The role of the intelligent infrastructure in the development and deployment of autonomous vehicles

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Outline

- Avant-propos
- Introduction
- The role of the infrastructure
- Examples of intelligent infrastructures
- Coming challenges
- Conclusion

Avant-propos

- Autonomy = Independance ?
- Towards telecommunications and infrastructure
- V2X connectivity:
  - Passive / active safety
  - Cooperative driving
  - Standardization efforts
- Infrastructure ?

☞ **The evolution of infrastructure has always been dictated by technology and social evolution**

8000 BC **3500 BC** **Sumer**

Settlement
Sedentarization

Horses taming

Travois and sled

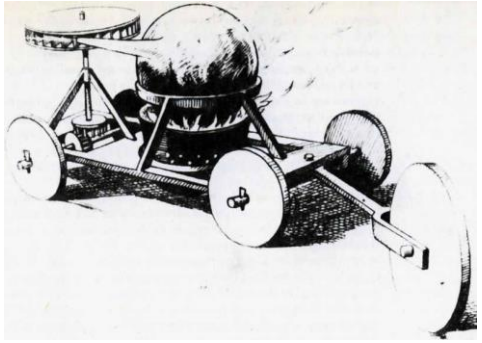
Invention of the wheel ➔ *carts*

Trails & paths

Ridgeways

Paved roads

312 BC | **8th century A.D.** | **1668 AD** | **1909**



Roman Empire

Use of tar (napht) (Bagdad)

Steam vehicle Ferdinand Verbiest

Via Appia (Roman roads)

1st Highway (Germany)

Since then….

Introduction: context

- Last century: the transportation industry has been focused on the supply of infrastructure to support the ever growing fleet of vehicles and the greater number of miles covered by each vehicle.
- Our focus has been planning, funding, designing, building and maintaining roadways.
- We have experienced demand growth since the first model T was launched from the factory.
- Congestion in urban areas, safety and the economic need to move people and goods and to compete in a global economy has driven our thinking.
- The ability to supply infrastructure has been the measure of transportation performance.

Introduction: motivation

- Would the arrival of the AV represent a milestone ?
  - Where is the breakthrough ?
  - Independance or cooperation between AV and infrastructure ?
- What/where are the interactions VA/infrastructure ?
  - Examples
  - Where are the benefits ?
- What is expected from the infrastructure ?
  - Technical performance
  - Cost, timeline
  - Adaptation to new driving

Specificity of the AV in relation with the infrastructure

- Autonomous sensing
  - Impact on the signage, signaling, marking… still needed or to be modified ?
  - Accurate localization: need for markings and/or Reference GNSS base and/or new feature
    ➔ Increase #lanes
  - Specific toll crossing stations with dedicated guidance ?

- Connectivity
  - Need of fast and secure (5G)-connectivity
  - Need for traffic centers
  - Need for roadside units and sensing
  - Remote payment ➔ accurate localization: are toll areas still needed ?

- Electric / autonomous charging ?
  - Need of recharging/parking lots
  - Need for dedicated lanes (induction charging concepts)

Specificity of the AV in relation with the infrastructure

- Safe driving
  - No more need for rail guards ?
  - Narrower lanes ?
  - Provide roadside sensing abilities

- Nominal performance
  - Need of dedicated maintenance for nominal QoS
  - Need for dedicated lanes: fast lanes, pooling, service lanes, platooning lanes…
  - Narrower lanes

- New mobility in urban areas
  - Car sharing, ride sharing… ➔ No more/less need to Parking lots
  - Dedicated lanes (mass transportation, lanes with high level of service…)

Role of the intelligent infrastructure

❑ The infrastructure will likely need to evolve in 5 ways:

1. **Account for AV sensing capabilities**

2. **Adapt to the requirements of transportation modes enabled by AV's**
   - the infrastructure will have to accommodate new driving behaviors and traffic patterns
     - Ex: Better use of land allocated for Parking
     - Dedicated lanes, charging spots, materials…
3. **Provide complementary sensing and communication capabilities**:
   - Act as a distributed sensor network: supporting data sharing and providing information to vehicles
     - Ex: Variable speed limits, traffic detection at signalized intersections, and traffic signal coordination (e.g. traffic lights, green waves)
     - The constant exchange of information between infrastructure and AVs can facilitate the identification of nonconformities and road hazards ➔ virtuous cycle of data sharing that benefits the safety and mobility of both drivers and the public at large.

Role of the intelligent infrastructure

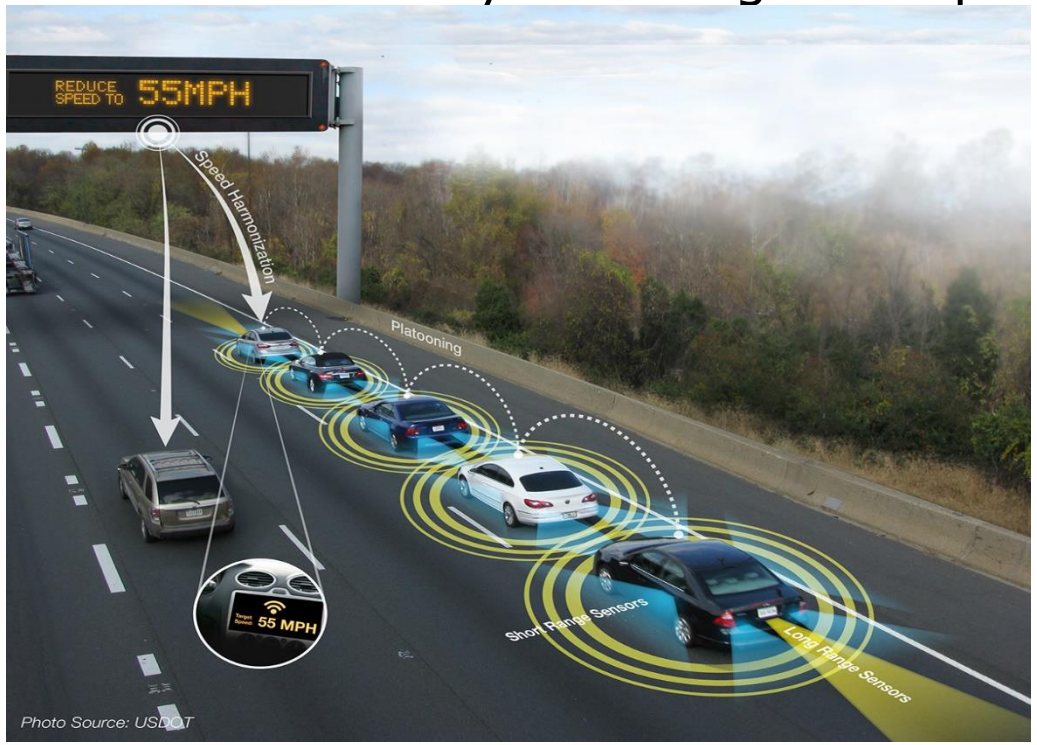
- Real-time dynamic digital map updating
  - Ex: road work, local road closures, weather, and other factors

4. **Become the cyberphysical backbone for AVs: using an Internet of Things approach**
   - E.g. Precipitation sensors may alert AVs to potentially hazardous driving conditions,
   - E.g. Smart traffic cones may locate themselves safely on the road while communicating to nearby vehicles about their placement and the reason for their presence.

5. **Allow true cooperative driving:**
   1. Afford centralized fusion and situation assessment ➔ roadside computations
   2. Send recommendations to vehicles
      - Ex: conflicting intersections (lack of visibility)
      - Manage traffic flows

Examples of intelligent infrastructures

- **Machine-readable signs:**
- Today, road signs and traffic lights are detected using computer vision techniques
- In the future, machine-readable code will have to be embedded in signs and transmitted or broadcast.
- An alternative is to embed the information in the dynamic digital map.

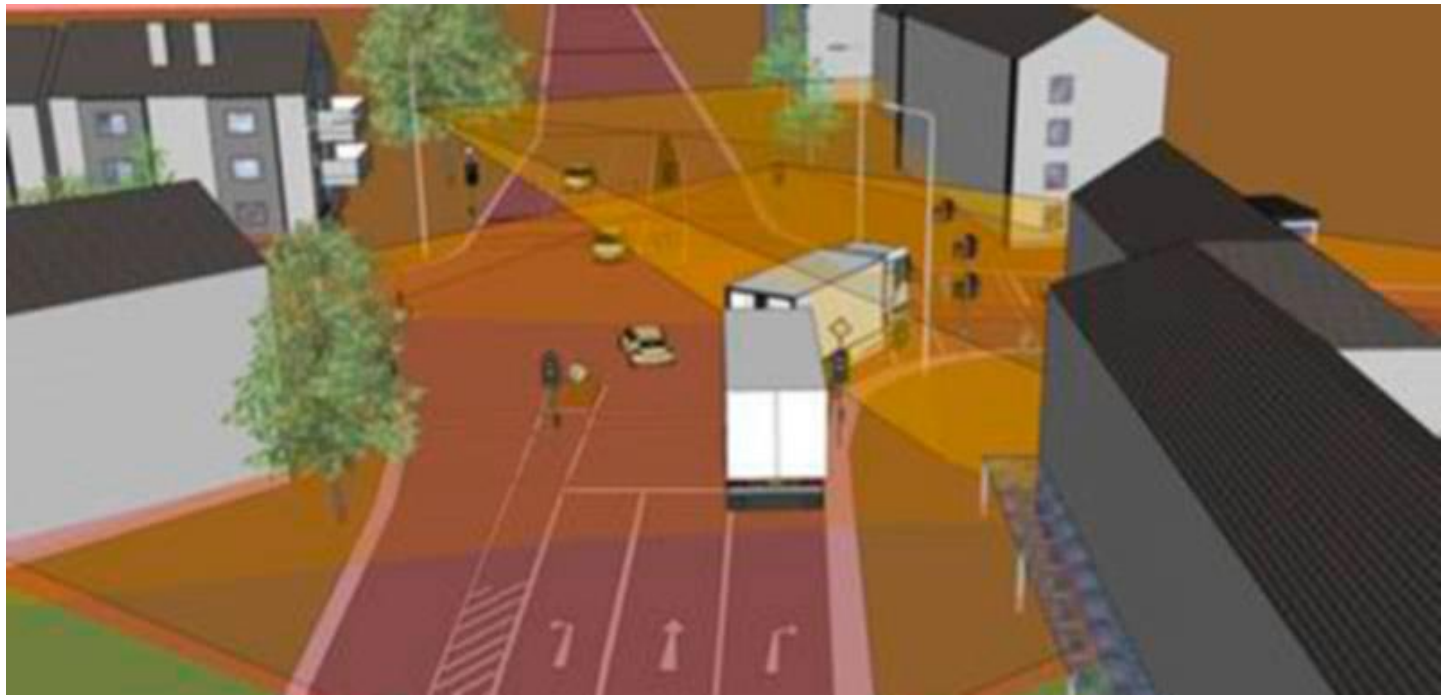


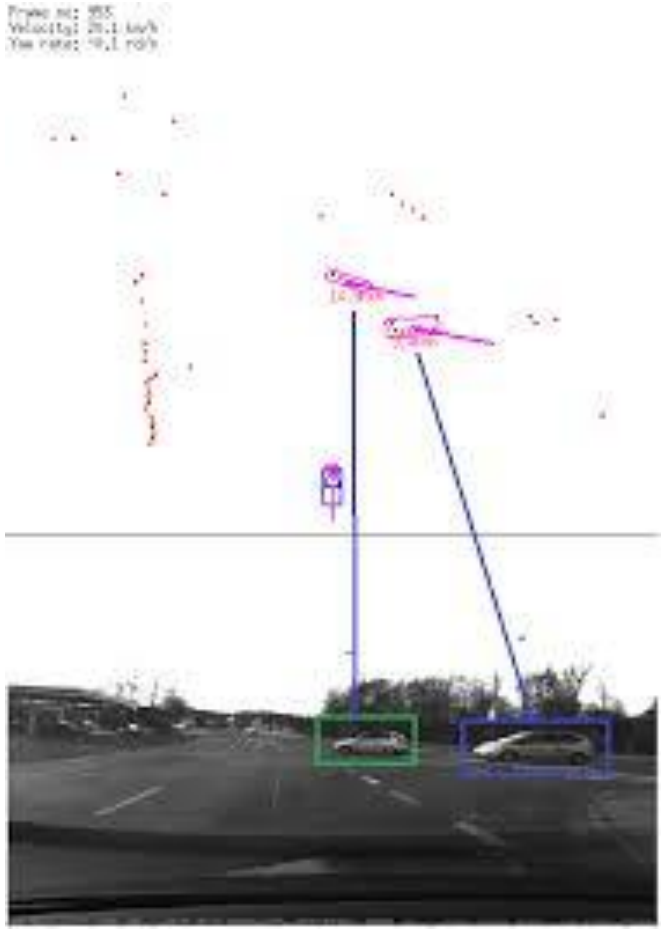
On-bord signaling:

Ecole des Mines de Paris
June 2000

Examples of intelligent infrastructures

- **Roadside connected sensors as perception systems:**
- When designing roads for the AV generation, city planners should include roadside sensors on lanes, curbs, and sidewalks to allow vehicles to foresee dangerous or unexpected situations far ahead.
  - Ex: INTERSAFE projects





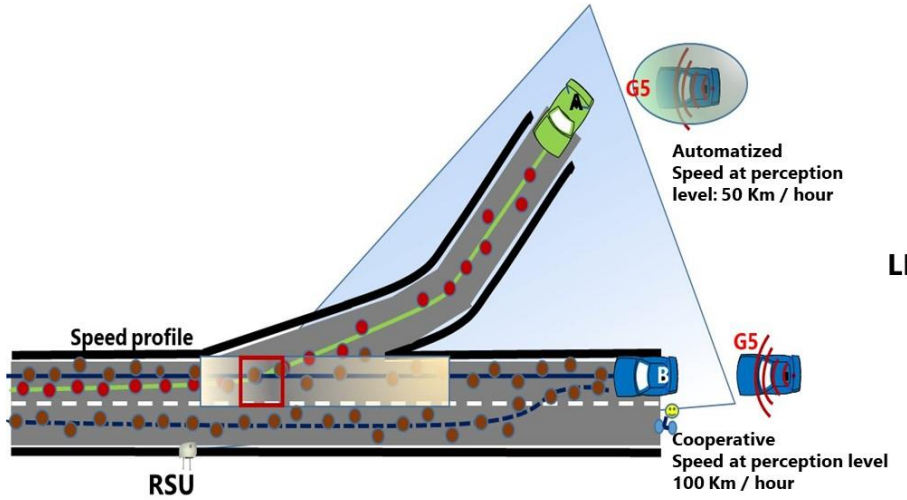
Examples of intelligent infrastructures

Roadside connected sensors as perception systems:

Roadside units can also act as an extended and augmented perception system, communicating to vehicles needed information

- E.g. **PAC V2X project (FR)**
- five applications of urban and highway scenarios:

- Intersection crossing assist (ICA):
- Lane merging assist (LMA)
- Lane Change Assist (LCA): at bus and toll stations
- Wrong way driver warning (WWA)
- Contextual speed adapting (CSA)



LMA-M1- C1 Cycle:

Examples of intelligent infrastructures

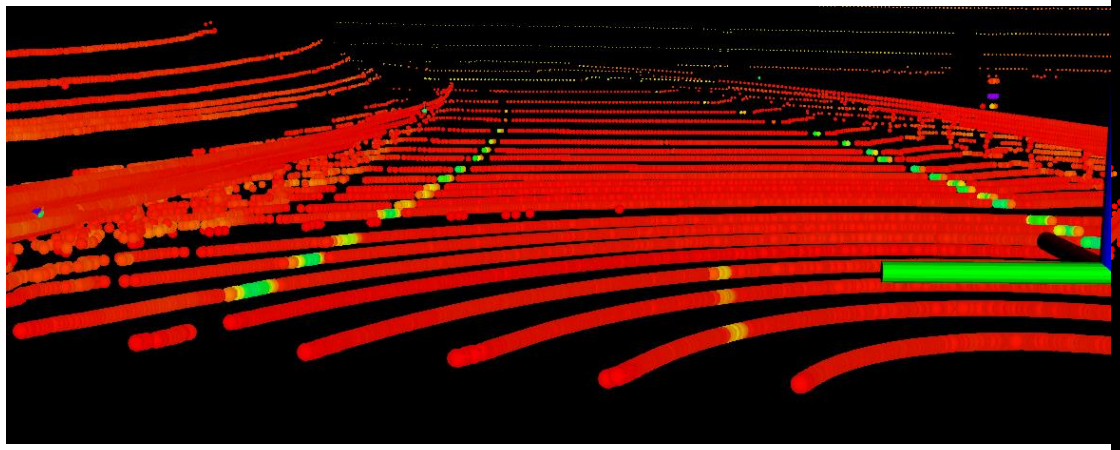
C-ITS system deployment for traffic management and early warning dedicated to AV's

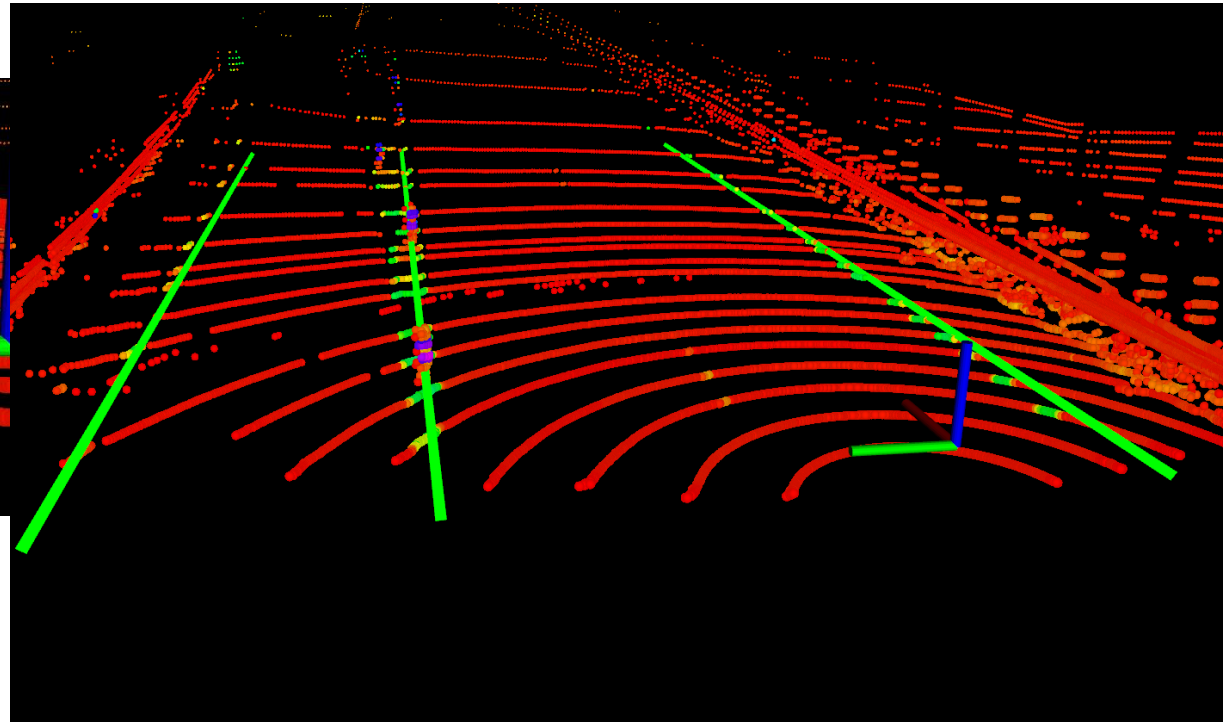
Roadside units can relay and broadcast information from/to AV's and traffic centers.

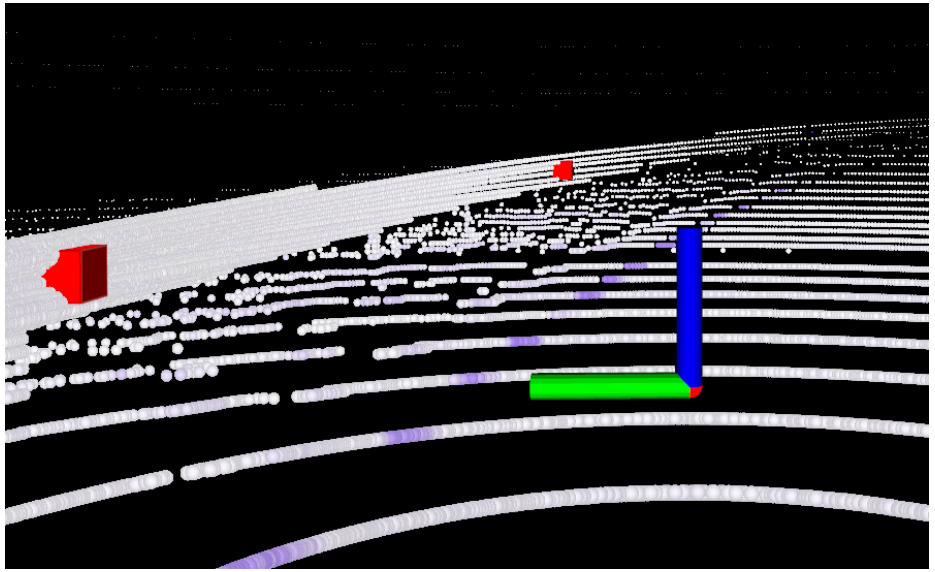
- E.g. **AUTOCITS project (EU)**

Examples of intelligent infrastructures

- **Lane markings:**
- Poor road markings are forcing automakers to develop more sophisticated sensors and maps, but they definitely don’t encourage the broader adoption of AVs.
- Self-driving cars will require machine-readable radar-reflective road markings and reflectors. These can be manufactured out of cold plastic to make lidar’s job easier at night and in nasty weather.





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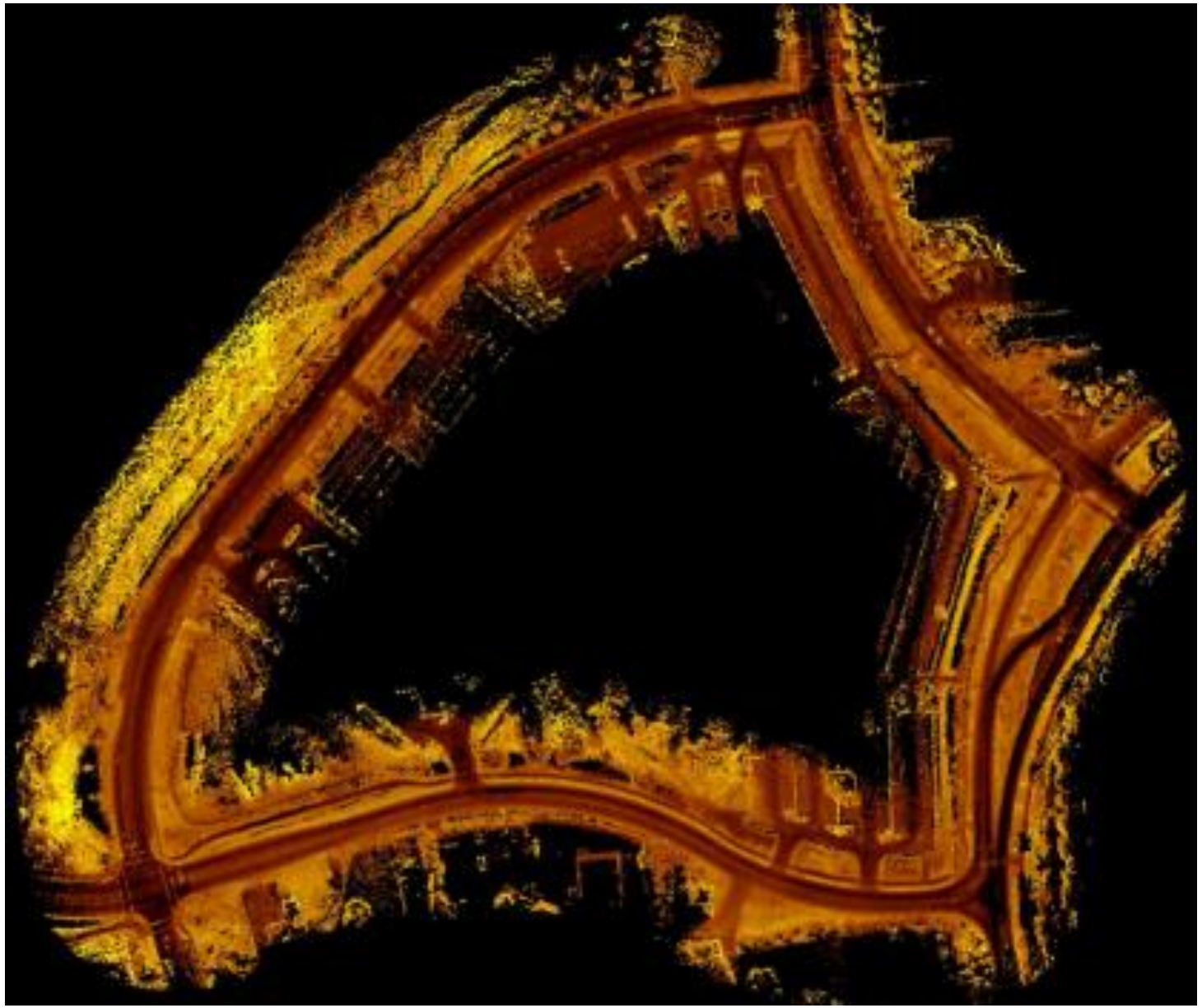
Reflectivity grid map

Laser based localization

Source: Renault/Inria



Trends of intelligent infrastructures

- **Parking facilities will become obsolete**
- Autonomous vehicles and smart infrastructure will help cities get rid of nearly all types of parking.
- This will all be thanks to ride sharing and MaaS schemes, which are among the top trends in the future of autonomous vehicles.
- Self-driving cars are way better at maneuvering and can use narrower driving lanes.

➔ The remaining parking spaces will be able to accommodate more cars.

➔ The space currently used for parking can be used in new ways in modern cities.

Connected intelligent infrastructures

Connectivity will be the new gold as telecoms and other companies will need to expand their networks

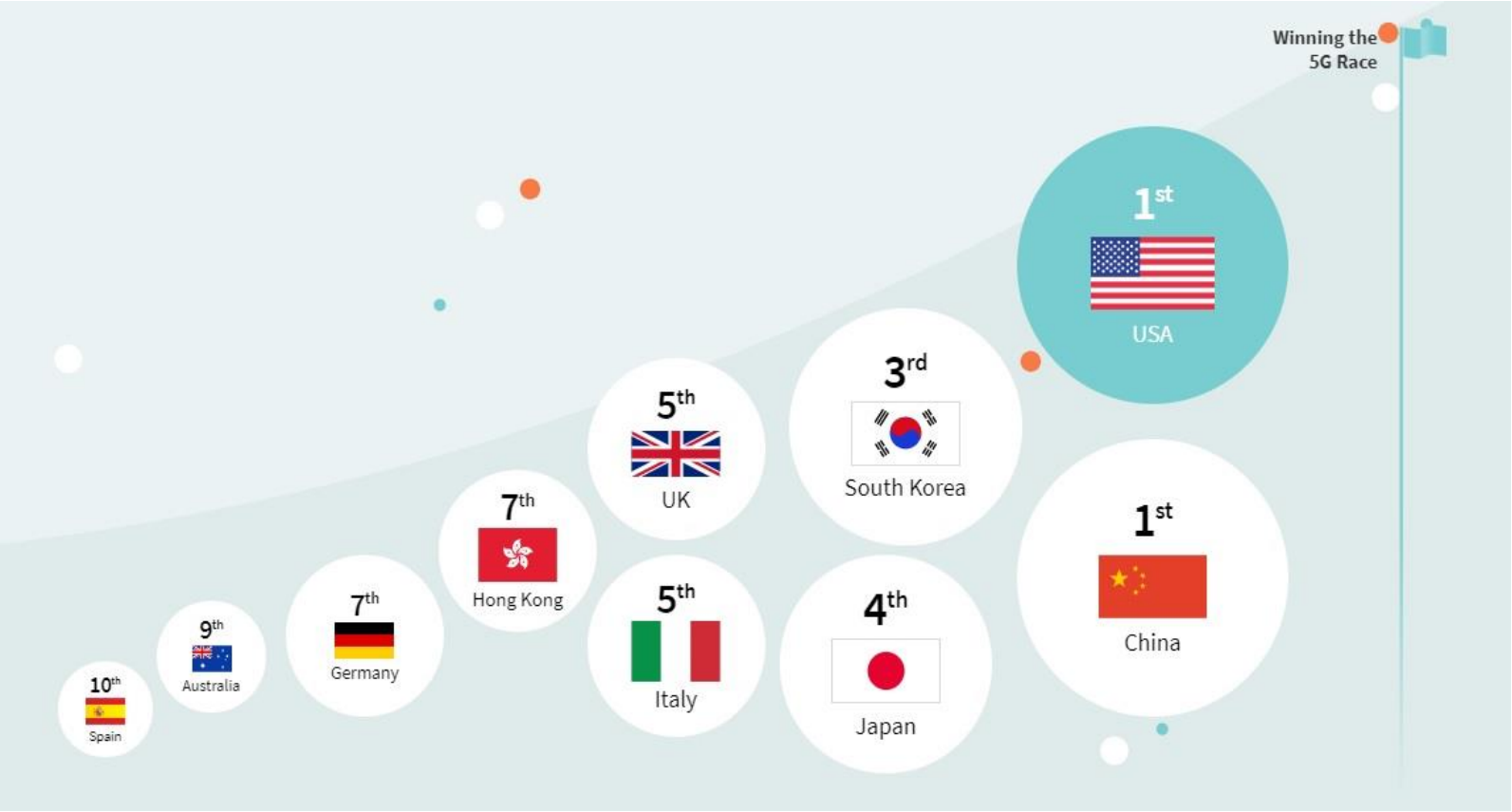
- Autonomous driving infrastructure – from traffic signs to traffic cones – is all about connectivity. Infrastructure changes for autonomous vehicles will pack cities with:
  - fiber and sensor networks,
  - IoT devices,
  - facilities for safe public Wi-Fi,
  - …and superspeed 5G. Fleets of autonomous vehicles will receive and transmit enormous amounts of data all the time.
- Various devices will occupy the "driver's" hands instead of a steering wheel, which will naturally produce an extra load on the wireless network. Maintaining such loads is a job for supreme means of connectivity.

Connected Intelligent infrastructures

- **The decisive impact of 5G on the automotive industry**
  - In the US, the wireless industry supports over 4.7 million jobs and contributes roughly $475 Bn annually to the American economy.
  - Expecting the creation of 3M jobs, $275 Bn investment, $500 Bn economic growth [Deloitte, 2017]
- Rolling out 5G wireless technology requires extensive infrastructure:
  - Central offices, cell towers and other types of cell sites, virtual infrastructure running on commodity servers will be areas of particular interest.
  - Embedding thousands of mini data centers in cell towers and aggregation hubs will allow combining high-powered servers and storage devices with high-speed fiber and software facilities.
- Need of a conduit for power lines and fiber-optic cables will have to be placed throughout the new infrastructure.
- Boosting **Urban grid in smart cities**: involving AV's
  - Vehicle-to-grid (V2G) connectivity of electric vehicles (EVs) is tested to assess the potential for the fleet operators to provide ancillary services to the city's electrical system

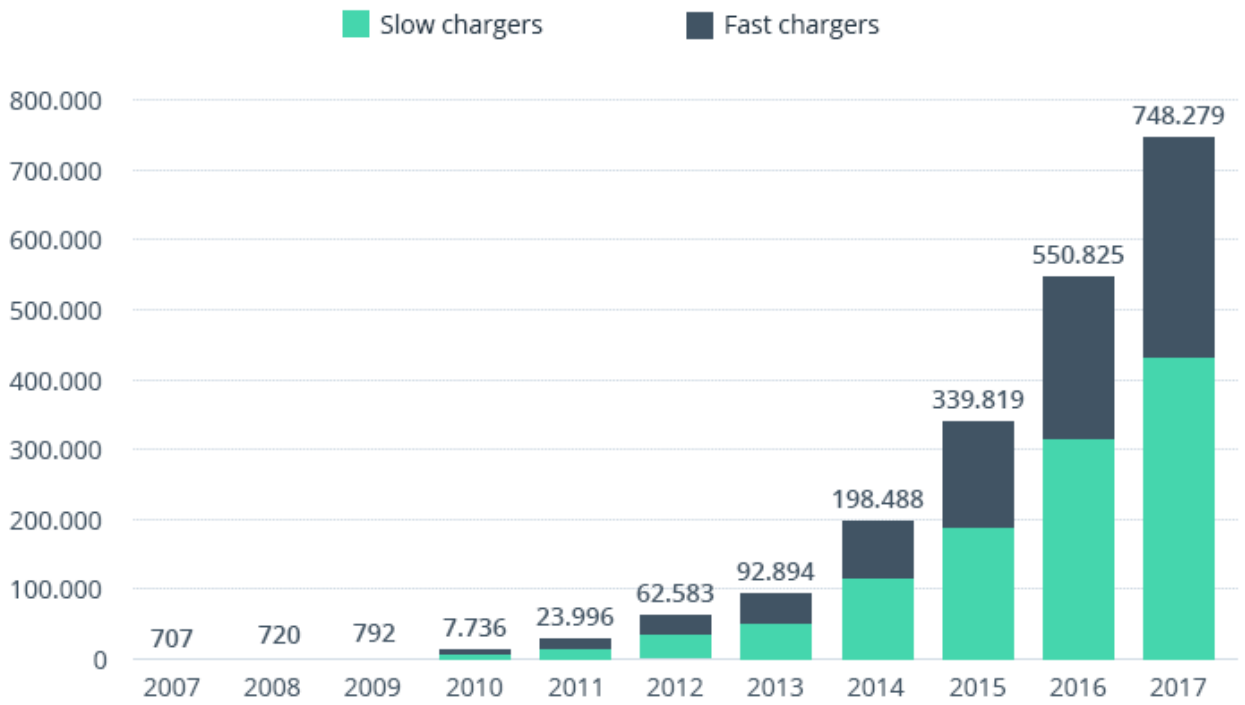
Connected intelligent infrastructures

- **The race for 5G**



Intelligent infrastructures vs. electric autonomous vehicles

- **Potential electric charging of AVs can bring about a revolution in renewable energy production**



Source: [Statista – E-Car Charging Infrastructure Becoming Mainstream]

Future challenges

- As AV technology is continuously progressing, infrastructure changes will have to accommodate new and unforeseen technologies.

- Increased interaction between technologically sophisticated vehicles and infrastructure

➔ Closer collaboration between the automotive technology development, and infrastructure communities, road owners and operators, transportation planners, federal states, and local agencies

➔ The difference in the deployment time horizons for sensor and vehicle technologies (years), and for infrastructure (decades) will create planning, design, and funding challenges.

➔ For decades, automotive and infrastructure communities have to cope and collaborate

Future challenges

- **AV community should :**
- Should consider and design within the context of infrastructure planning, funding, and maintenance.
- Should plan for the availability and deployment of future infrastructure.
- Take into account the type and periodicity of maintenance and repairs (e.g., road markings and pavement quality) for the effective implementation of
- Be more robust and resilient to infrastructure deficiencies and may be capable of navigating those remote areas even without particular infrastructure support

- **Infrastructure community should :**
- Stay abreast of vehicle and sensor technology development to understand how infrastructure may impede or accelerate the adoption of sensor technologies and Avs
- Assess the impact of AVs on road capacity and land use. Will AVs increase or reduce vehicle miles traveled (VMT) and thus road use? How will AVs affect traffic flow and volume? How will land use change as the need for surface and garage parking evolves?
- Electrification can offer synergies with certain aspects of AVs—e.g., by streamlining data sharing or widespreading electric charging stations—and will play an increasingly important role in infrastructure.

- **Cybersecurity:** securing and leveraging these data communications will require coordination among the three communities.

CONCLUSION

Driving in all conditions !

Conclusion

- AV's will be deployed progressively
- First in private environments and in "controlled" areas
- And very likely in infrastructure-aided environments (lanes, highways)

- Infrastructure must adapt to the coming of AV's
- AV's developers must consider high/medium/low support from the infrastructure

- New technologies and designs should be implemented and deployed as part of new viable and sustainable MaaS services and systems