Optimizing 5G for V2X -
Requirements, Implications and Challenges

IEEE VTC Mission-Critical 5G for Vehicle IoT

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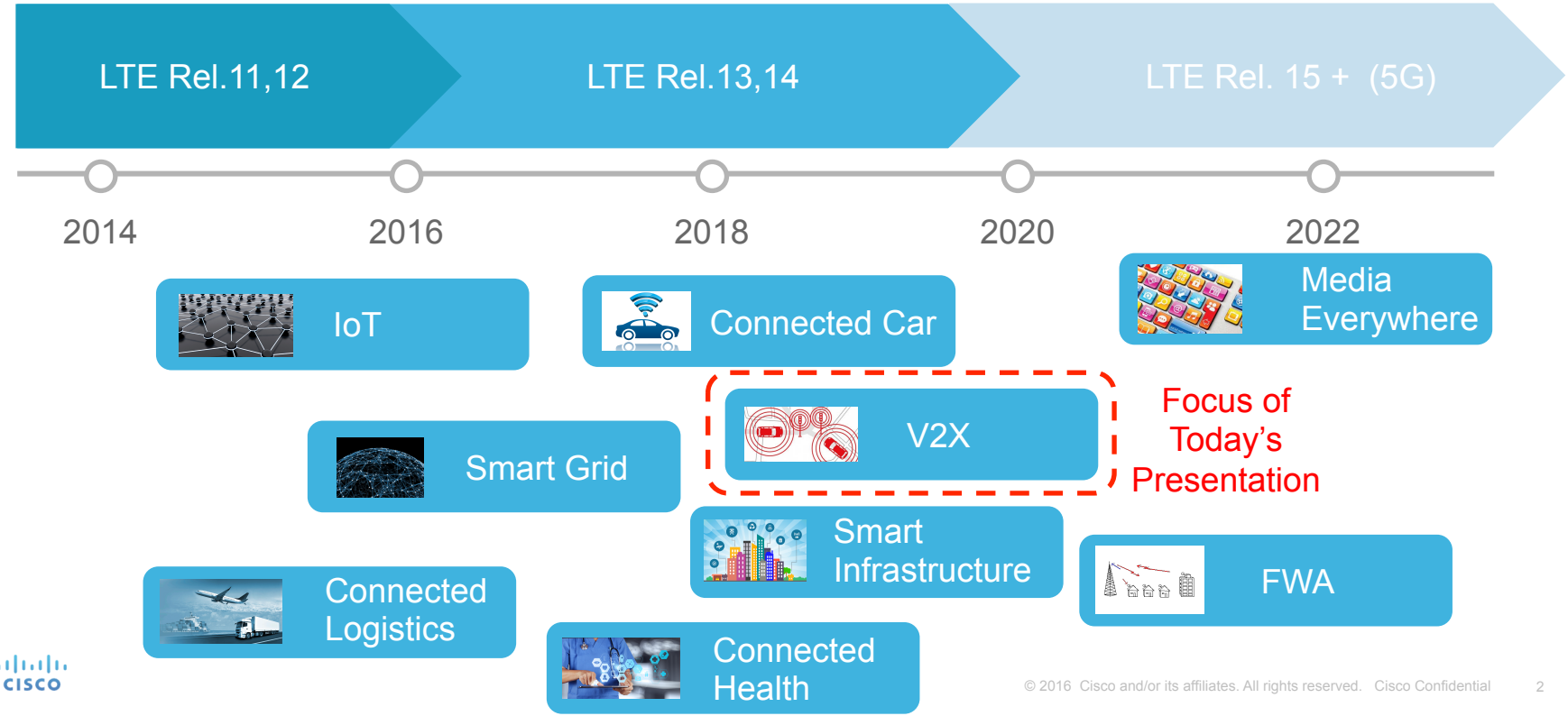
5G will support multiple use cases in diverse environments, meaning a range of heterogeneous capabilities and RATs



Introduction to V2X -
What is V2X, and what are the key applications for 5G?

V2V

Vehicle to Vehicle
Driverless vehicles, advanced driver assistance, collision avoidance, position & speed data

V2I

Vehicle to Infrastructure
Traffic management, speed regulation, safety notifications, operational data exchange, flow control

V2P

Vehicle to Pedestrian
Pedestrian safety notifications, collision avoidance

V2N

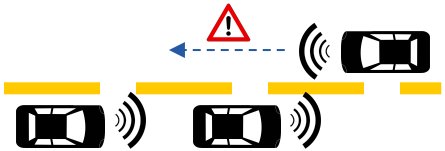
Vehicle to Network
Communication with V2X application servers

5G will need to support both V2V and V2I use cases for Safety, ADAS, Situational Awareness, and Mobility Services

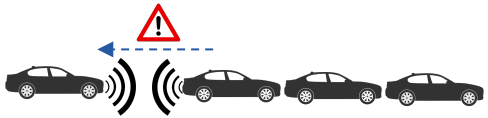
Sample V2V Use Cases

Forward Collision Warning

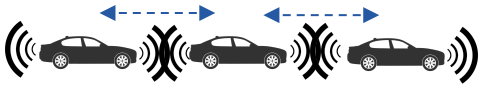
Do Not Pass Warning



Queue Warning

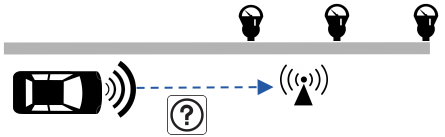


Co-operative Adaptive Cruise Control / Platooning



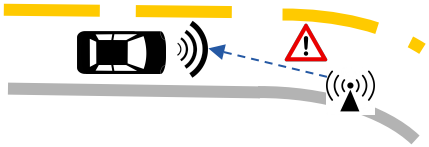
Sample V2I Use Cases

Parking Discovery

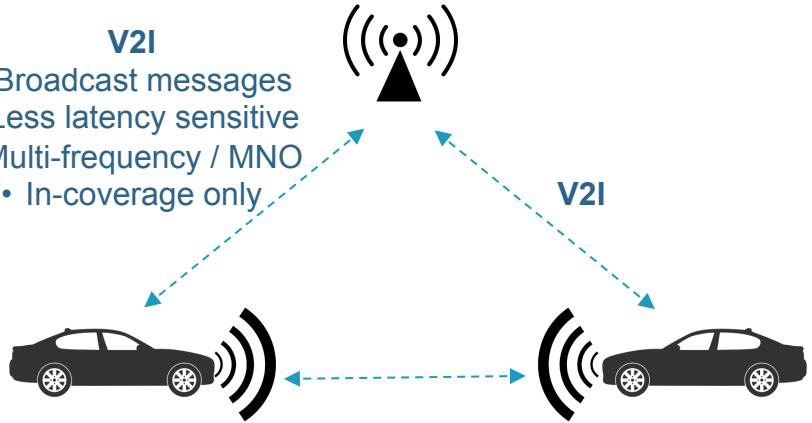


Optimal Speed Advisory

Curve Speed Warning



Five *key requirements* for 5G arise mostly from v2v use cases and safety applications



Key Requirements

1. Support dynamic mobility and high relative velocities between transmitter and receiver
2. Extremely low-latency
3. High capacity (multi Gbps) for high message volume
4. High reliability and availability
5. Bulletproof security and privacy

REQUIREMENT 1. Support dynamic mobility and high relative velocities between transmitter and receiver

- Appreciable Doppler shift
- Requires increased reaction times at highway speeds (e.g. > 4 seconds)

IMPLICATIONS for 5G

- Higher link budget (coding gain, transmit power, transmission period) for double the range* (hundreds of meters)
- Improved synchronization techniques and signal enhancements (e.g. greater # of reference symbols)

Support for High Relative Vehicular Speeds

Up to 280 km/h relative speeds - Included LTE Rel.14
(160 km/h absolute vehicle speeds)

Up to 500 km/h relative speeds - 5G target

*vs. DSRC

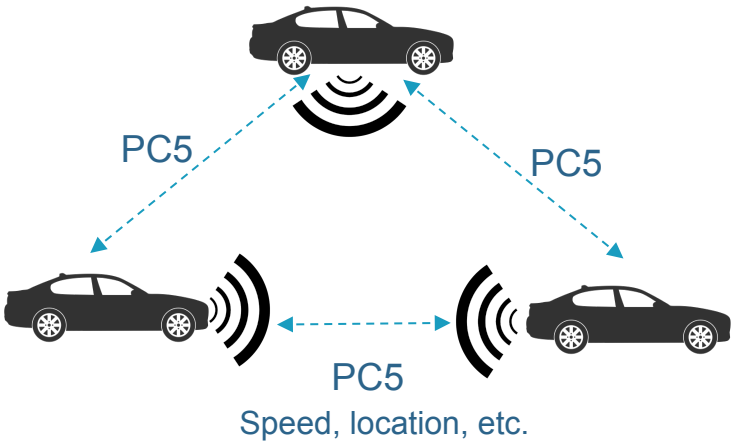
REQUIREMENT 2. Support for extremely low-latency

- ADAS, situational awareness, safety apps. require extremely low latency (e.g. “pre-crash sensing warning message”)
- Messaging across different MNOs presents a challenge

IMPLICATIONS for 5G

- Need a direct communications interface for both in and out of network coverage
- 100 ms end-to-end latency (LTE Rel.14), 1 ms latency design target for 5G
- Enhancements to LTE D2D, PHY/MAC, better channel estimation, OFDM variants

PC5 Interface* Enhances LTE D2D for V2V



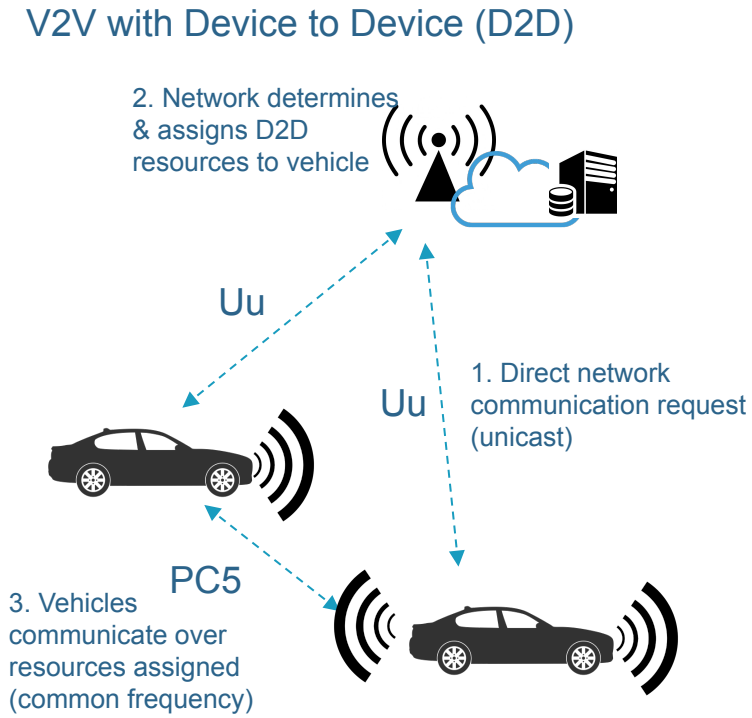
*Included in LTE Rel.14

REQUIREMENT 3. High capacity (multi-Gbps) for high message volume

- Multiple transmitters generating multiple messages result in high network load (e.g. 10 BSMs per second, 5 Kbyte/s)
- More than just status data – e.g. ADAS
- V2V messages (e.g. pre-crash warning message) are local, relevant only to other vehicles in the vicinity

IMPLICATIONS for 5G

- Greater resource allocation efficiency: e.g. D2D enhancements
- Control-Plane User-Plane Separation scaling
- Advanced antenna techniques (e.g. adaptive beam-forming / tracking)



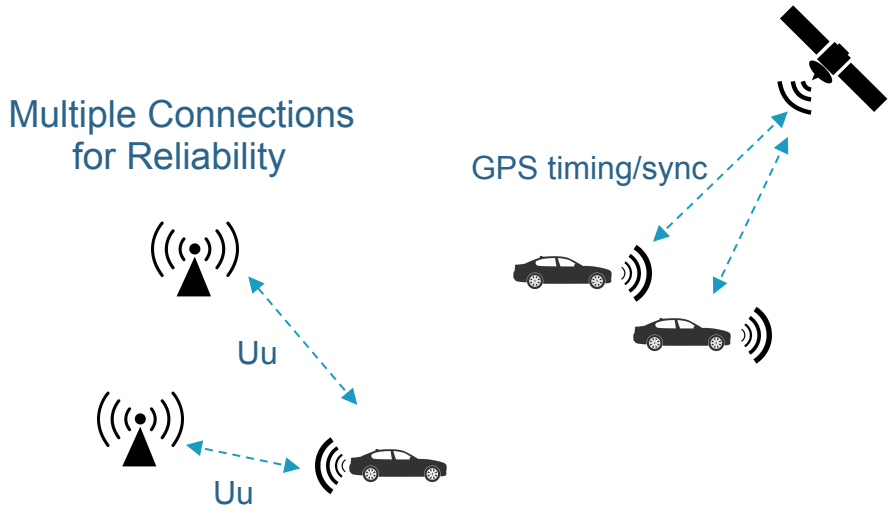
REQUIREMENT 4. Provide high reliability and availability

- Need high reliability and availability, especially for safety applications
- Need time synchronization when vehicles are out of network coverage

IMPLICATIONS for 5G

- PHY / MAC enhancements for D2D
- Enhance LTE to use GPS timing / sync for out of network areas
- Provide for multiple connections for failure survivability and link redundancy

Maintaining Timing/sync Out of Network



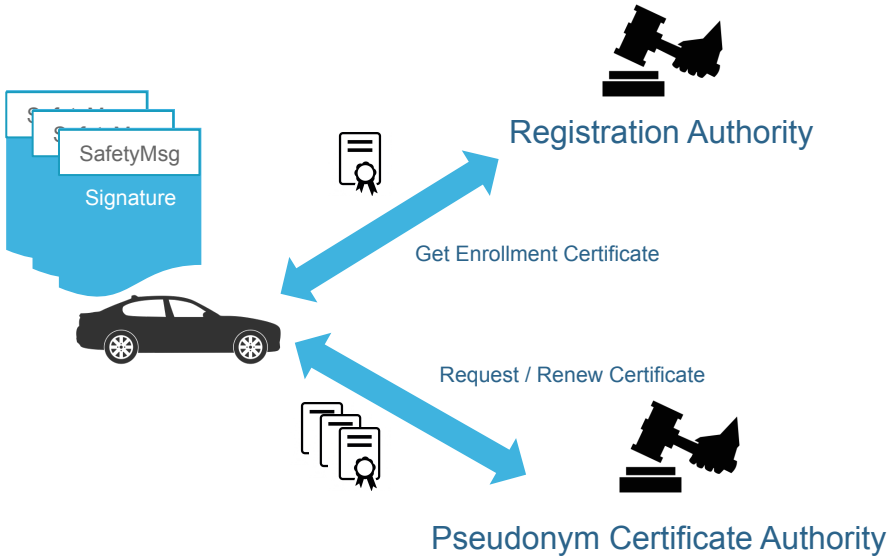
REQUIREMENT 5. Bullet-proof security and privacy

- SIM/IMSI only provides in network authentication, does not protect privacy
- MNOs must not be able to re-construct identity, location and speed
- Vehicles should communicate without pre-shared keys

IMPLICATIONS for 5G

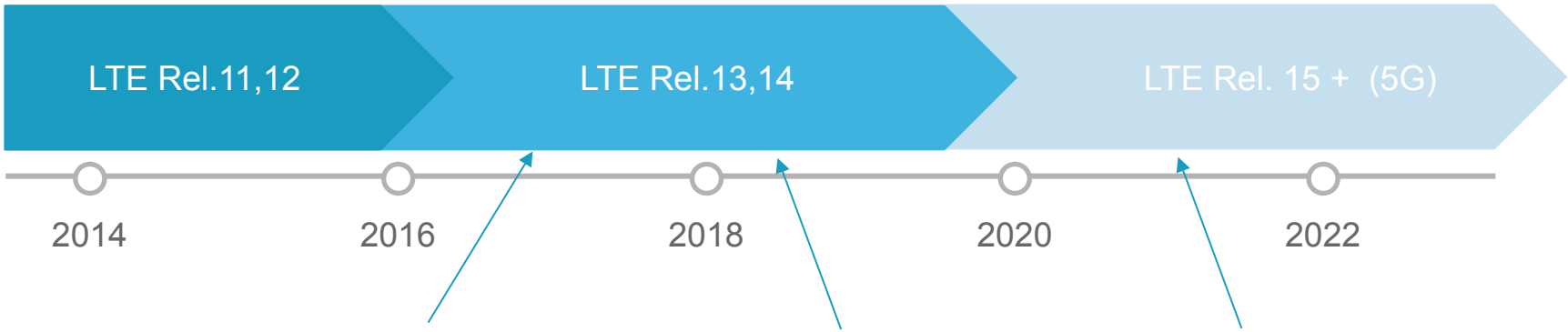
- Balance security, privacy, performance
- Public-Key Infrastructure (PKI) to distribute & manage digital certificates
- Separation of authorities among functions
- Re-use IEEE 1609 security? (SCMS)

Simplified Security Architecture – SCMS*



*Security Credential Management System

Why 5G (vs. current LTE) – evolution of cellular V2X



LTE Rel 13 (3/16) sufficient for some V2I use-cases, lacks low-latency & high-mobility support

- May not perform in high congestion
- Point to multipoint support eMBMS is static
- Unacceptable latency results when UEs on different MNO networks

LTE Rel 14 has V2X support

- PC5 and Uu interfaces
- Advanced Driving Assistance System (ADAS)
- V2X specification expected by early 2017

Enhancements for true V2V will not be seen until Rel 16 (5G), which is not expected until 2023

5G vs. DSRC / 802.11p – which will prevail?

5G

- Builds upon existing, ubiquitous LTE infrastructure
- 5G will standardize post 2020, but c-V2X here today
- MNOs play critical leading roles
- Enhanced range over 802.11p, from 300m to several km
- High throughput suitable for connected car applications (entertainment, navigation, etc.)
- Could leverage DSRC PKI standards for security & privacy, service and application layers

DSRC / 802.11p

- DSRC (based on 802.11p) is here today, de-facto standard?
- Multiple field trials / 10 yrs testing, auto industry support, DOT cert.
- Vehicle OEMs / Transport Agencies playing leading role
- No evolution path for PHY/MAC layer range, robustness, reliability
- Limited high-speed mobility support
- Lack of standards activity for more advanced use cases such as fully automated vehicles
- Some apps. need ubiquitous RSEs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