4G for Vehicular Communication

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Abstract

IEEE 802.11p has been the default standard for V2V communication. But it offers limited V2I connectivity and has many other challenges. This document talks about drastic improvements that have been brought about by LTE for Vehicular Communication, comparison with 802.11p, bottlenecks that it faces and finally enhancements to deal with those bottlenecks.

Introduction to LTE

LTE (Long Term Evolution) has been used for providing wireless connectivity in H2H communication over cellular networks. Because of its promising features, it has been considered over IEEE 802.11p (default standard) for implementation in Intelligent Transportation Systems (ITS) applications (road safety, traffic efficiency and infotainment).

Advantages over 802.11p

- High data rate (up to 300 Mbps)
- Wide coverage area (up to 30 km) overcoming installation of large scale RSU(Road Side Unit) problem
- High bandwidth (1.4 to 20 MHz)
- Low latency, high speed terminal support

Disadvantages over 802.11p

- Lack of V2V support
- Frequent mobile terminal updates in heavy traffic challenges LTE capacity

[1]

Architecture

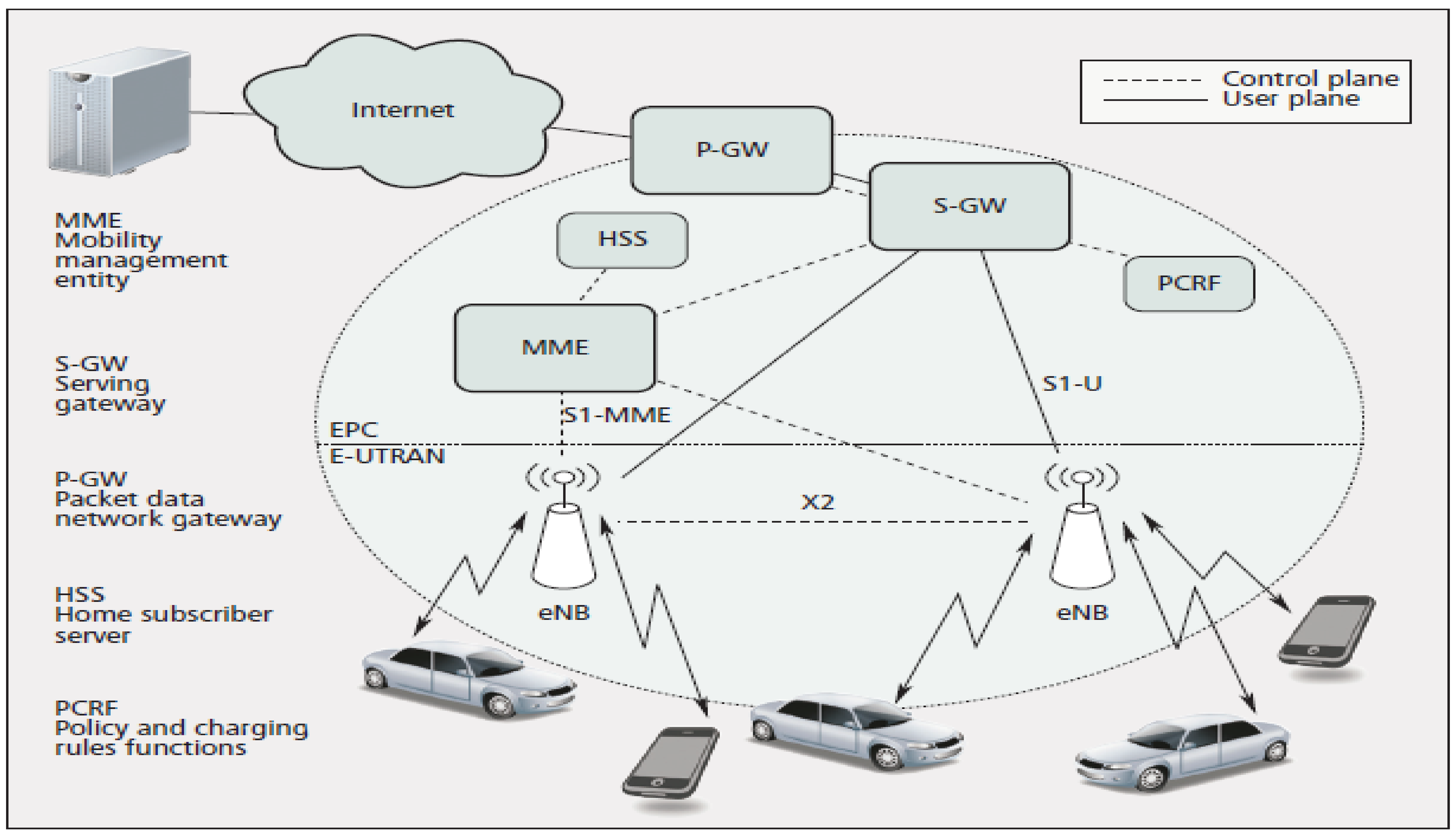


Fig 1: [1]

Functional entities:

a. Access network: eNodeB - Manages handover takeover events

b. Core network: 1. Mobility Management Entity (MME) – Authentication, security, users position information, 2. Serving Gateway (S-GW) – Routing and data forwarding, 3. PDN Gateway (P-GW)- Communication with IP, 4. Home Subscriber Server (HSS) - Stores subscriber information, roaming capabilities, 5. Policy Control and Charging Rules Function (PCRF) – Charging

c. GeoServer : Aggregates vehicles' information updates and reflects it to concerned vehicles in a relevant geographical area through a process called geocasting.

Media Access Technologies: OFDMA for Downlink and SC-FDMA for Uplink. OFDM symbols can be grouped into Physical Resource Blocks (PRBs) containing Physical Resource Elements in Time-Frequency grid. Data rate can be increased by using different modulation techniques ranging from QPSK to 64 QAM.

This architecture makes a good utilization of the channel by supporting Multimedia Broadcast Multicast Service (MBMS). [1]

Functional Areas and Mechanism

Functional areas: 1. Road safety, 2. Traffic efficiency, 3. Infotainment

1. Road Safety applications: Concerned with safety on road by reducing the possibilities of car accidents. This entails two types of safety messages: CAM (Cooperative Awareness Message) and DENM (Decentralized Environmental Notification Message).

CAM: Time triggered messages by vehicles which provides information on emergency vehicle warning, intersection collision warning, speed limit notification etc.

DENM: Event triggered messages broadcasted to vehicles about road hazards like stationary vehicle accident, hazardous location, road works etc. It can be Vehicle Intelligent Transportation Systems (V-ITS) triggered or Centralized Intelligent Transportation Systems (C-ITS) triggered.

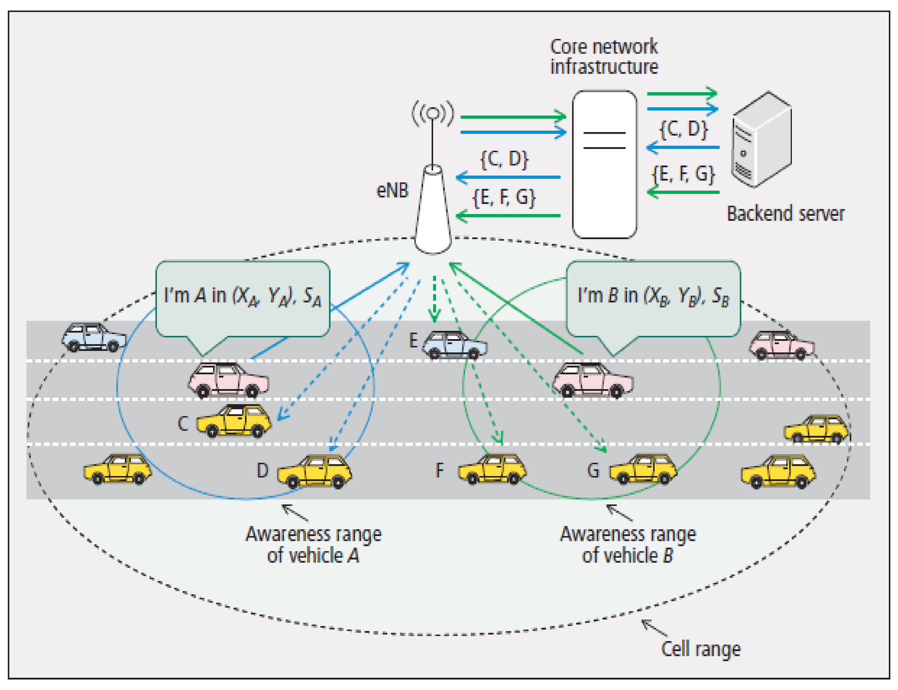
2. Traffic Efficiency applications: Concerned with optimizing travel time and reducing traffic congestion. This is achieved through periodic decentralized Floating Car data (FCD) information transmissions from vehicles to infrastructure and distribution of updated traffic information back to the vehicles.

In both the cases, V-ITS communicate with C-ITS and GeoServer delivers data through geocasting.

3. Infotainment applications: Information and Entertainment applications supporting services like VoIP, media streaming, social networking etc.

These types of applications need an evaluation of KPIs like Packet Delivery Ratio and Throughput of the network for implementation and also a comparison with the already existing system. [1]

Multicast CAM delivery



Multicast DENM delivery

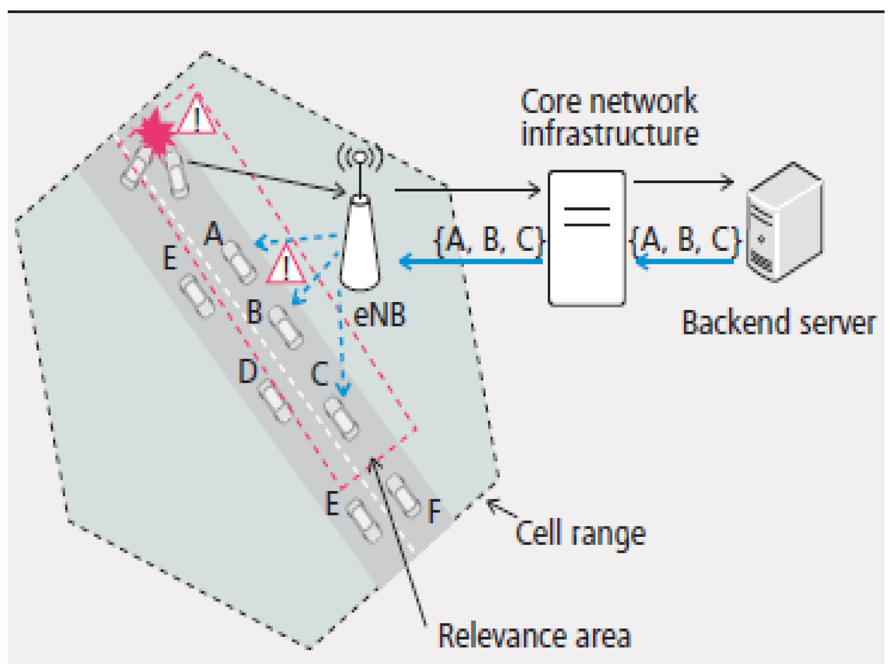
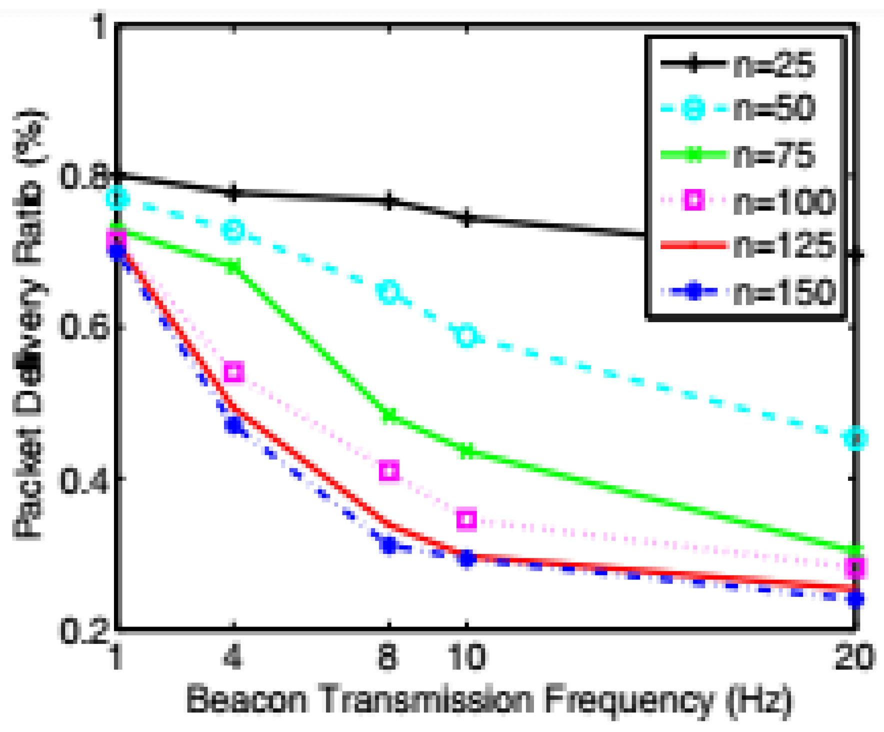


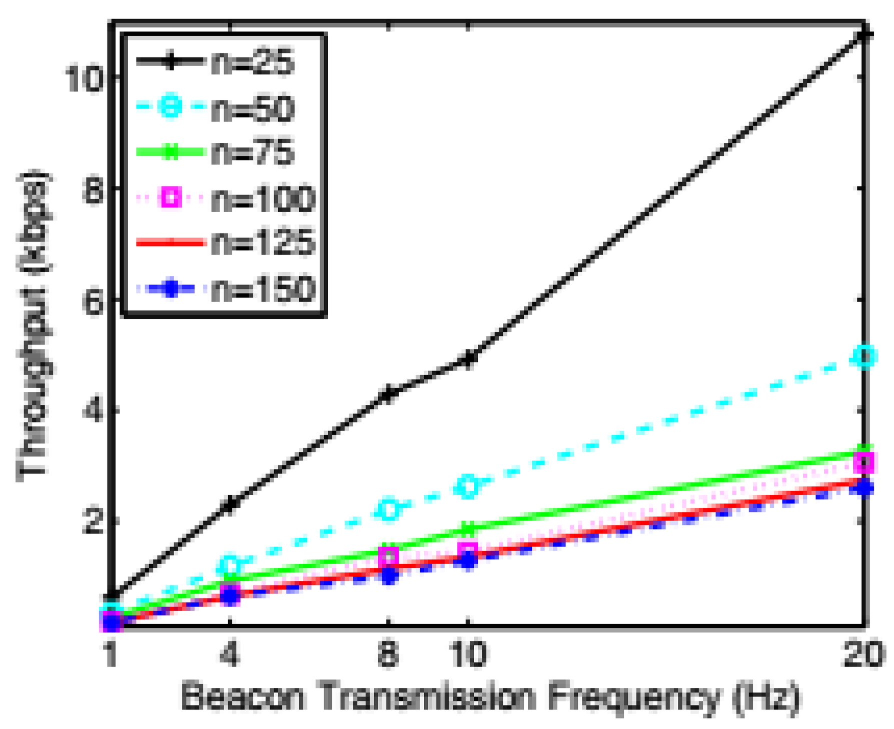
Fig 2 and 3: [1]

Performance Evaluation, Challenges, Solutions & Proposals

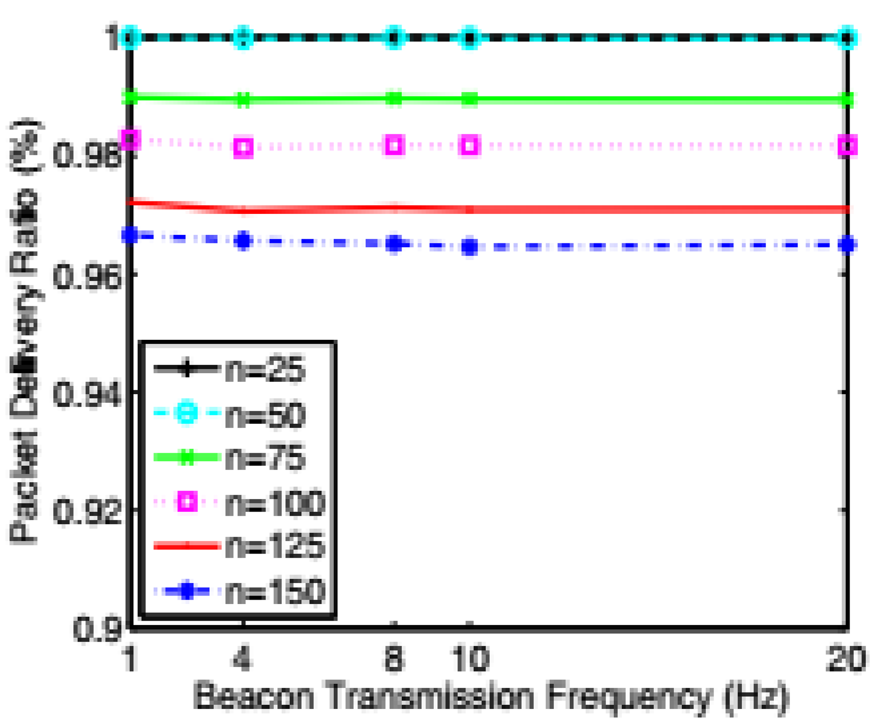
Packet Delivery Ratio (802.11p)



Throughput (802.11p)



Packet Delivery Ratio (LTE)



Throughput (LTE)

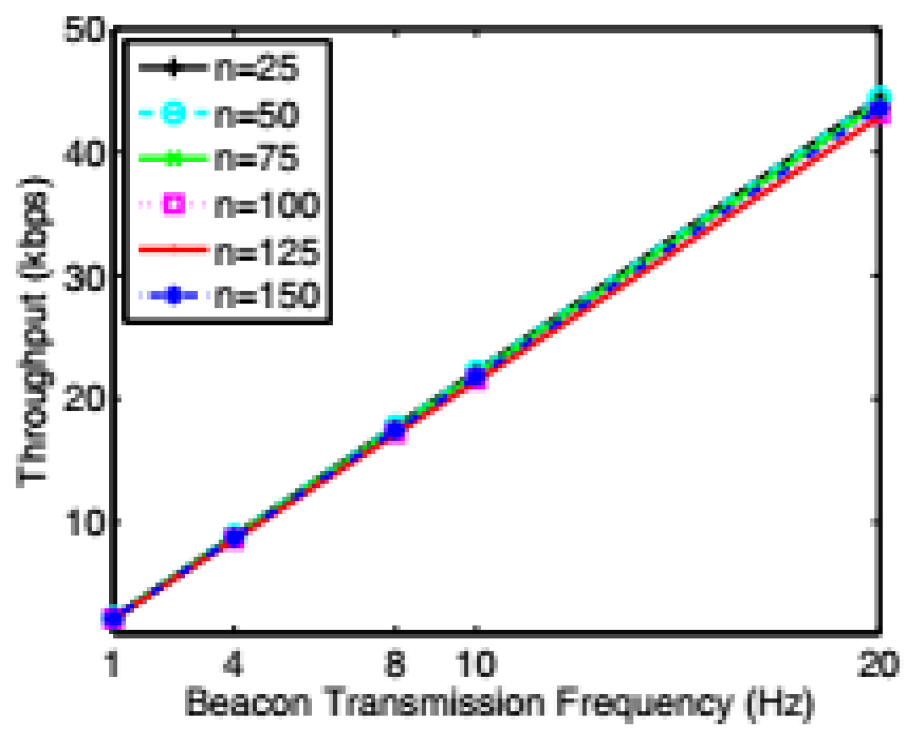


Fig: 4, 5, 6 and 7: [2]

Results: Simulations show that LTE outperforms 802.11p in Packet Deliver Ratio and Throughput

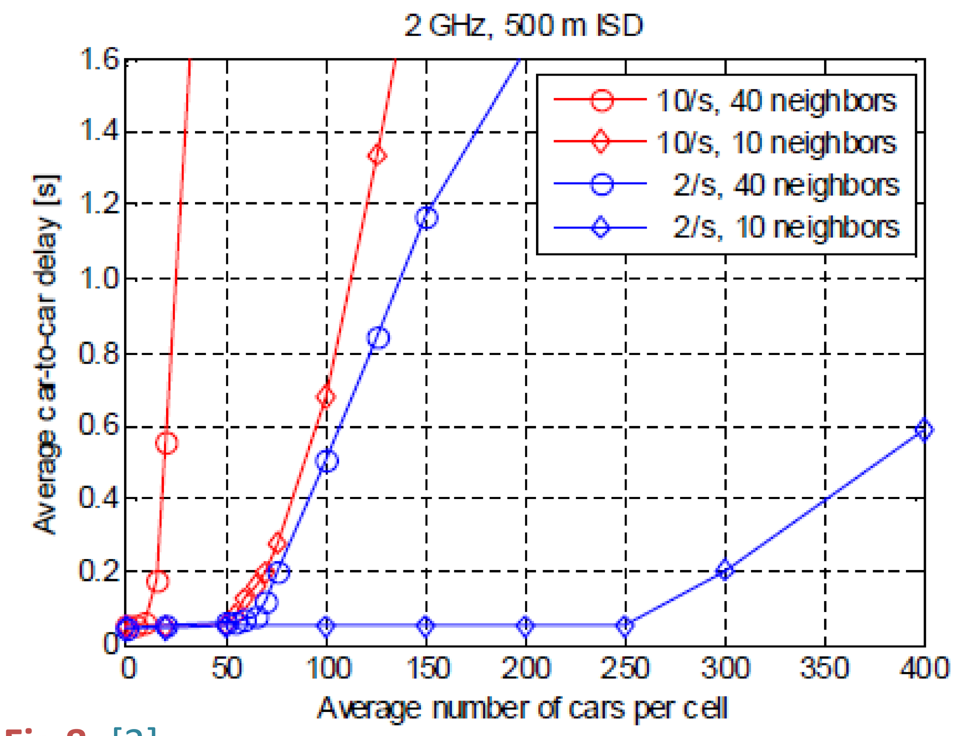


Fig 8: [3]

Problem (CAM):
In heavy traffic condition, frequent updates from high number of vehicles challenge channel capacity.
Solution:
CAM rate has to be reduced. [3]

Problem (DENM):
Event Reporting by large number of vehicles in large geographical area in unicast mode can challenge channel capacity.
Solution:
Smart aggregation and relevant reflection by the back-end server. [1,3]

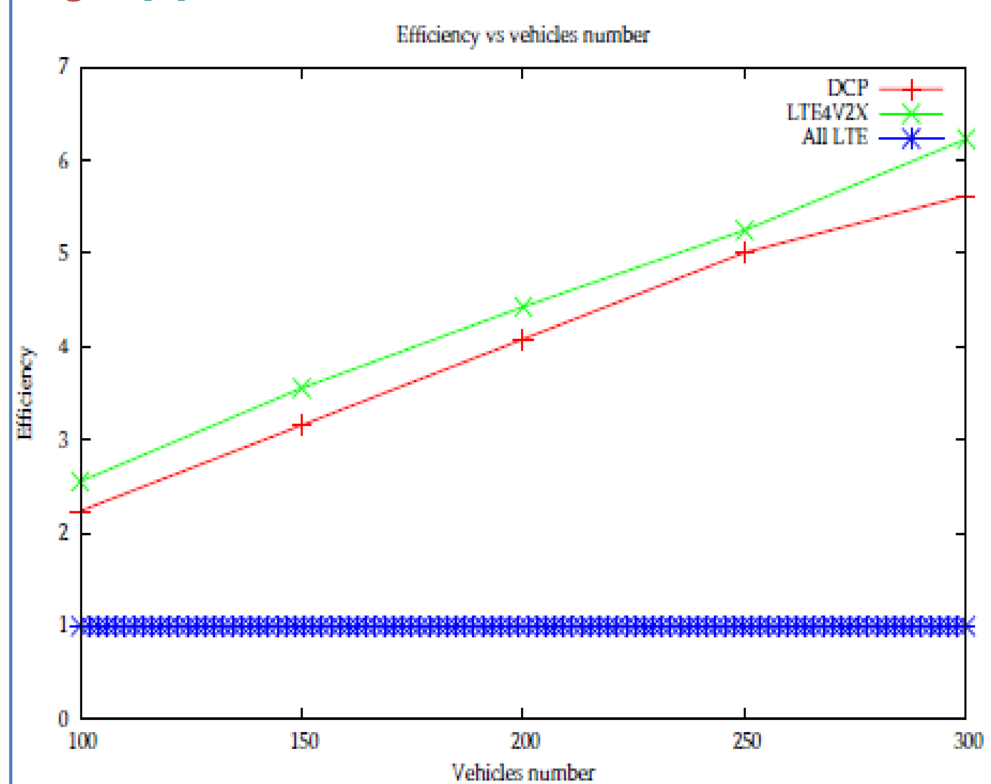


Fig 9: [4]

Problem (FCD): FCD generated by large number of vehicles saturate uplink channel.
Solution:
Hybrid clustering (based on LTE and 802.11p): eNodeB chooses a Cluster Head which delivers the aggregated FCD from all the members in a cluster in a single frame to eNodeB. This has been implemented in LTE4V2X [4]

Proposal (Packet Scheduling): By default, LTE uses Dynamic Scheduling but Semi-Persistent Scheduling (SPS) used for VoLTE can be proposed for better efficiency in ITS . [5]

Enhancements

Enhancements through LTE-A: Localized V2V communication can be implemented in LTE- A by exploiting the concepts of D2D. D2D and H2H share the same network resources. From the implementation perspective if equal QoS for both of these heterogeneous networks can be guaranteed, then implementation will give achievable results. [1]

Conclusion

This document discusses fairly about 3 different flavors: IEEE 802.11p, LTE and LTE-A. IEEE 802.11p is till now the widely used standard for Vehicular Communication. LTE, with a few challenges, definitely offers better productivity than 802.11p. With further enhancements in LTE-A it will become the next default standard for Vehicular Communication.

References: [1] *Giuseppe Araniti, Claudia Campolo, Massimo Condoluci, Antonio Iera, and Antonella Molinaro, University Mediterranea of Reggio Calabria LTE for Vehicular Networking: A Survey May 2013*

[2] *Hameed Mir and Filali LTE and IEEE 802.11p for vehicular networking: a performance evaluation EURASIP Journal on Wireless Communications and Networking2014*

[3] *ETSI TR 102 962, "Intelligent Transport Systems (ITS); Framework for Public Mobile Network," Feb. 2012.*

[4] *Guillaume R´emy, Sidi-Mohammed Senouci, Franc¸ois Jan, Yvon Gourhant Orange Labs, Lannion, France, +DRIVE Laboratory, University of Bourgogne, France LTE4V2X - Impact of High Mobility in Highway Scenarios IEEE Aug. 2011*

[5] *Lung-Chih Tung, Mario Gerla LTE Resource Scheduling for Vehicular Safety Applications 2013 10th Annual Conference on (WONS)*