Automotive Communication via Mobile Broadband Networks

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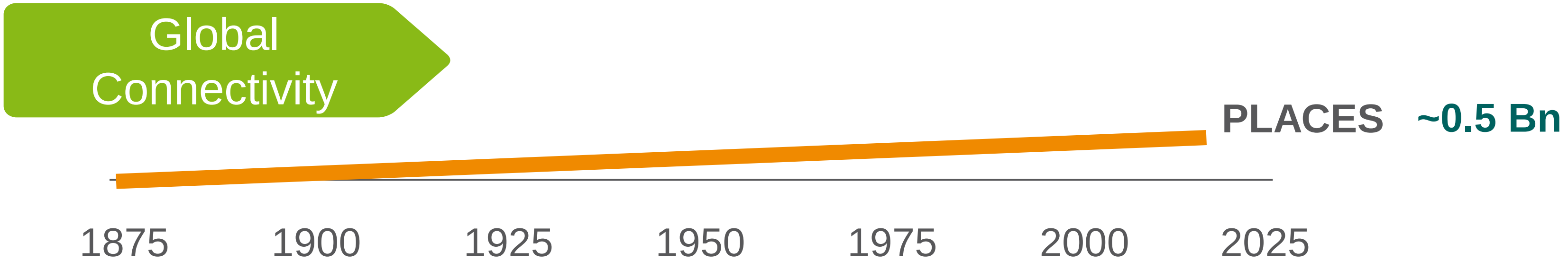
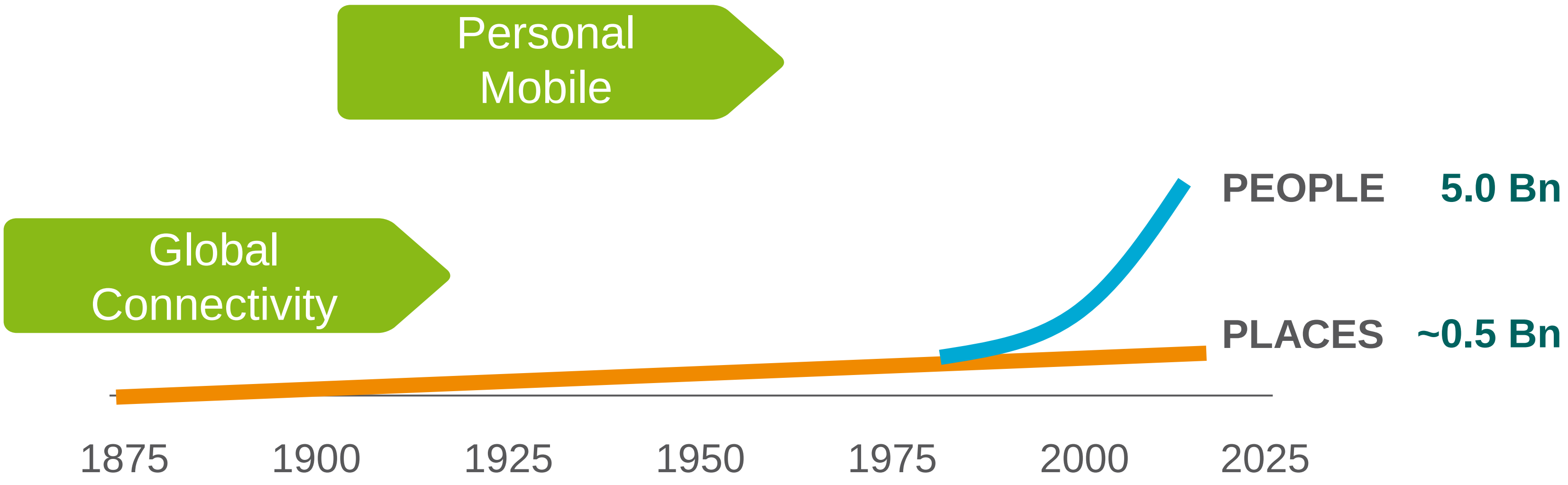
Where are we in telecommunications ?



Source: Ericsson

Where are we in telecommunications ?



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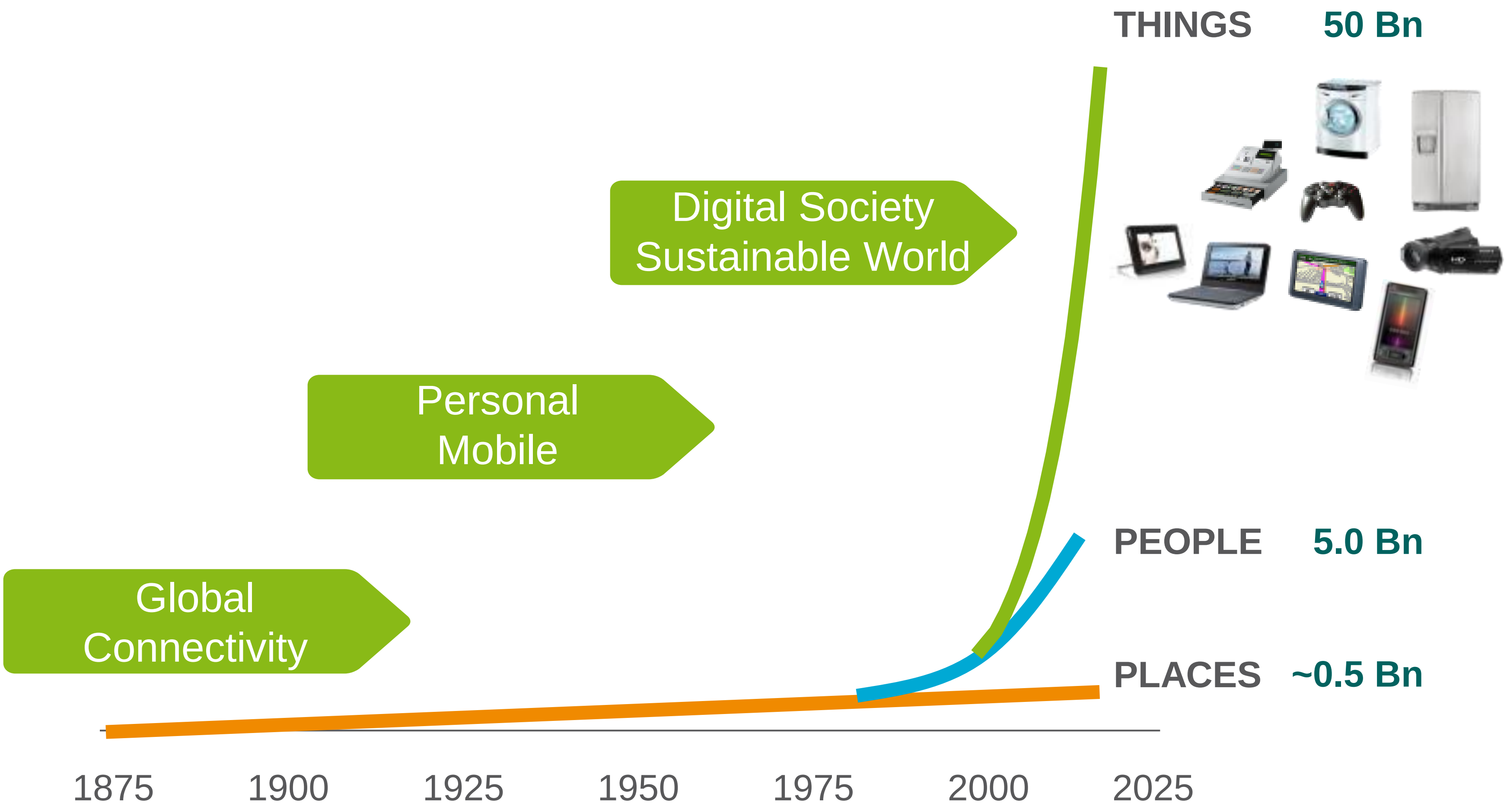

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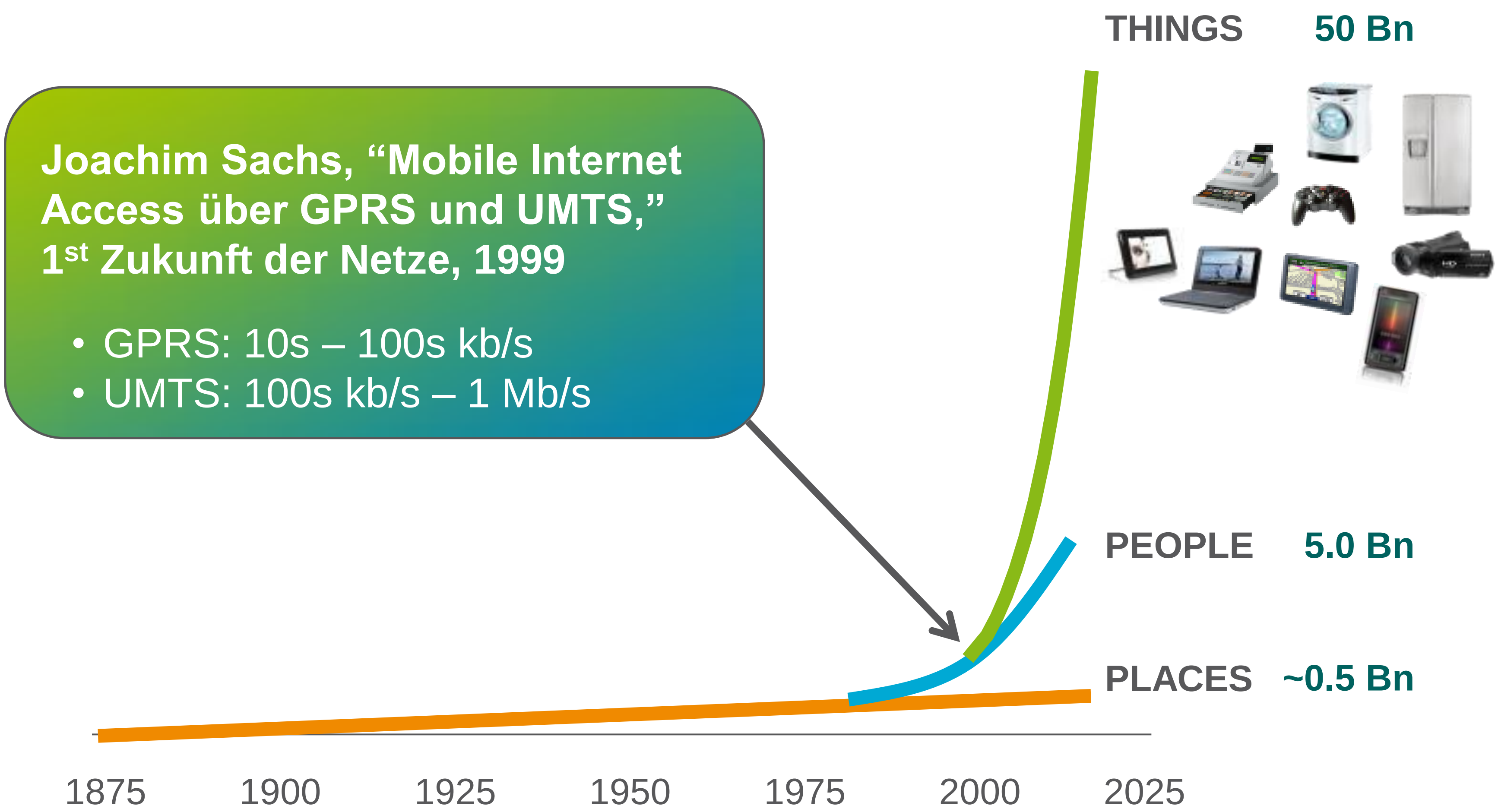
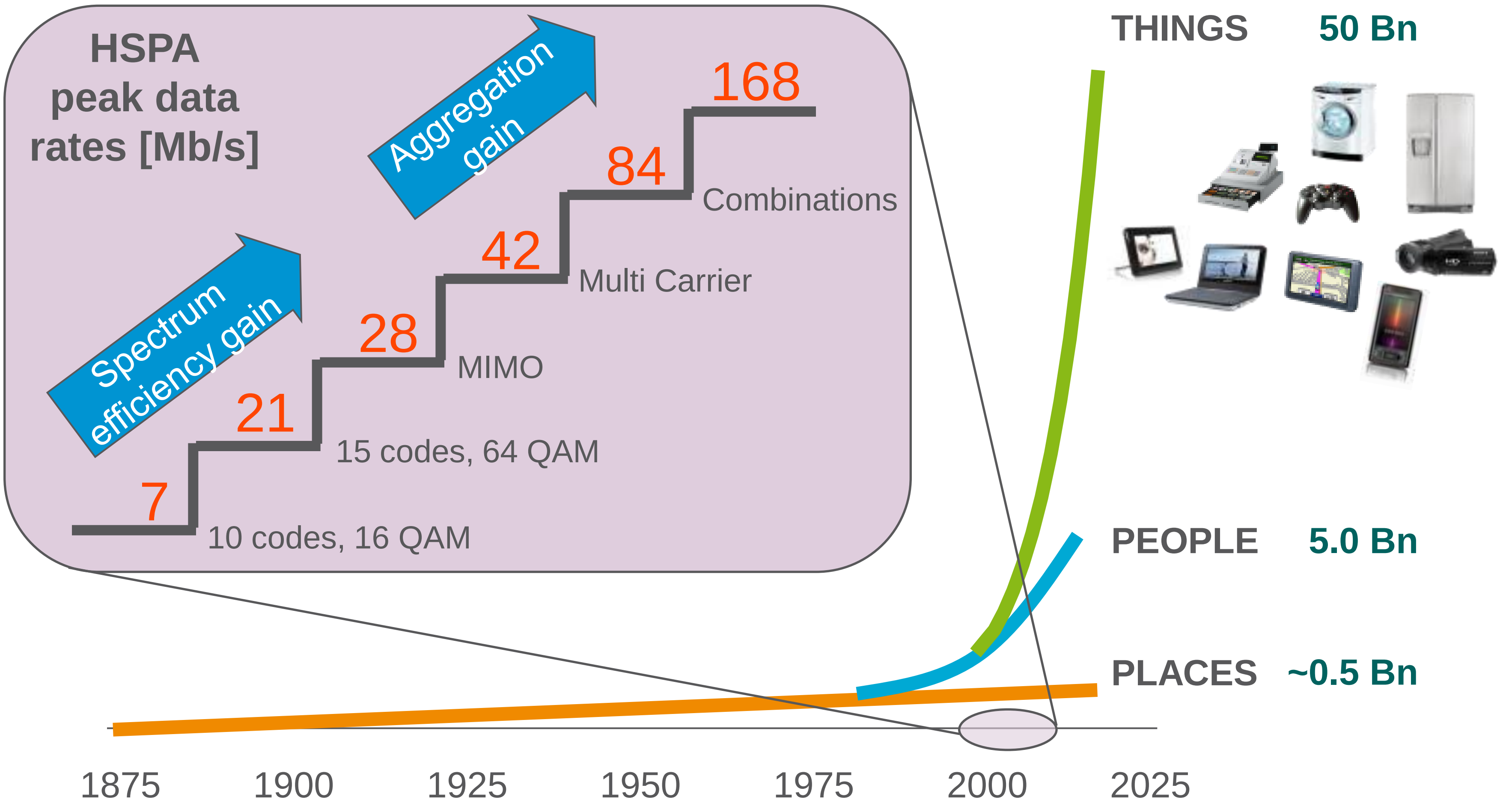


Source: Ericsson

One decade of UMTS/HSPA evolution



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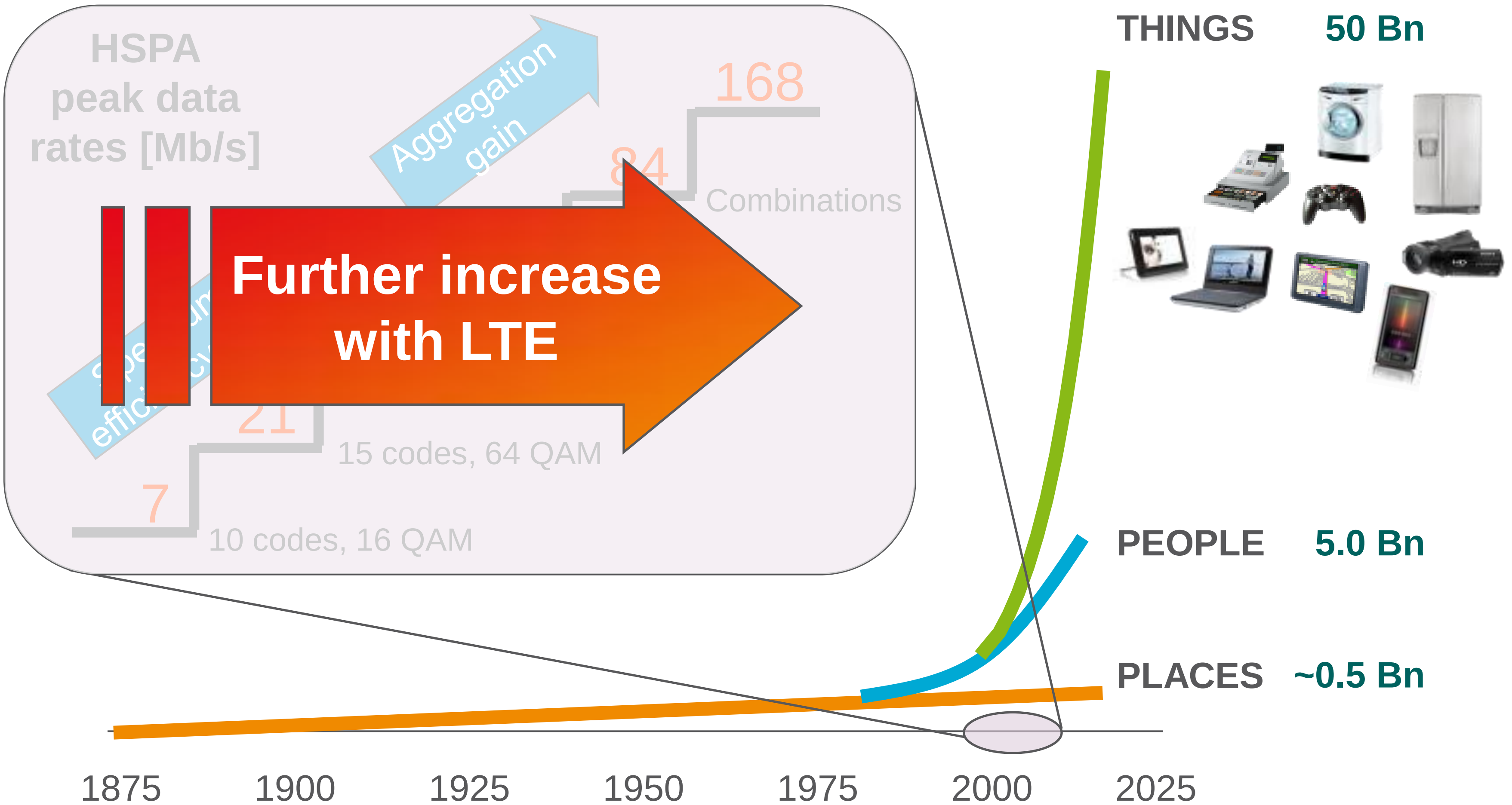
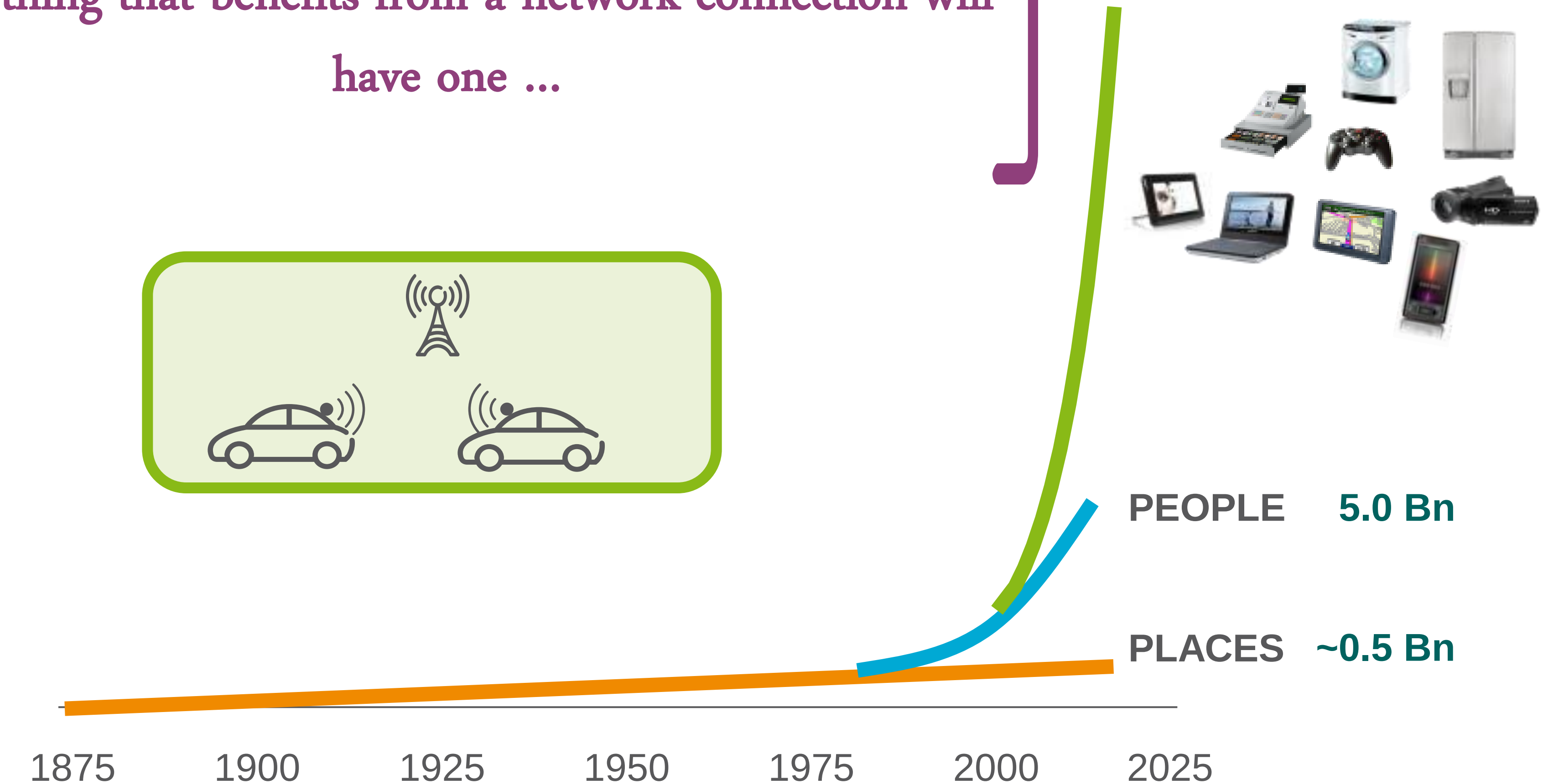
One decade of UMTS/HSPA evolution



Source: Ericsson

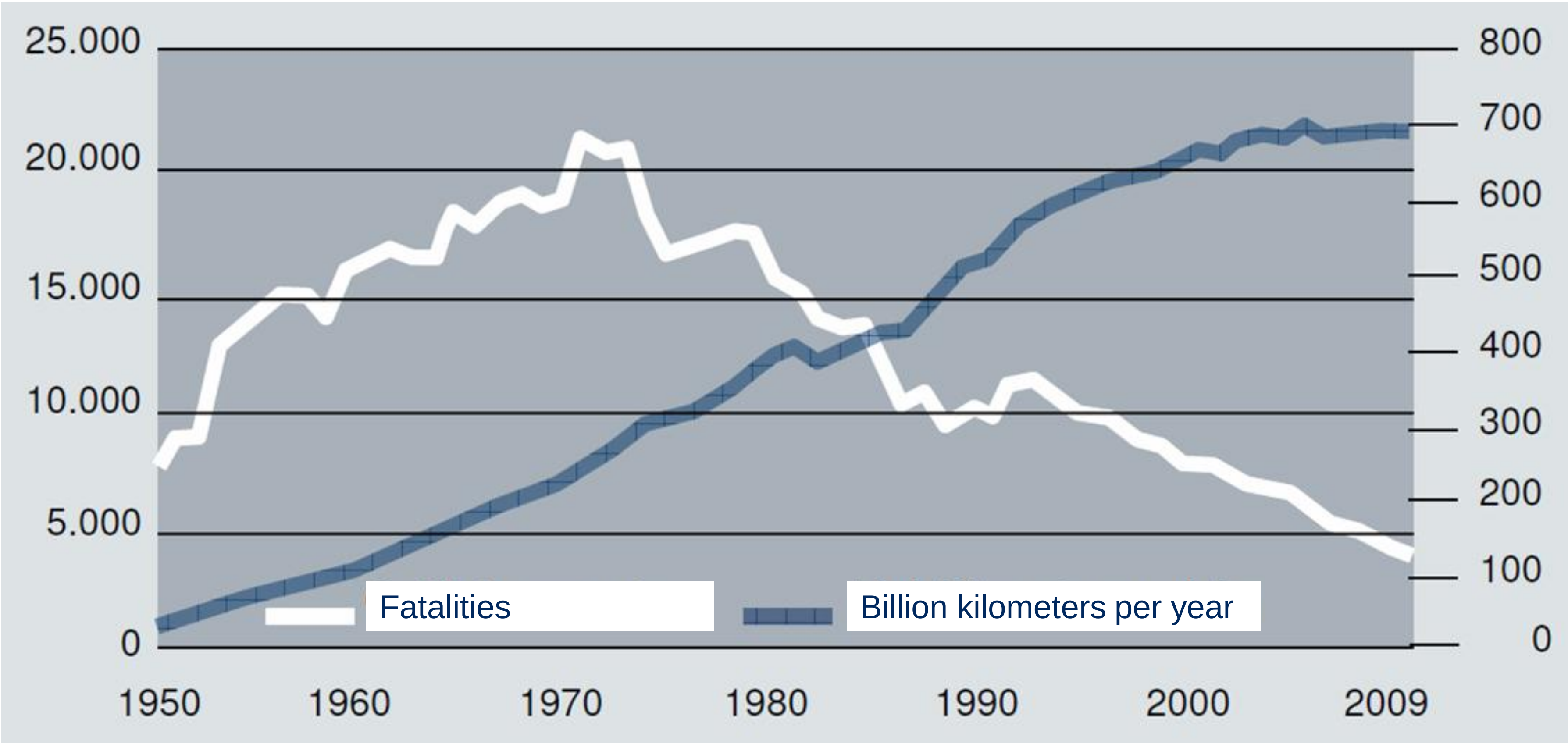
Machine-to-machine and the Networked Society

everything that benefits from a network connection will have one …



Source: Ericsson

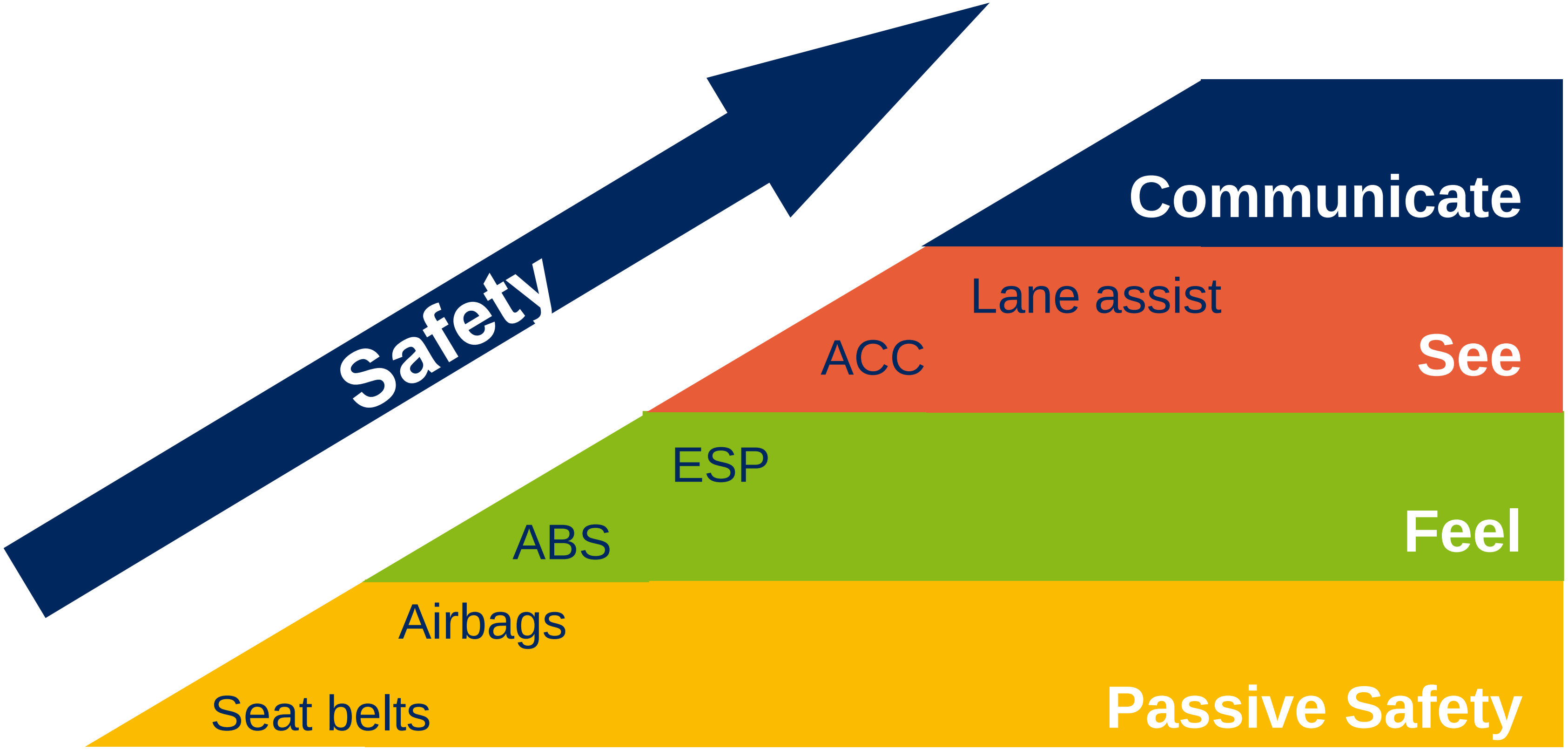
Why should cars communicate?



› Constant decrease despite increasing traffic volumes

Source: German Federal Statistical Office

Why should cars communicate?



› Next big step in vehicle safety through communication

ETSI Standardization

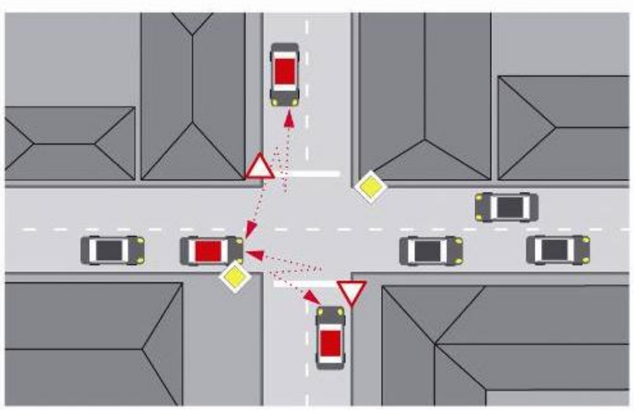
- C-ITS – Cooperative Intelligent Transport Systems
  - Goals, e.g.:
    - Improved traffic efficiency
    - Increased road safety

- Automotive Messaging Types
  - CAM – Cooperative Awareness Message
  - DEN – Decentralized Environmental Notification

Cooperative Awareness Message CAM - Use Cases

Use Case	Min frequency (Hz)	Max latency (ms)
Emergency Vehicle Warning	10	
Intersection Collision Warning	10	
Collision Risk Warning	10	
Slow Vehicle Indication	2	100
Motorcycle Approaching Indication	2	
Traffic Light Optimal Speed Advisory	2	
Speed Limits Notification	1 to 10	

Intersection assistance



- **Sent by vehicle or roadside unit**
- **Periodically transmitted**
- **Vehicle information (position, direction, velocity, …)**
- **Destination: neighboring hop**

Decentralized Environmental Notification DEN – Use Cases

Use Case	Triggering condition	Terminating condition	Latency (s)
Emergency electronic brake light	Hard braking of a vehicle	Automatically after the expiry time	0.2
Collision risk warning	Detection of a turning/crossing/merging collision by roadside unit	End of collision risk	0.2 - 1 s
Stationary vehicle – accident	eCall triggering	Vehicle involved in accident is removed	< 5
Stationary vehicle – vehicle problem	Vehicle breakdown or vehicle with activated warnings	Vehicle is removed from the road	< 5
Traffic jam warning	Traffic jam detection	End of traffic jam	< 5
Road work warning	Signalled by fixed or moving roadside station	End of road work	> 1 min
Precipitation	Detection of a heavy rain or snow (activation of windscreen wrappers)	Detection of the end of the heavy rain or snow situation	< 5
Road adhesion	Detection of a slippery road condition (ESP activation)	Detection of end of the slippery road condition	< 5

Decentralized Environmental Notification DEN – Use Cases

Use Case	Triggering condition	Terminating condition	Latency (s)
Emergency electronic brake light	Hard braking of a vehicle	Automatically after the expiry time	0.2
Colli			0.2 - 1 s
Sta acc			< 5
Sta veh		n	< 5
Tra			< 5
Ro			> 1 min
Preci	snow (activation of windscreen wrappers)	of the heavy rain or snow situation	< 5
Road adhesion	Detection of a slippery road condition (ESP activation)	Detection of end of the slippery road condition	< 5

- **Main usage Road Hazard Warnings (RHW)**
- **Sent when road hazard is detected**
  - **event based (road hazard exists)**
  - **periodic repetition and continuous broadcast (until expiry or termination message)**
- **Distribution to all vehicles within a relevance area**

Car-to-car using dedicated short range radio (DSRC)

Why not use cellular?

availability, coverage and performance

9 GHz

uipment

000 meters

› Highway networks
  – US: 75000 km
  – Germany: 12000 km
  – Sweden: 1800 km
  – Rural and urban not included

Gefördert vom Bundesministerium für Bildung und Forschung

CoCarX

Cooperative cars projects

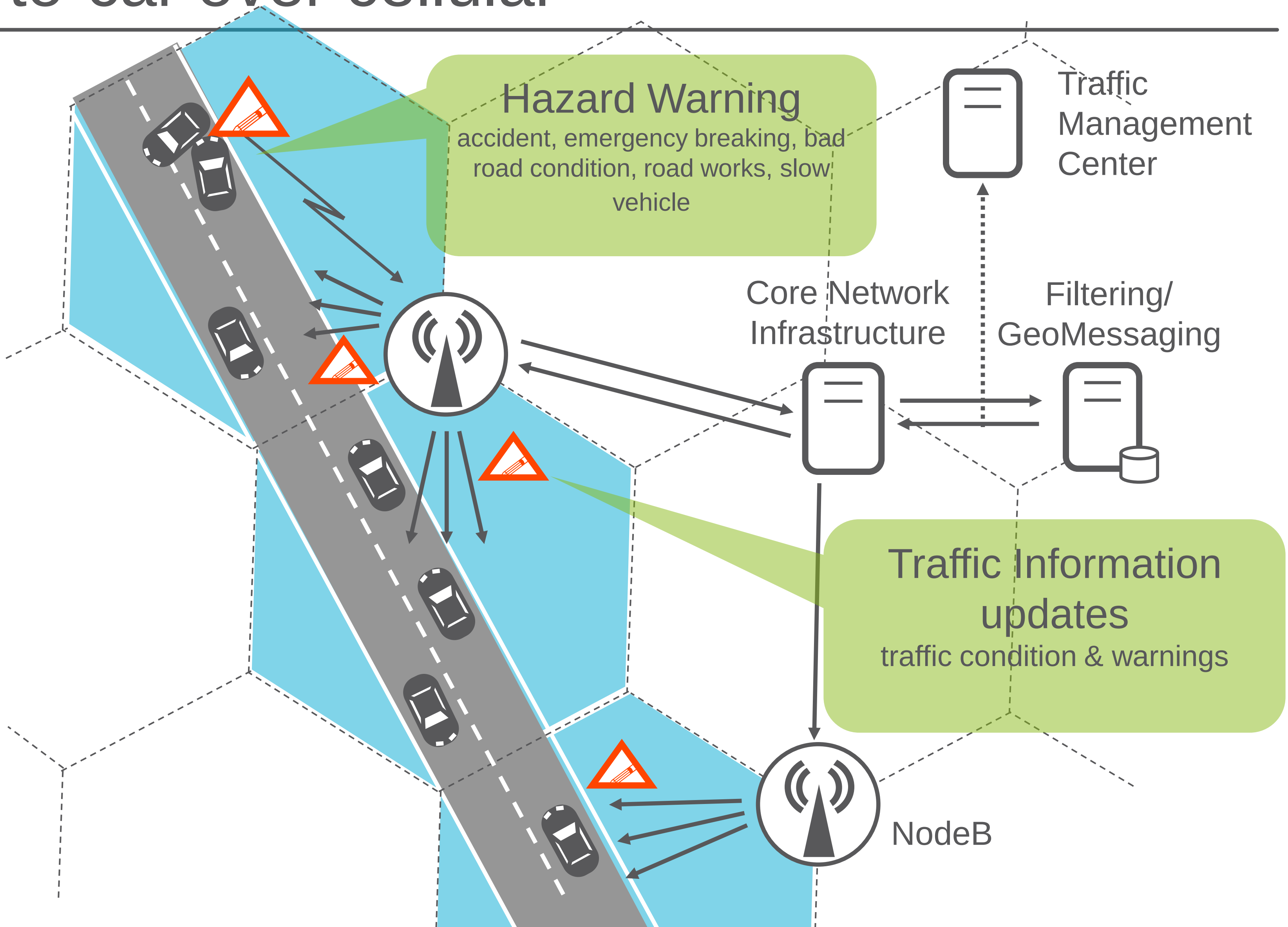
› Cooperative Cars (CoCar, 2006-2009)
  – Basic research on cellular car-to-car communication using UMTS and HSPA
  – Reference case: Road Hazard Warnings

DAIMLER MAN vodafone ERICSSON

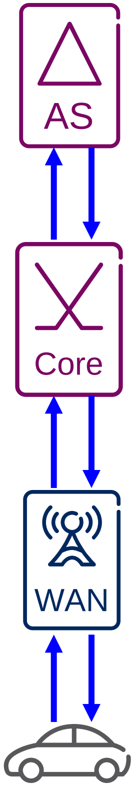
› Cooperative Cars eXtended (CoCarX, 2009-2011)
  – LTE, session management, heterogeneous approach

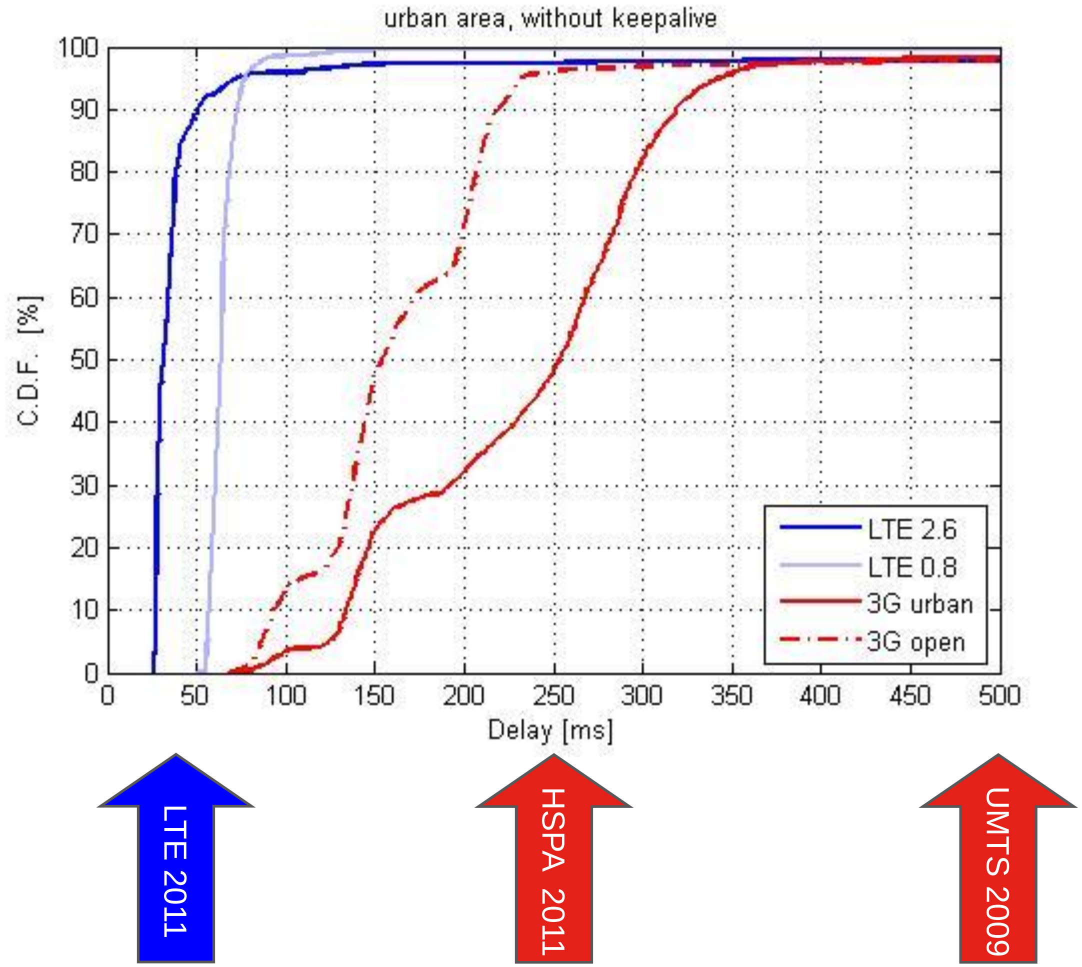
Ford BMW vodafone ERICSSON bast

Car-to-car over cellular



Cellular car-to-car delay





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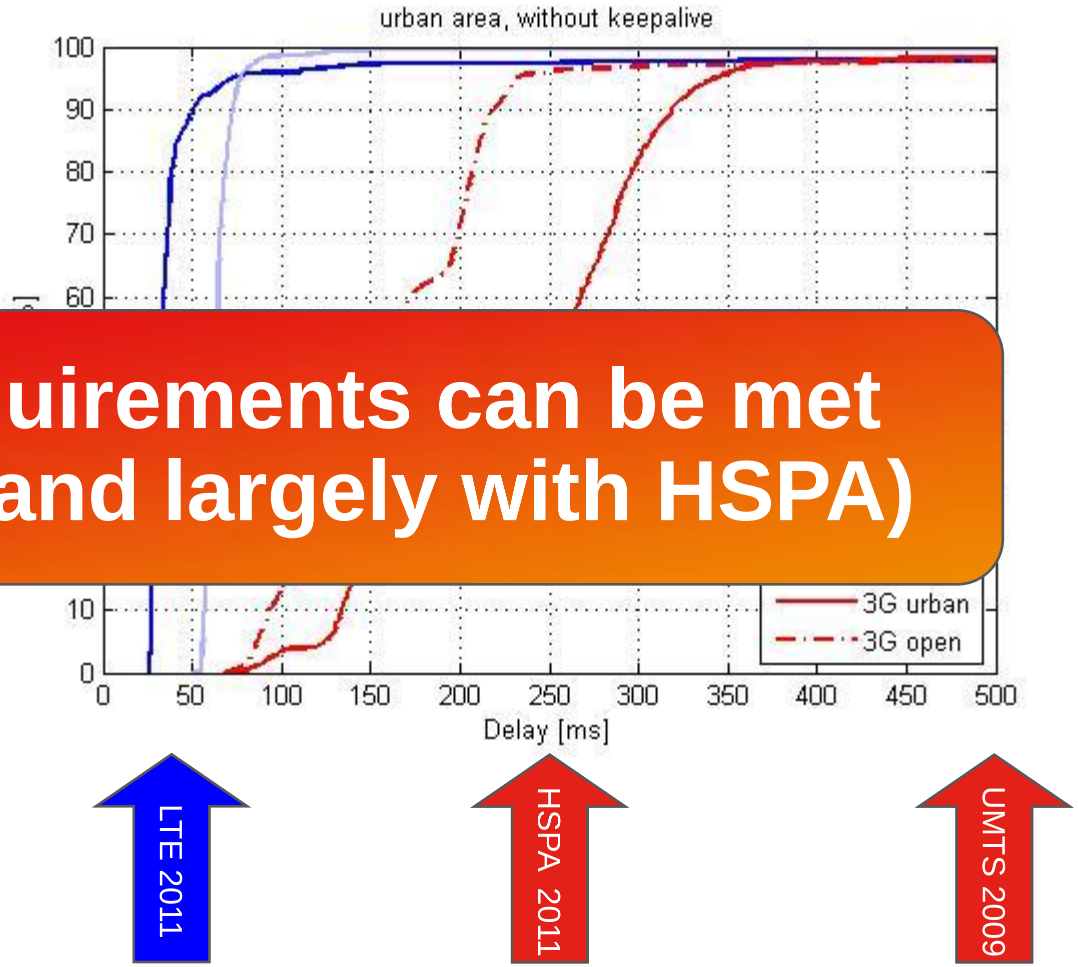
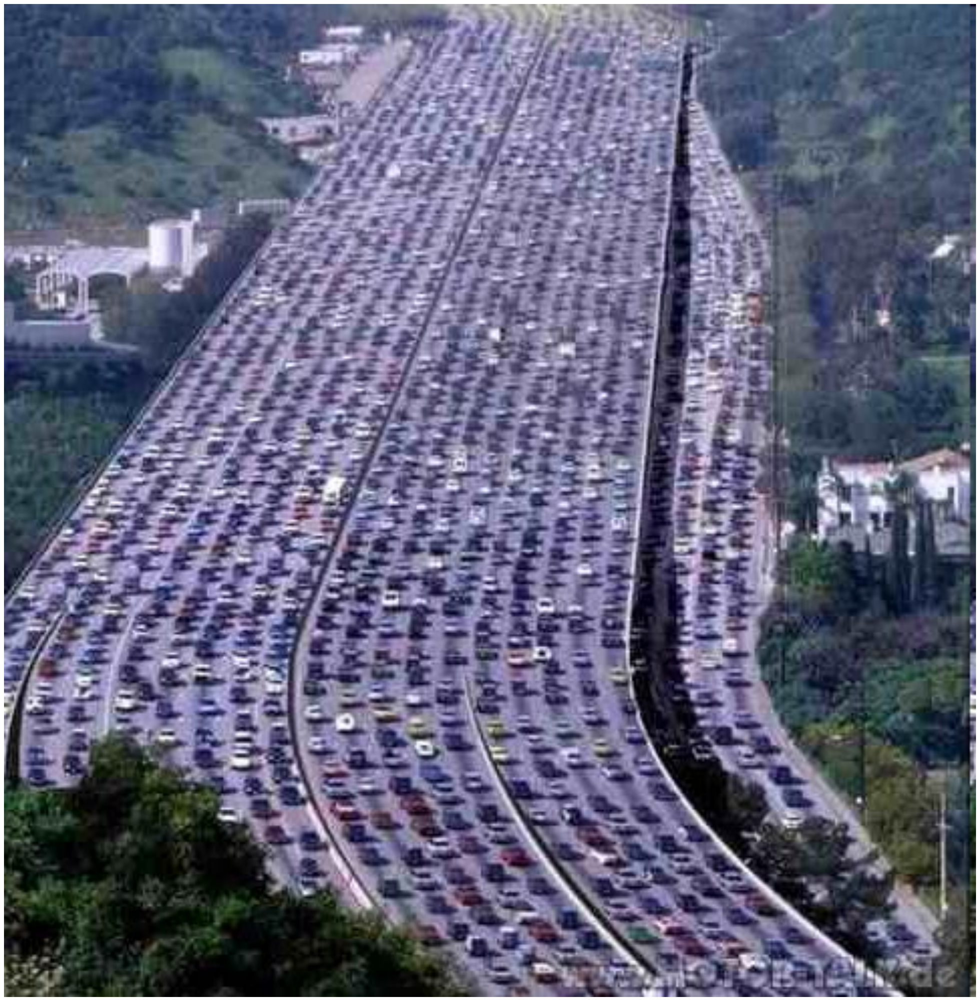
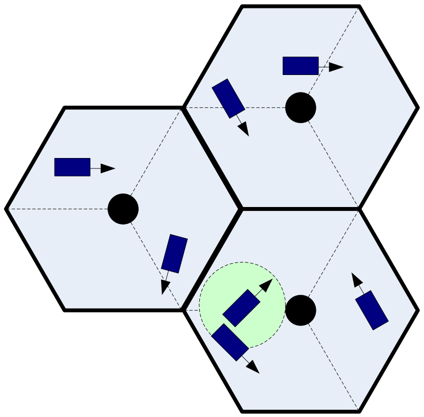


Delay requirements can be met with LTE (and largely with HSPA)

How about system capacity ?

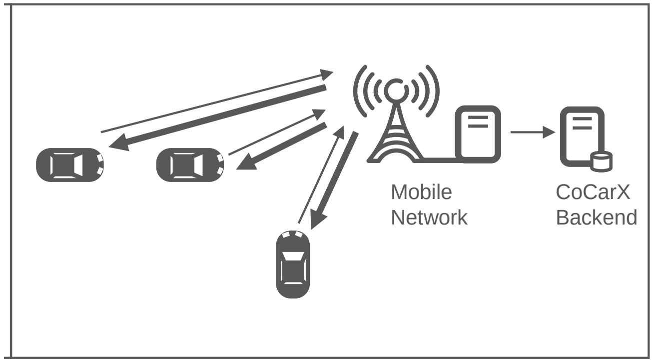


LTE Capacity evaluation
methodology



- LTE radio network simulations
  - Full protocol stack and mobility simulated
- Network size: 9 cells, 3 sites
- System bandwidth: 5 MHz for UL and DL
- Intersite-distance (ISD) and carrier frequency
  - A: 500 m at 2 GHz
  - B: 6 km at 800 MHz
- Tx / Rx antennas: 1 / 2 (SIMO)
- Over 5000 cars simulated
- User speed: 13.9 m/s = 50 km/h
- Message sizes based on ETSI DENM/CAM (120 byte)
- No cross traffic

LTE Capacity evaluation
Case 1: Periodic messages

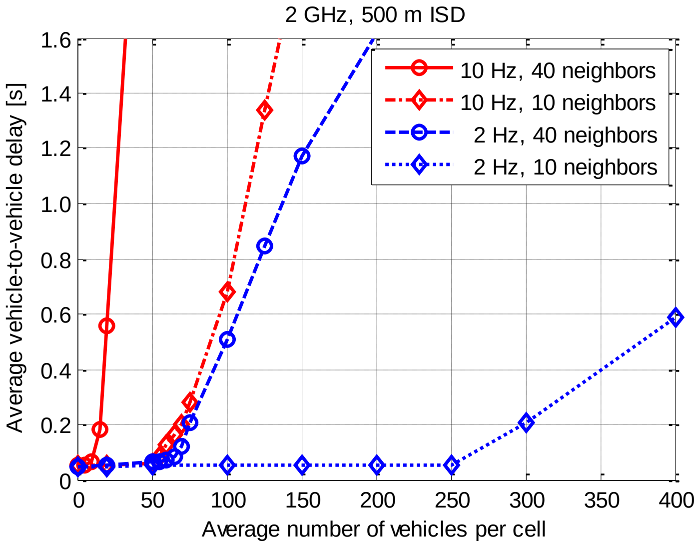


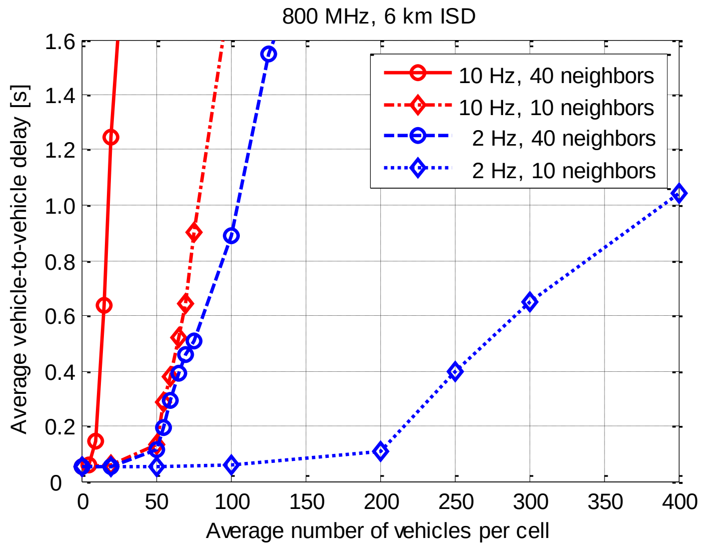
Communication through network infrastructure and backend

1.

1. Sender behavior
   – All cars sending CAM, 2 Hz and 10 Hz compared
2. Message distribution
   – CAM to all receivers in same cell immediately congests network
   – Regional filtering modeled
     › CAM distributed to 10 or 40 vehicles in the vicinity

CAM V2V delay
Urban vs. Rural environment

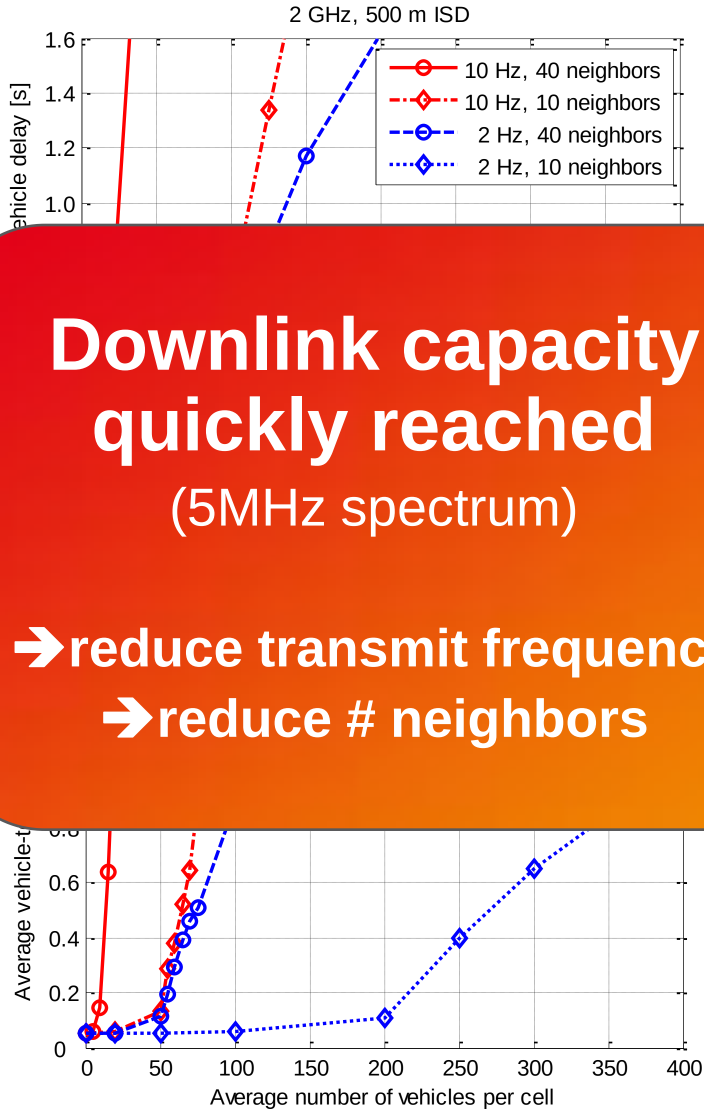




› **V2V delays < 100 ms**

Scenario		$N_{vehicles}$ per cell
UL+DL 10 Hz 40 neighbors	urban	≈ 13
	rural	≈ 9
UL+DL 10 Hz 10 neighbors	urban	≈ 57
	rural	≈ 47
UL+DL 2 Hz 40 neighbors	urban	≈ 67
	rural	≈ 49
UL+DL 2 Hz 10 neighbors	urban	≈ 275
	rural	≈ 199

CAM V2V delay
Urban vs. Rural environment



Downlink capacity quickly reached

(5MHz spectrum)

➔reduce transmit frequency

➔reduce # neighbors

› **V2V delays < 100 ms**

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	rural	≈ 9
UL+DL 10 Hz 10 neighbors	urban	≈ 57
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UL+DL 2 Hz 40 neighbors	urban	≈ 67
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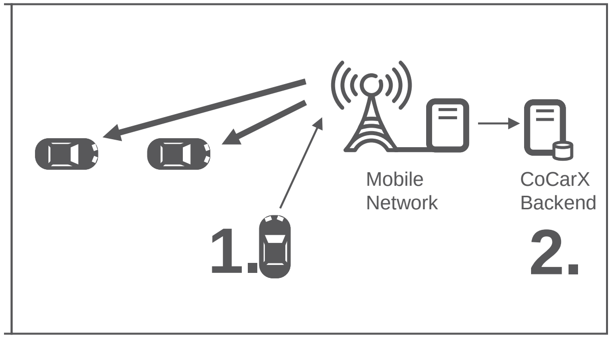
UL+DL 2 Hz 10 neighbors	urban	≈ 275
	rural	≈ 199

LTE Capacity evaluation

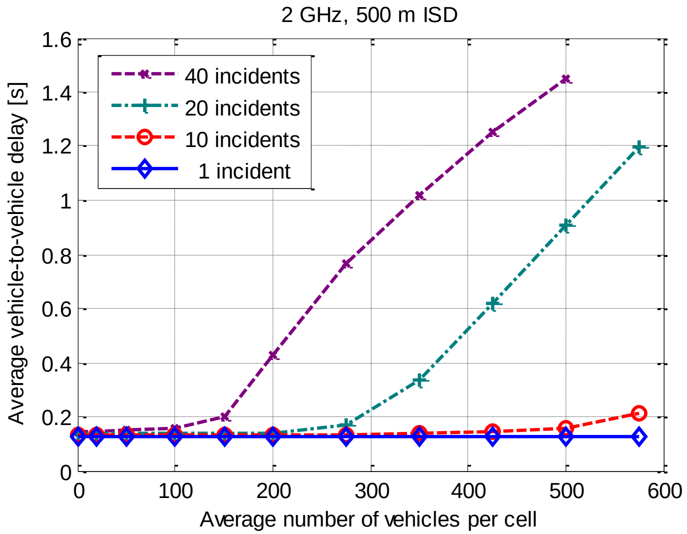
Case 2: Warning messages (DENM)

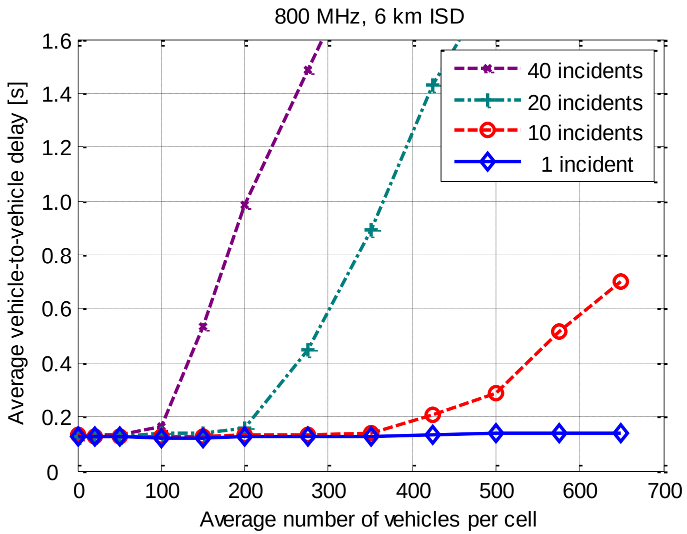


Communication through network infrastructure and backend

1. Sender behavior
   - 1, 10, 20, 40 cars per cell sending DENM with average 1 Hz
2. Message distribution
   - Simple GeoMessaging abstraction used
   - DENM sent to all vehicles in same cell (easy to implement)
   - Substantial potential for optimization (e.g. duplicate filtering in backend)

DEN V2V delay
Urban vs. Rural environment

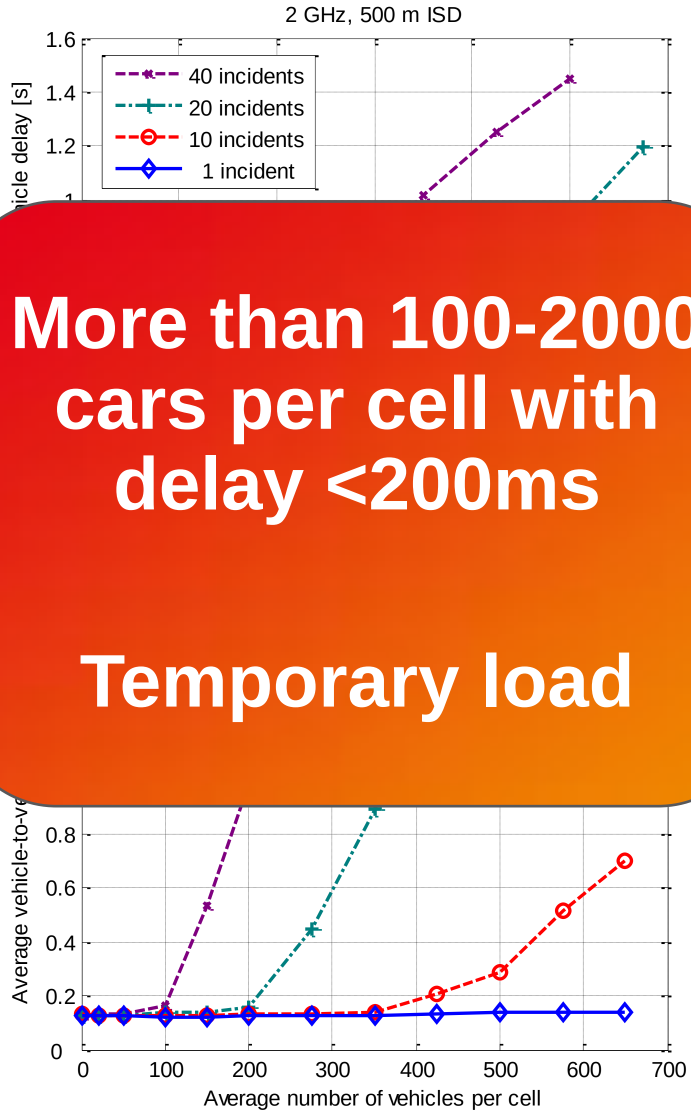




› **V2V delays < 200 ms**

Scenario		N_{cars} per cell
UL+DL 1 incident	urban	2500
	rural	2250
UL+DL 10 incidents	urban	550
	rural	400
UL+DL 20 incidents	urban	280
	rural	200
UL+DL 2/s 40 incidents	urban	140
	rural	100

DEN V2V delay
Urban vs. Rural environment



More than 100-2000 cars per cell with delay <200ms

Temporary load

› **V2V delays < 200 ms**

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UL+DL 1 incident	urban	2500
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UL+DL 10 incidents	urban	550
	rural	400
UL+DL 20 incidents	urban	280
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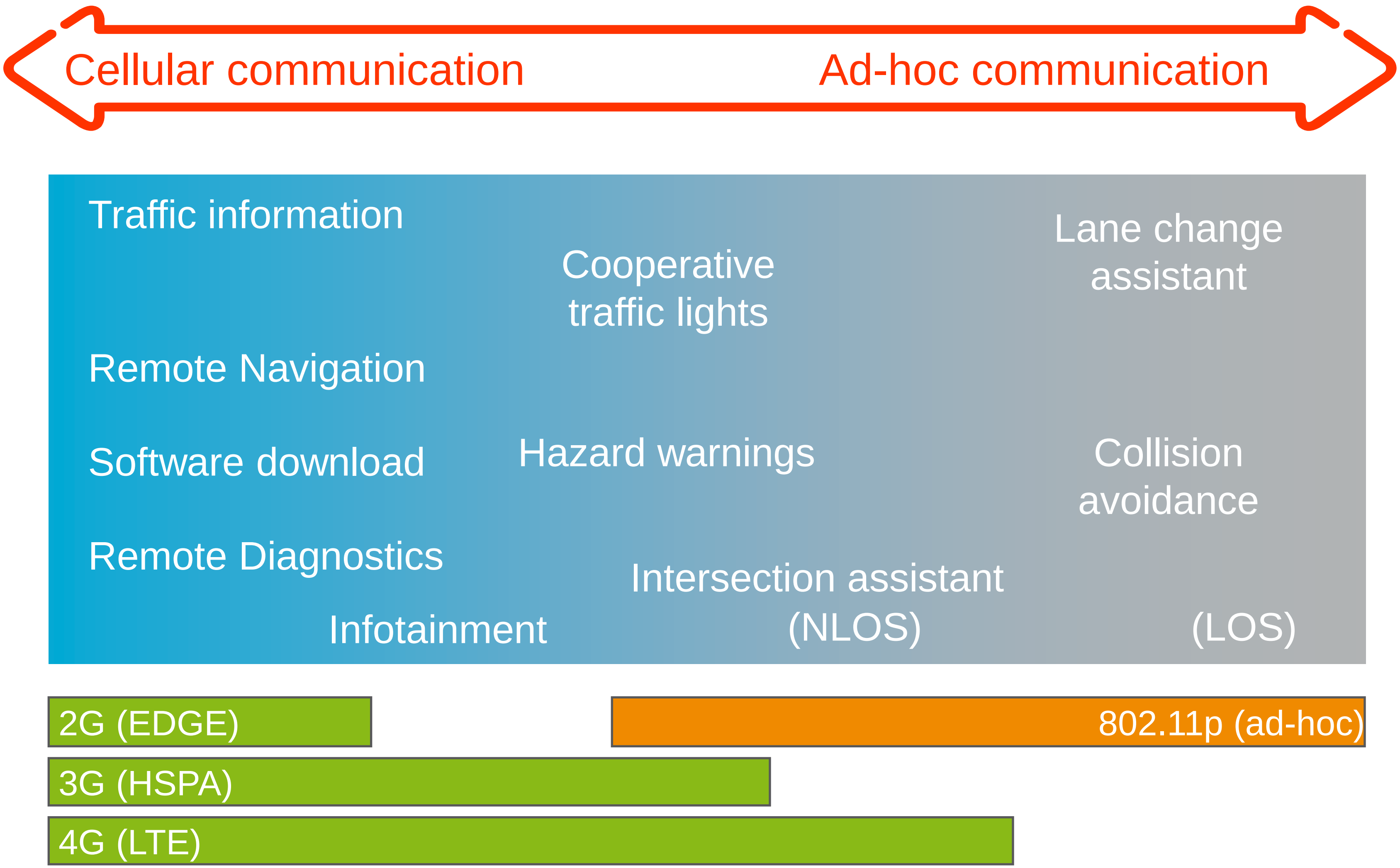
UL+DL 2/s 40 incidents	urban	140
	rural	100

Conclusion

- **CAM could in theory be supported** by LTE networks
  - High radio resource usage for little new information
  - Heavy backend filtering required
  - Can 802.11p cope with this load?
- **DEN can efficiently be supported** by LTE networks
  - Warning essential to increase road safety
  - Delay requirements can be met
  - Capacity only needed in case of incident → temporary effect
  - Requires intelligent backend filtering for distribution in relevance area
- **Possible capacity improvements**
  - Solution using Multimedia Broadcast Multicast Service
- **Other important vehicular communication use cases much easier**
  - Remote diagnostics, road traffic management, …

Complementary solutions? cellular and ad-hoc DSRC



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