Simulation-based Study on the MAC Layer Performance of Cellular Vehicle to Everything (C-V2X) Communication

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Abstract

Intelligent Transportation Systems (ITS) promise to deliver novel services related to various modes of transportation management, allowing users to have more coordinated and safer road trips. Cellular Vehicle to Everything (C-V2X) is a communication technology which can be integrated into ITS. It is introduced by 3GPP to be implemented as an LTE or 5G technology for the information transfer among vehicles or vehicles and other roadside infrastructure. Upon implementation of Mode 4 of C-V2X, the communication can be continued without the support of a base station. This study introduces the analysis of delay in C-V2X Mode 4 simulations on the popular simulator NS-3. It also has a comparison of delay and other parameters like Packet Reception Ratio (PRR) with results of a previous analytical model study. The simulation environment is built using available C-V2X related modifications of NS-3. An automation script is developed to run simulations efficiently for a range of different input scenarios of packet generation periods, node counts, Resource Reservation Intervals (RRIs), Resource Re-selection Probabilities (RRPs) and in random static User Equipment (UE) positions. The queuing behavior in transmitting packets is added newly to the simulator with both Cooperative Awareness Messages (CAM) and Decentralized Environmental Notification Messages (DENM) queues, hence the queuing delay is integrated with the results. The obtained PRR and delay variation comply with the analytical model. Furthermore, an analysis is done on the time difference between transmission and reception of a packet in the simulator, without adding the queuing delay, for comparison purposes.

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List of Abbreviations

P_{rk} Resource Keep Probability

3GPP 3rd Generation Partnership Project

BSM Basic Safety Message

C-V2X Cellular Vehicle to Everything

CAM Cooperative Awareness Messages

CSMA/CA Carrier-Sense Multiple Access with Collision Avoidance

CSR Candidate Single-subframe Resource

D2D Device to Device

DENM Decentralized Environmental Notification Messages

DSRC Dedicated Short-Range Communications

ETSI European Telecommunications Standards Institute

IEEE Institute of Electrical and Electronics Engineers

ITS Intelligent Transportation System

LTE Long-Term Evolution

MAC Media Access Control

NIST National Institute of Standards and Technology

PHY Physical Layer

PIR Packet Inter-Reception

PRB Physical Resource Block

ProSe Proximity-based Services

PRR Packet Reception Ratio

PSCCH Physical Sidelink Control Channel

PSSCH Physical Sidelink Shared Channel

RB Resource Block

RC Re-selection Counter

RRC Radio Resource Control

RRI Resource Reservation Interval

RRP Resource Reselection Probability

RSRP Reference Signal Received Power

RSSI Received Signal Strength Indicator

SCI Sidelink Control Information

SPS Semi-Persistent Scheduling

SUMO Simulation of Urban MObility

TB Transport Block

TTI Transmission Time Interval

UE User Equipment

V2I vehicle-to-infrastructure

V2N vehicle-to-network

V2P vehicle-to-pedestrian

V2V vehicle-to-vehicle

V2X Vehicle to Everything

WAVE Wireless Access in Vehicular Environments

WINNER Wireless World Initiative New Radio