LTE-Direct Broadcast of Periodic Safety Messages

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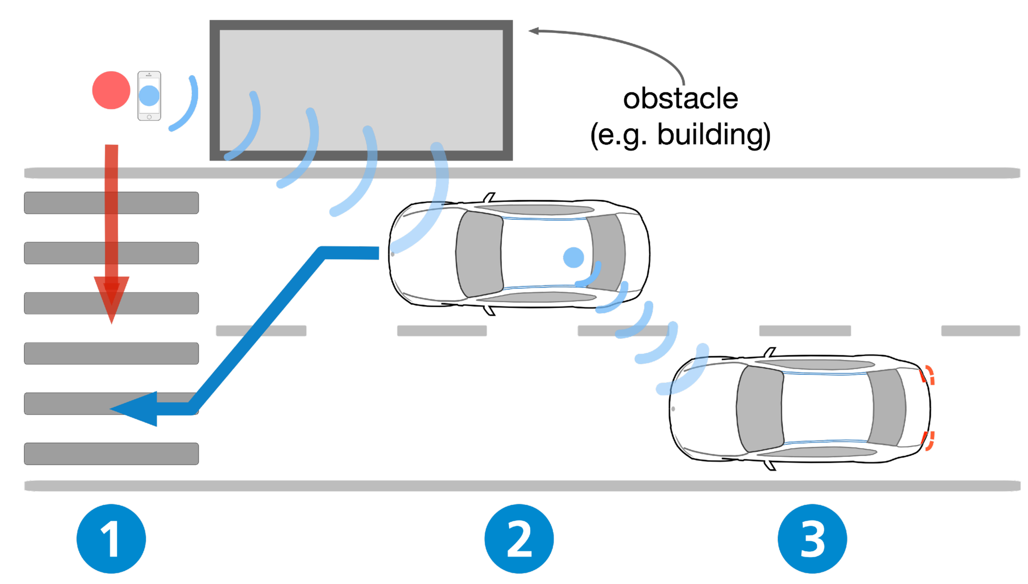
Highly Autonomous Driving Vehicles

- Need for periodic safety communications between road users:
  - Autonomous driving requires awareness of surrounding traffic
  - Information from local sensors might not be sufficient (reactions could be delayed and non optimal)
  - Cooperative mapping and localization applications



1 Via periodic transmissions, a hidden pedestrian suddenly crossing the road is detected

2 A close incoming car performs an emergency maneuver to avoid a collision

3 Farther incoming vehicles become aware of the maneuver and act so to leave the necessary space

LTE broadcast of safety messages

\+ **Advantages** of LTE-based periodic safety transmissions:

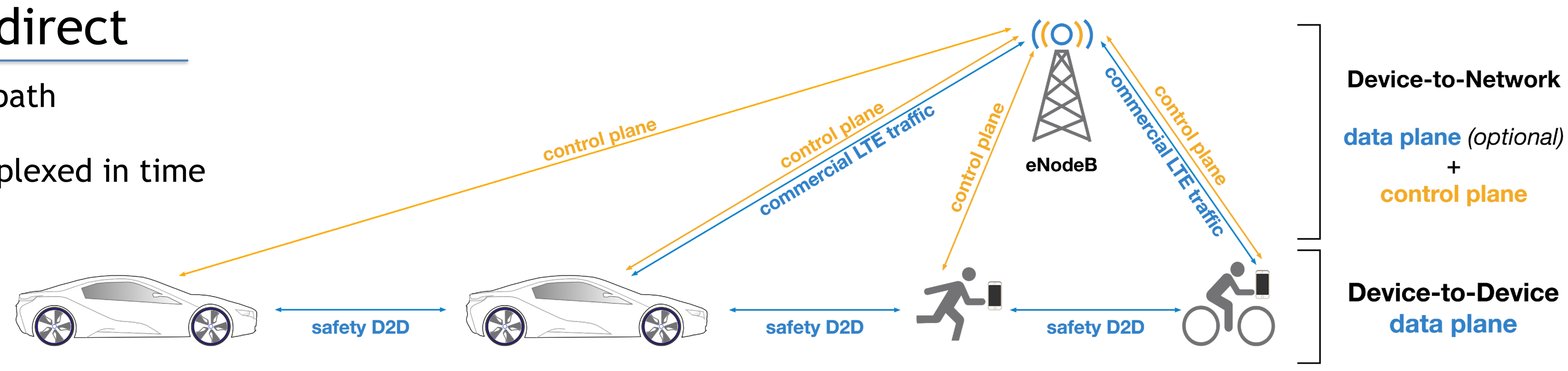
- Network widely available and in expansion
- PHY optimized for high speed mobility
- Allows for integration with smartphones, which:
  1) will initially compensate for slower adoption rate of connected cars
  2) will extend safety features to vulnerable users (pedestrians, cyclists)

\- **Issues** with LTE-based periodic safety transmissions:

- Latency
- Basestation (eNodeB) becomes a *single point of failure*
- Massive mobility management by the network can cause further delay
- Can generate considerable traffic (that must coexist with regular traffic)
- Broadcast of safety messages difficult to handle

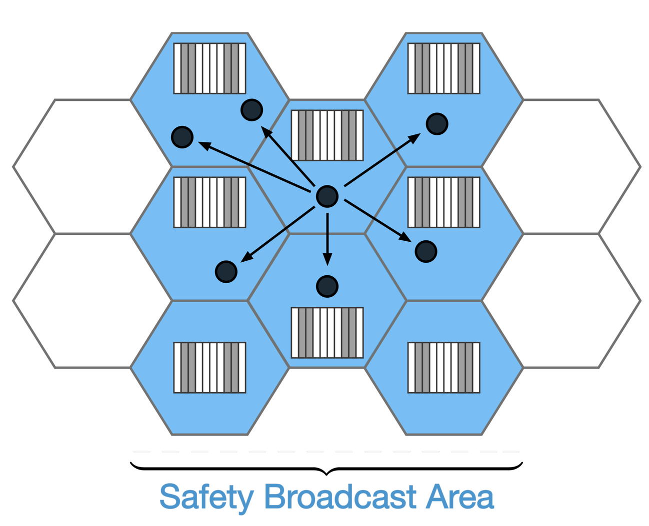
Proposed solution: broadcast LTE-direct

- Safety messages follow a direct Device-to-Device path
- Control plane transmitted by the eNodeBs
- D2D and commercial LTE traffic can coexist, multiplexed in time
- Energy efficient for battery-powered devices
- Divided in two phases:
  1) Resource Allocation
  2) Distributed Resource Access Scheduling



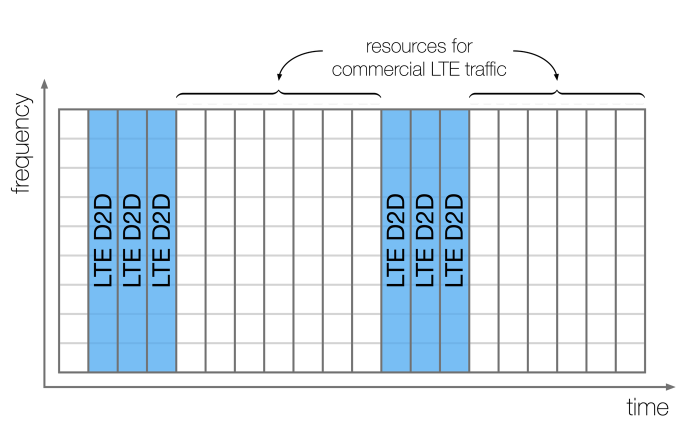
Resource Allocation

Safety Broadcast Area:
periodic pool of common dedicated resources (LTE subframes) allocated over an area covering multiple cells, allowing broadcast among users spread over neighboring cells

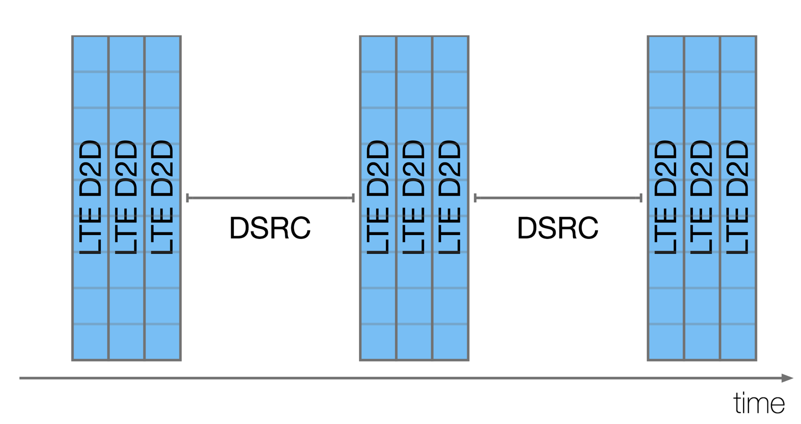


Operation modes:

Band sharing with LTE: D2D subframes interweaved with commercial LTE subframes



Dedicated band: D2D subframes allocated in reserved band (5.9 GHz). Allows time sharing with DSRC

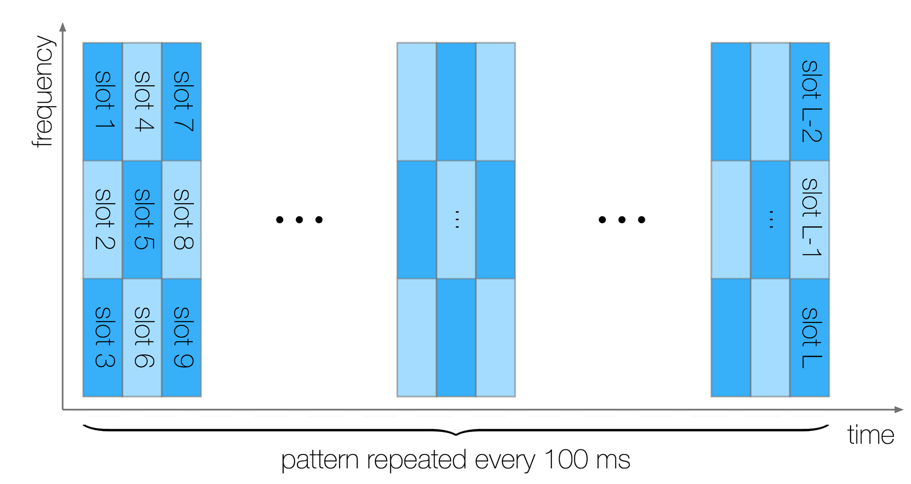


Features:

- Quasi static pool of resources available over a wide area (time/frequency coordinates are periodically broadcast in control channel)
- Does not require connection procedure with eNodeB
- No network-side mobility management
- Network has the flexibility to reallocate resources
- Periodic pattern:
  - Provides a certain degree of eNodeB failure-resilience
  - Allows for energy saving (TX/RX duty cycle) without losing awareness
  - Allows for time sharing with other D2D technologies as DSRC

Distributed Resource Access Scheduling

Organization of LTE Resource Blocks into a TDMA-like scheme



Resource blocks belonging to the subframes dedicated to LTE D2D broadcast are collected into slots the size of a CAM packet

The slots within 100 ms form a frame (transmission rate of 10 Hz)

Multiple access can be treated as a *TDMA-like* system

TDMA scheme: Optical Orthogonal Codes (OOC)

- Repetition based: multiple (re)transmissions per frame *(w)*
- Max number of collisions per frame between two users: bounded to λ

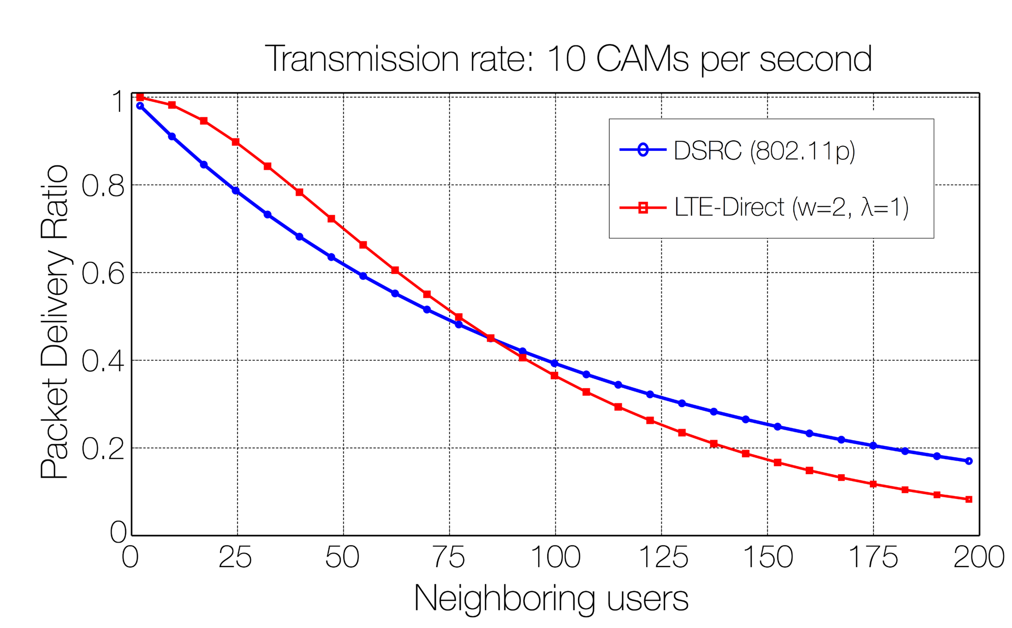
Congestion Control:

- same Decentralized Congestion Control as DSRC can be applied

Performance comparison with DSRC (802.11p)

Metric: Packet Delivery Ratio
Channel Rate: 6 Mbps
Modulation: QPSK
TX Rate: 10 packets/s
Bandwidth: 10 MHz
Packet size: 300 bytes
LTE D2D time occupation: 50%

LTE D2D outperforms DSRC up to ~ 80 neighbors



Current and future development:

- Adoption of location aware multiple access: **Self Organizing TDMA**
- Definition of a suitable waveform for LTE-direct

Reference: Gallo L., Härri J. *"Short Paper: A LTE-Direct Broadcast Mechanism for Periodic Vehicular Safety Communications"* 2013 IEEE Vehicular Networking Conference (VNC), 16-18 December 2013, Boston USA

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