

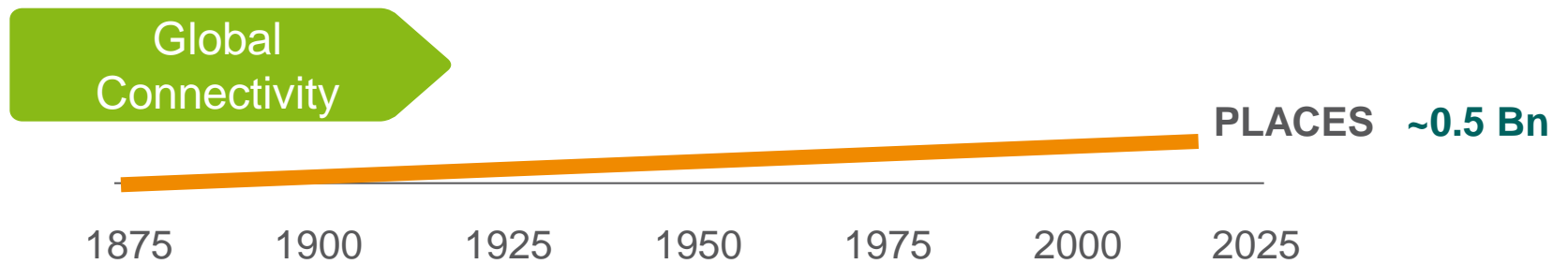


Automotive Communication via Mobile Broadband Networks

Dr. Joachim Sachs
Ericsson Corporate Research, Aachen

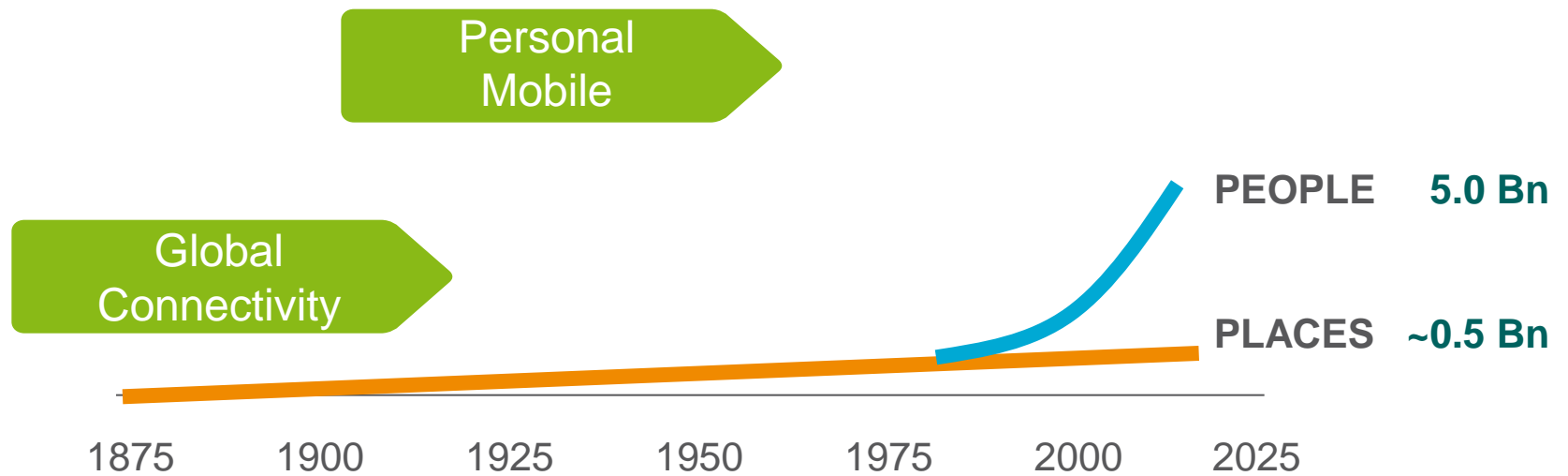
Contributors:
René Rembarz, Mai-Anh Phan, Sabine Sories

Where are we in telecommunications ?



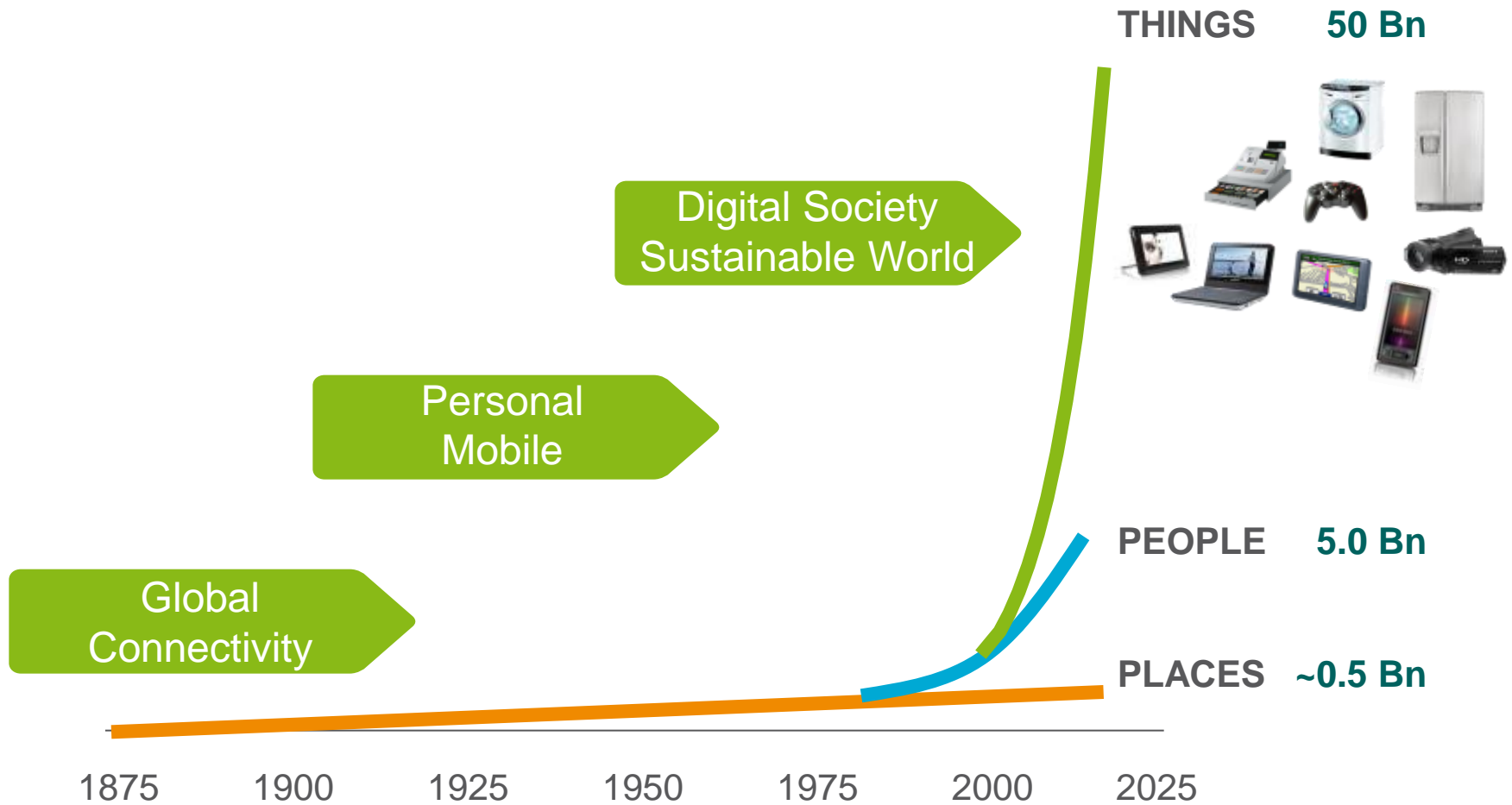
Source: Ericsson

Where are we in telecommunications ?



Source: Ericsson

Where are we in telecommunications ?

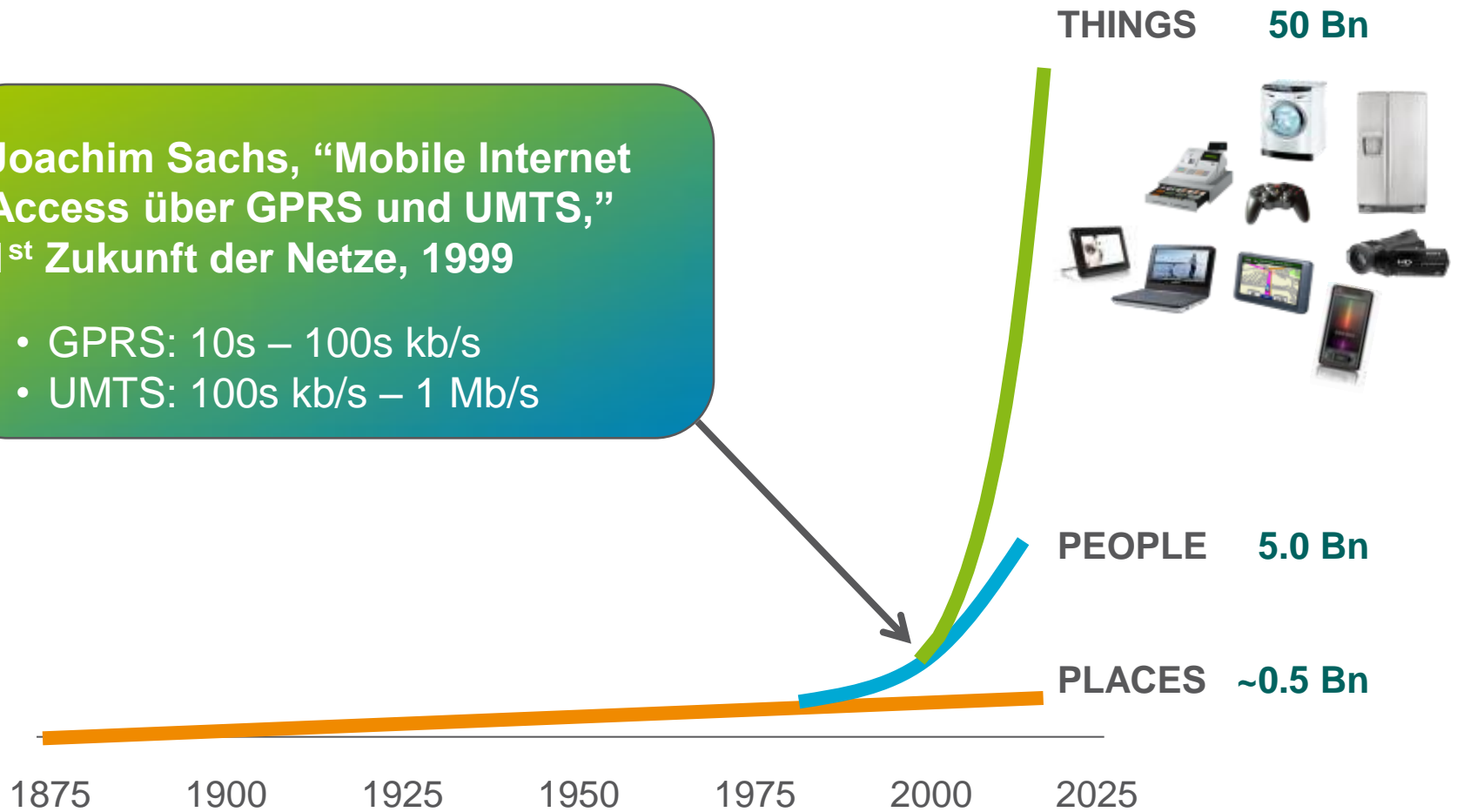


Source: Ericsson

Where are we in telecommunications ?

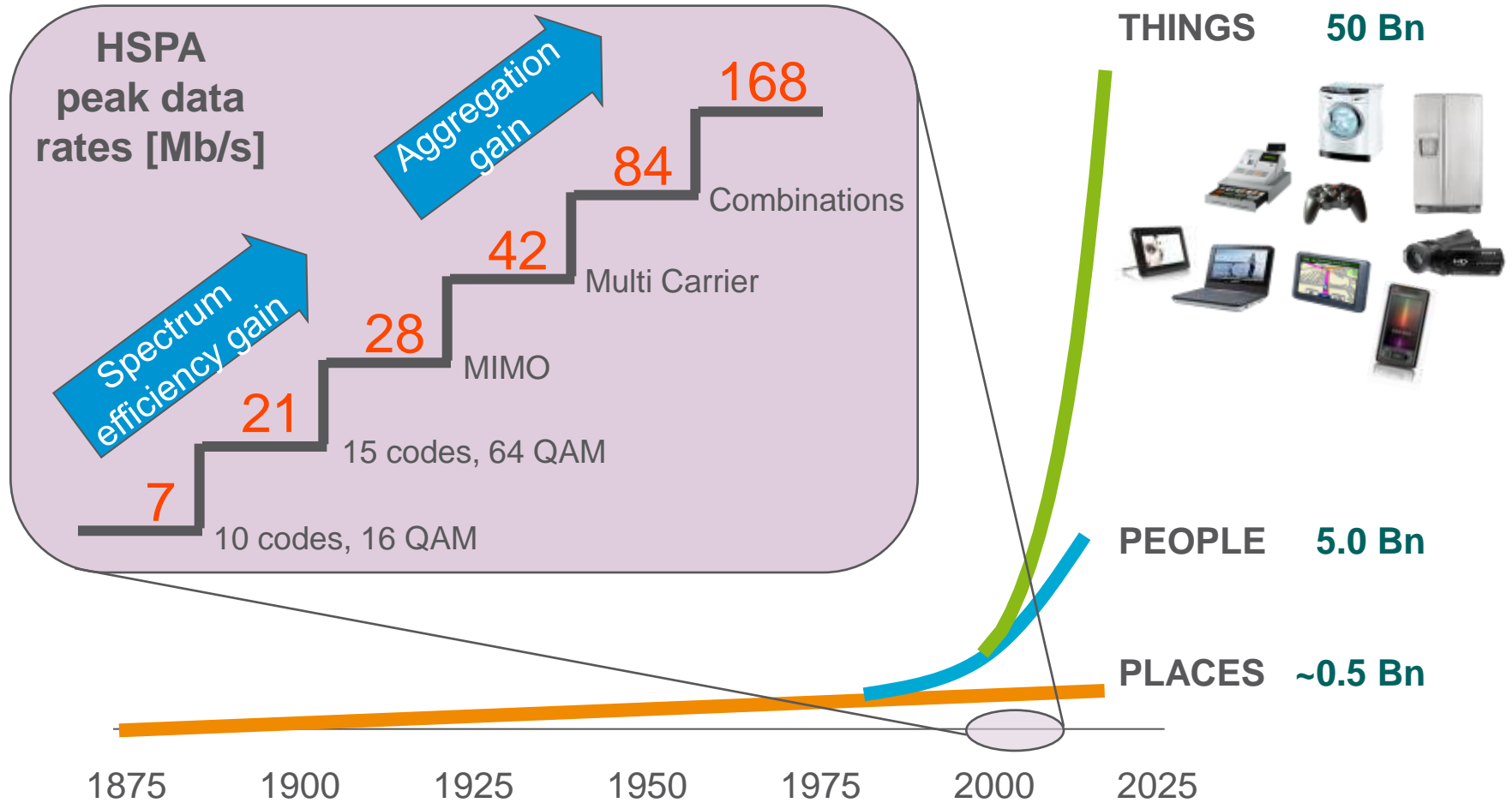
Joachim Sachs, "Mobile Internet Access über GPRS und UMTS," 1st Zukunft der Netze, 1999

- GPRS: 10s – 100s kb/s
- UMTS: 100s kb/s – 1 Mb/s



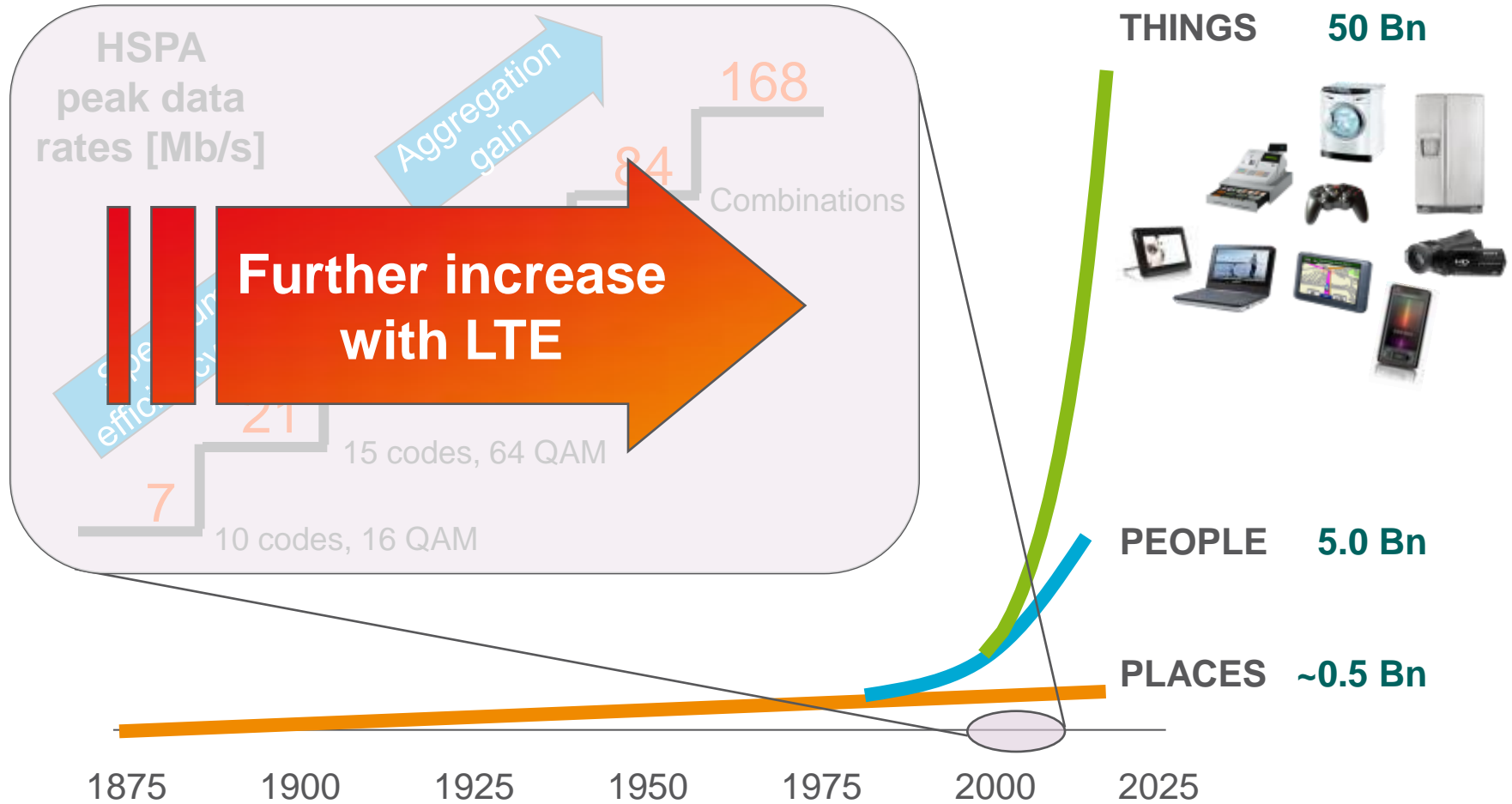
Source: Ericsson

One decade of UMTS/HSPA evolution



Source: Ericsson

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 ...



THINGS 50 Bn



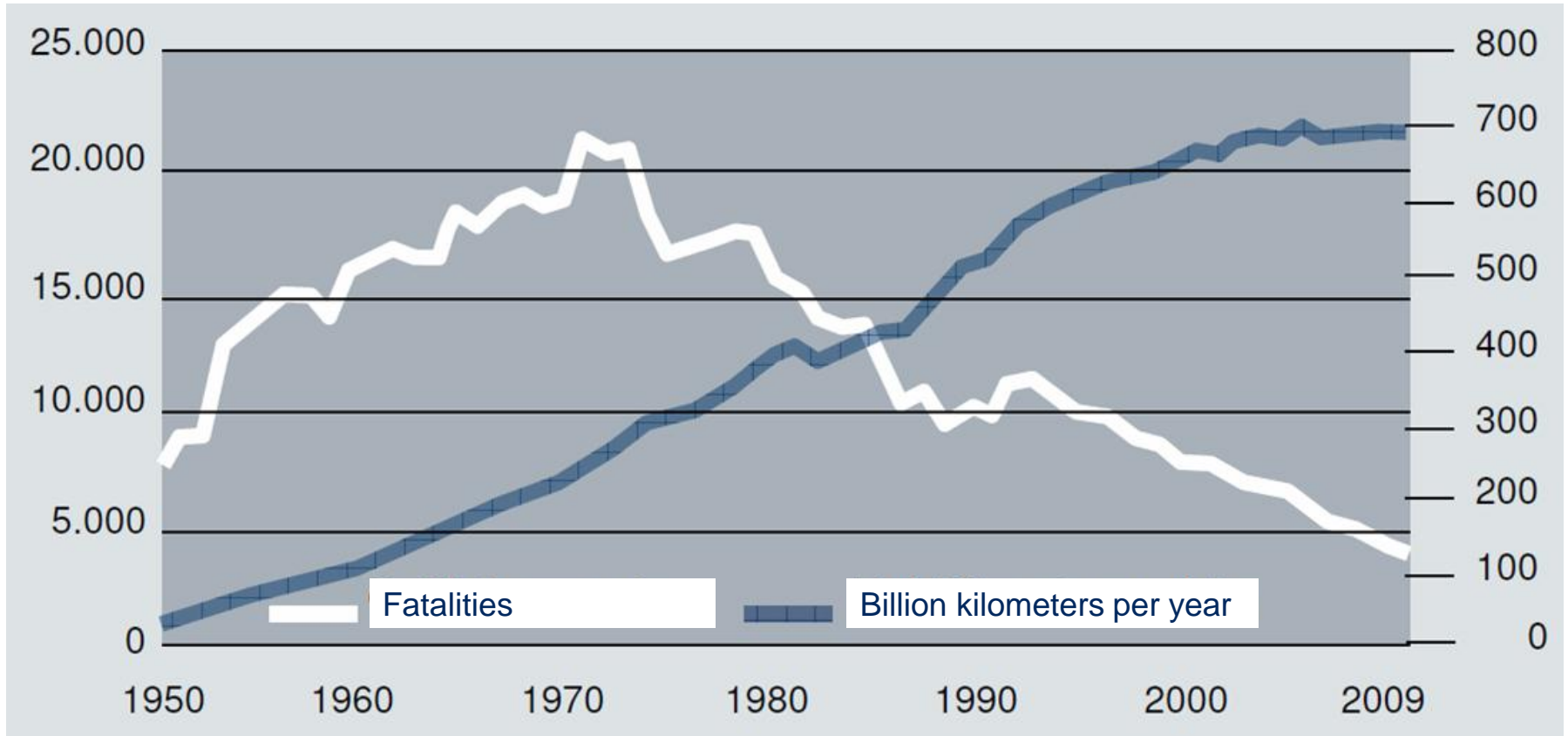
PEOPLE 5.0 Bn

PLACES ~0.5 Bn

1875 1900 1925 1950 1975 2000 2025

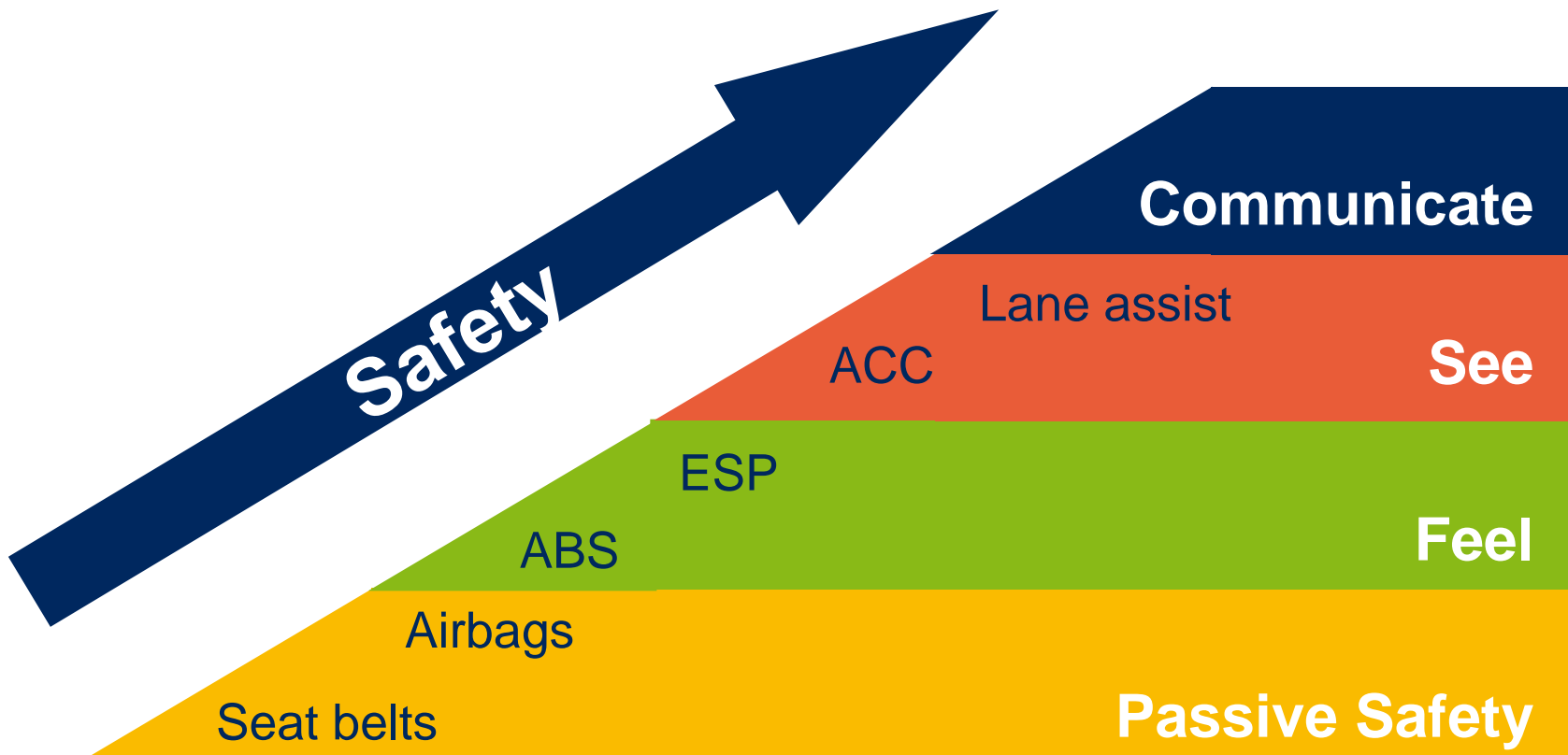
Source: Ericsson

Why should cars communicate?



› Constant decrease despite increasing traffic volumes

Why should cars communicate?



› Next big step in vehicle safety through communication

ETSI Standardization

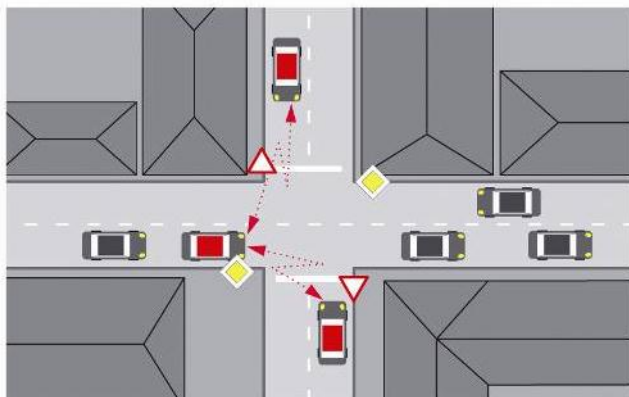
- › C-ITS – Cooperative Intelligent Transport Systems
 - Goals, e.g.:
 - › Improved traffic efficiency
 - › Increased road safety

- › 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	100
Slow Vehicle Indication	2	
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

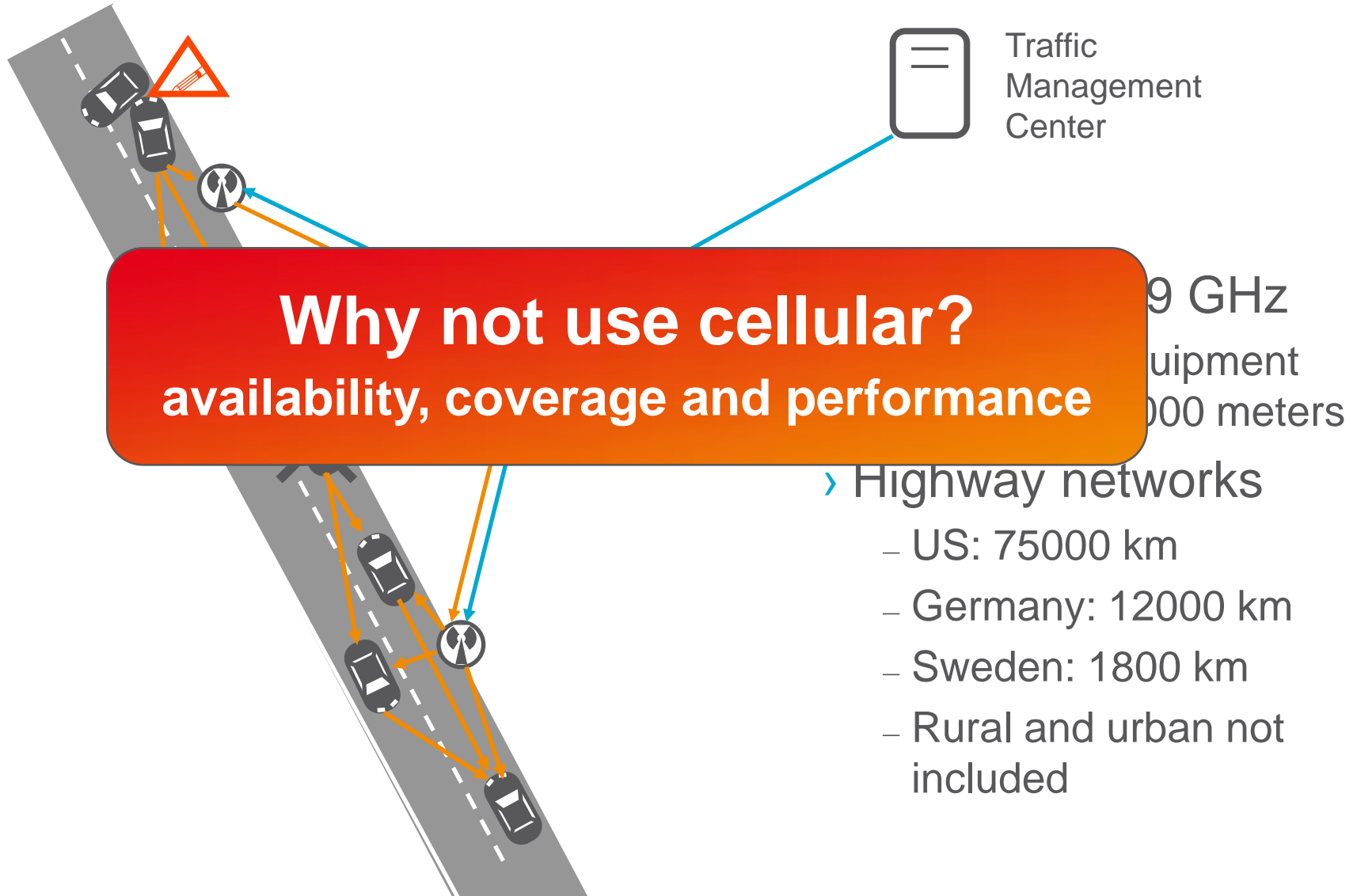
Decentralized Environmental Notification

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
Collision			0.2 - 1 s
Stable road adhesion			< 5
Stable road adhesion			< 5
Tram			< 5
Road			> 1 min
Precipitation			< 5
	snow (activation of windscreen wrappers)	the heavy rain or snow situation	
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)



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



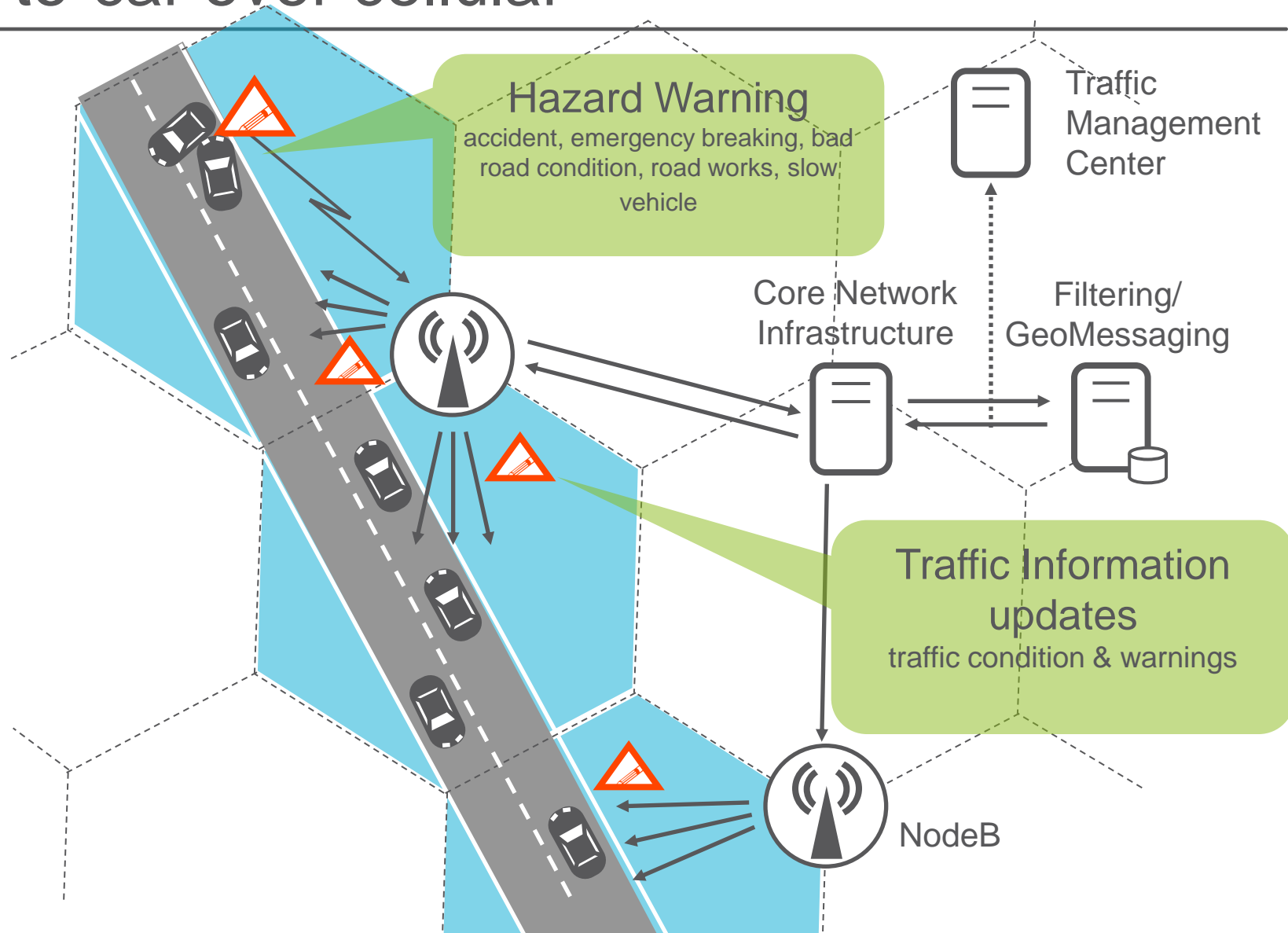
> Cooperative Cars eXtended (CoCarX, 2009-2011)

- LTE, session management, heterogeneous approach

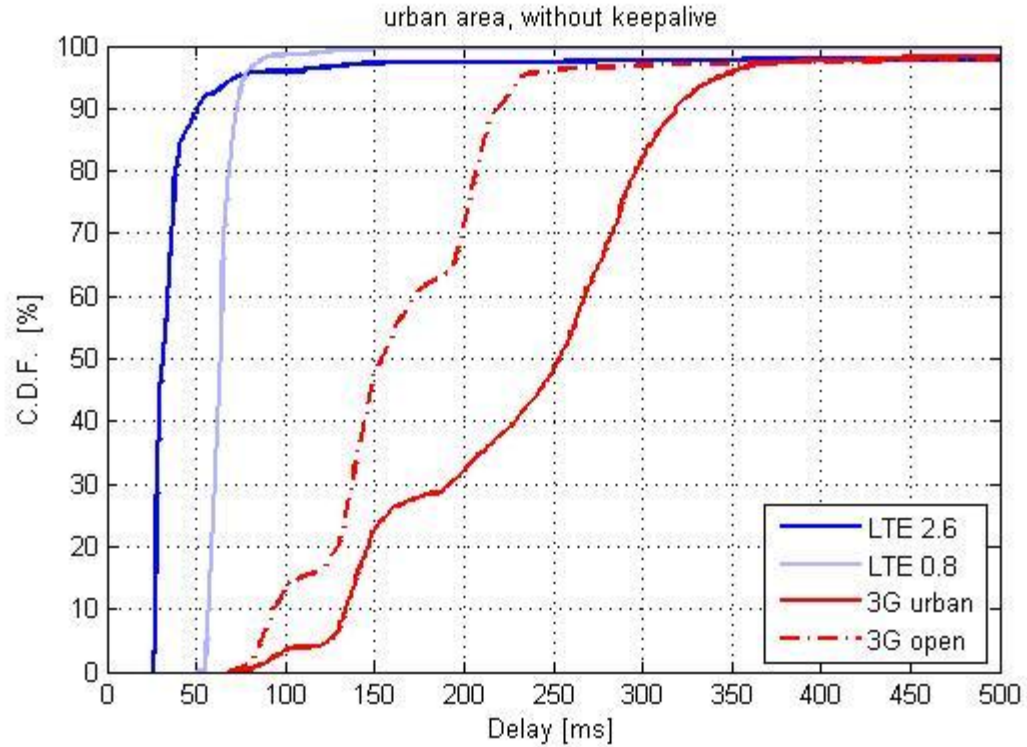
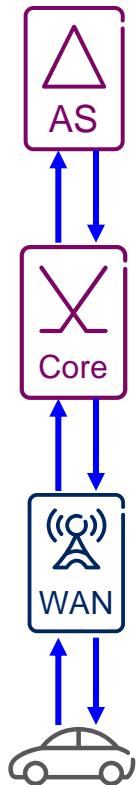


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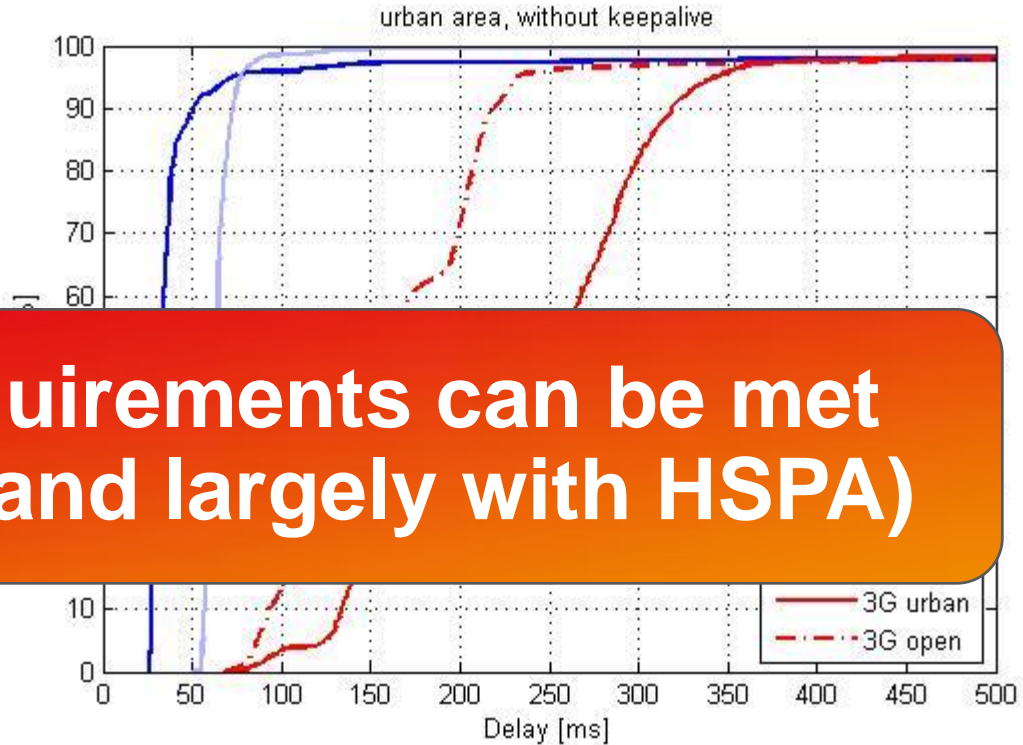
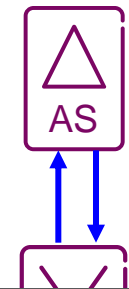
Car-to-car over cellular



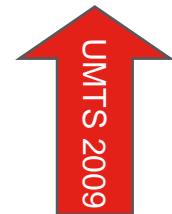
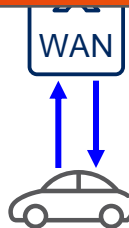
Cellular car-to-car delay



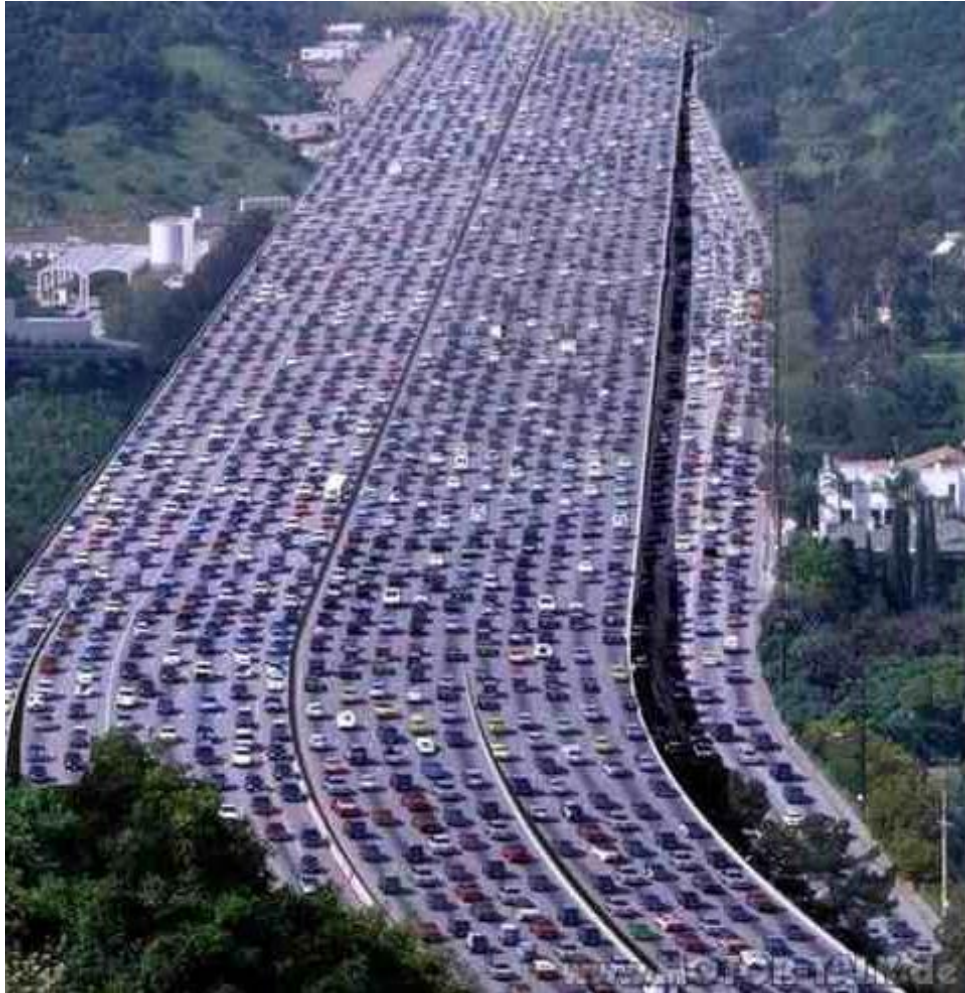
Cellular car-to-car delay



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



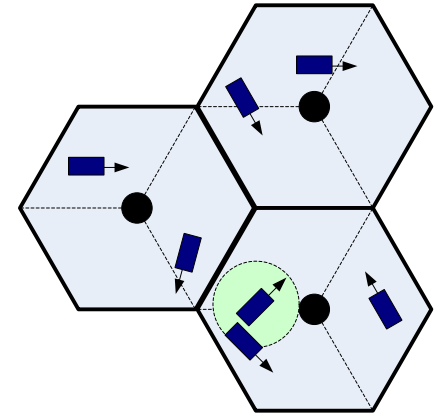
How about system capacity ?



LTE Capacity evaluation

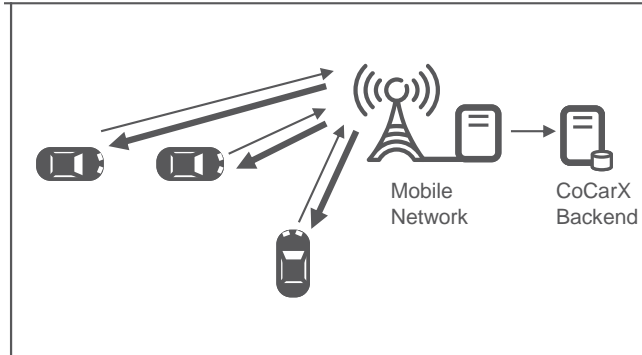
methodology

- › 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

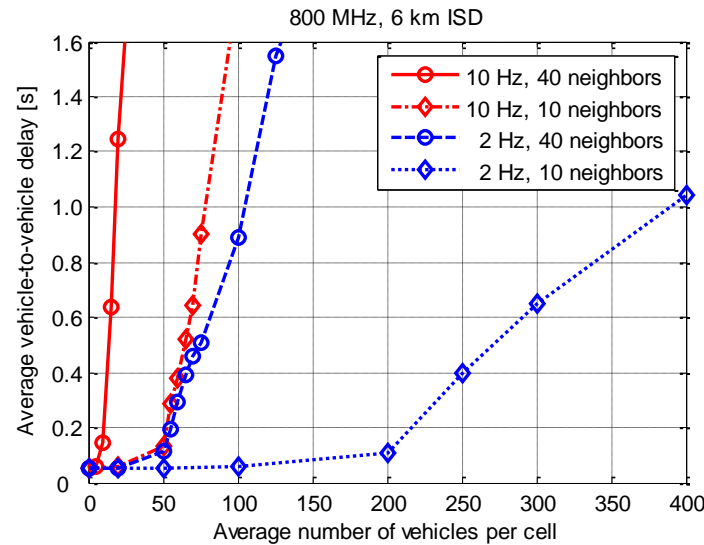
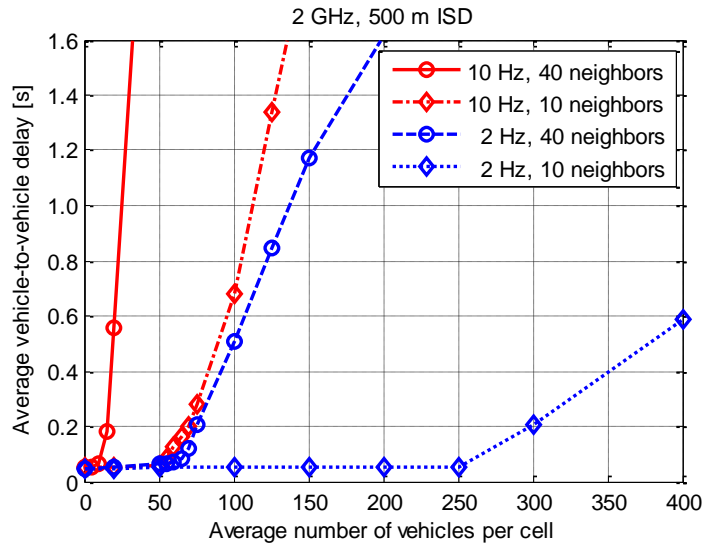
2. Message distribution

- 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

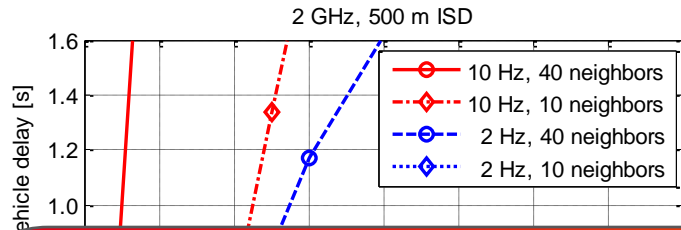


Scenario		$N_{\text{vehicles per cell}}$
UL+DL 10 Hz 40 neighbors	urban	≈ 13
	rural	≈ 9
UL+DL 10 Hz 10 neighbors	urban	≈ 57
	rural	≈ 47
UL+DL 2 Hz 40 neighbors	urban	≈ 67
	rural	≈ 49
UL+DL 2 Hz 10 neighbors	urban	≈ 275
	rural	≈ 199

CAM V2V delay

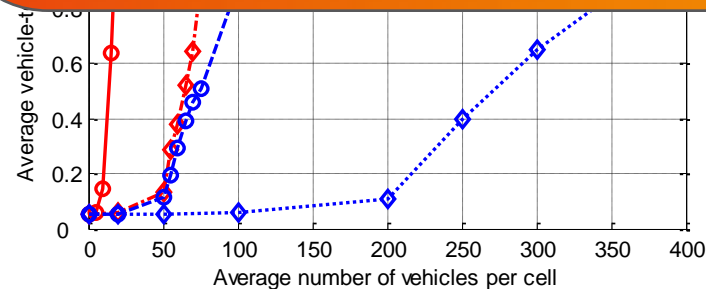
Urban vs. Rural environment

› V2V delays < 100 ms



Downlink capacity quickly reached
(5MHz spectrum)

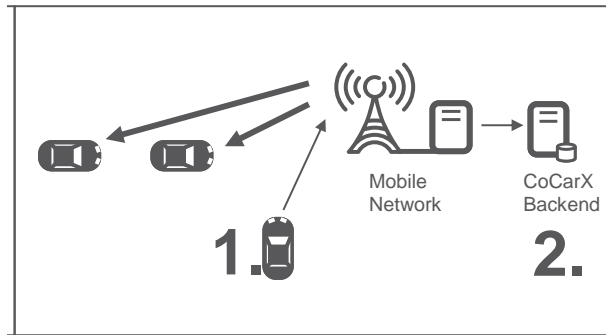
→ reduce transmit frequency
→ reduce # neighbors



Scenario		$N_{\text{vehicles per cell}}$
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

LTE Capacity evaluation

Case 2: Warning messages (DENM)



Communication through network infrastructure and backend



1. Sender behavior

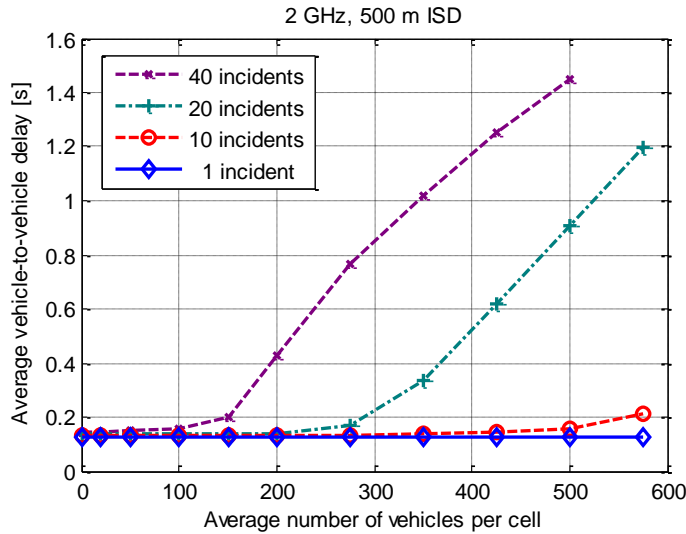
- 1, 10, 20, 40 cars per cell sending DENM with average 1 Hz

2. Message distribution

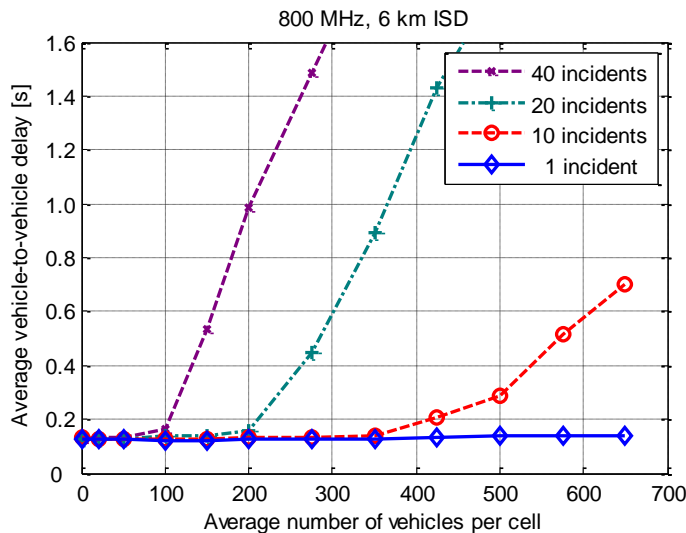
- Simple GeoMessaging abstraction used
- DENM sent to all vehicles in same cell (easy to implement)
- Substantial potential for optimization (e.g. duplicate filtering in backend)

DEN V2V delay

Urban vs. Rural environment



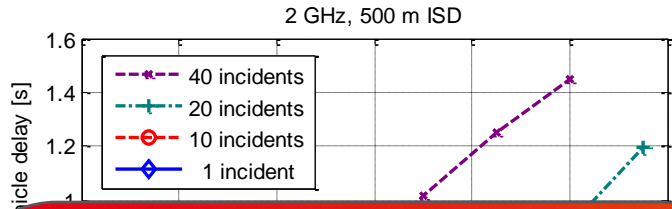
> **V2V delays < 200 ms**



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

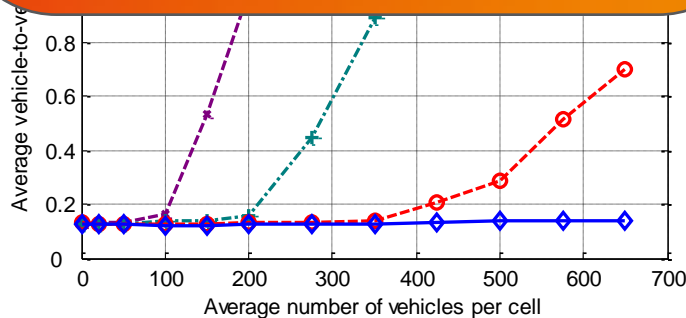
Urban vs. Rural environment



> V2V delays < 200 ms

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

Temporary load



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

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



Traffic information	Cooperative traffic lights	Lane change assistant
Remote Navigation		
Software download	Hazard warnings	Collision avoidance
Remote Diagnostics	Intersection assistant (NLOS)	(LOS)
Infotainment		



References

- › G. Jodlauk, R. Rembarz, Z. Xu: 'An Optimized Grid-Based Geocasting Method for Cellular Mobile Networks', to appear at ITS World Congress 2011, Orlando, Florida, October 2011.
- › M. Phan, R. Rembarz, S. Sories: 'A Capacity Analysis for the Transmission of Event and Cooperative Awareness Messages in LTE Networks', to appear at ITS World Congress 2011, Orlando, Florida, October 2011.
- › D. Westhoff (ed.), "ITS Services and Communication Architecture", Cooperative Cars eXtended (CocarX) project deliverable D3, September 2011.



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