Enhancing QoS in Vehicle-to-Infrastructure Approaches through Adaptive Cooperative Communications

Radwa Ahmed Osman[*#], Xiao-Hong Peng[*]and M. A. Omar[#]
[*]School of Engineering & Applied Science, Aston University
Birmingham, UK
[#]College of Engineering & Technology, Arab Academy for Science, Technology & Maritime Transport
Alexandria, Egypt
email:{osmanmra, x-h.peng}@aston.ac.uk, mabd_elhamid@aast.edu

***Abstract*— In vehicle-to-infrastructure (V2I) communications, the challenge regarding how to achieve the intended performance at the minimal resource cost has yet been well addressed in the recent development of vehicular technologies. In this paper, we investigate some data transmission schemes, such as cooperative communications, for improving quality of service (QoS) in vehicular networks. We propose a method that facilitates V2I through vehicle-to-vehicle (V2V) communications and, for this approach, we derive the closed-form expressions of the outage probability, throughput, energy efficiency and packet loss rate for four different transmission schemes investigated. The QoS performances can be optimized by finding appropriate transmission schemes with a certain number of relays within a given transmission distance. The proposed approach is also aimed to achieve the best performance trade-off between system reliability and efficiency under various environmental conditions.**

Keywords*— *QoS; V2I; V2V; cooperative communications.

I. INTRODUCTION

In Vehicle-to-Infrastructure (V2I) communication networks, mobile users are able to access Internet services such as traffic condition broadcast, video streaming, digital map downloading, and information of road hazard and accident alarm, via fixed roadside units. The most recent research in this area has been focused on the vehicular ad-hoc networks (VANET) [1] [2], including its connection to the Fourth-Generation or Long-Term Evolution (LTE and LTE-Advance) cellular networks and the provision of good solutions to V2I in order to ensure low latency and high reliability communication [3].

IEEE 802.11.p is one of the commonly used standards for V2I to support vehicular communications in highly mobile, often densely populated, and frequently non-line-of-sight environments [4] [5]. In addition, the IEEE 802.15.4 standard, comprising a simple physical (PHY) layer and an energy efficient medium access control layer, is also designed to support both real-time and contention-based services and has been considered as a promising candidate for Internet of vehicles (IoV) and vehicular sensor networks [6]. To tackle the problem of high packet loss rate the cooperative communications techniques can be applied to enhance transmission reliability by creating diversity [7]. In this case, mobile nodes (vehicles) can help each other through relaying other node's data and sharing their limited resources, to improve loss performance and increase transmission coverage. However, the performance enhancement by using relays nodes is constrained by the power (energy) budget imposed and high mobility in the vehicular network [8]. This issue can potentially impede the delivery of quality of service (QoS) in the V2I approach.

In this work, we investigate both cooperative and non-cooperative transmission schemes, and intend to reveal how these schemes perform in the context of a vehicular network, in terms of energy consumption, throughput and packet loss rate under different conditions, such as transmission distance, relaying method and channel condition (path loss exponent). These findings are used to identify proper transmission schemes that can optimize the system performance for the whole network in a changing environment. The proposed approach is unique in the sense that it provides an efficient way to find the best transmission method for transmission between any V2I links. We propose a method that facilitates V2I, which is assisted by vehicle-to-vehicle (V2V) communications when needed, and evaluate the performance of this approach based on the models we derive.

The remainder of this paper is organized as follows. Section II discusses the relevance of this research with other work. The system models for both cooperative and non-cooperative transmission schemes for V2I communications are presented in Section III. Simulation results produced by Matlab and NS-2 and discussions are presented in Section IV. Finally, the paper is concluded in Section V.

II. RELATED WORK

Cooperative communications have been studied extensively for VANETs and two of the most common protocols of this technology are Amplify-and-Forward (AF) and Decode-and-Forward (DF) [9]. Cooperative or polarization diversity is created in these protocols through exploiting the broadcast nature of wireless channels and using relays to improve link reliability and throughput in a vehicular network [10]. In addition, the use of graph theory to formulate the problem of cooperative communications scheduling in vehicular networks is proposed in [11], in order to improve the throughput and spectral efficiency of vehicular networks.

Enhancing system efficiency is a key issue in applying cooperative communications in V2I approaches, depending on the connectivity probabilities in V2I and V2V communication scenarios in one-way and two-way platoon based VANETs [12]. Smart Antenna technology can also contribute to the increment of the service coverage and system throughput of V2I [13]. The capacity of V2I communications can be maximized by an iterative resource-allocation method [14] and the efficiency of V2I communications can be improved by applying a scheme called Distributed Sorting Mechanism (DSM) [15]. To improve power efficiency in vehicle-to-roadside infrastructure (V2I) communication networks, [16] proposed a joint power and sub-carrier assignment policy under delay-aware QoS requirements. In addition, the strong dependence on the environment due to multipath propagation is also presented for a distributed energy efficient routing method [17].

Most of the works have demonstrated the possibility of improving the system performance of vehicular networks by using different methods. However, there is a lack of information regarding how to choose a specific transmission scheme under different conditions in terms of the number of relaying branches and the number of relays for a given distance between source and destination nodes, in order to find a solution for ensuring the best QoS.

In this paper, our focus will be the identification of the conditions for establishing appropriate transmission strategies among different commonly used transmission schemes, including both cooperative and non-cooperative schemes for V2I communications. Our approach is based on the development of analytical models for these transmission schemes and the assessment of their performances in reliability, energy efficiency and throughput. It also reveals the trade-offs between cooperative and non-cooperative transmission schemes and shows how to utilize this property to achieve the optimized performance through adaptive cooperative communications.

III. SYSTEM MODEL

In this section, the analytical models of the required transmitting power, outage probability, energy efficiency, throughput and packet loss rate in the context of a V2I network are established for both cooperative and non-cooperative transmission schemes. Based on these models, an adaptive transmission strategy can be developed to optimize the system performance.

Given a V2I network with N vehicles, for any vehicle-to-infrastructure pair (V, I), where $V \epsilon \{1, \ldots, N\}$, the goal of optimizing the transmission QoS is achieved by minimizing the total energy consumed per bit (or energy efficiency) with a given outage probability target, maximizing the end-to-end throughput, and minimizing the packet loss rate based on the transmission distance between V2I pairs, i.e.

$$Min \sum E_{bi} \qquad s.t.\{p_{outVI}\} \text{ and}$$

$$Max \sum S_{thi} \qquad s.t.\{d_{VI}\} \qquad (1)$$

where E_{bi} and S_{thi} are the energy consumed per bit and throughput, respectively, of the i-th path between a vehicle (V) and infrastructure (I), p_{outVI} and d_{VI} are the fixed outage probability target and the total transmission distance between V and I.

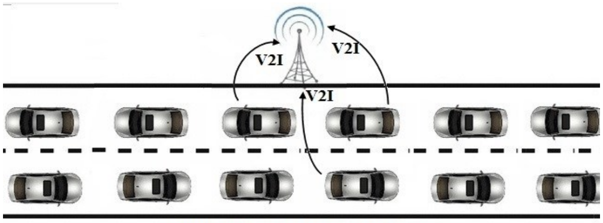

Figure 1.a Direct V2I Transmission

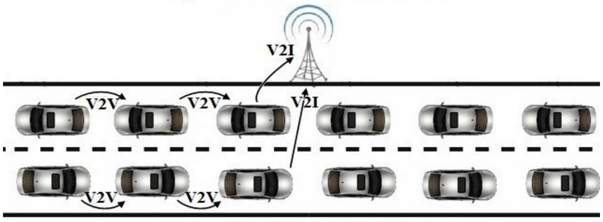

Figure 1.b Multi-hop V2I Transmission

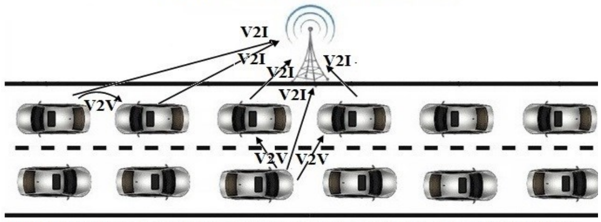

Figure 1.c Cooprtative V2I Transmission (muliple branches with one relay)

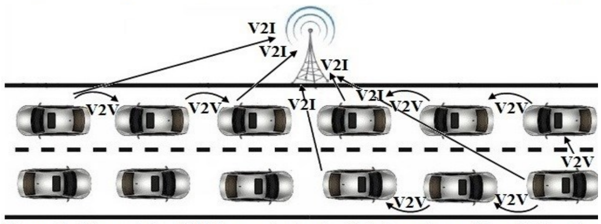

Figure 1.d Cooprtative V2I Transmission (muliple branches with multiple relay

Figure1. Different V2I transmission schemes.

Four transmission schemes in the context of V2I are identified in Figure1, including single-hop direct V2I (1a), multi-hop V2I via V2V (1b), cooperative V2I with a single relay (1c), and cooperative V2I with multiple relays (1d). In this work, we intend to examine the performances of different transmission schemes in terms of energy efficiency, throughput and packet loss rate, and to optimize them under different environmental conditions.

We consider a V2I network in which the transmission links are subject to narrowband Rayleigh fading with additive white Gaussian noise (AWGN) and propagation path-loss. The channel fades for different links are assumed to be statistically mutually independent. For medium access, vehicle nodes are assumed to transmit over orthogonal channels through using the service channels specified in IEEE801.11p [2], thus no mutual interference is considered in this system model. These channels can be reused by other vehicle away from a certain distance.

A. Non-Cooperative Transmission Scheme

Consider the transmission scheme for a direct link (*V, I*) as shown Figure 1a where no relaying paths are involved. We use P_{SDir} to denote the source transmission power for this case. For the direct transmission in the *V-I* link, the received symbol r_{VI} and the spectral efficiency R can be modeled as:

$$r_{VI} = \sqrt{P_{SDir}\, d_{VI}^{\ \ \alpha}}\, h_{VI}\, s + N_o \tag{2}$$

$$R = \frac{1}{2}\log_2\left(1 + SINR_{VI}\right) \tag{3}$$

where d_{VI} is the distance and h_{VI} is the channel coefficient of the *V-I* link, α is the path loss exponent, s is the transmitted symbol with unit power and N_o is the Gaussian noise.

The log-normal environment shadowing path loss model at a distance d_{ij} rom node i and node j is given by [18]:

$$\gamma_{ij}[dB] = PL\left(d_o\right) + 10\alpha\log_{10}\frac{d_{ij}}{d_o} + X_\sigma \tag{4}$$

where X_σ is a zero-mean Gaussian distributed random variable with standard deviation σ and with some time correlation. This variable is zero if no shadowing effect exists. The $PL(d_o)$ is the path loss at a reference distance d_o in dB. The Signal-to-Noise Ratio (SNR) of the *V-I* link is:

$$SINR_{VI} = \frac{P_{SDir}\left|h_{VI}\right|^2 \gamma_{VI}}{N} \tag{5}$$

where $N = N_0 B$ is the noise power spectral density, and B is the system bandwidth in Hertz.

An outage occurs when the SNR at the receiver falls below a threshold β which allows error free decoding. This threshold is defined as $\beta = 2^{2R_s}-1$, where R_s is the required system spectral efficiency. The outage probability of the single-hop transmission is given by [19]:

$$p_{outVI} = p\left(SINR_{VI} \le \beta\right) = 1 - e^{\left(\frac{\left(2^{2R_s}-1\right)N}{P_{SDir}\left|h_{VI}\right|^2 \gamma_{VI}}\right)} \tag{6}$$

Energy consumption is largely proportional to the requirement of maintaining a certain level of transmission reliability or the successful transmission rate. In order to maintain a required level of reliability, denoted by U, which is related to the reliability of a transmission link, the minimum outage probability is defined as:

$$p_{out} \le 1 - U \tag{7}$$

Combining (6) and (7) and taking the nature logarithm on the both sides of expression, we have:

$$\frac{\left(2^{2R_s}-1\right)N}{P_{SDir}\left|h_{VI}\right|^2 \gamma_{VI}} \le \ln\left(U^{-1}\right) \tag{8}$$

The main objective for the performance optimization of a V2I network is to minimize the total energy consumption under different environmental conditions. Thus, the transmit power required to satisfy the reliability requirement or be constrained by the outage probability for the direct transmission must be:

$$P_{SDir} \ge \left(2^{2R_s} - 1\right)\frac{N}{\left|h_{VI}\right|^2 \gamma_{VI}}\left(\ln\left(U^{-1}\right)\right)^{-1} \tag{9}$$

Therefore, the total consumed energy per bit (J/bit) for the direct transmission mode can be expressed as:

$$E_{bDir} = \frac{P_{AM,Dir} + P_C}{R_b}, \quad where\, P_C = P_{Tx} + P_{Rx} \tag{10}$$

$$P_{AM,Dir} = \frac{\xi}{\eta} P_{SDir} \tag{11}$$

where $P_{AM,Dir}$ is the power amplifier consumption for direct transmission which depends on the drain efficiency of the amplifier η, the average peak-to-peak ratio ξ, and the transmit power P_{SDir}, $R_b = R_s B$ is the data rate in bits/s, B is the system bandwidth, P_C is the power consumed by the internal circuitry for transmitting (P_{Tx}) and receiving (P_{Rx}).

The throughput S_{th} and packet loss rate PL can simply be defined, i.e.

$$S_{th} = \frac{Total\,\mathrm{Re}ceived\ Payload}{Total\,Transmitted\,Time} \tag{12}$$

$$PL = \frac{Total\,Sent\ Packets \quad Total\,\mathrm{Re}ceived\ Packets}{Total\,Sent\ Packets} \tag{13}$$

The multi-hop non-cooperative transmission scheme with n ($n \ge 1$) relays is shown in Figure 1b. Each relay is able to detect if the packet was received correctly or not and will forward the information to the destination only in the case of the packet being correctly received. Otherwise, the packet is considered lost.

Given the outage probability of individual hops, i.e., p_{outVR_1} (from a vehicle to relay 1), $p_{outR_1R_2}$ (from relay 1 to relay 2), …, p_{outR_nI} (from relay n to infrastructure), the outage probability of the multi-hop link, p_{outMH}, is given by:

$$p_{outMH} = 1 - \left(1 - p_{outVR1}\right)\left(1 - p_{outR1R2}\right)\ldots\left(1 - p_{outRnI}\right) \tag{14}$$

With the same mathematical treatment as in (6), p_{outMH} becomes:

$$p_{outMH} = 1 - e^{\left(2^{2R_s}-1\right)N}\, y \tag{15}$$

$$where\ \ y = \left(\frac{1}{P_{Vr1}\left|h_{Vr1}\right|^2 \gamma_{Vr1}} + \sum_{i\ 2}^{n}\frac{1}{P_{r1ri}\left|h_{r1ri}\right|^2 \gamma_{r1ri}} + \frac{1}{P_{rnI}\left|h_{rnI}\right|^2 \gamma_{rnI}}\right)$$

We set the transmit power to be proportional to the distance between two communicating nodes. For broadcast transmission, e.g., when the source transmits, the longest distance, i.e. the distance between the source and the destination d_{sd}, is considered. The power minimization problem is specified in a similar way to (7) and the total consumed energy per bit for the multi-hop direct transmission is expressed:

$$E_{bMH} = (p_{outMH}) \frac{P_{AM,MH} + P_C}{R_b} + (1 - p_{outMH}) \frac{(n * X + 1) P_{AM,MH} + (n+1) P_C}{R_b} \qquad (16)$$

where $P_{AM,MH}$ is the power amplifier consumption for multi-hop transmission.

B. Cooperative transmission Scheme

In cooperative transmission, the sender *V* broadcasts its symbol in to all potential receivers including the destination *I* and relays in the current time slot. Two types of cooperative transmission schemes are considered here: 1) using multiple cooperative relaying branches with one relay in each branch (Figure 1c), and 2) multiple relaying branches with multiple relays in each branch (Figure 1d). The selective decode-and-forward (SDF) relaying protocol is used in these two schemes and relays perform cooperation when the information from the source is correctly received by them. Based on the derivations methods used in Subsection III. A, the following close-form expressions can be readily obtained.

1): The outage probability of cooperative transmission with multiple (*K*) relaying branches:

$$p_{outMB} \approx \left(2^{2R_s} - 1\right)^{K+1} N^{K+1} z \qquad (17)$$

$$\text{where } z = \left(\frac{1}{P_{VI} |h_{VI}|^2 \gamma_{VI}} \left(\frac{1}{P_{VI} |h_{Vr}|^2 \gamma_{Vr}} + \frac{1}{P_{rI} |h_{rI}|^2 \gamma_{rI}} \right)^K \right)$$

2): The lower bound of power for the SDF scheme:

$$P_{SMB} \geq \left(2^{2R_s} - 1\right) N(y) \frac{1}{K+1} \left(\ln\left(U^{-1}\right)\right)^{\frac{1}{K+1}} \qquad (18)$$

3): The total consumed energy per bit:

$$E_{bMB} = (p_{outVr}) \frac{P_{AM,MB} + P_{Tx} + (K+1) P_{Rx}}{R_b} + (1 - p_{outVr}) \frac{(K * X + 1) P_{AM,MB} + (K+1) P_{Tx} + (K+2) P_{Rx}}{R_b} \qquad (19)$$

4): The total consumed power:

$$P_{totMB} = (p_{outVr}) (P_{AM,MB} + P_{Tx} + (K+1) P_{Rx}) + (1 - p_{outVr}) \left((K * X + 1) P_{AM,MB} + (K+1) P_{Tx} + (K+2) P_{Rx}\right) \qquad (20)$$

The transmit power at relays can be reduced and consequently the energy efficiency will be improved by implementing the cooperative communications schemes, which are particularly suitable for long-range transmission - the related results will be shown in Section IV.

IV. NUMERICAL RESULTS AND DISCUSSION

In this section, we examine the performances of different transmission schemes through Matlab and NS-2 simulations in terms of energy efficiency (energy consumption per bit), throughput and packet loss rate. We then reveal the conditions for selecting the optimal transmission schemes through comparisons between them. The network settings used for simulation is listed in TABLE 1. Assume the spectral efficiency *Rs* in this scenario to be 2 bit/sec/Hz, and the required system reliability level to be 0.999. To generate mobility, mobility-files are created in ns-2 simulation. In addition, we assume that all the vehicles are running at the same speed and keeping the same distance with each other.

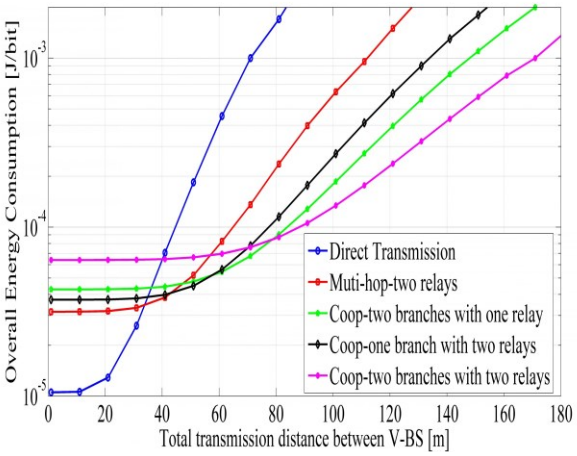

Figure 2. Total energy consumed vs total transmitted distance.

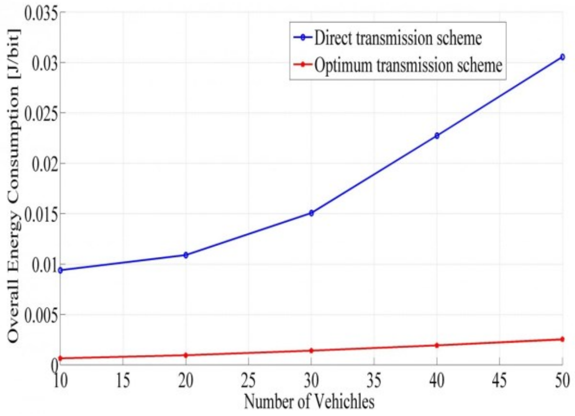

Figure 3. Overall energy consumption vs number of vehicles

In Figure 2 the energy performances of both cooperative and non-cooperative schemes are illustrated and compared. As we can see, the non-cooperative direct transmission has the lowest energy cost than all others transmission schemes for short-range (d_{VI}<33m); the non-cooperative transmission using multi-hop relays outperforms the direct transmission for the range 33m<d_{VI}<43m and, in particular, transmission using two intermediate relays (*n*=2) nodes has the lowest energy consumption for this range.

The cooperative transmission outperforms the non-cooperative transmission schemes for the range 43m<d_{VI}<58m, and the transmission using one branch with two relays (*K*=1, *n*=2) has the lowest energy consumption for this range. As distance continuously increases, the lowest energy consumption is achieved by transmission using two branches with one relay (*K*=2, *n*=1) for 58<d_{VI}< 80m, and by transmission using two branches with two relays (*K*=2, *n*=2) for d_{VI}>80m.

TABLE 1. SIMULATION PARAMETER

Parameters	Value
N_0	−174 dBm
B	10 kHz
R_s	2 bit/sec/Hz [20].
P_{TX}	97.9 mW [20]
P_{RX}	112.2 mW [20]
η	0.35
ξ	0.5
Packet Size	512 bytes
fc	5.9 GHz
α	3
Simulation time	1000 Sec
Nodes	10/20/30/40/50
Velocity	5 km/h, 20 km/h, 60 km/h
Traffic Agent	TCP
Mac Protocol	IEEE 802.11p
Queue	PriQueue with size of 50 Packets
Propagation model	Log-normal shadowing Model (LOS)
Antenna	Omni-directional with height of 1m
Routing Protocol	AODV
Number of Seed	3

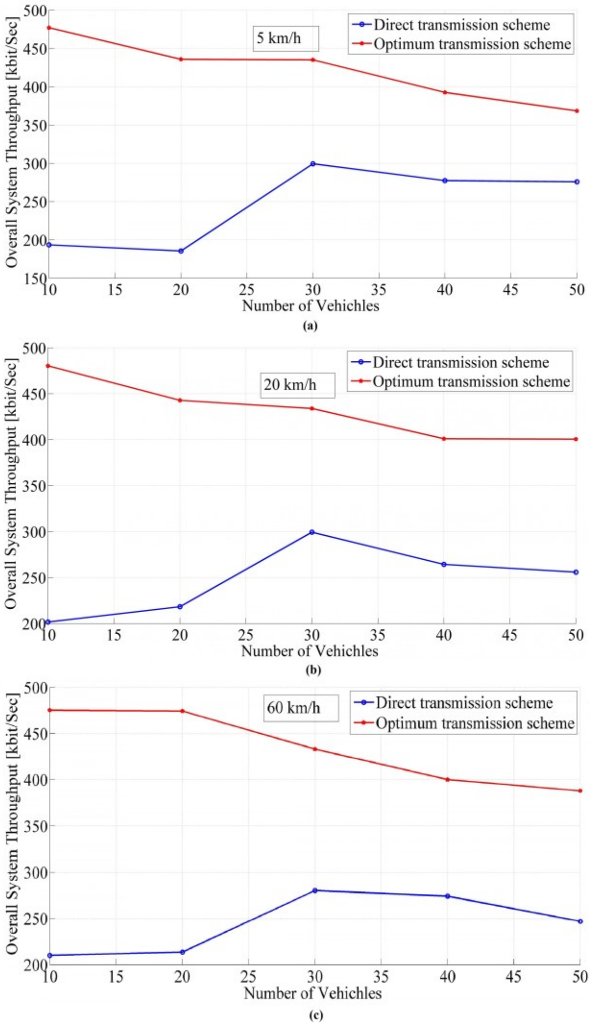

Figure 4. Overall system throughput vs number of vehicles.

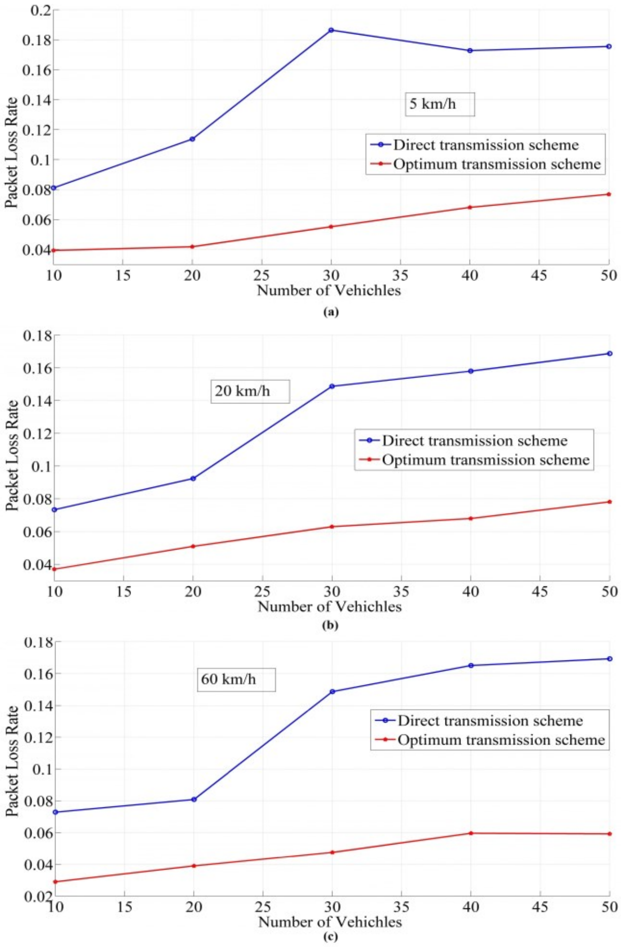

Figure 5. Packet loss rate vs number of vehicles

As shown in Figure 3, the non-cooperative direct transmission has much higher energy consumption than the optimum transmission scheme which is chosen based on the transmission distance between vehicles and infrastructure.

The overall system throughput is shown in Figure 4 for three different vehicle velocities. The optimum transmission schemes clearly outperform the direct transmission schemes in all cases due to the impact of diversity created by cooperative transmission. It is also noticed that the throughput of the optimum transmission scheme decreases when the number of transmitting vehicles increases. This is mainly due to congestion in medium access and increased operation overhead at the nodes that are the source, as well as the relay at the same time.

Figure 5 depicts the overall system packet loss rate for direct transmission and optimum transmission schemes versus the number of transmitting vehicles for different vehicle velocities. As it is shown, the packet loss rate increases when the number of transmitted vehicles increases for all the transmission schemes, which is caused by network congestion and correlated with the corresponding performance in throughput as shown in Figure 4. It is worth mentioning that the optimum transmission schemes have much lower packet loss rates than the direct transmission schemes as when relays are used the transmission distances between adjacent nodes are reduced and, at the same time, the transmission reliability is improved due to the diversity generated in cooperative communications.

Due to the scenario settings in our work where most vehicles have a fairly large distance between them and the roadside base station, no major difference in performance is observed when increasing the velocity of vehicles, as shown in Figures 4 and 5. In contrast, as discussed above, the performance such as throughput is correlated with the number of vehicles which are connected to the same base station,

There are a number of factors affecting energy consumption, throughput and packet loss rate in V2I networks. Cooperative transmissions utilize additional paths and intermediate nodes which may cost more energy, but the diversity it creates can save energy by reducing the probability of link failure and consequently reducing the number of retransmissions. Diversity increases with the number of relay branches used but this increase could be marginal when the number of branches is large as it is difficult to ensure that all the branches are uncorrelated.

Clearly, to achieve the best energy performance as discussed in this paper, proper transmission schemes should be selected for the given transmission conditions such as the overall distance, d_{sd}, and channel quality in terms of α. The findings of this work can assist deciding when and how the cooperative or non-cooperative transmission scheme should be employed. Based on our investigation, an energy-efficient transmission strategy can be formed in a V2I network by adaptively choosing proper transmission schemes under different network and transmission conditions. This involves determining the number of relaying branches and the number of relays if the cooperative scheme is to be used. By doing so, energy saving could be significant even with the direct transmission scheme in certain conditions, as shown from our results.

V. CONCLUSION

We have investigated different transmission schemes in terms of their energy and throughput performances for V2I communications. We have shown that both cooperative and non-cooperative transmission schemes can exhibit the best performance under certain environmental conditions. The optimal transmission scheme can be identified given the distance between the source and destination nodes in a V2I network. The results presented in this paper can be used to form an adaptive transmission strategy that is able to select an appropriate transmission scheme in a changing environment to maintain the best QoS performance in a dynamic way, in terms of achieving the highest throughput with a fixed energy budget or the lowest energy cost for the given throughput target.

REFERENCES

[1] S. Wu, C. Chen, and M. Chen, “An asymmetric and asynchronous energy conservation protocol for vehicular networks,” IEEE Trans. Mobile Compu., Vol. 9, pp. 98-111, January 2010.

[2] M. J. Booysen, S. Zeadally, and G.-J. V. Rooyen, “Survey of media access control protocols for vehicular ad hoc networks,” IET Commu., Vol. 5, pp. 1619-1631, March 2011.

[3] G. el mouna Zhioua, N. Tabbane, H. Labiod, and S. Tabbane, “A fuzzy multi-metric QoS-balancing gateway selection algorithm in a clustered VANET to LTE-advanced hybrid cellular network,” IEEE Trans. on Veh. Technology, Vol. 64, pp. 804 - 817, February 2015.

[4] O. Goubet, G. Boudic, F. Gabry, and T. J. Oechtering, “Low-complexity scalable iterative algorithms for IEEE 802.11p receivers,” IEEE Trans. on Veh. Technology, vol. 64, pp. 3944-3956, September 2015.

[5] X. Wu, S. Subramanian, R. Guha, R. G. White, J. Li, K. W. Lu, A. Bucceri, and T. Zhang, “Vehicular communications using DSRC: challenges, enhancements, and evolution,” IEEE journal on Selected Area in Commun., Vol. 31, pp. 399-408, September 2013.

[6] C. Wang, C. Chou, P. Lin, and M, Guizani, “Performance evaluation of IEEE 802.15.4 non beacon-enabled mode for internet of vehicles,” IEEE Trans. on Intelligent Transportation Systems, vol. 16, pp. 3150-3159, December 2015.

[7] A. Nasri, R. Schober, and I. F. Blake, “Performance and optimization of amplify-and-forward cooperative diversity systems ingeneric noise and interference,” IEEE Trans. Wireless Commun.,vol. 10, pp.1132-1143, January 2011.

[8] D. Xie, W. Wei, Y. Wang, and H. Zhu, “Tradeoff between throughput and energy consumption in multirate wireless sensor networks,” IEEE. Sensor Journal, Vol. 12, pp. 3667 - 3676, August 2013.

[9] H. Hakim, H. Bouijemaa, and W. Ajib, “Single relay selection schemes for broadcast networks,” IEEE Trans. Wireless Commun.,vol. 12, pp.2646-2657, May 2013.

[10] S. Sohaib and D. K. C. So, “Asynchronous cooperative relaying for vehicle-to-vehicle communications,” IEEE Trans. on Commun.,Vol. 61, pp.1732-1738, May 2013.

[11] K. Zheng, F. Liu, Q. Zheng, W. Xiang, and W. Wang, “A graph-based cooperative scheduling scheme for vehicular networks,” IEEE Trans. Vehicular Technology vol. 62, pp. 1450-1458, May 2013.

[12] C. Shao, S. Leng, Y. Zhang, A. Vinel, and M. Jonsson, “Performance analysis of connectivity probability and connectivity-aware MAC protocol design for platoon-based VANETs,” IEEE Trans. on Veh. Technology, vol. 64, pp. 5596-5609, December 2015.

[13] S. Pyun, H. Widiarti, Y. Kwon, J. Son, and D. Cho, “Group-based channel access scheme for a V2I communication system using smart antenna,” IEEE Commun. Letter, vol. 15, pp.804-806, August 2011.

[14] S. Pyun, W. Lee, and D. Cho, “Resource allocation for vehicle-to-infrastructure communication using directional transmission,” IEEE Trans. on Int. Trans., vol. 17, pp. 1183-1188, April 2016.

[15] T. Wu, S. Guizani, W.-T. Lee, and K. Liao, “Improving RSU service time by distributed sorting mechanism,” Ad Hoc Netw., vol. 10, pp. 212-221, March 2012.

[16] A. Goldsmith, Wireless Communications, 1st edition. Cambridge University Press, 2005.

[17] A. S. Ibrahim, Z. Han, and K.J.R. Liu, “Distributed energy-efficient routing in wireless networks,” IEEE Trans. Wireless Commun., vol. 7, pp. 3930 - 3941, October 2008.

[18] T. Nguyen, O. Berder, and O. Sentieys, “Energy-efficient cooperative techniques for infrastructure-to-vehicle communications,” IEEE Trans. on Int. Trans. Sys., vol. 12, pp. 659-668, September 2011.

[19] H. Zhang, Y. Ma, D. Yuan, and H-H. Chen, “Quality-of-service driven power and sub-carrier allocation policy for vehicular communication networks,” IEEE Journal on Selected Area in Commun., vol. 29, pp. 197-206, January 2011.

[20] L. Azpilicueta, C. Vargas-Rosales, and F. Falcone, “Deterministic propagation prediction in transportation systems,” IEEE Vehicular Tech. Mag., vol. 11, pp. 29-37, September 2016.