LTE and IEEE802.p for vehicular networking: a performance evaluation

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Outline

- Introduction
- Related Work
- Vehicular network with IEEE 802.11p and LTE
- Vehicular networking applications and requirements
- Performance evaluation
- Discussion
- Conclusion

Introduction

- Reliable and low-latency communication
- Select the most appropriate technology
- Know the strengths and weakness of each technology

Comparison of 802.11p and LTE

- How do different networking parameters such as beaconing frequency, vehicle density, and vehicle average speed affect the performance of IEEE 802.11p and LTE?
- For what settings of parameter values that the performance of IEEE 802.11p and LTE degrades against a set of vehicular networking application requirements?
- Does the performance in terms of delay, reliability, scalability, and mobility support degrade significantly or trivially with the change in different parameter values?
- What types of applications would be supported by IEEE 802.11p and LTE?

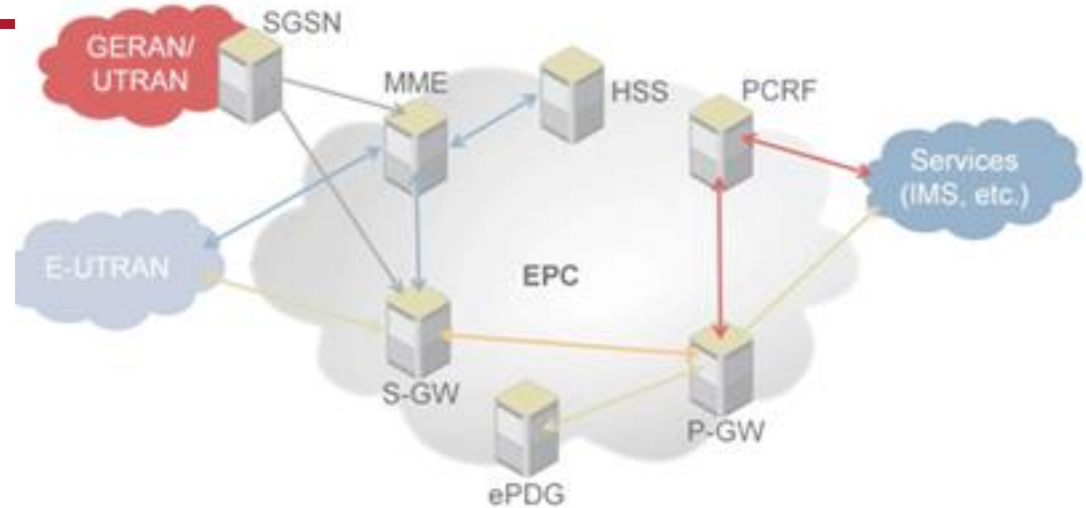
Related Work

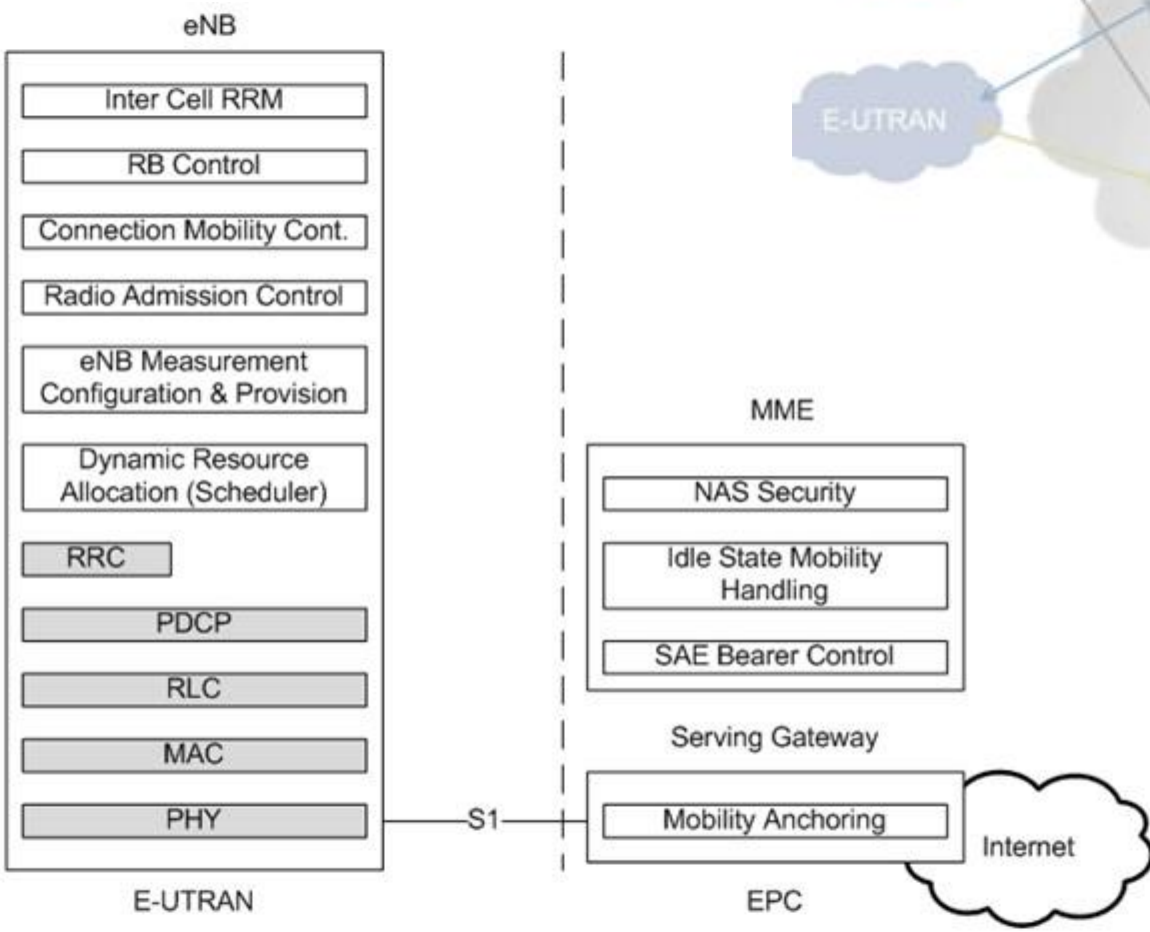
- Describe references that describe the technologies used for vehicular network
- Examples are WiMax, 3G, Bluetooth, Wave

Vehicular network with IEEE 802.11p and LTE

- Describe the WAVE technologies.
  - OBUs – Onboard unit
  - RSU – roadside unit
- Describe the elements of LTE
  - Next slide

Lte Architecture





Simulation Scenario

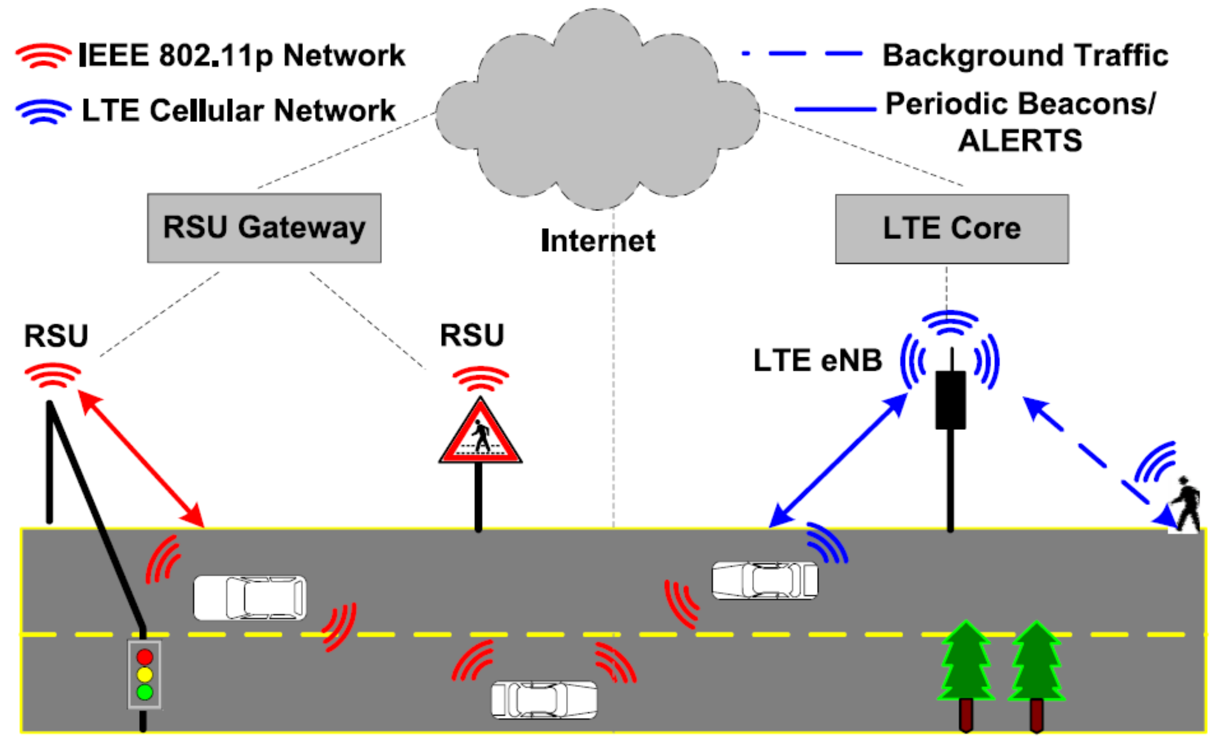


Figure 1 Vehicular networking scenario using IEEE 802.11p and LTE.

Vehicular networking applications and requirements

- Active Road Safety Applications
  - Lower latency < 100ms
  - Short to long coverage (300m to 20 km)
  - Minimum transmission frequency 10 Hz (10 beacons per second)
  - Low to medium data rate (1 to 10Kbps)
- Cooperative traffic efficiency
  - Medium latency < 200 ms
  - Short to medium distance (300m to 5 km)
  - Message to 1 to 10 Hz
  - Low to medium data rate (1 to 10Kbps)
- Infotainment

Performance evaluation

- Performance comparison using ns-3
- End-to-end delay
  - computed as the sum of all mean delays for each vehicle, normalized over the total number of flows in the network, where mean delay is defined as the ratio between the sums of all delays and the total number of received packets.
- Packet delivery ratio (PDR)
  - computed as the ratio between the number of received packets and the transmitted packets during the simulation time.
- Throughput
  - defined as the sum of received data frame bytes at the destinations, averaged over the total number flows in the network.

Simulation Environment

- 5x5 Manhattan grid with 25 block
- Six vertical and six horizontal two-lane roads
- Vehicles routes and movement generate in SUMO
- Number of vehicle
  - Varies from 25 to 150
  - steps of 25
- Average speed
  - from 20 to 100 km/h
  - Increment of 20 km/h

Simulation Environment

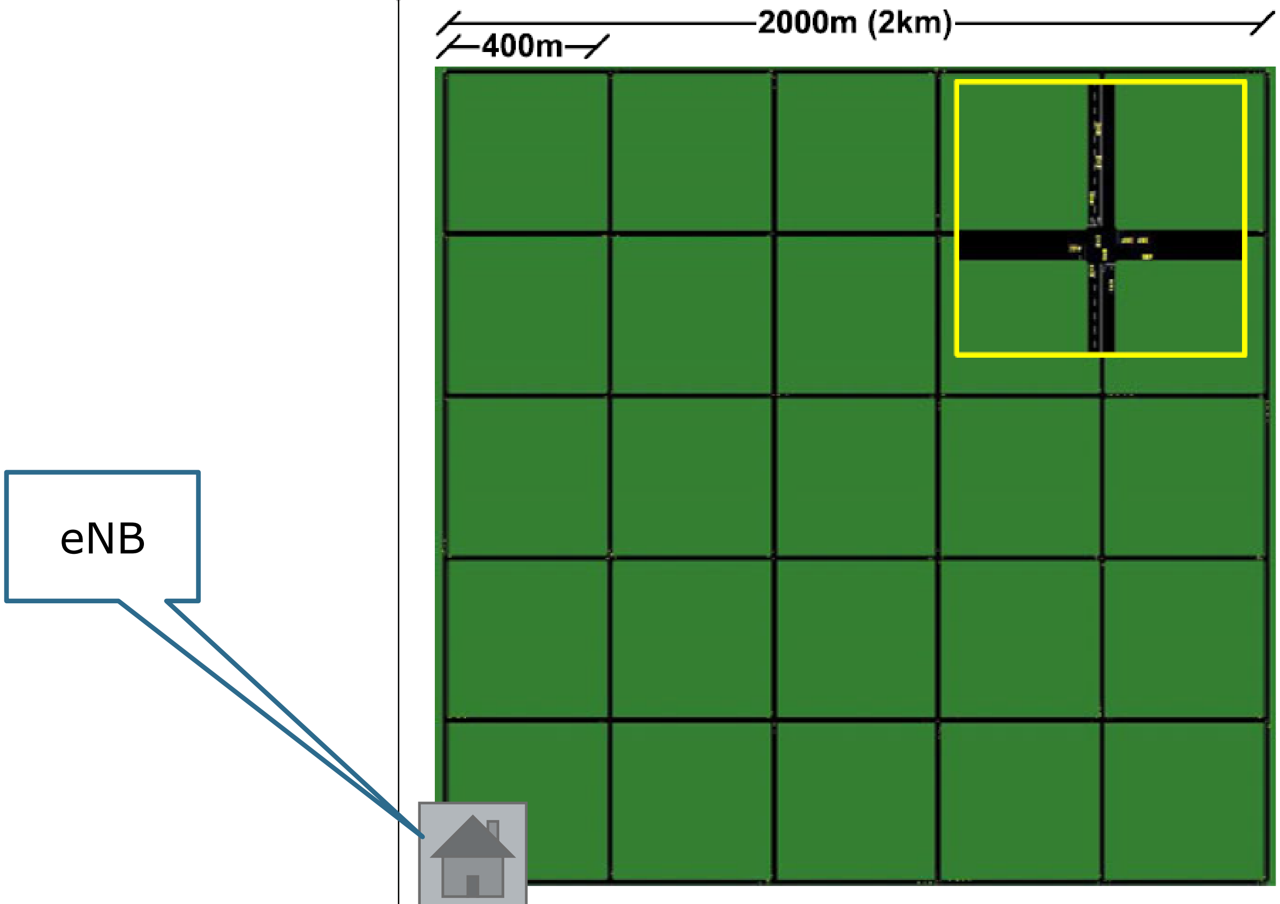


Figure 2 Road network, 5 × 5 Manhattan grid.

802.11p simulation parameter

- Communication range 250 m
- EnergyDetectionThreshold
  - Set to -83 dBm
  - If the received power of a signal is above that threshold then the packet can be decoded (probably successfully)
- CCAModelThreshold
  - set −86 dBm
  - threshold when the node senses the wireless channel.

802.11p simulation parameter

- Nakagami fading channel
  - 5.8 GHZ central frequency
  - Data rate 6 Mbps
- Transmit 256 bytes beacons
  - UDP based
- Single hop broadcast without using RSU

Lte parameters

- Single LTE cell
- Frequency Information
  - Downlink band 2110 MHz
  - Uplink band 1710 Mhz
  - Each bandwidth of 10Mhz
- Transmission power
  - eNB 40 dBm
  - Vehicle 20 dBm
- Omni direction antenna
- Single input single output

Lte parameters

- Traffic profile of background traffic
  - Video bit rate 44 kbps
  - Packet Size 1203 bytes
  - Exponential distribution with arrival rate of 1
  - Duration is until the end of the simulation

Simulation parameters table

Table 1 Simulation parameters and values

Simulation parameters	Values	
Number of vehicles (periodic vehicular traffic)	25, 50, 75, 100, 125, 150	
Vehicle average speed	20, 40, 60, 80, 100 km/h	
Beacon transmission frequency	1, 4, 8, 10, 20 Hz	
Antenna type	Isotropic/omnidirectional	
Simulation area	2,000 m × 2,000 m (2 km × 2 km)	
Simulation duration	100 s	
Number of vehicles (background traffic)	25	
Vehicular traffic (packet size)	256 B	
Background traffic (packet size)	1,203 B	
Background traffic (data rate)	440 kbps	
	IEEE 802.11p	LTE
Frequency	5.8 GHz	DL-2,110 MHz UL-1,710 MHz
Channel bandwidth	10 MHz	10 MHz
Transmission power	25 dBm	eNB (40 dBm)/UE (20 dBm)
Propagation loss model	Three log distance Nakagami fading	Friis
Data rate/RB allocation	6 Mbps	DL (50)/UL (50)

For all the other parameters, we used default values in ns-3 (3.17) network simulator.

Simulations Results

Impact of varying beacon transmission frequency

Information common to both graph and parameters

- Results from 802.11p
- Results from LTE

End to End Delay 20Km/h

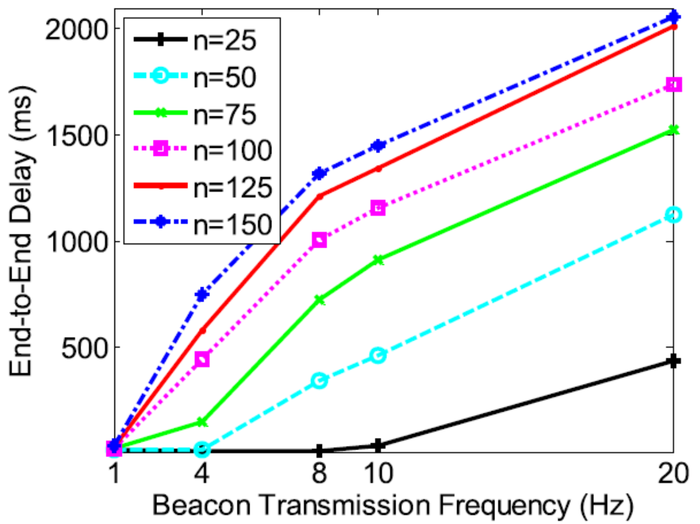
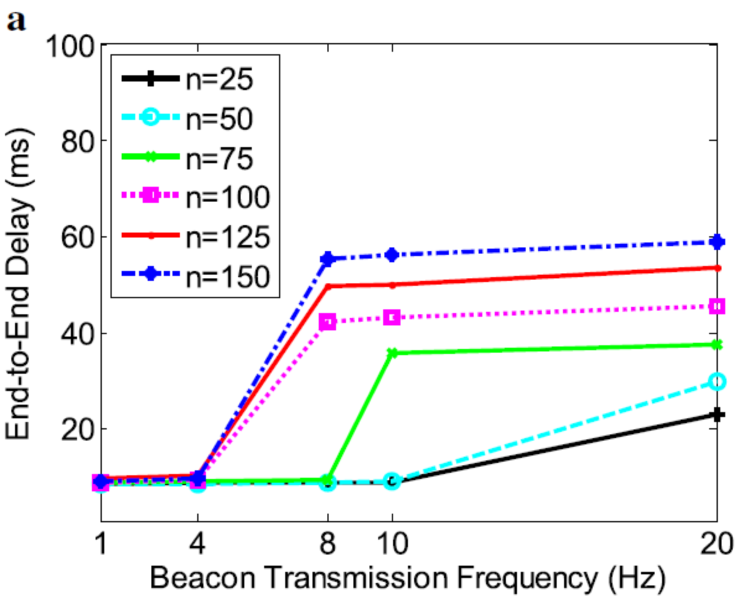


Figure 3 End-to-end delay (ms) vs. beacon transmission frequency (Hz), IEEE 802.11p-based vehicular network.



Packet Delivery Rate 20 km/h

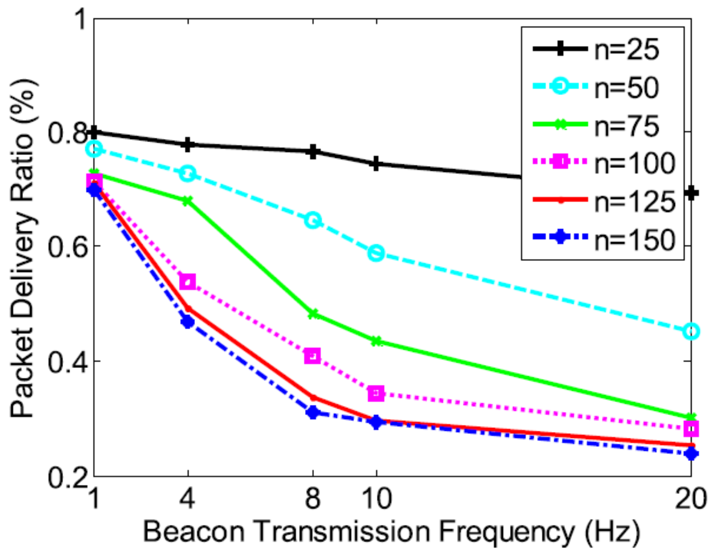


Figure 5 Packet delivery ratio (%) vs. beacon transmission frequency (Hz), IEEE 802.11p-based vehicular network.

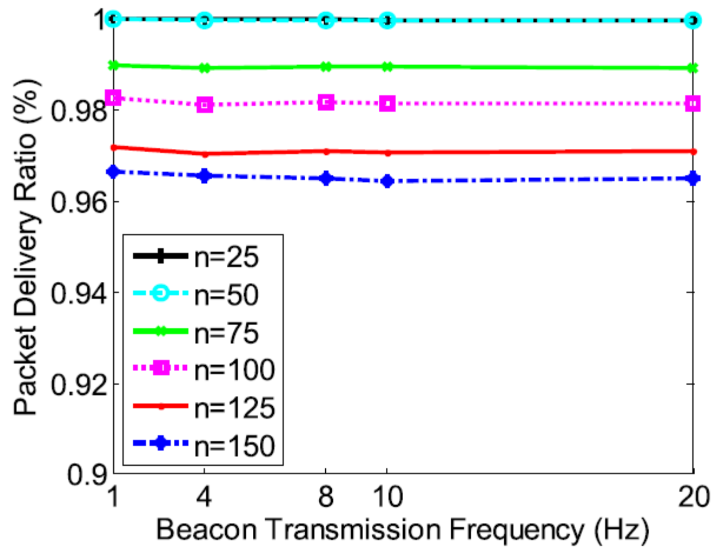


Figure 9 Packet delivery ratio (%) vs. beacon transmission frequency (Hz), LTE-based vehicular network.

Throughput 20 km/h

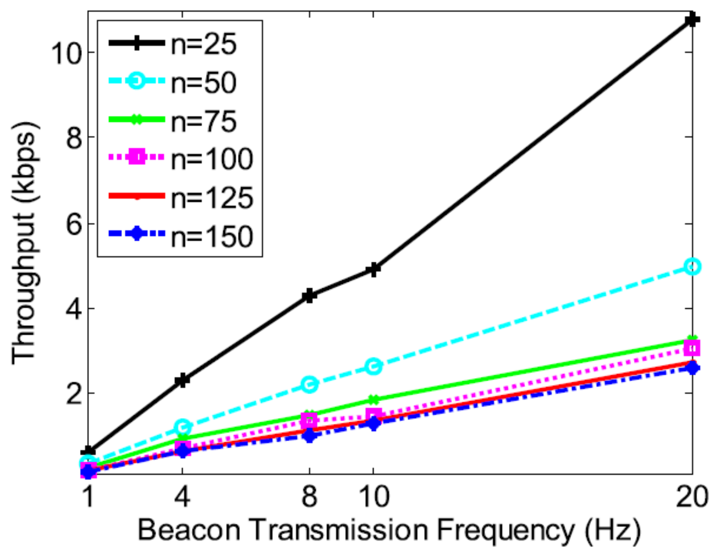


Figure 7 Throughput (kbps) vs. beacon transmission frequency (Hz), IEEE 802.11p-based vehicular network.

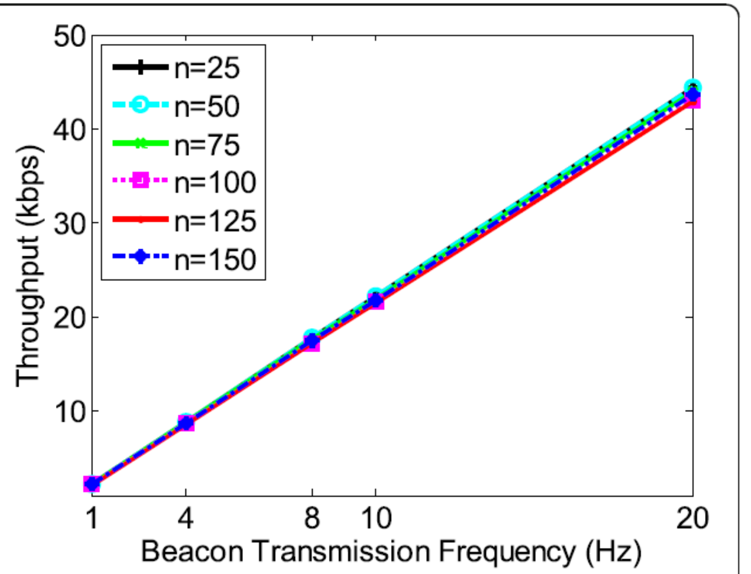


Figure 10 Throughput (kbps) vs. beacon transmission frequency (Hz), LTE-based vehicular network.

Simulations Results

Impact of varying car speed

Information common to both graph and parameters

- Results from 802.11p
- Results from LTE

End to End Delay
Packet Rate 10 Hz

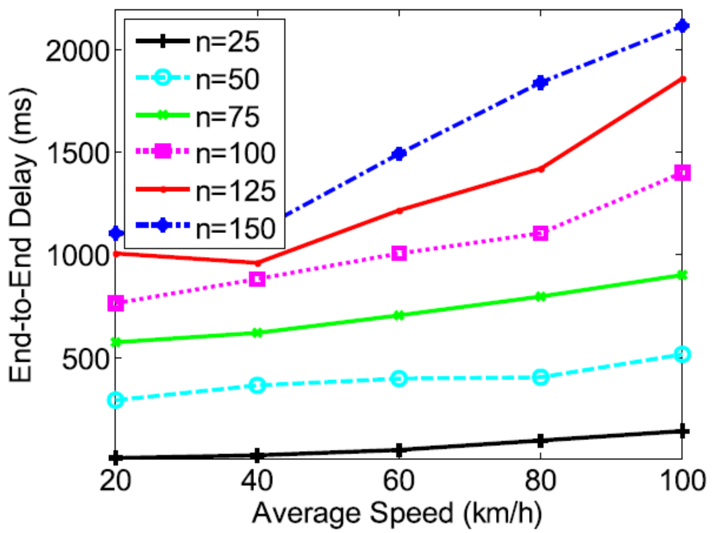


Figure 11 End-to-end delay (ms) vs. average speed (km/h), IEEE 802.11p-based vehicular network.

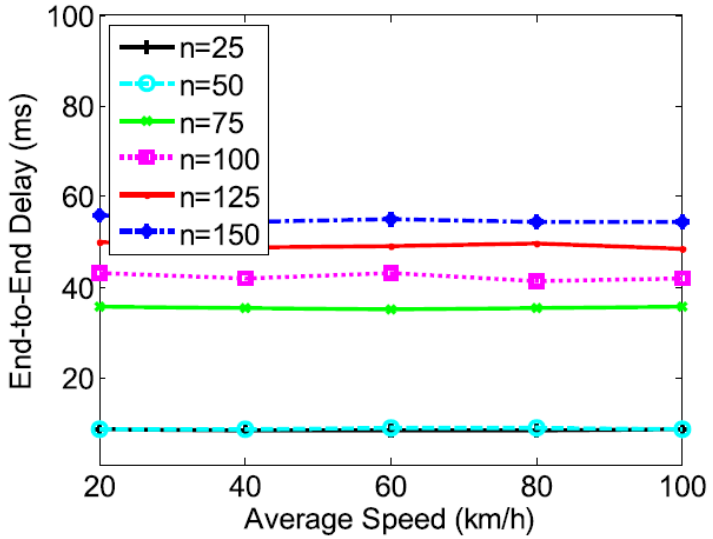


Figure 16 End-to-end delay (ms) vs. average speed (km/h), LTE-based vehicular network.

Packet Delivery Rate
Packet Rate 10 Hz

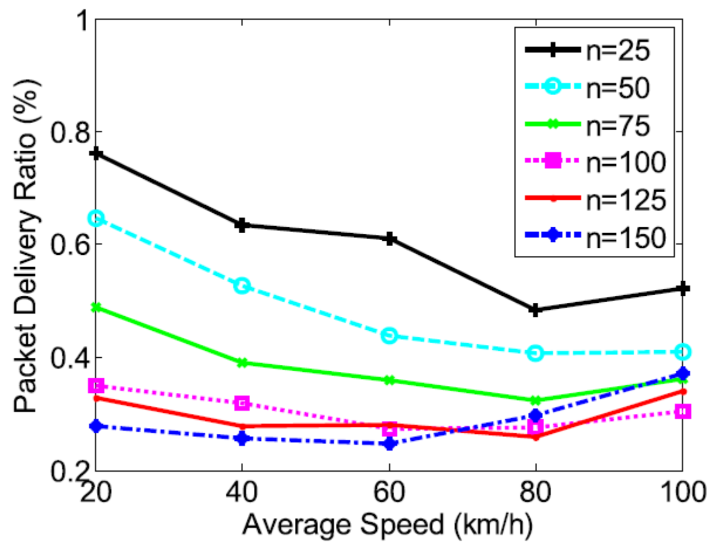


Figure 13 Packet delivery ratio (%) vs. average speed (km/h), IEEE 802.11p-based vehicular network.

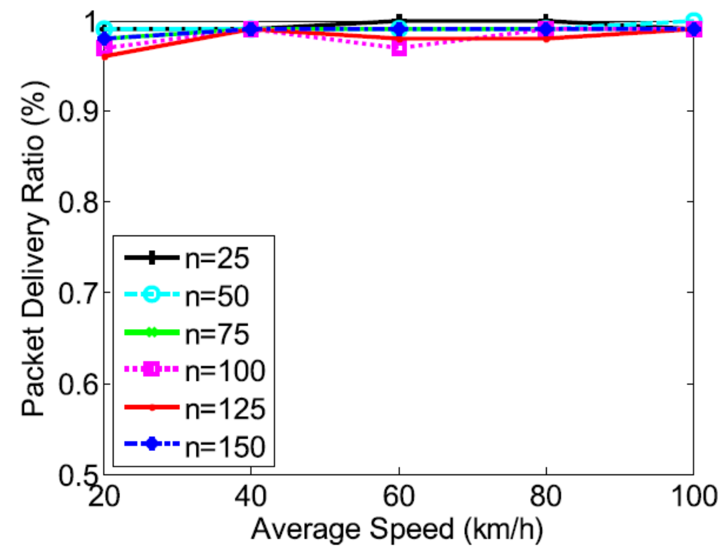


Figure 17 Packet delivery ratio (%) vs. average speed (km/h), LTE-based vehicular network.

Throughput
Packet Rate 10 Hz

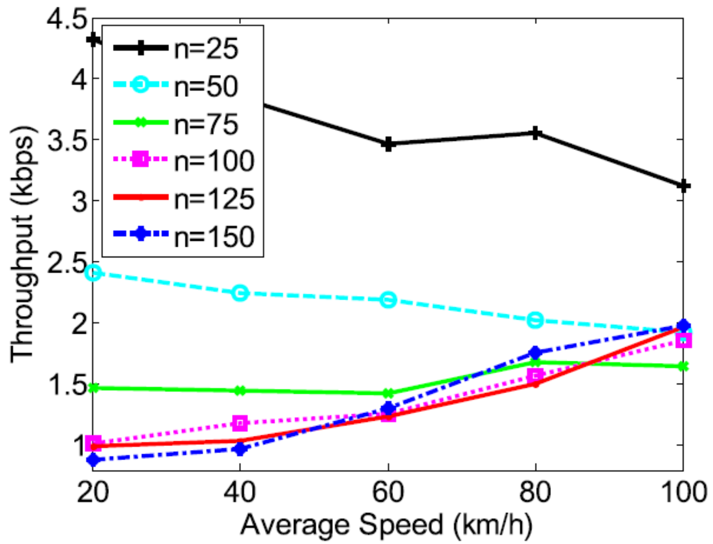


Figure 15 Throughput (kbps) vs. average speed (km/h), IEEE 802.11p-based vehicular network.

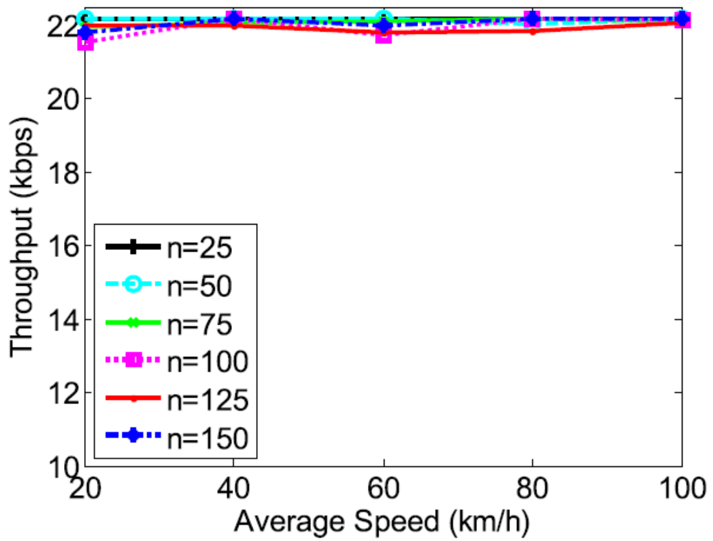


Figure 18 Throughput (kbps) vs. average speed (km/h), LTE-based vehicular network.

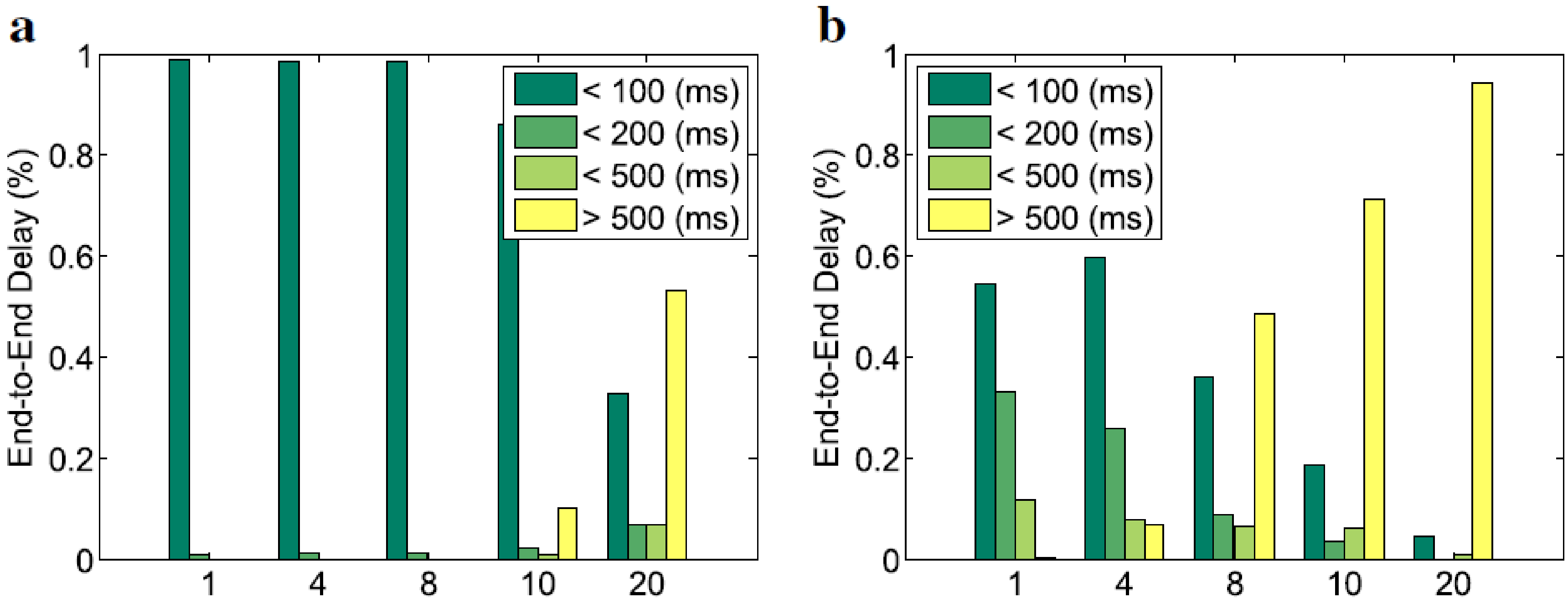
Results of 802.11p

Results without direct comparison with LTE

End to End Delay 20 km/h 802.11p only

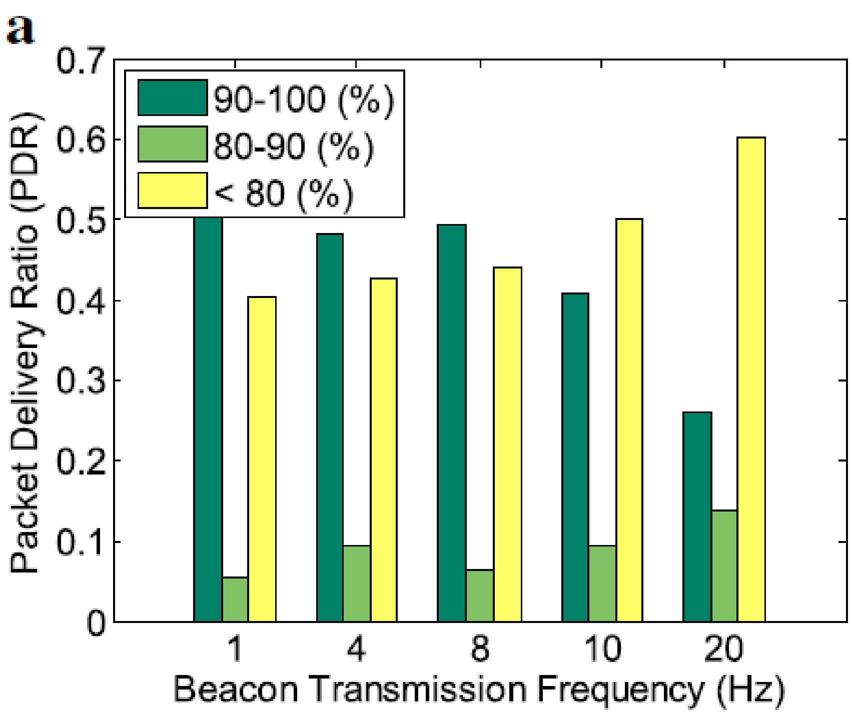
25 vehicles

50 vehicles

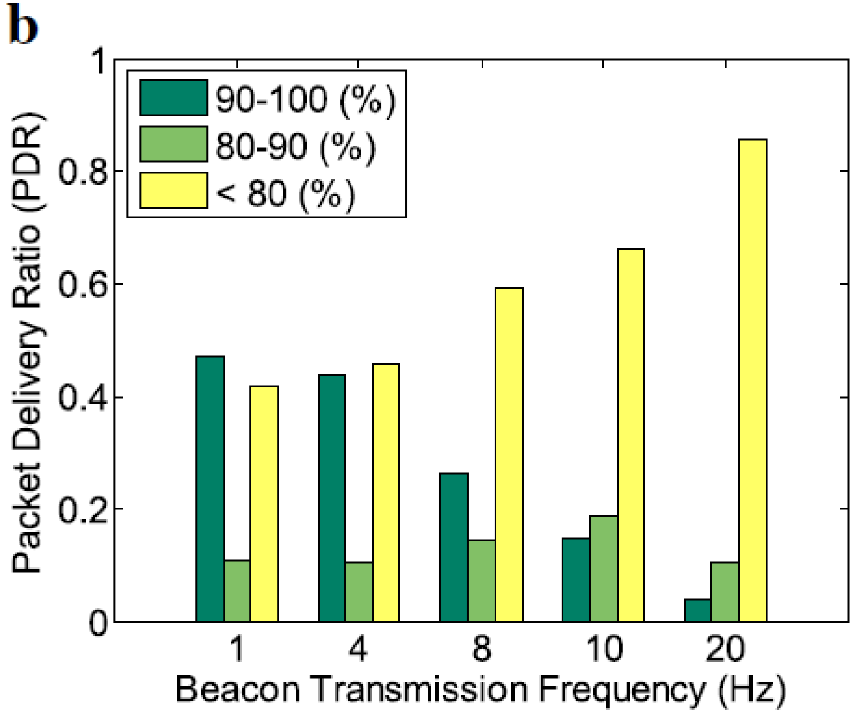


Packet Delivery Ratio 20 km/h 802.11p only

25 vehicles



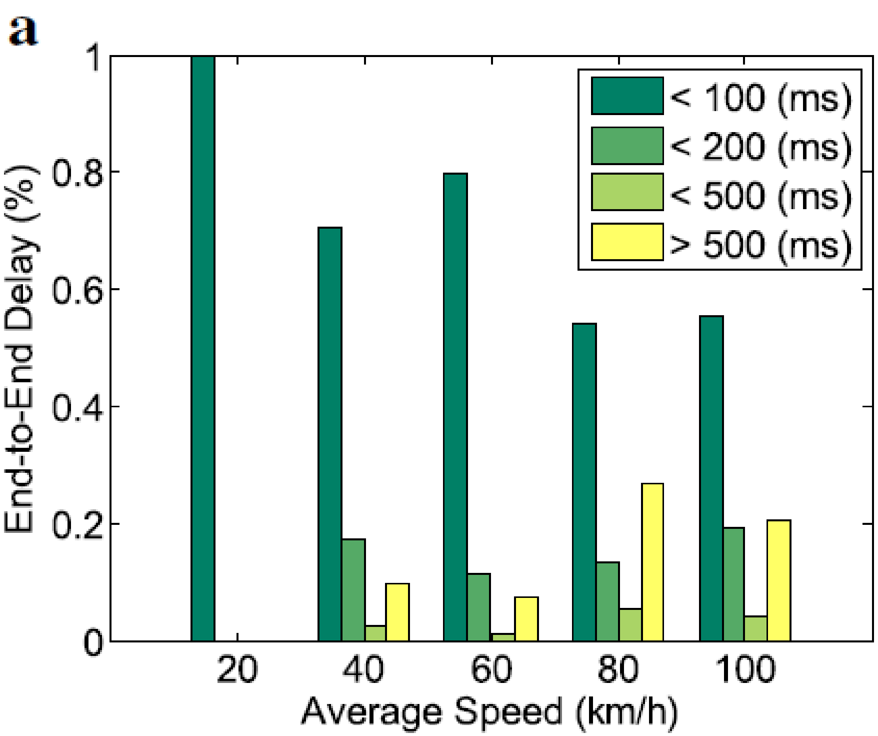
50 vehicles

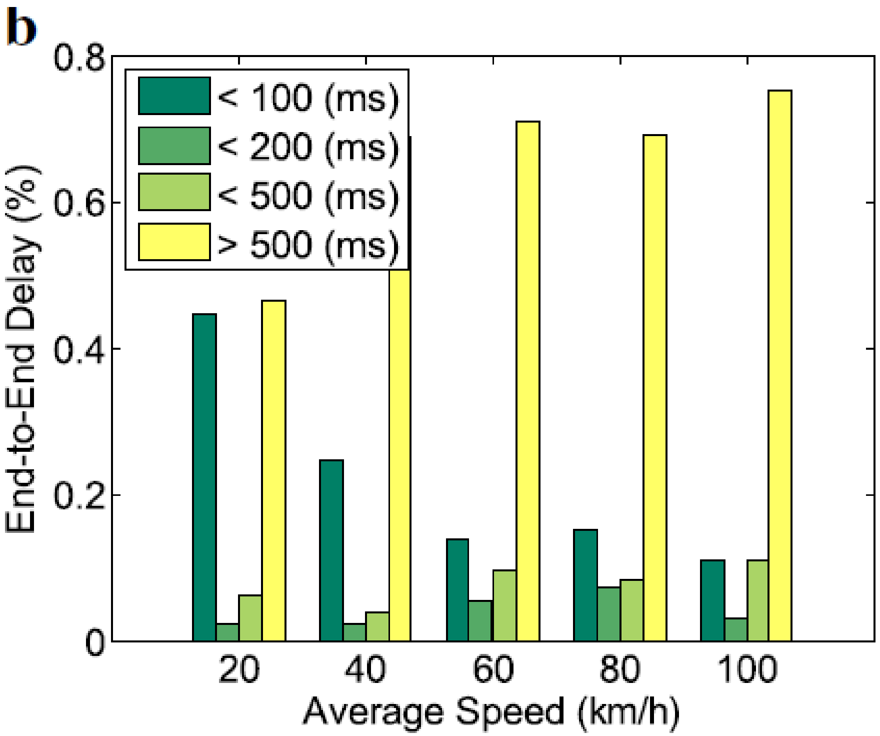


End to End Delay
Packet ratio 10 Hz 802.11p only

25 vehicles

50 vehicles

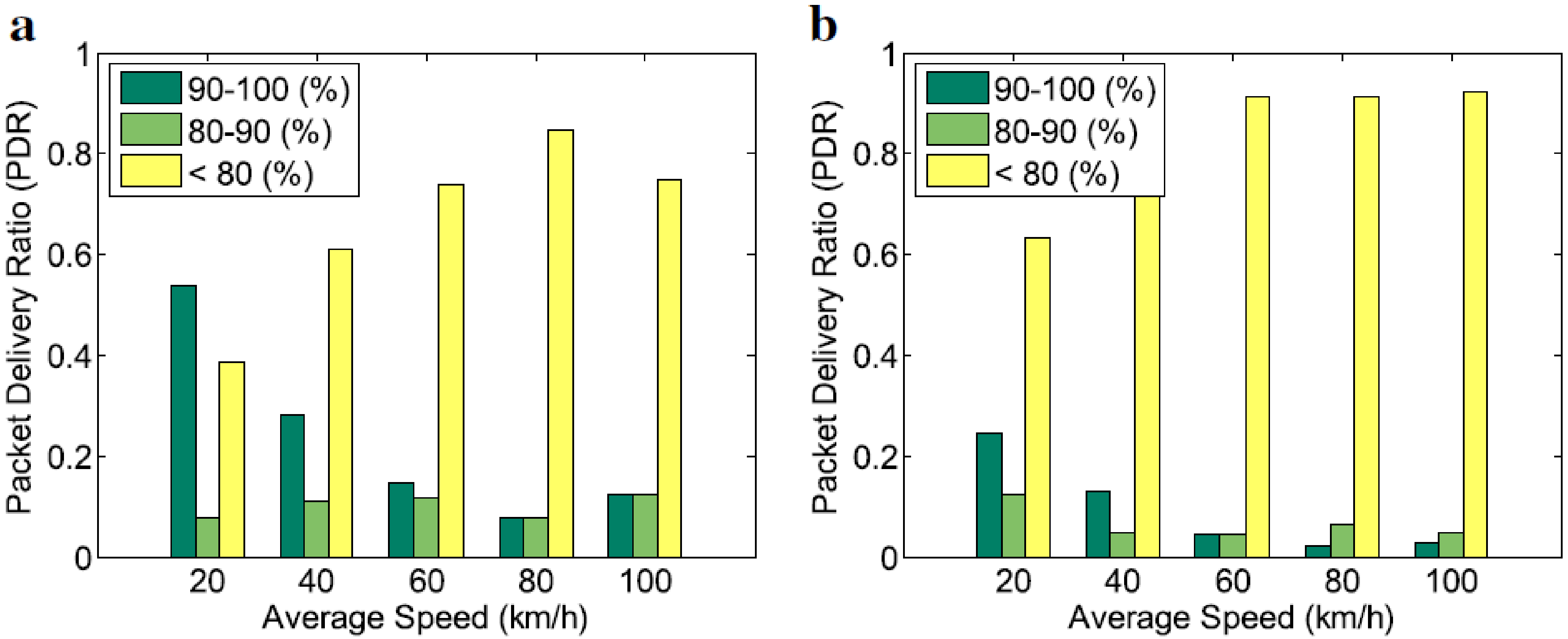




Packet Delivery Ratio
Packet ratio 10 Hz 802.11p only

25 vehicles

50 vehicles



Results of LTE

Results without direct comparison with 802.11p

End-to-end delay

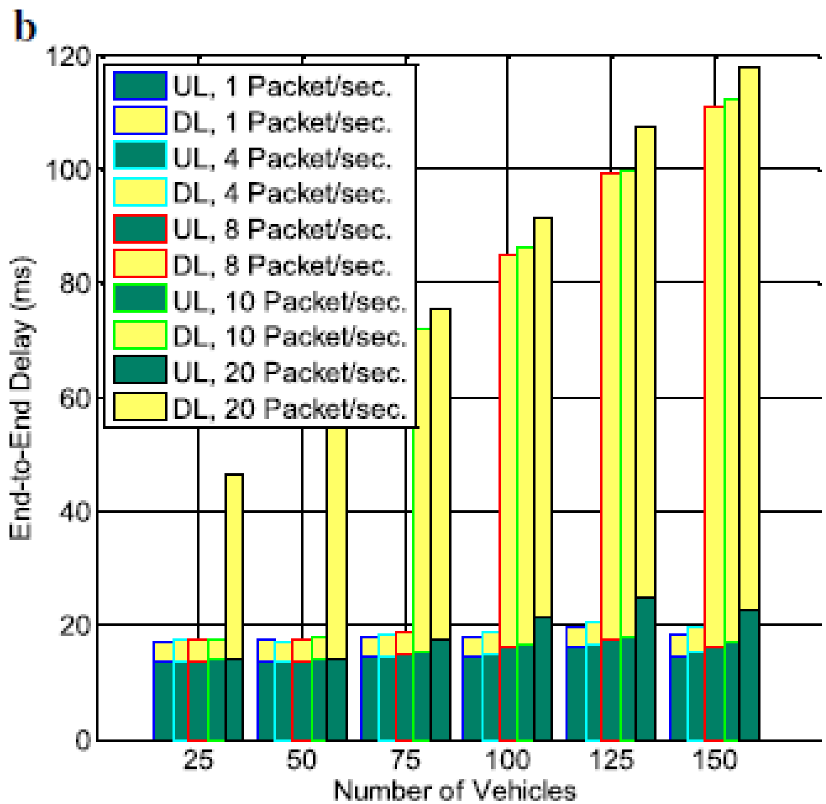


Figure 8 End-to-end delay for the LTE network with vehicular traffic application. (a) End-to-end delay (ms) vs. beacon transmission frequency (Hz), LTE-based vehicular network. **(b)** End-to-end delay (UL/DL) (ms) vs. number of vehicles, LTE-based vehicular network.

Conclusion

- LTE scale better, delivers data reliably and meets latency.
- LTE is suitable for most of the applications
- The LTE gains is attributed to fewer network elements and infrastructure-assisted scheduling and access control
- Performance degradation of 802.11p lack of coordinated channel access and distributed congestion control

Personal Comments

- The LTE don’t make handover
- The background traffic is not well defined and probably would be much higher in a Manhattan scenario
- Should have another scenario in highway that LTE would have problem with the allocation and handover
- The 802.11p using UDP is not the correct protocol. Should use WSMP

WAVE protocol stack