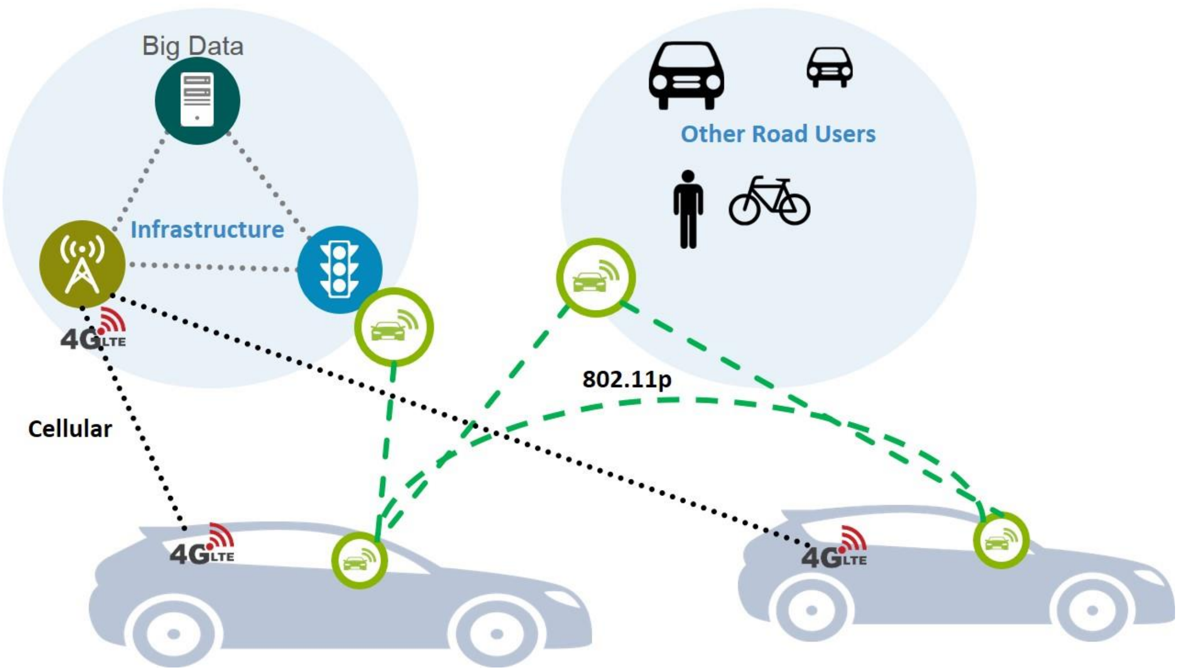
Intelligent Transportation Systems

Rolland Vida, BME TMIT

802.11p or LTE

- Requirements for Cooperative ITS systems
  - High relative speeds between transmitters and receivers
  - Extremely low latency in safety-related applications (<50 ms)
  - Tolerate high load generated by periodic transmission of multiple messages, and high vehicle density
  - V2x messages are mostly local in nature, are important for nearby receivers

Cellular and IEEE 802.11p for C-ITS



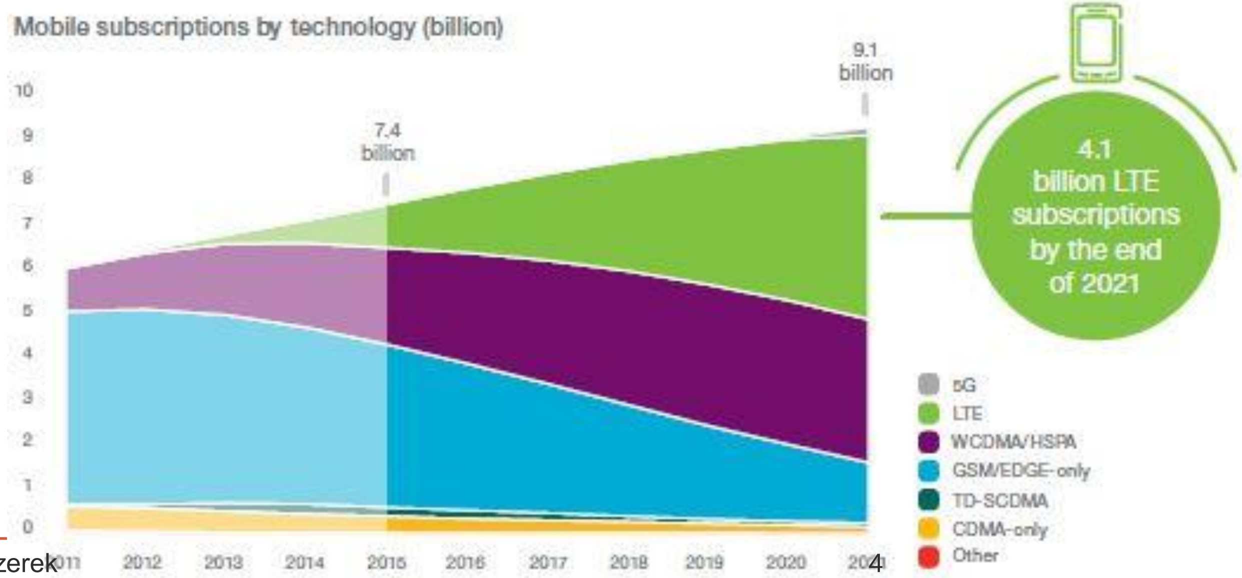
802.11p or LTE

- **802.11p is here today**
  - Standard approved in 2009
  - Several ETSI ITS plug-test events
    - Testing the interoperability of different implementations, products
  - Extensive field trials
    - Safety Pilot, Drive C2X, Score@F, simTD, etc.

- Significant efforts in the last 10 years to validate 802.11p
  - This should be re-done for any other alternative technology

802.11p or LTE

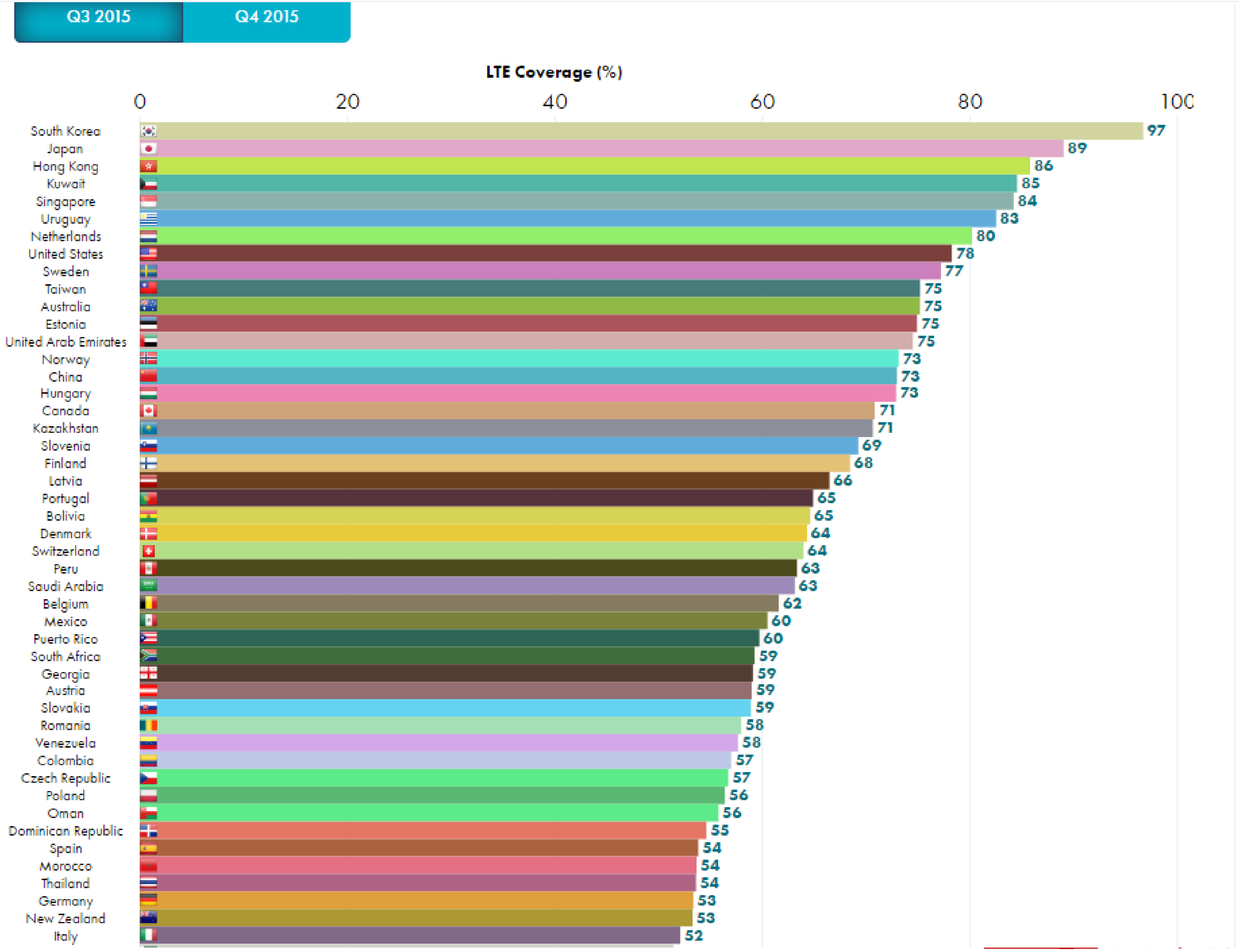
- **(Some argue that) Cellular for V2V is still far out**
- Cellular technology is by far the most successful wireless standard
  - 4.1 billion LTE subscriptions expected for 2021
- LTE (Rel. 8) dates back to 2009, 5G expected for 2020
  - Extensive cellular infrastructure, it takes time to upgrade
- Current versions of LTE can only address basic ITS use cases
  - No support for low latency and high mobility use cases
  - 3GPP V2x study group established in 2015



Mobile subscriptions worldwide.
Source: Ericsson Mobility Report, Nov 2015

State of LTE in 2016

- LTE coverage still far from 100%
  - Around 50% is Germany, France, Italy
  - Extensive 3G infrastructure



LTE support for V2x applications

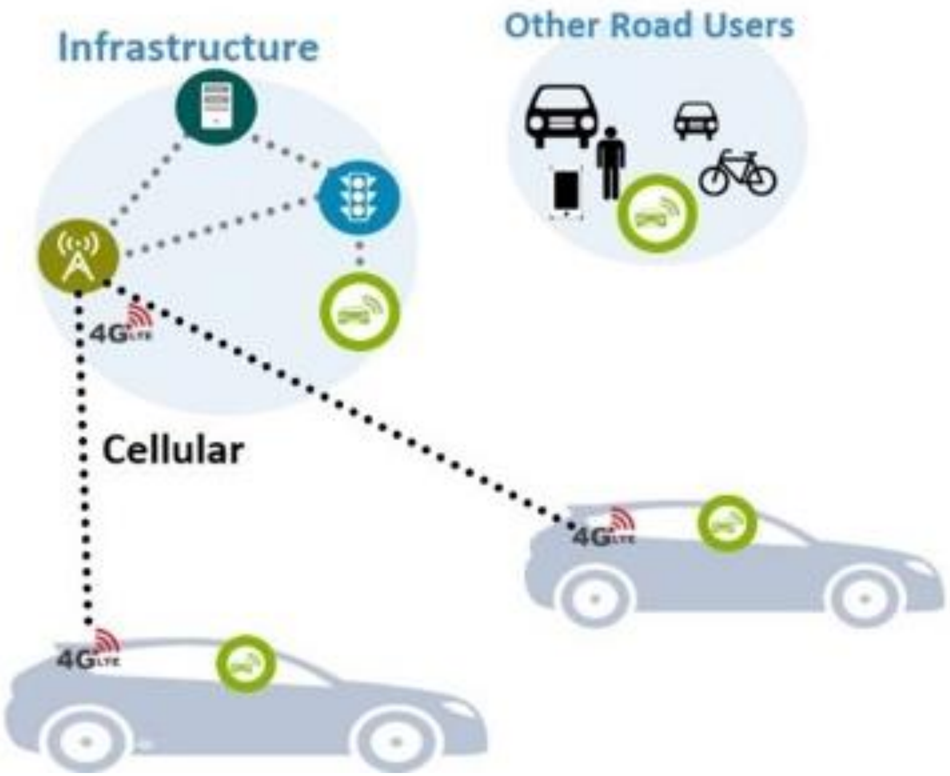
- LTE Release 8 can cover most of the V2I – I2V non-safety use cases
- Unclear how it will perform in very congested scenarios
  - evolved Multimedia Broadcast/Multicast Service (eMBMS) in LTE-A (Rel. 9)
    - Designed to support static scenarios – crowds in football stadiums
    - Not efficient when a large number of incoming and outgoing vehicles
- Unclear how handovers between MNOs (mobile network operators) and cooperation between application service providers will be managed
- Is there an I2V business case to justify the large investments?
  - Vehicles traditionally a lower priority for cellular industry
  - 8 billion cellular subscribers, but only 100 million cars per year worldwide

LTE support for V2x applications

- Safety-related use cases represent the real challenge
  - In theory could work, if there is complete coverage along the roads (which is not yet the case)
  - In practice it would need to handle high bandwidth with very low latency, not ready for this
- Some V2V use-cases require **continuous information exchange** (1 – 20 Hz)
    - **Think about cooperative awareness, autonomous cars**
  - Too much data for LTE networks to handle
  - A single car generates 0.5 Gbyte per month (256 bytes/message, 5 Hz, 4 hours of driving/day)
  - At the receiver side, assuming 30 cars in the area of interest, roughly 15 Gbytes per month
    - 1 autonomous car in 2020 – **4 Tbyte per day**
- MNOs typically bill based on resources used ($ / bit / s), but V2V traffic should be free
  - Alternative business model to be developed to justify investments
- eMBMS might help, but not widely deployed

LTE support for V2x applications

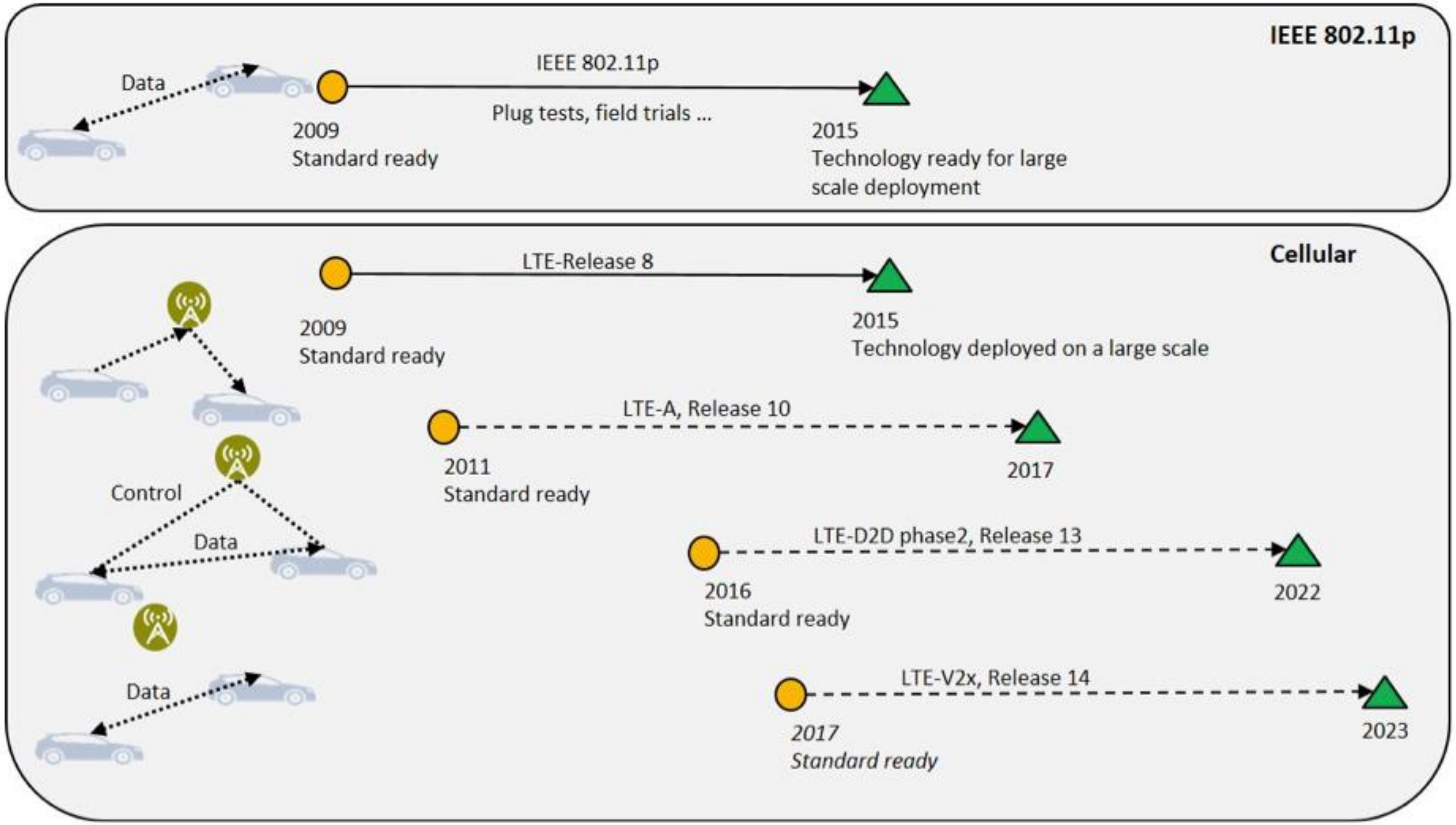
- Some V2V use cases do not require high bandwidth, but **very low latency**
  - event-based broadcasting of Decentralized Environmental Notification messages (DENM)
- Could work in the cellular network, but not always
  - Across multiple MNOs, across borders, across cells



- **Another solution: develop direct communication technology, as part of the cellular system**
  - **Device-to-Device** communication, part of Release 12, but not suitable for V2V
    - If two devices want to communicate directly, the network allocates the time / frequency resources
    - The network manages the interference generated by the D2D communication
    - Signalling/control via the eNodeB
    - Direct data sending between the UEs
  - D2D will not work if no continuous network coverage

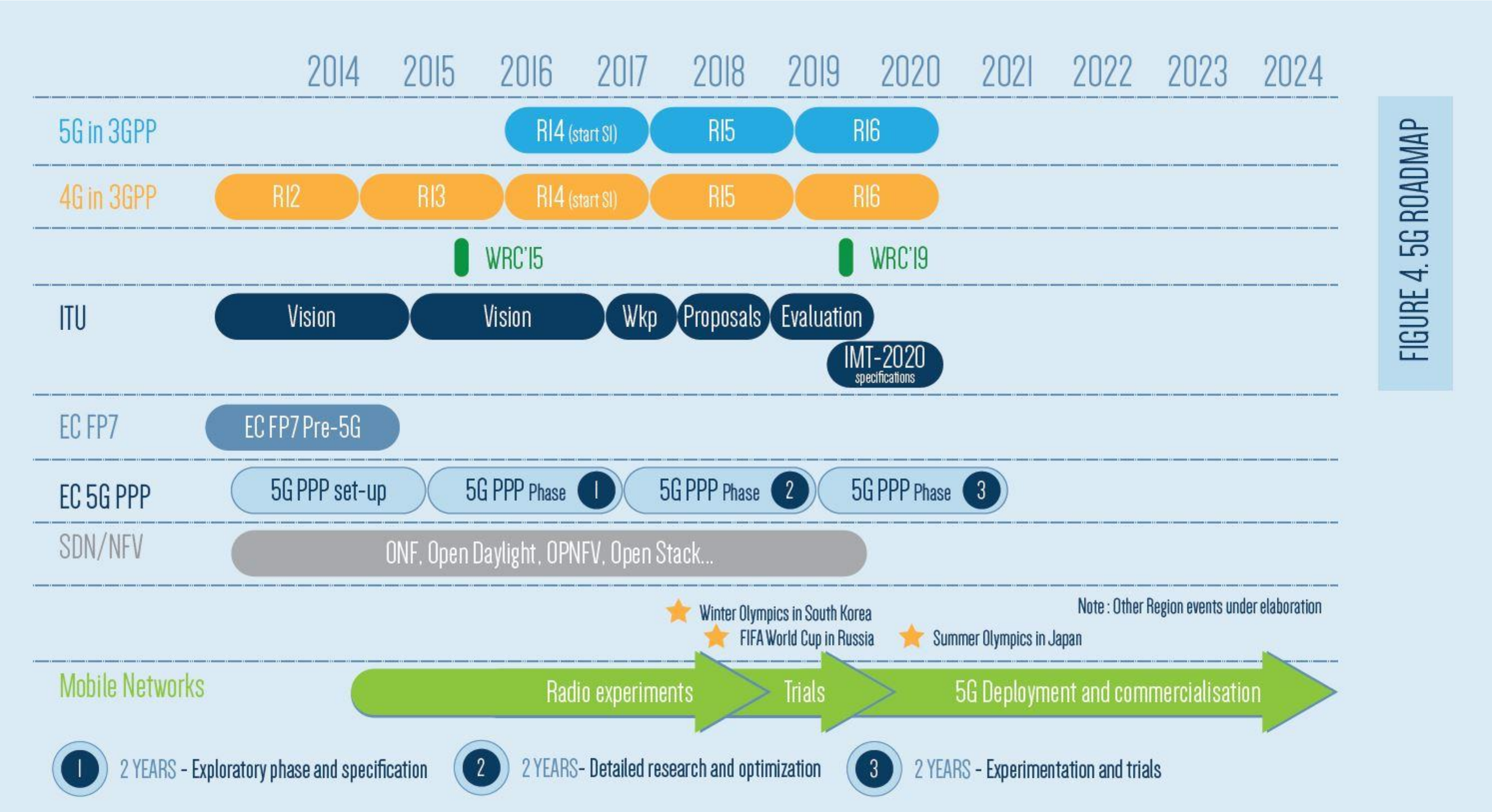
Timeline for cellular V2x

- 3GPP will surely find the technical solution, the question is **"when?"**
  - LTE-V2x probably in release 14, 15, by the end of 2017
  - Much time ahead until large scale deployment



V2x in 5G

- V2x probably part of 5G
  - Fundamentally redesigned hardware to support the architectural changes
  - Not before 2020



5G roadmap
Source: 5G Infrastructure Public Private Partnership (5G-PPP), 2015

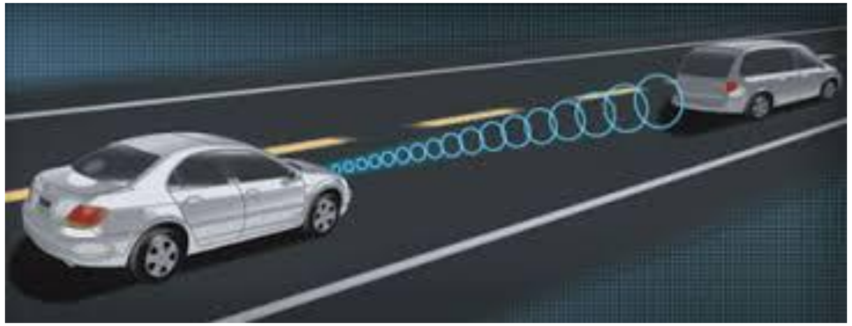
Unmanned systems and vehicles

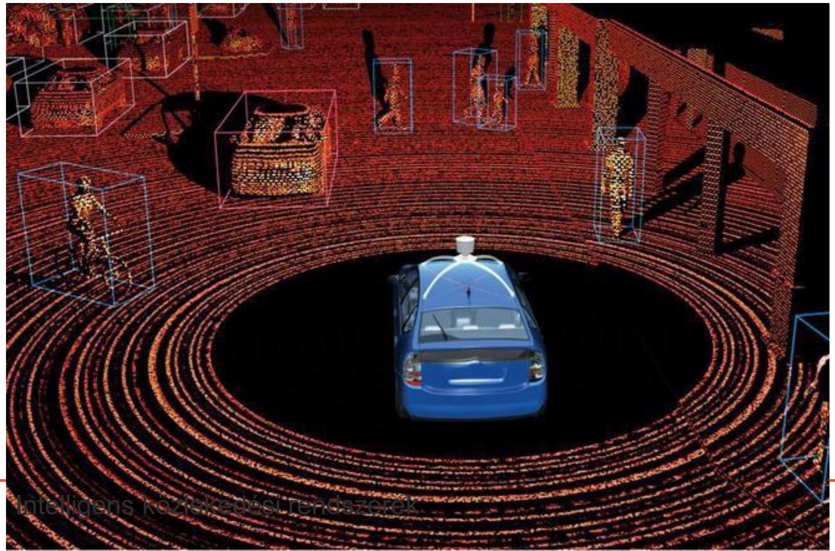
- **Unmanned system**: any electro-mechanical system which has the capability to carry out a prescribed task or portion of a prescribed task automatically, without human intervention
- **Unmanned vehicle**: a vehicle that does not contain a person
  - Can be tele-operated
  - Can be autonomous – takes decisions independently

- Unmanned vehicles can come in several flavors: **UxV**
  - Land: UGV (Unmanned Ground Vehicle)
  - Air: UAV (Unmanned Aerian Vehicle)
  - Maritime: UUV, USV (Unmanned Underwater / Surface Vehicle)

Autonomous / Self-driving cars

- A vehicle capable of sensing the environment, and navigating without human input
- Different techniques to detect their surroundings
  - **Radar** (RAdio Detection And Ranging) – radio waves to determine range, angle and velocity of objects
  - **Lidar** (LIght Detection And Ranging) – illuminating the target with a pulsed laser light, and measuring the reflected pulses
  - **Odometry** (*odos* – route, *metron* – measure) – use motion sensor data to estimate position change over time, relative to a starting location
  - **Computer vision** – detect other cars, objects on the road, road signs, traffic lights, based on image processing, machine learning and artificial intelligence





Autonomous / Self-driving cars

- **Benefits**
  - Reduced mobility costs (no driver needed)
  - Enhanced mobility for children, disabled and elderly people
  - Increased safety, increased consumer satisfaction, increased traffic flow, lower fuel consumption
  - Less need for insurance
- **Obstacles to widespread adoption**
  - Technological challenges – **less and less**
  - Disputes on liability in case of accidents
  - Long time period to replace the existing stock of vehicles
  - Resistance of individuals to hand over the control
  - Implementation of regulations, legal framework
  - Privacy and security concerns (car hacking)
  - Loss of driving-related jobs

"Does your car have any idea why my car pulled it over?"