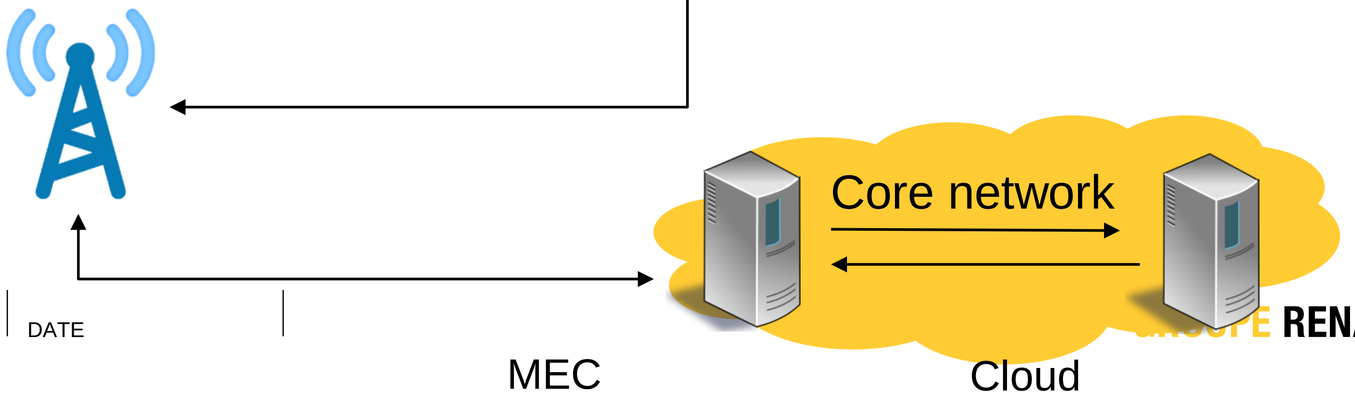
Stack latency

Measurements show few ms average latency for low speed Converging to the POTI injection rate for high speed (Higher transmission frequency)

Low density → similar to tx (~few ms)
High density → latency increases because of security, and because of large amount of data to process.



ETSI specification allows for 300ms for collision avoidance applications



EXAMPLE OF LATENCY BREAKDOWN

Radio latency depends on the access layer type
Short range → depends on congestion control protocol and highly depend on the density of users
Low density →

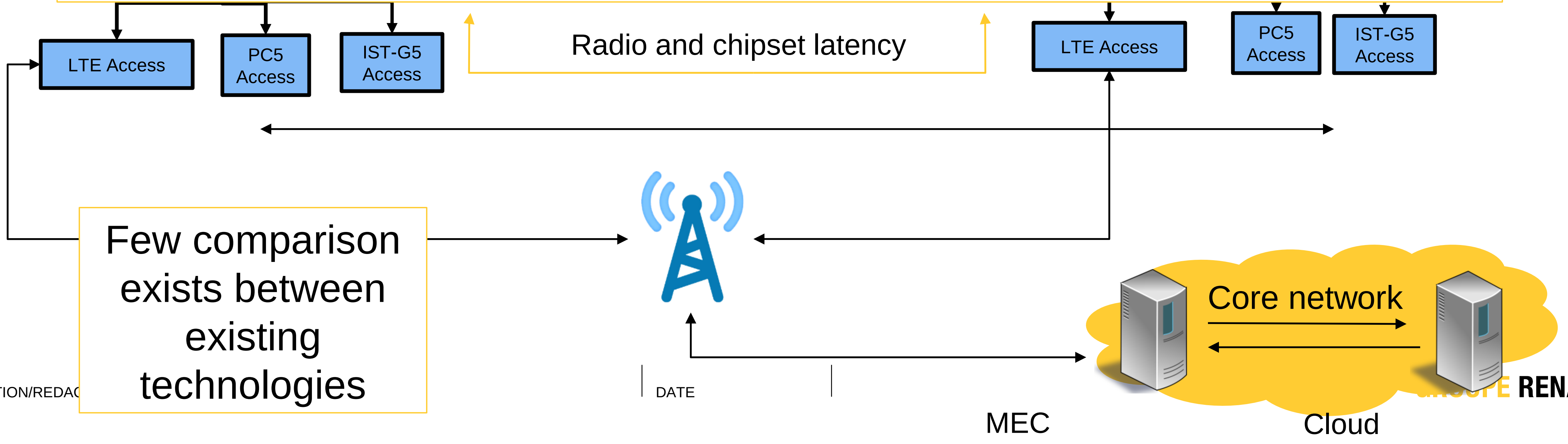
- 802.11p → lower latency, fastest access to spectrum, leanen carrier, shortest symbols → **order of ms**
- Pc5 → bounded to the 1ms subframe, blind retransmissions **few tenth of ms**

High density →

- 802.11p latency could highly increase → looking for free resources
- Pc5 → bounded latency (20, 100ms configurable) → but inducing collisions → **increasing PER**

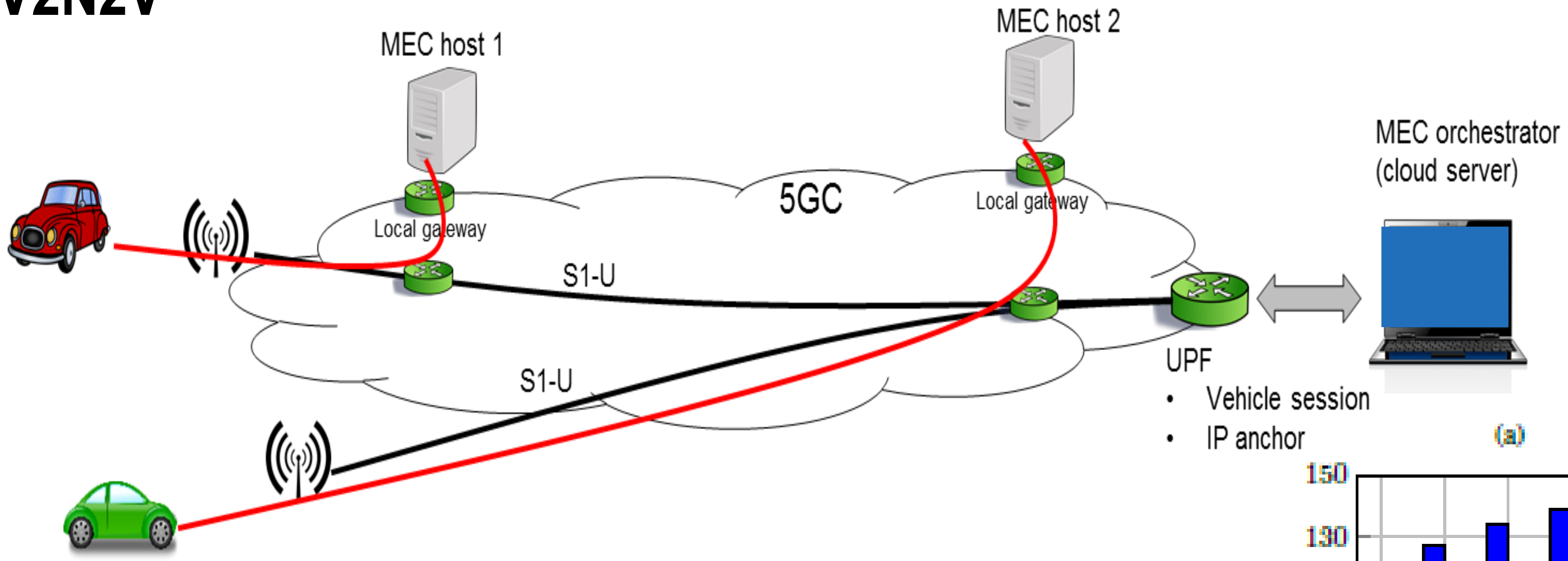
Long rante (LTE) → depends on parametrization (SR, SPS etc..)

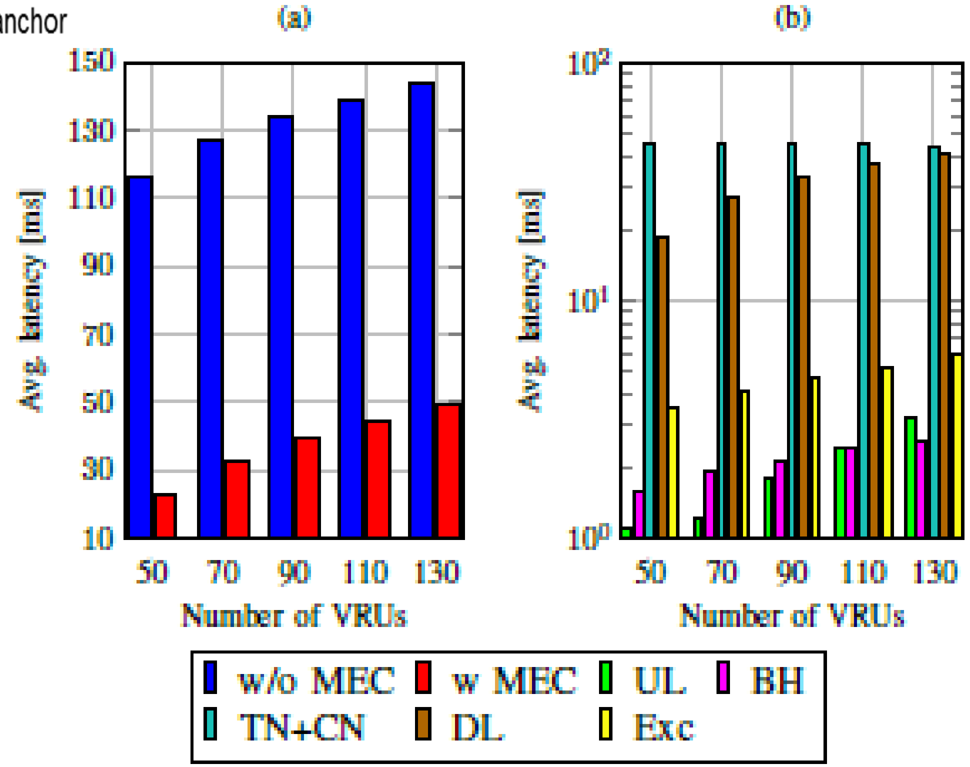
- Typically ~100ms -150ms



Few comparison exists between existing technologies

V2N2V

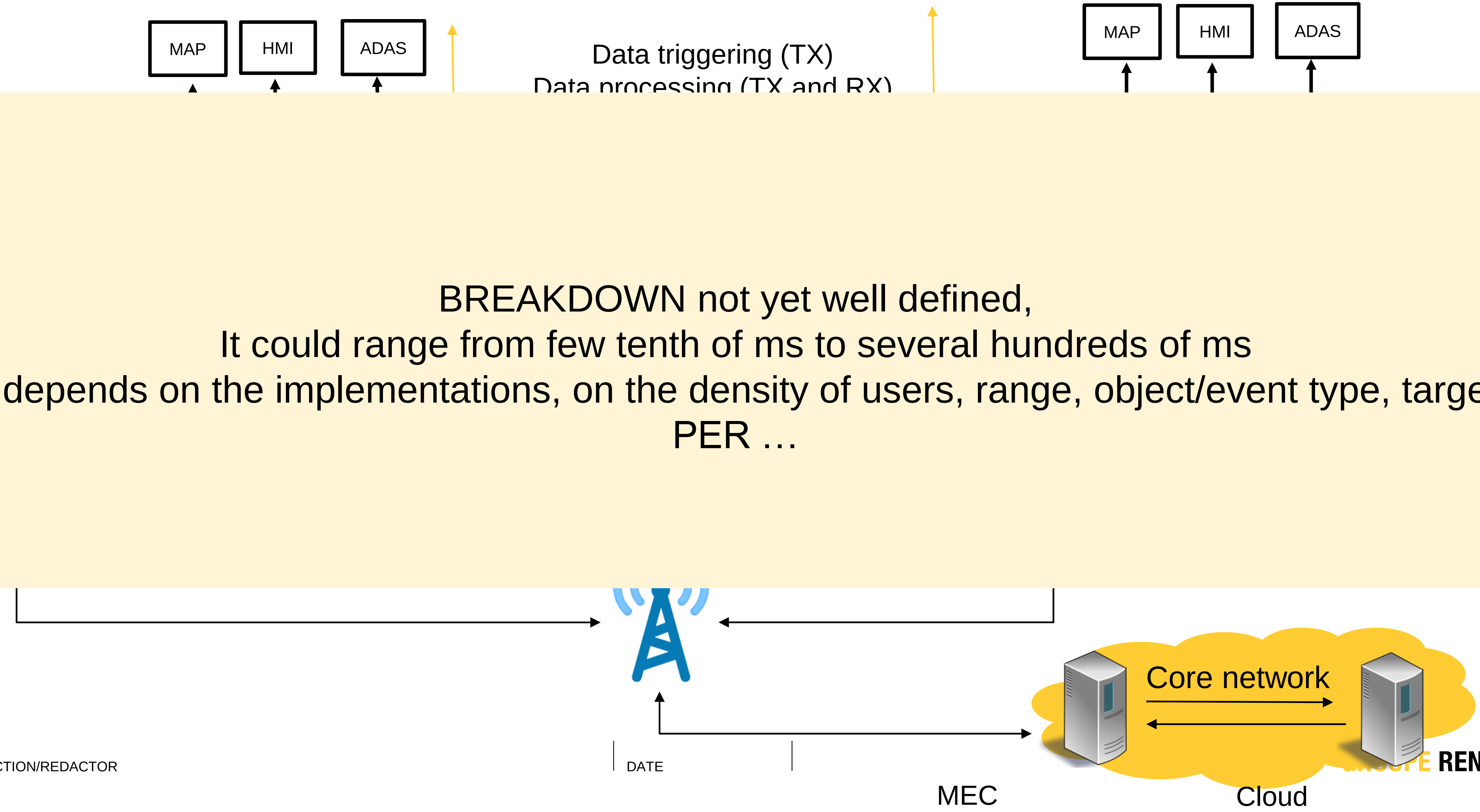




MEC architectures to reduce latencies for indirect V2N2V

(*) MEC assisted End-to-End latency Evaluation for C-V2X Communications, M. Emara et Al.

EXAMPLE OF LATENCY BREAKDOWN



BREAKDOWN not yet well defined,
It could range from few tenth of ms to several hundreds of ms
It depends on the implementations, on the density of users, range, object/event type, target PER …

CHALLENGES

- **Predictive QoS → appropriate slicing**
  - Not only latency but application dependent metric to be guaranteed with tight requirements in specific applications only
  - Configurablility of the QoS tradeoff depending on the applications
- **V2X as a sensor:**
  - First as redundancy → Initially guaranteed QoS by allowing a limited availability
  - Going towards synchronization and coordination → going towards guaranteed QoS and high availability
  - Redundancy within (independent) communication links as a mean to improve the reliability
  - Use of indirect V2N2X → E2E latency in the same order of magnitude as for direct V2V ? Possible?
- **MEC based architecture ?**
  - How close? Which distribution of function ?
- **E2E secured communication link is a must**
  - Trustable content?
- **Safety is a must**

DIRECTION/REDACTOR

DATE

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