International Telecommunication Union

THE FULLY NETWORKED CAR

Towards a European Solution for Networked Cars

-Integration of Car-to-Car Technology into Cellular Systems for Vehicular Communication in Europe

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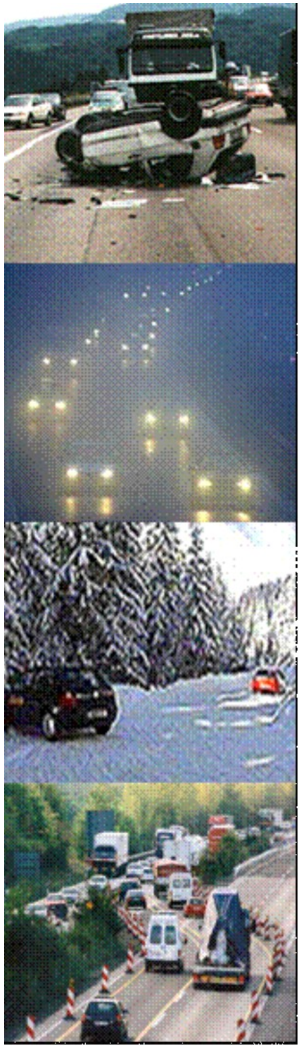
Outline

- Introduction
- Car-to-Car Communication for Safety Services
- Vehicular Communication with Cellular Systems
- C2C vs. Cellular: Competing or Complementary?
- A Hybrid Solution
- Conclusion

Motivation

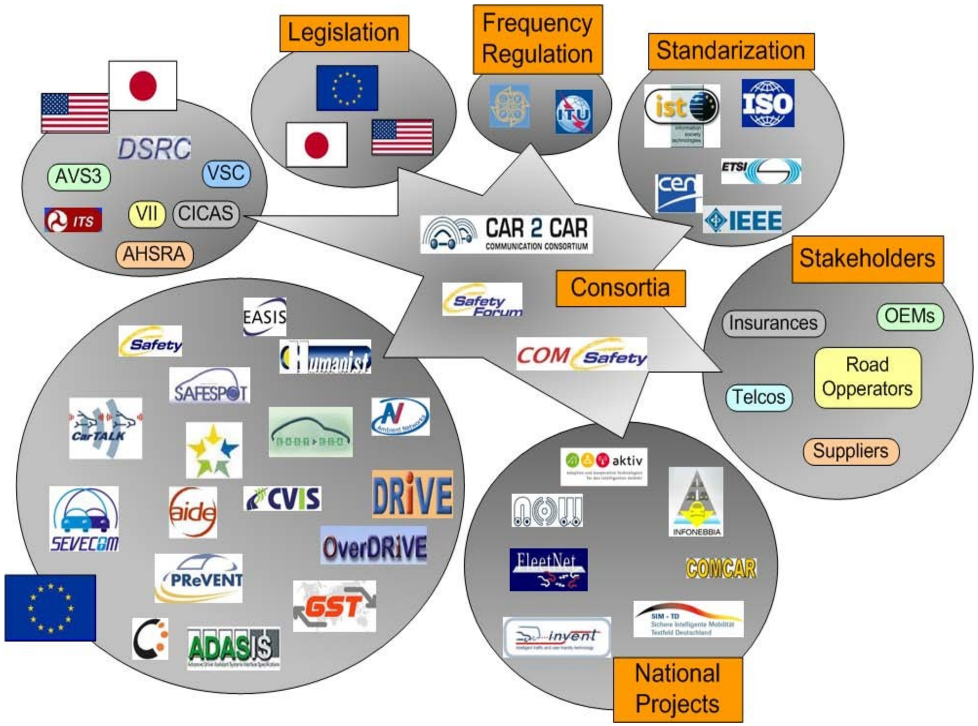
- Automobile accidents in Europe
  - 1,300,000 accidents
  - 40,000 dead persons per year (2005)
  - 1,700,000 casualties
  - 160 bn. € economic damage
- „eSafety“ concept from the European Union
  - Half number of dead persons until 2010
  - Passive safety systems reducing the severity of the accident are not enough
  - Target is only reachable with active safety systems that completely prevent accidents
- Traffic efficiency
- Infotainment services for driving comfort



*Photos from EU PReVENT project

Introduction

- Spectrum regulation worldwide
  - 5.9GHz DSRC
- Standardization efforts
  - EU C2C-CC
  - IEEE WAVE
  - ITU CALM
- Projects
  - EU projects
    - CVIS, PReVENT, eSafety, SEVECOM,
  - German national projects
    - AKTIV, FleetNet, NOW, SIM-TD



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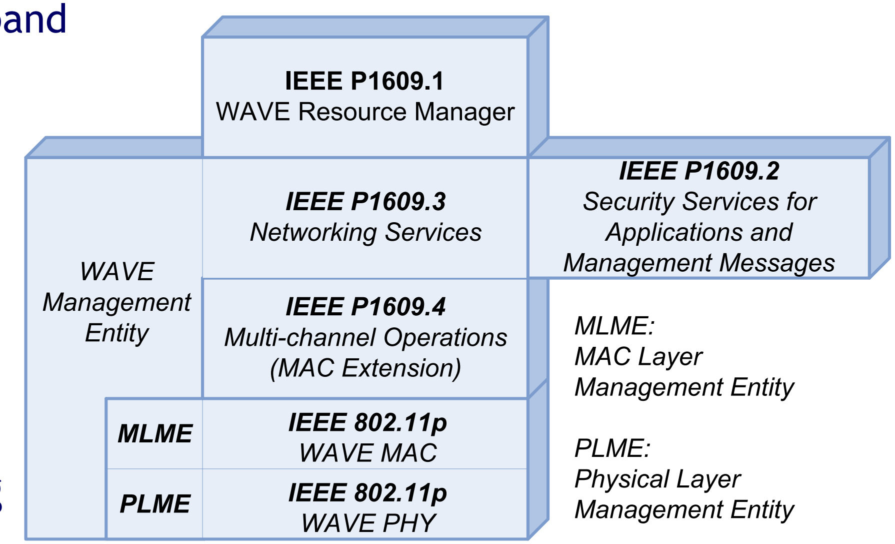
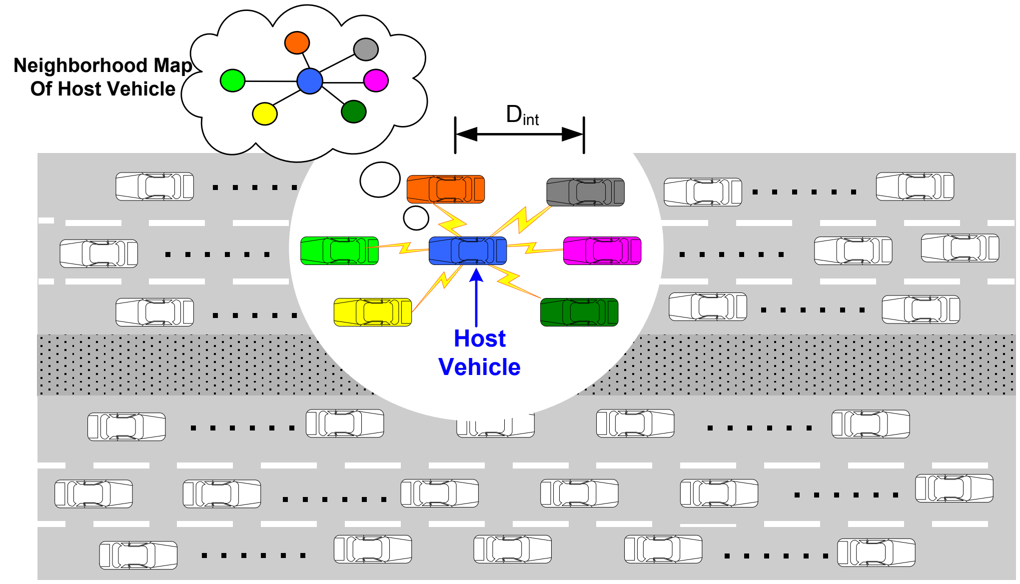
Car-to-Car Communication

- Spectrum for ITS in Europe
  - Aug. 2008
  - 30 MHz at 5.9 GHz (5.875GHz – 5.905GHz)
- Wireless Access in Vehicular Environments (WAVE)
  - Physical layer (PHY)
    - 10MHz channel at 5.9GHz ITS band
    - IEEE 802.11p (802.11a, OFDM)
  - Medium Access Control (MAC)
    - Basic IEEE 802.11 MAC
    - CSMA/CA
    - MAC-X IEEE P1609.4
  - Upper layers
    - IEEE 1609.x
- Services
  - Wireless local danger warning
  - Cooperative danger warning
  - Traffic information dissemination
  - P2P file sharing



Simulation Study of C2C Communication Performance

- Maneuvering assistance
  - Periodical information exchange among neighboring vehicles
  - Information update frequency 10 Hz
- Interested metrics
  - Information Update Interval
  - Channel Busy Time

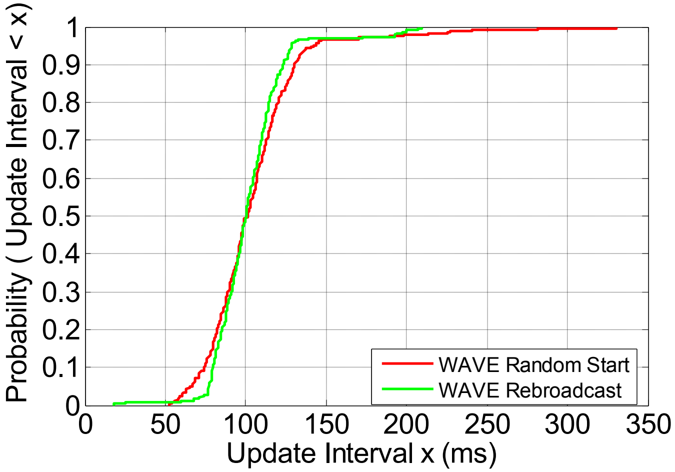


Parameter	*Low Density*	*High Density*
Average Inter-vehicle Distance (D_{int})	80 m	10 m
Average Vehicle Speed	160 km/h	20 km/h
Market Penetration Rate	100%	100 %
PHY Mode	BPSK ½ (3 Mb/s)	BPSK ½ (3Mb/s)
Hazard Warning Packet Size	100 B	100 B
Manoeuvring Message Frequency	10 Hz	10 Hz
Warning Message Priority	VI (AC2)	VI (AC2)
Transmit Power Level	20 dBm	20 dBm

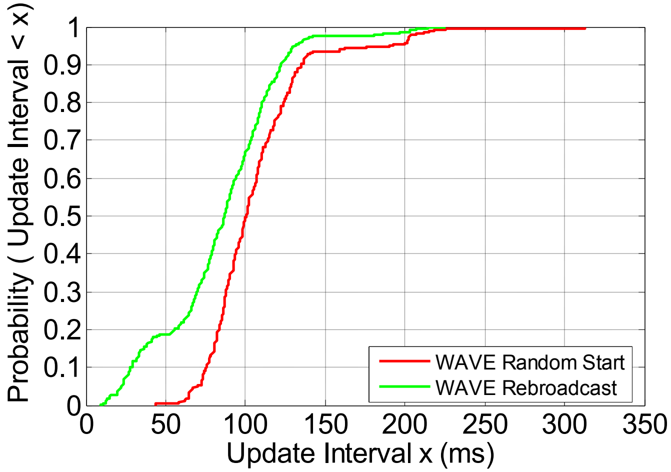
Performance: Maneuvering Assistance

- With 100% penetration rate, WAVE system works well in both low and high density scenarios

Low density scenario



High density scenario

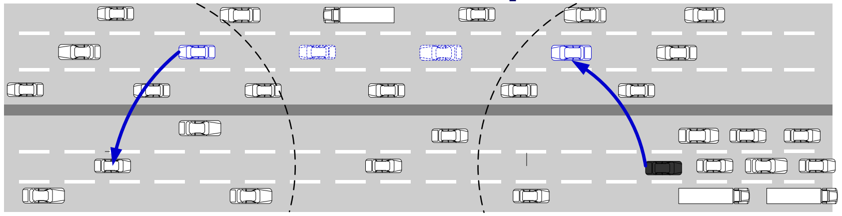


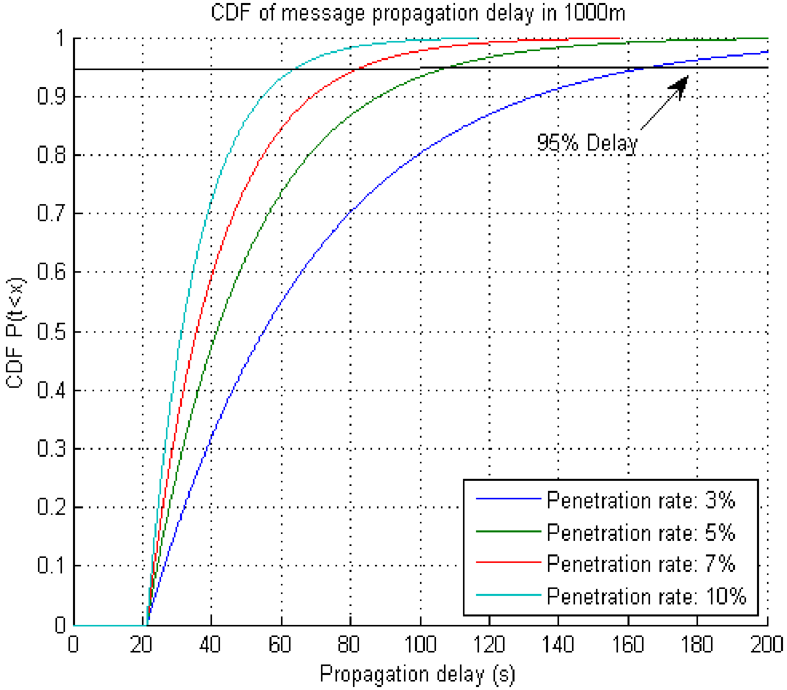
Broadcast Algorithm	*CBL (%)*	*Update Interval*			
		Max (ms)	*Min (ms)*	*Mean (ms)*	*Standard Deviation*
WAVE Random Start	12	330.5	52.2	104.3	31.6542
WAVE Rebroadcast	13	209.8	18.1	102.4	23.2994

Broadcast Algorithm	*CBL (%)*	*Update Interval*			
		Max (ms)	*Min (ms)*	*Mean (ms)*	*Standard Deviation*
WAVE Random Start	35	313.0	53.6	106.5	33.0032
WAVE Rebroadcast	42	225.5	9.4	84.1	36.8479

Performance: Message Propagation with Low Penetration Rate

- With low penetration rate, the vehicular ad-hoc network suffers from fragmented network problem
- Message propagation relies on vehicles on the opposite direction
- The end-to-end delay depends on the network density and market penetration rate



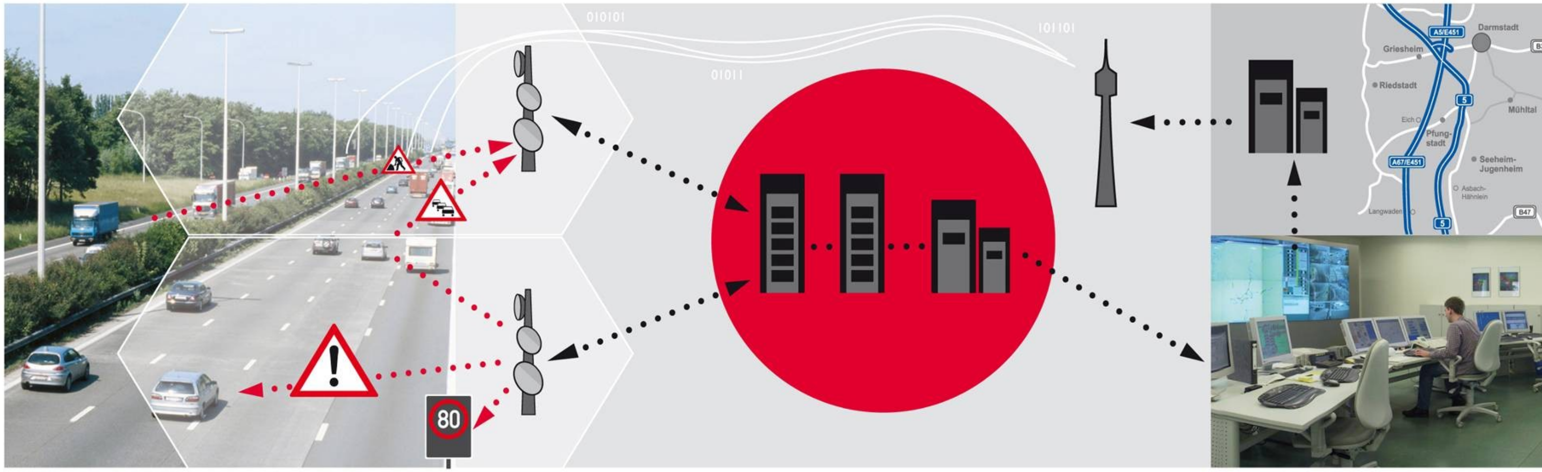


$$P(\tau < t) = 1 - e^{-\lambda_{tr}(2R + v_{tr}t - r_u)}, \quad t > \frac{r_u - 2R}{v_{tr}}$$

Comm. Range: R=250m
Speed: v_{tr}=85km/h
Vehicle density: λ_{tr}=29 Vehicle/km
Distance to go: r_u=1000m

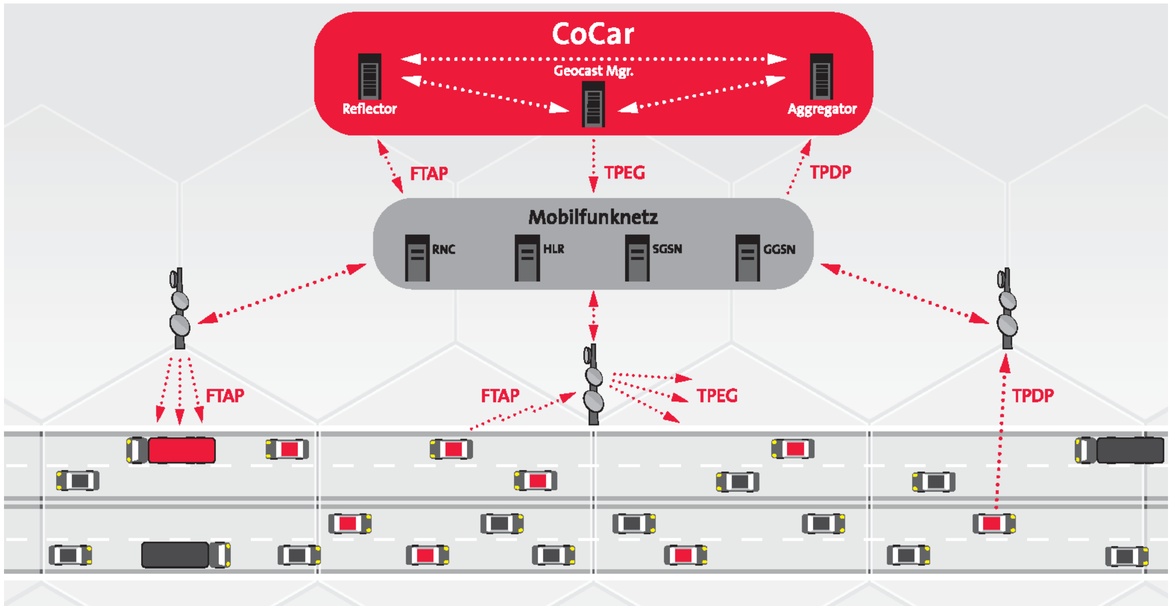
[1] Schoenhof, M., et al, Coupled Vehicle and information flows: Message transport on a dynamic vehicle network, Physica A, Apr., 2006. p73-81

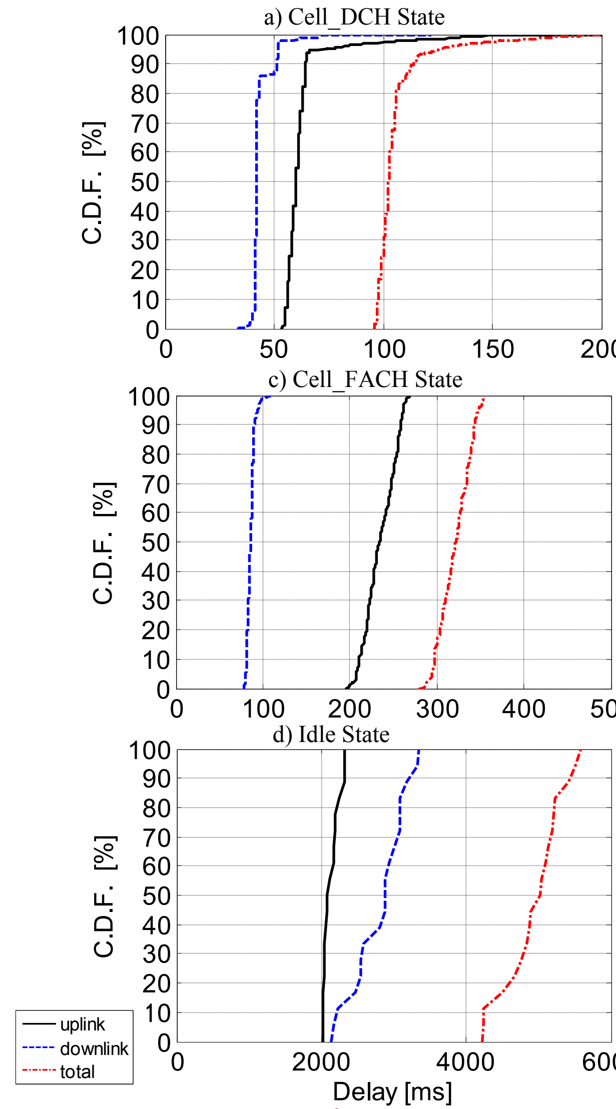
Cooperative Cars – CoCar



- German BMBF funded research project
  - basic research for V2V and V2I communication using cellular mobile communication technologies
  - Consortium
    - Ericsson (project leader), Vodafone, Daimler, MAN, Volkswagen
- Cellular technologies (GPRS, UMTS, HSPA, LTE) (HSPA = HSDPA+HSUPA)
  - Sufficient coverage
  - Increasing data rate and capacity
  - Improved Latency
- Services
  - Safety
  - Infotainment

Performance of Cellular System (UMTS) for Vehicular Applications





- Infrastructure ensures timely message dissemination throughout large areas
- Broadcast enables efficient message dissemination for many-user scenario
- End-to-end delays of below 500 ms can be achieved using in today's UMTS networks, but not guaranteed

*) Results from [2] S. Sories, J. Huschke, M.-A. Phan, *Delay Performance of Vehicular Safety Applications in UMTS*, 15th World Congress on ITS, New York, 2008

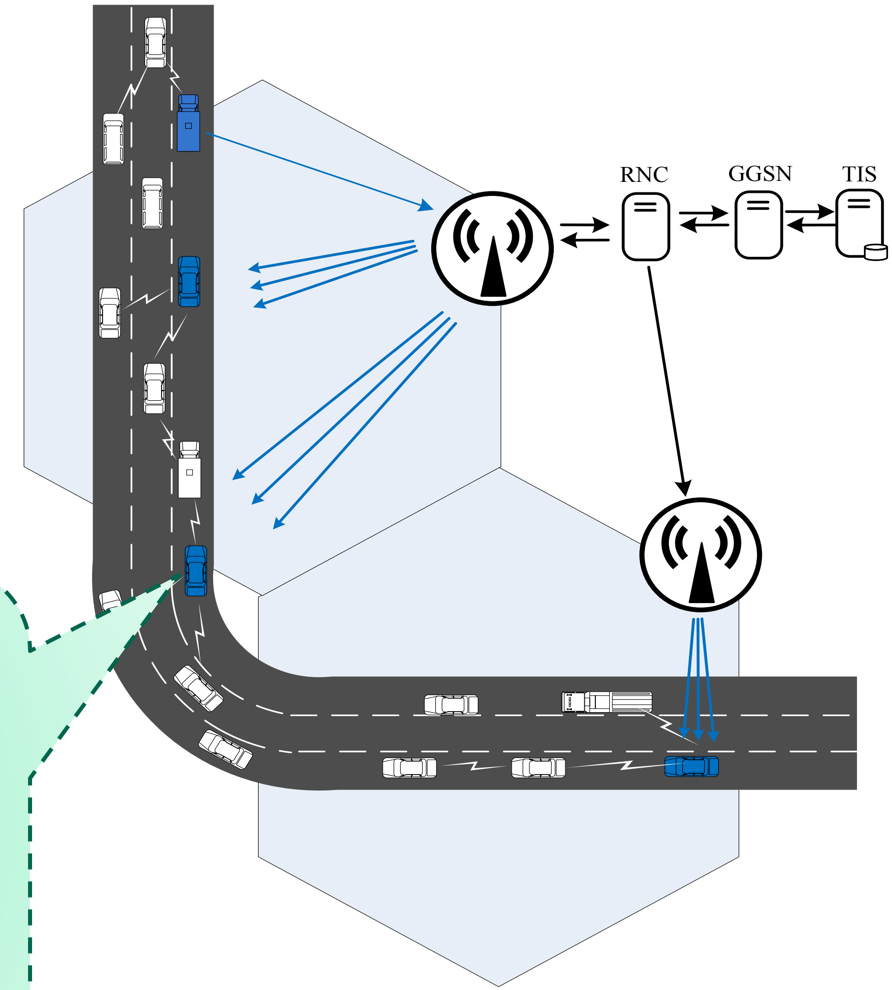
Cellular System vs. C2C

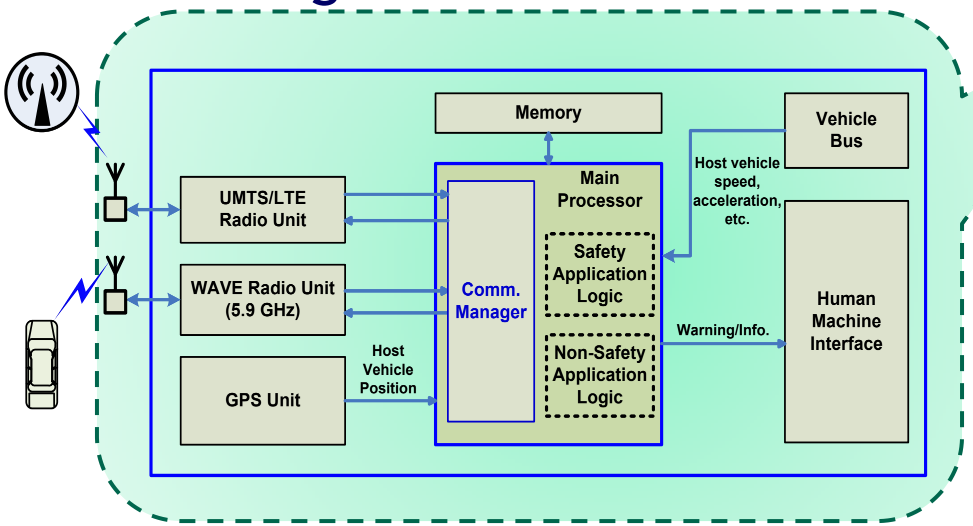
	Cellular (UMTS)	C2C (WAVE)
Network infrastructure	Infrastructure based system	Infrastructure-less system, but some services require infrastructure support
	Infrastructure ready	No infrastructure ready in Europe
Communication range	Network coverage range	Ad-hoc network with single hop distance of 300 m-1 km
System Capacity	Interference limited system with limited resource of each cell	Scalable adaptive ad-hoc network
Processing/network Delay	Minimum end-to-end delay around 100 ms (HSPA) for local hazard warning service, but not guaranteed	Minimum end-to-end delay < 100 ms for local hazard warning guaranteed
	Delay performance of long distance communication is independent of penetration rate	Without supports from roadside infrastructure, the delay performance of long distance communication depends on the penetration rate
Cost	Licensed spectrum	Cost-free spectrum
	Well developed network reduces the cost of developing and maintaining the infrastructure	Huge investment is expected in deploying and maintaining dedicated roadside infrastructure, if there will be any WAVE roadside infrastructure
Security and anonymity	Centralized	Distributed protocol relying on infrastructure

: Pros
: Cons

Hybrid Solution with Cellular and C2C

- Shared application module
- Parallel WLAN and cellular communication modules
- Infrastructure support from cellular system
- Time critical applications through C2C





Conclusion

- Car2Car:
  - With high penetration rate, Car2Car system works well
  - With low penetration rate, VANET suffers from fragmented network problem
- Cellular:
  - Infrastructure ensures timely message dissemination throughout large areas
  - Infrastructure already in place
  - Weak on very time critical safety applications
- The hybrid solution combines benefits of both technologies

Thanks for your attention!

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