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A Mixed Game Theory and Ranking Approaches for Vertical Handover Decision in 4G Heterogeneous VANETs

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Abstract: A vehicular ad-hoc network is a technology for implementing Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communications. The present vehicular mobility framework is not considering real-time constraints such as vehicle priority, congestion, group-communications, etc. The proposed Nash-Equilibrium and Ranking approaches for Media Independent Soft Handover Decision (NRMISHD) framework is equipped with important criterion like congestion avoidance between vehicles, QoS based (bandwidth, delay, jitter, velocity and bit-error rate) and cost. The optimal and sub-optimal decision for selecting the network is based on Nash-Equilibrium and Ranking Method, respectively. Hence, enabling QoS for differentiating the services according to vehicular priorities and providing group communications, alongside vehicular collision avoidance will be implemented.

Key words: WAVE, WiMAX, UMTS, Long Term Evolution (LTE), VANET

INTRODUCTION

The recent advances in wireless networks have led to the introduction of a new type of networks called Vehicular Networks. Vehicular Ad Hoc Network (VANET) is a form of Mobile Ad Hoc Networks (MANET). VANETs provide us with the infrastructure for developing new systems to enhance drivers' and passengers' safety and comfort. VANETs are distributed self-organizing networks formed between moving vehicles equipped with wireless communication devices. This type of networks is developed as part of the Intelligent Transportation Systems (ITS) to bring significant improvement to the transportation systems performance.

Each vehicle node is equipped with WAVE (IEEE 802.11p) protocol known as OBUs (On Board Unit). There are mainly two types of communications scenarios in vehicular networks: Vehicle to Vehicle (V2V) and Vehicle to RSU (V2R or V2I). The RSUs can also communicate with each other and with other networks. Vehicular networks are expected to employ variety of advanced wireless technologies such as Dedicated Short Range Communications (DSRC) which is an enhanced version of the WAVE (IEEE 802.11p) technology suitable for VANET environments. The DSRC is developed to support the data transfer in rapidly changing communication environments. The basic VANET communication scenario is shown in Fig. 1.

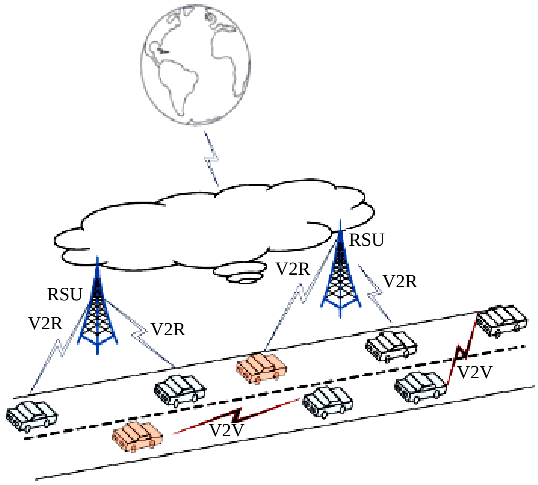

Fig. 1: Basic VANET scenario

VANET applications are safety applications, Cooperative Collision Avoidance (CCA), Emergency Warning Messages (EWM), Cooperative Intersection Collision Avoidance (CICA), Traffic Managements, Advertisements, entertainment and comfort applications like electronic toll collection.

A new MAC protocol known as the IEEE 802.11p is used by the WAVE stack. The IEEE 802.11p basic MAC protocol is the same as IEEE 802.11 Distributed Coordination Function (DCF) which uses the Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA)

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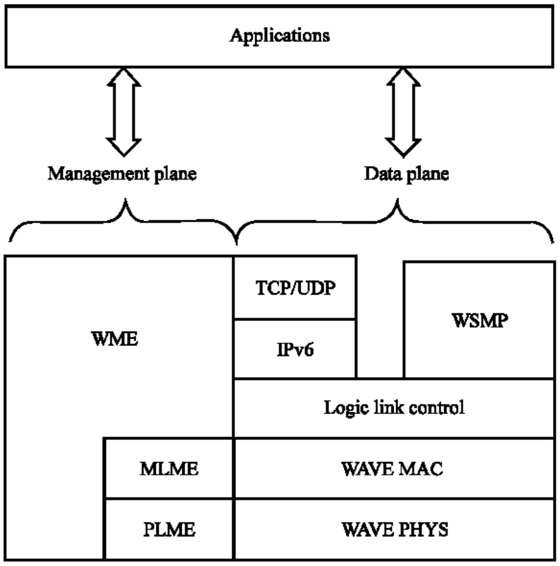

Fig. 2: Protocol architecture of IEEE 802.11p DSRC

Method for accessing the shared medium. The IEEE 802.11p MAC extension layer is based on the IEEE 802.11e (IEEE, 2003) that uses the Enhanced Distributed Channel Access (EDCA) like Access Category (AC), virtual station and Arbitration Inter-Frame Space (AIFS). Using EDCA, the Quality of Service (QoS) in the IEEE 802.11p can be obtained by classifying the data traffic into different classes with different priorities. The basic communication modes in the IEEE 802.11p can be implemented either using broadcast where the Control Channel (CCH) is used to broadcast safety critical and control messages to neighboring vehicles or using the multi-channel operation mode where the Service Channel (SCH) and the CCH are used. The later mode is called the WAVE Basic Service Set (WBSS).

In the WBSS mode, Stations (STAs) become members of the WBSS in one of two ways, a WBSS provider or a WBSS user. Stations in the WAVE move very fast and it's very important that these stations establish communications and start transmitting data very fast. Therefore, the WBSSs don't require MAC sub-layer authentication and association. The provider forms a WBSS by broadcasting a WAVE Service Advertisement (WSA) on the CCH. The potocol architecture of IEEE802.11p DSRC is shown in Fig. 2. V2V uses DSRC based WAVE protocol for collision avoidance messages and V2I uses WiMAX or UMTS/LTE networks for lane-changes/assigning vehicle priorities.

MATERIALS AND METHODS

Vehicular mobility issues: The survey contains information about VANET Mobility Models, several architectures for mobility management, integration of network and traffic simulator, performance issues in VANET. Several issues and parameters were considered.

Khairnar and Pradhan (2011) has analyzed Mobility Models for vehicular adhoc network. Mobility Model is important characteristic of vehicular networks. Mobility Models can be commonly classified into Macroscopic Models, Mesoscopic Models and Microscopic Models. The Random Way-Point Model evaluates its effect in VANETs by NS-2 simulations. Fernandes *et al.* (2010) presents a tool for simulating heterogeneous vehicular networks. The existing microscopic traffic simulator, DIVERT has been extended by adding NS-3 support resulting in a very tightly integrated simulator. Hybrid approaches provide a fully integrated framework with the ability to simulate both the mobility and network components.

Durrani *et al.* (2010) propose a new equivalent speed parameter and develop an analytical model to explain the effect of vehicle mobility on the connectivity of highway segments in a VANET. They prove that the equivalent speed is different from the average vehicle speed and it decreases as the standard deviation of the vehicle speed increases. Mittag *et al.* (2011) addresses the network simulators typically abstract physical layer details (coding, modulation, radio channels, receiver algorithms, etc.) while physical layer ones do not consider overall network characteristics (topology, network traffic types and so on). In particular, network simulators view a transmitted frame as an indivisible unit which leads to several limitations.

Arbabi and Weigle (2010) proposed highway mobility in vehicular network and they described the first implementation of a Vehicular Mobility Model integrated with the networking functions in NS-3. Boban *et al.* (2011) studied about vehicle as obstacle in vehicular network. The impact of vehicles as obstacles on Vehicle to Vehicle (V2V) communication has been largely neglected in VANET research, especially in simulations. Useful models accounting for vehicles as obstacles must satisfy a number of requirements, most notably accurate positioning, realistic mobility patterns, realistic propagation characteristics and manageable complexity.

Spaho *et al.* (2011) present a simulation system for VANET called CAVENET (Cellular Automaton based Vehicular network). In CAVENET, the mobility patterns of nodes are generated by 1-dimensional cellular automata. Campolo and Molinaro (2011) investigated the feasibility of V2R communications by considering the 802.11p/WAVE features and capabilities. In order to increase the number of vehicles able to make the best of a short-lived RSU coverage, the proposed a solution that exploits both the repetition of BSS advertisements during the CCH interval and the piggybacking over beacons to spread the BSSs parameters.

Naumov *et al.* (2006) report on a investigation of the effectiveness of AODV and GPRS in an inner city environment and on a highway segment. This evaluation is based on traces obtained from a microscopic vehicle traffic simulation on the real road maps of Switzerland. Choffnes and Bustamante (2005) analyzes ad-hoc wireless network performance in a vehicular network in which nodes move according to a simplified vehicular traffic model on roads defined by real map data. This research work indicate that the packet delivery ratio for common topology-based ad-hoc routing algorithms varies significantly between an environment using a model of vehicular movement confined to real roads and one using the Random Way-Point Model.

The study describes about benefit function and penalty function. The decision for network selection is based on reward (Qutub and Anjali, 2010). The study focuses on vertical handover decision on multi-mode terminal using Nash-equilibrium based game theory approach. The decision includes the various QoS parameters for network selection (Radhika and Reddy, 2011).

NRMISHD mobilty framework: Vehicular Ad-Hoc Network (VANET) communication has recently become an increasingly popular research topic in the area of wireless networking as well as the automotive industries. The goal of VANET research is to develop a Vehicular Communication System to enable quick and cost-efficient distribution of data for the benefit of passengers' safety and comfort. While it is crucial to test and evaluate protocol implementations in a real world environment, simulations are still commonly used as a first step in the protocol development for VANET research. Several communication networking simulation tools already exist to provide a platform to test and evaluate network protocols such NS-3, NS-2, OPNET and Qualnet.

One of the most important parameters in simulating ad-hoc networks is the node mobility. It is important to use a Realistic Mobility Model so that results from the simulation correctly reflect the real-world performance of a VANET. For example, a vehicle node is typically constrained to streets which are separated by building, trees or other objects. Such obstructions often increase the average distance between nodes as compared to an open-field environment. Many prior studies have shown that a realistic mobility model with sufficient level of details is critical for accurate network simulation results.

Vehicular node mobility is represented by Mobility Model. Mobilit Models represent the movement of mobile users and how their location, velocity and acceleration change over time. Such models are frequently used for simulation purposes when new communication or navigation techniques are investigated. Mobility of vehicular nodes is crucial issue in VANET. Mobility of vehicular node represented by Mobility Models. The widely used Mobility Model for vehicular adhoc network is Random Waypoint Mobility Model. This Mobility Models for vehicular ad-hoc networks do not provide realistic vehicular node movement scenarios. The Random Waypoint Mobility Model includes pause times between changes in direction and/or speed. A vehicular node begins by staying in one location for a certainperiod of time (i.e., a pause time). In Random Waypoint Mobility Model, once this time expires, vehicular node the chooses a random destination and a speed that is uniformly distributed between [minspeed, maxspeed]. The vehicular node then travels toward the newly chosen destination at the selected speed. Upon arrival, the vehicular node pauses for a specified time period before starting the process again. This Mobility Model ignore many real time constrains such as traffic signal, speed limit and so on.

The proposed solution for this problem is resolved by introducing new real-time mobility framework. Real-time mobility framework include real world constraints such as traffic signal, speed limit, number of lanes (whether interstate highway, national high way), speed will increasing/decreasing while intersection of street vehicular node turn left/right/go straight, vehicle over taking behavior and also it support bidirectional highway.

The NRMISHD mobility framework is shown in Fig. 3. Each vehicle is equipped with 802.11p based DSRC unit. Vehicles communicate with neighbor vehicle for collision avoidance/warning, safety like applications using WAVE protocol. Also vehicles information communicated to Infrastructures (WiMAX or LTE) for assigning vehicle priorities and lane-changes applications. The vertical and horizontal handover is shown in Table 1. The factors of 3G-4G access technologies were tabulated in Table 2. The module description as follows:

- Network discovery: It discovers and reports the available network links using INFORMATION services of MIHF
- Congestion estimation: The network congestion to be evaluated under fully loaded condition

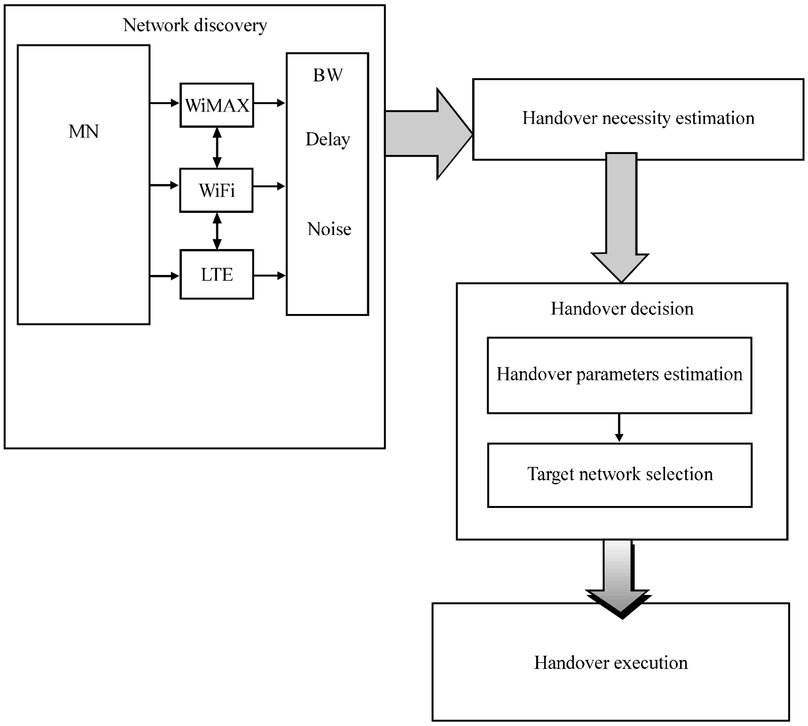

Fig. 3: NRMISHD mobility framework for VANET

Table 1: Vertical and horizontal handovers

Parameters	Horizontal handover	Vertical handover
Access technology	Not changed	Changed
QoS parameters	Not changed	May be changed
IP address	Changed	Changed
Network interface	Not changed	May be changed
Network connection	Single connection	More than one connection

Table 2: 3G-4G access technologies

Factors	802.11p/WAVE	WiMAX	LTE
Peak data rate	802.11p = 6-27 Mbps	DL = 70 Mbps UL = 70 Mbps	DL = 100 Mbps UL = 50 Mbps
Bandwidth	5.9 GHz	5-6 GHz	20 MHz
Multiple access	DSRC/TDMA	OFDM/OFDMA	W-CDMA
Coverage	1000 m	16 km	Wider area
Mobility	Low	Medium	Higher

- Handover necessity estimation: The necessity has to be ensured and so that unnecessary switching handover cost to be minimized
- Handover decision: The decision could be arrived using Bayesian Nash-Equilibrium and Ranking Methods

NRMISHD vehicular mobility framework: The dual-mode mobile stations (Vehicle nodes) which roam between wireless local area network (i.e., WAVE) and WAVE. The Vehicles moving at vehicular speeds. The act of transitioning from WAVE to cellular (i.e., LTE/UMTS or WiMAX) is commonly referred to as a Vertical Handoff (VHO).

Steps for seamless communication in V2I (OBU-RSU):

- RSU1 (UMTS/LTE) broadcasts TB (timing beacons) to OBUs (WAVE) at vehicle nodes
- OBU/MN send coordination request to RSU1
- RSU1 broadcasts the revised TB
- Communication takes place between OBUs and RSU1
- Vehicle Node (OBU) sends WAVE HO_Request to RSU1
- RSU1 sends HO_Confirm to Distributed
- HO_Controller
- HO_Controller send HO_Request to RSU2
- RSU2 broadcasts the TB
- OBU respond with coordination request to RSU2
- RSU2 sends HO_Confirm to HO_Controller
- A New TB is send to OBU and messages are communicated

NRMISHD algorithm:
Consider the multiplayer game
Discover the various networks under the coverage of the mobile node
The parameters such as Bandwidth (B), Jitter (J), Delay (D), Velocity (V) and Error-rate (E) are considered
Threshold (th) values for the different parameters are set
Using the pair wise matrix the nash equilibrium is evolved using the game theory. The normalized QoS and Cost denoted by QNS_{i*} and UP_{j*}, respectively:

$$QNS_i = \frac{U_i}{\sum_{k=1}^{m} U_k}$$

Where:

QNS_{i^*} = max $\{QNS_i/i = 1, 2, ..., m\}$
Up_{j^*} = min $\{Up_j/j = 1, 2, ..., n\}$
U_i = $f_{B,i} \times f_{D,i} \times f_{V,i} \times f_{P,i} \times f_{E,i}$

The network utility is calculated as follows:

$$f_{B,i} = \begin{cases} 1.5 & \text{if } B_i \geq B_{th} \\ 1 + \dfrac{0.5\,(B_i - B_{req})}{(B_{th} - B_{req})} & \text{if } B_{req} \leq B_i < B_{th} \\ \exp\left[-\dfrac{(B_i - B_{req})^2}{4 \times B_{req}^{\ 2}}\right] & \text{if } B_i < B_{req} \end{cases}$$

$$f_{D,i} = \begin{cases} 1.5 & \text{if } D_i \geq D_{th} \\ 1 + \dfrac{0.5\,(D_{req} - D_i)}{(D_{req} - D_{th})} & \text{if } D_{th} \leq D_i < D_{req} \\ \exp\left[-\dfrac{(D_i - D_{req})^2}{4 \times D_{req}^{\ 2}}\right] & \text{if } D_{req} < D_i \end{cases}$$

$$f_{V,i} = \begin{cases} 1.5 & \text{if } V_i \geq V_{th} \\ 1 + \dfrac{0.5\,(V_i - V_{req})}{(V_{th} - V_{req})} & \text{if } V_{req} \leq V_i < V_{th} \\ \exp\left[-\dfrac{(V_i - V_{req})^2}{4 \times V_{req}^{\ 2}}\right] & \text{if } V_i < V_{req} \end{cases}$$

$$f_{J,i} = \begin{cases} 1.5 & \text{if } J_i \leq J_{th} \\ 1 + \dfrac{0.5\,(J_{req} - J_i)}{(J_{req} - J_{th})} & \text{if } J_{th} \leq J_i < J_{req} \\ \exp\left[-\dfrac{(J_i - J_{req})^2}{4 \times J_{req}^{\ 2}}\right] & \text{if } J_{req} < J_i \end{cases}$$

$$f_{E,i} = \begin{cases} 1.5 & \text{if } E_i \leq E_{th} \\ 1 + \dfrac{0.5\,(E_{req} - E_i)}{(E_{req} - E_{th})} & \text{if } E_{th} \leq E_i < E_{req} \\ \exp\left[-\dfrac{(E_i - E_{req})^2}{4 \times E_{req}^{\ 2}}\right] & \text{if } E_{req} < E_i \end{cases}$$

The user utility is calculated using the equation:

$$UP_j = C_i \times Q_j$$

Where:

C_i = Cost per bit of the ith network
Q_j = QoS requirement of the jth network

$\{1$, if $B_i > B_{req}$, $D_i < D_{req}$, $V_i > V_{req}$, $J_i < J_{req}$, $E_i < E_{req}$
∞, otherwise$\}$
i-offered and req-requested values of {bandwidth, delay, velocity, jitter and bit-error-rate}

The pair wise matrix is designed based on the utility of the network (i) and the user utility (j) such as (i, j)
If there is no equilibrium then the sub optimal solution is evolved using the ranking method

RESULTS AND DISCUSSION

The optimal and sub-optimal solutions are obtained by using Nash-Equilibrium and Ranking Methods, respectively.

Nash-equilibrium method: The sample QoS offered and requested values are presented in Table 3 and 4, respectively. The threshold parameters are given in Table 5. Also, the normalized cost per bit for each network is given in Table 6. The pair-wise Nash equilibrium solution is shown in Table 7. It is observed from the pair-wise matrix that the equilibrium is achieved for various traffic classes and hence the decision can be made optimally.

The performance graph shows that network-utilization and QoS ratio are relatively high in LTE networks which is shown Fig. 4 and 5. The pair-wise solution matrix shows that equilibrium solutions arrived for VoIP, straming and intreactive traffic classes at LTE-A, LTE-A and WiMAX networks, respectively. But there is no solution point for E-mail services, hence the sub-optimal solution is obtained using ranking method.

Ranking Method: The following table gives the sub-optimal solution using ranking concepts. If there is no optimal solution found, the system uses ranking method for network selection. The approach computes reward based on the following relation:

$$\text{Reward} = \{\text{benefit sets}\} - \{\text{penalty sets}\} \qquad (1)$$

The benefit sets includes {B, D, V, J and E} and penalty set includes {cost, momentary-switching}. The level of ranking for various QoS classes is given in Table 8. The weight of first preference network is 1/2, 2nd preference network is 1/3 and 3rd preference network is 1/6. Consider that there are 4 traffic classes. Suppose that the user is in the conversational environment and is experiencing a Handoff, researchers have found that LTE is the best network by considering maximum QoS and minimum cost as parameters. Similarly, researchers have found the results for other traffic classes. The ranking-solution for conversational, streaming, interactive and background classes are given in Table 9-12, respectively.

Table 3: Offered QoS parameters

Parameter/ QoS classes	Bandwidth (Mbps)	Packet delay (msec)	Supported velocity (kmph)	Jitter (msec)	BER (per 10^8)
Wifi	50	160	10	200	200
WiMax	70	120	20	60	150
LTE-A	150	80	30	30	100

Table 4: QoS required parameters

Parameter/QoS classes	Bandwidth (Mbps)	Packet delay (msec)	Supported velocity (kmph)	Jitter (msec)	BER (per 108)
UGS(Voice-VoIP)	10	200	5	60	400
rtPS (Streaming-Video)	25	300	5	60	400
NrtPS (Interactive-HTTP)	15	300	5	200	250
BE (Background-Email)	20	400	5	300	250

Table 5: QoS threshold parameters

B_{Th}	D_{Th}	V_{Th}	J_{Th}	E_{Th}
80	100	60	50	150

Table 6: Cost per bit offered by each network

Network	WiFi	WiMAX	LTE-A
Cost	0.2	0.4	0.6

Table 7: Pair-Wise Nash-Equilibrium matrix

Traffic classes	WiFi	WiMax	LTE-A
Conversational	0.254900, ∞	0.16000, ∞	0.5850, 0.6
Streaming	0.263800, ∞	0.17230, ∞	0.5638, 0.6
Interactive	0.135200, ∞	0.3114, 0.4	0.5532, 0.6
Background	0.17610, 0.2	0.3362, 0.4	0.4875, 0.6

Table 8: QoS classes-level of ranking

Traffic classes	WLAN	WiMAX	LTE
Conversational	(L, 0.25)	(M, 0.3)	(H, 1)
Streaming	(H, 1)	(M, 0.7)	(L, 0.25)
Interactive	(L, 0.2)	(H, 1)	(M, 0.5)
Background	(L, 0.3)	(H, 0.9)	(M, 0.5)

Table 9: Conversational-ranking

Traffic classes	WLAN	WiMAX	LTE	Rank
Conversational	0.0410	0.100	0.500	0.641
Streaming	0.1667	0.233	0.125	0.375
Interactive	0.0330	0.333	0.250	0.616
Background	0.0500	0.300	0.250	0.600

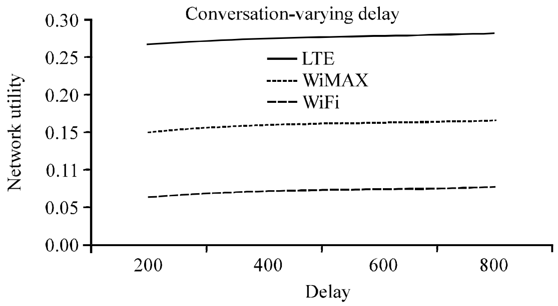

Fig. 4: Delay vs. network-utility

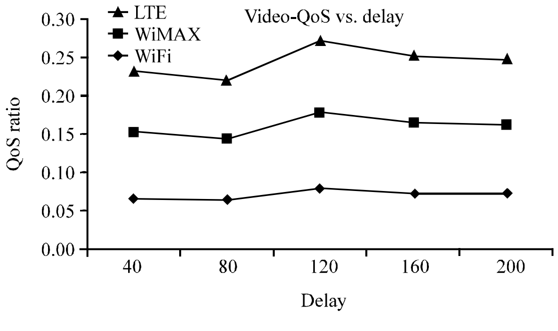

Fig. 5: Delay vs. QoS-ratio

Table 10: Streaming-ranking

Traffic classes	WLAN	WiMAX	LTE	Rank
Conversational	0.125	0.0999	0.1670	0.39190
Streaming	0.500	0.2331	0.0417	0.77487
Interactive	0.100	0.3330	0.0835	0.51650
Background	0.150	0.2997	0.0835	0.53320

Table 11: Interactive-ranking

Traffic classes	WLAN	WiMAX	LTE	Rank
Conversational	0.0069	0.0490	0.16650	0.2230
Streaming	0.0270	0.1160	0.04162	0.1860
Interactive	0.0050	0.1665	0.08325	0.2550
Background	0.0080	0.0832	0.24140	0.2414

Table 12: Background-ranking

Traffic classes	WLAN	WiMAX	LTE	Rank
Conversational	0.001160	0.02490	0.05440	0.0815
Streaming	0.004000	0.05820	0.01386	0.0760
Interactive	0.000900	0.08320	0.02772	0.1190
Background	0.001397	0.07492	0.02772	0.1245

CONCLUSION

The Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communications were done using WAVE and WiMAX/UMTS heterogeneous networks, respectively. The horizontal and vertical handover decisions were made effectively using NRMISHD and ranking approaches. In future, enhanced systems considering more real-time constraints like congestion-free mobility in the narrow roads or high density roads for implementing Vehicular Mobility Models. Safety and emergency reporting messages must be delivered on time with higher priority.

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