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ADAPTIVE VEHICLE TO VEHICLE HETEROGENEOUS TRANSMISSION IN COOPERATIVE COGNITIVE NETWORK VANETS

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Abstract. *The vehicle-to-vehicle (V2V) communication system is an active radio broadcast system to receive information of disseminated road congestion and accident in real-time situation. V2V and vehicle-to-infrastructure (V2I) communication are developed based on the IEEE 802.11p technology, ad hoc principles, and wireless multi-hop techniques using geographical positions. Cognitive radio (CR) system can dynamically access any available resources in radio spectrum in an opportunistic fashion, which not only significantly improved the spectrum utilization, but also better satisfied the user service requirements. In this paper, the simulation results indicate that, when vehicles are unable to communicate directly with other available network nodes, infrastructure or vehicles, relaying information is crucial in such perceiving environment.*
Keywords: V2V, V2I, Cognitive radio, IEEE 802.11p

1. **Introduction.** Newer technologies such as MIMO systems are starting to increase the number of bits per second per hertz of bandwidth through spatial multiplexing and improve the robustness/range of the wireless link for a given data rate through space-time coding and beam forming. However, all these improvements come at the cost of multiple RF front ends at both the transmitter and the receiver. Cooperative communication techniques described in this article are fundamentally different in the relaying nodes technology which can forward information fully or in part.

Cooperative techniques are done by utilizing the broadcast nature of wireless signals by observing that a source signal which can be overheard at neighbor nodes is intended to be transmitted to a particular destination. These neighbor nodes are called relays, partners or helpers, process the overheard signals and transmit towards the destination [1]. Position and traffic information is needed by drivers to select an optimal entertainment information which is welcomed by passengers to enjoy the travel [2].

Vehicular communication can provide great benefits to all road users and achieve where a major step toward safer, cleaner and smarter roads [16]. Vehicular communication has been known with specific characteristics and requirements: intermittent access to a communication infrastructure, self-organization, high node mobility, scalability with a number of nodes ranging from sparse to dense scenarios, information dissemination in geographical regions, reliable data transmission with short delay and fairness in resource usage.

CR is a special type of software defined radio which is able to estimate the communication parameters and can intelligently adapt itself to the environment. In order to achieve the desired objective (i.e., to maximize throughput and channel utilization), intelligent decision making algorithms would be required for cognitive radios [17]. CR is suitable in VANETs due to its highly mobile and dynamic networking environment such that spatial and temporal reuse of the licensed spectrum can be realized in a much easier and cheaper way compared with other types of wireless networks [18].

In this paper, we proposed a cooperative inter-vehicle heterogeneous communication combined with adaptive cognitive network in VANETs. The major contributions of this paper are as follows: 1) Reduce the transmission time and enhance stability through heterogeneous communication interface and cooperative communication between each car; 2) Enlarge the transmission range and enhance lifetime of inter-vehicle communication and high performance transmission; 3) By cognitive network characteristic, different communication interfaces represent different inter-vehicle communications in VANETs.

The rest of this paper is organized as follows. Section 2 discusses the related literature. Section 3 then describes the proposed system model and mechanism. Next, Section 4 presents the heterogeneous networks for cognitive radio model. Section 5 compares the proposed method with existing methods with reference to both analytical, simulation result and conclusions which are presented in Section 6.

2. **Related Work.** This section briefly summarizes a representative cooperative transmission, cognitive radio, and also introduces V2V communications.

2.1. **Cooperative communications.** Multiple antennas systems, such as MIMO, can create spatial diversity and therefore significantly increase wireless channel capacity. However, installation of multiple antennas on a wireless device may confront with many practical obstacles, such as increase in cost and size of hardware. Cooperative transmission takes advantage of the broadcast nature of wireless networks, and exploits spatial diversity and multi-user diversity. Broadcasting was traditionally used in many network protocols as an efficient way to distribute control information throughout the network.

Emerging wireless applications such as sensor and wireless mesh networks have an increasing demand for small and low cost devices that are densely deployed over a wide area. The limited battery lifetime of devices and the scarce bandwidth shared by a large number of users often hinder the development of these systems [6].

2.2. **CR system.** The cognitive radio technology lays the foundation for the deployment of smart flexible networks that cooperatively adapt to increase the overall network performance. The cognitive radio terminology was coined by Mitola [14], and refers to a smart radio which has the ability to sense the external environment, learn from the history, and make intelligent decisions to adjust its transmission parameters according to the current state of the environment. The potential contributions of cognitive radios to spectrum sharing and an initial framework for formal radio etiquette have been discussed in [15].

2.3. **V2V communications.** VANETs are a subset of MANETs. V2V systems, in which both the transmitter and receiver are moving and have low-elevation antennas, differ from conventional fixed-to-mobile cellular radio systems, in which only one terminal (mobile station) is moving while the other base station is fixed [10].

Most V2V measurement campaigns have focused on single-antenna applications, leading to the development of single-input single-output (SISO) systems [19-21]. Multiple-input multiple-output (MIMO) systems, with multiple antennae at both ends, have great potential future communication systems and are increasing in importance in IEEE 802.11 standards. However, only a few measurement campaigns [22] have so far been conducted for MIMO V2V channels. Therefore, more MIMO V2V wideband measurement campaigns must be performed are needed to develop future V2V systems. The channel can be defined in terms of the complete set of parameters associated with all paths that transmit electromagnetic waves in the frequency band of interest from the transmitter to receiver over the spatial region of interest [23].

3. **System Model.** In this work, we proposed a new mechanism that $\{v_1, \cdots, v_K\}$ group of cars to communicate with each other in cooperative communication network. In heterogeneous communication environment, each communication protocol and $\{v_1, \cdots, v_K\}$ cars are different. Different distance of each group leader causes data transfer rate and data integrity, we proposed adaptive V2V heterogeneous for CCN system model to solve this kind problem. By adapting cognitive model in receiver side, we can realize modulation mechanism and each parameter through analyzing each modulation signal. Then we can choose an appropriate modulation model to get a quality source signal which is shown as Figure 1.

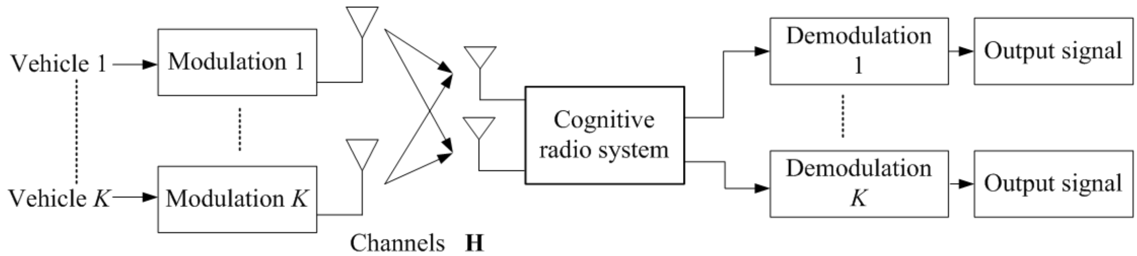

FIGURE 1. Adaptive V2V heterogeneous network for CCN system model

In cooperative communication structure, the stability of data transfer rate is influenced by distance of each car and communication environment. In order to enhance the stability while receiving data, adaptive cooperative communication is quiet appropriate. The shorter car distance from source, the more possibility for it to receive the complete data and consuming shorter data transfer time. Also, car which is close from source than others can relay the information to other car. Thus, car which is far from source may has two communication paths, one of the source path may has weak radio reception and the other one is a relay path that relay information from other cars. Through this kind of mechanism, we can reduce bit error rate and enhance date transfer rate.

The major contributions of this paper are follows: 1) Reduce the transmission time and enhances stability through heterogeneous communication interface and cooperative communication between each car; 2) Enlarge the transmission range, enhances lifetime of inter-vehicle communication and high performance transmission; 3) By cognitive network characteristic, different communication interfaces represent different inter-vehicle communication in VANETs.

3.1. **Cooperative vehicle transmission channels.** We presented a cooperative transmission for an uncoded multihop CDMA system. The system consists of K vehicle nodes $\{U_1, U_2, \cdots, U_K\}$ (assuming that K is an even number), communicating with an infrastructure of U_d node. Each vehicle node is equipped with a transmitter and a receiver. Due to the limitation in the signal processing capability of hardware, a separated channel has to be allocated for the relaying and a vehicle node transmits and relays during different time period. We assumed that the user's spreading codes are non-orthogonal and the coherence time of the channel denotes M periods, it is denoted for all the fading parameters remain approximately unchanged for M periods.

3.1.1. *Direct transmission.* In the synchronous direct-sequence CDMA communication system with K users, the k^{th} user $1 \leq k \leq K$ is assigned a normalized spreading waveform $s_k(t)$, given by

$$s_k(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} c_k(n)\psi(t - nT_c), \quad 0 \leq t \leq T, \quad 1 \leq k \leq K, \tag{1}$$

where N denotes the processing gain, $c_k's$ are signature sequence of ∓ 1 assigned to the k^{th} user, $\psi(\bullet)$ denotes the normalized chip waveform of duration $T_c = T/N$, with T denotes the interval. Let $b_k \in \{-1, +1\}$ be the transmitted bits and P_k be the transmission power of U_K. The BPSK modulated baseband signal sent by the k^{th} user is expressed as

$$x_k(t) = \sqrt{P_k/T} b_k s_k(t) \tag{2}$$

Let M be the length of a data frame. Transmitted signals $x_k(t)$ undergo a narrow-band quasi-static Rayleigh fading channel, i.e., the channel state remains constant over the length of one data frame, but varies independently from one to another, At the base station, the channel-affected signals are further perturbed by the white Gaussian noise and the discrete-time received signals are expressed by

$$y\,[m] = \sum_{k=1}^{K} h_{k,d} x_k\,[m] + n_d\,[m], \quad 1 \leq m \leq M, \tag{3}$$

where $h_{k,d}$ denotes the fading amplitude of user k's uplink channel (from user k to the destination base station (BS)) and n_d denotes the independent additive white Gaussian noise at the BS, with variance $E[n_d[m]n_d[n]] = \sigma^2\delta_{mn}$, where δ_{mn} denotes Kronecker delta function. The destination node correlates the received signals with a matched filter bank with K corresponding PN codes. The received signal vector $\mathbf{Y}$ denotes the output of the matched filter bank is given

$$\mathbf{Y} = \mathbf{RAHb} + \mathbf{Z} \tag{4}$$

where A and H denote $K \times K$ diagonal matrices with $(\mathbf{A})_{k,k} = \sqrt{P_k/T}$ and $(\mathbf{H})_{k,k} = h_{k,d}$ and $\mathbf{b} = [b_1[m], b_2[m], \cdots, b_k[m]]^T$. The Gaussian noise vector $\mathbf{Z} \sim N(0, \sigma^2 R)$ and $\mathbf{R} = \{\rho_{i,j}\}$, with $\rho_{i,j} = \langle s_i, s_j \rangle = R_0^T s_i(t)s_j(t)dt$ denote the cross correlation matrix between signature waveforms of different users, given by

$$R = \begin{bmatrix} 1 & \rho_{12} & \cdots & \cdots & \rho_{1K} \\ \rho_{21} & 1 & \cdots & \cdots & \rho_{2K} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \rho_{K1} & \rho_{K2} & \cdots & \cdots & 1 \end{bmatrix} \tag{5}$$

3.1.2. *Cooperative transmission.* The cooperation strategy is described as follows: K users are divided in two subsets of same size, denoted by S_T and S_R respectively. We pick up a node, say from S_T and pair it with another node from S_R to transmit data cooperatively. We place the restriction that there is one-to-one mapping from S_T to S_R or vice verse. Without loss of generality, the nodes with odd indices, i.e., $U_1, U_3, \cdots, U_{K-1}$, are grouped into S_T and those with even indices, $U_2, U_4, \cdots, U_K$, into S_R.

Suppose that U_1 is the node of interest. The received signals at the relay and the base station during $m = 1$ are respectively given by

$$\begin{aligned} y_d\,[1] &= \sum_{k=1, k\in S_T}^{K} h_{k,d}\left(x_k\,[1] + \hat{x}_{k+1}\,[0]\right) + n_d\,[1] \\ y_2\,[1] &= \sum_{k=1, k\in S_T}^{K} h_{k,2}\left(x_k\,[1] + \hat{x}_{k+1}\,[0]\right) + n_2\,[1] \end{aligned} \tag{6}$$

where $h_{k,2}$ denotes the fading amplitude of the inter-user channel from user k to user 2. n_d and n_2 denote the additive white Gaussian noise at the destination and the relay node. The vehicle node U_2 receives an attenuated and the noisy version of its partner's (U_1's) transmitted signals. It detects the data and modulates the estimate of U_1's bit, denoted by $\hat{b}_1[1]$, with $\psi_1(t)$. Then it constructs a packet in conjunction with its own data, $\hat{b}_2[1]$, modulated by $\psi_2(t)$, and sends the packet towards the destination in $m = 2$. Thus, the destination obtains two versions of U_1 data, respectively from the direct path and the relay path. Different from the direct transmission system, the transmission power has to be split and allocated for the new bit and the estimation of the partner. For a fair comparison with the direct transmission, P_k is divided into $P_{k,d}$ and $P_{k,c}$, with

$$\begin{array}{l} |x_k[m]|^2 = P_{k,d}/T \\ |\hat{x}_k[m-1]|^2 = P_{k,c}/T \\ P_{k,d} + P_{k,c} = P_k \end{array} \tag{7}$$

Detectors at the destination and relay nodes have a bank of K matched filters with corresponding waveforms, $S_1(t), S_2(t), S_3(t), \cdots, S_K(t)$. The relay node U_2 is only interested in the new bit from its source U_1, while the destination have to detect transmissions from all nodes in S_T. A similar setup can be employed for $m = 2$, with the role of S_R and S_T switched. The received signals at the relay node and BS are given in sufficient statistics as

$$\begin{array}{l} \mathbf{Y}_2[1] = \mathbf{R}\mathbf{A}_{d1}\mathbf{H}_2\mathbf{b}_1 + \mathbf{Z}_2[1] \\ \mathbf{Y}_d[1] = \mathbf{R}\mathbf{A}_{d1}\mathbf{H}_{d1}\mathbf{b}_1 + \mathbf{Z}_d[1] \\ \mathbf{Y}_d[1] = \mathbf{R}\mathbf{A}_{d2}\mathbf{H}_{d2}\mathbf{b}_2 + \mathbf{Z}_d[2] \end{array} \tag{8}$$

where data vectors $\mathbf{b}_1$ and $\mathbf{b}_2$ are given by

$$\begin{array}{l} \mathbf{b}_1 = [b_1[1], \hat{b}_2[0], b_3[1], \hat{b}_4[0], \cdots, b_{K-1}[1], \hat{b}_K[0]]^T \\ \mathbf{b}_2 = [b_1[1], \hat{b}_2[2], b_3[1], \hat{b}_4[2], \cdots, b_{K-1}[1], \hat{b}_K[2]]^T \end{array} \tag{9}$$

$\mathbf{A}_{d1}$, $\mathbf{A}_{d2}$, $\mathbf{H}_{d1}$ and $\mathbf{H}_{d2}$ are K-by-K diagonal matrices, with

$$\begin{array}{ll} (\mathbf{A}_{d1})_{kk} = (\mathbf{A}_{d2})_{k+1,k+1} = \sqrt{P_{k,d}/T}, & \text{if } k \text{ odd} \\ (\mathbf{A}_{d1})_{kk} = (\mathbf{A}_{d2})_{k-1,k-1} = \sqrt{P_{k,c}/T}, & \text{if } k \text{ even} \\ (\mathbf{H}_{d1})_{kk} = (\mathbf{H}_{d2})_{k+1,k+1} = h_{1d}, & \text{if } k \text{ odd} \\ (\mathbf{H}_{d1})_{kk} = (\mathbf{H}_{d2})_{k-1,k-1} = h_{kd}, & \text{if } k \text{ even} \end{array} \tag{10}$$

Zero-mean noise vectors $\mathbf{z}_j[m]$, $j \in \{2, d\}$, $m \in \{1, 2\}$, have the covariance matrix $\mathrm{E}[\mathbf{z}_j[m]\mathbf{z}_j[m]^T] = \sigma^2\mathbf{R}$

$$\begin{array}{l} \mathrm{E}[\mathbf{z}_j[m]\mathbf{z}_j[n]^T] = 0, \text{ for } m \neq n \text{ or } i \neq j \\ \mathbf{R}_d = \begin{bmatrix} \mathbf{R} & \mathbf{I}_K \\ \mathbf{I}_K & \mathbf{R} \end{bmatrix}, \mathbf{A}_d = \begin{bmatrix} \mathbf{A}_{d1} & \mathbf{I}_K \\ \mathbf{I}_K & \boldsymbol{A}_{d2} \end{bmatrix} \text{ and } \mathbf{H}_d = \begin{bmatrix} \mathbf{H}_{d1} & \mathbf{I}_K \\ \mathbf{I}_K & \mathbf{H}_{d2} \end{bmatrix} \end{array} \tag{11}$$

The received signal vector at the BS can be expressed as

$$\mathbf{Y}_d = \mathbf{R}_d\mathbf{A}_d\mathbf{H}_d\mathbf{b}_d + \mathbf{Z}_d \tag{12}$$

We assumed that the channel between transmitting terminals (inter-user channel) and each terminal to the BS (forward channels or uplinks) are mutually independent in a cooperative transmission system. The fading amplitude is reciprocal, for instance, $h_{1,2} = h_{2,1}$, given U_1 and U_2 cooperating with each other. Additionally, receivers have processes but the transmitters do not exploit such information [5].

3.2. **Cooperative of vehicle navigation information.** Hybrid wireless relay network is emerging as wireless system that integrates conventional cellular network paradigm with the emerging wireless relay network paradigm. Hybrid wireless relay networks leverages the respective advantages of cellular network and WLAN relay network to achieve better system performance. A hybrid wireless network introduced in [7] integrates cellular WWAN and WLAN to from a two-hop-relay route that relays traffic from areas with low cellular data rates to areas with high data rates. A two-hop-relay system is shown in Figure 2(a).

In the cellular relaying networks, fixed relay stations (RS) are employed at the edge of high data-rate service coverage. The user traffic can be served either with or without an RS. The RSs on the routing path keep the received packets in a buffer and forward them to the destination [13]. In Figure 2(b), $\hat{C}_{ij}$ is the achievable data rate from base station (BS) to node j with or without relaying. The achievable data rate from BS i to node k can be obtained as

$$1/\hat{C}_{ik} = \min_{j \in N_k} [1/C_{ik}, 1/C_{ij} + 1/C_{jk}] \tag{13}$$

where N_k denotes the set of node k's neithbor nodes. We focused on the fixed RS case, which allows at most two hops, our choice is whether to relay or not. We employed a two-step approach to select the optimal routing path for mobile station. We modeled the instantaneous data rate C_{ij} from node i to j with Shannon capacity of a Gaussian channel and SINR:

$$C_{ij} = W \times log_2(1 + \gamma_{ij}) \tag{14}$$

where $W[Hz]$ denotes the total allocated bandwidth per cell.

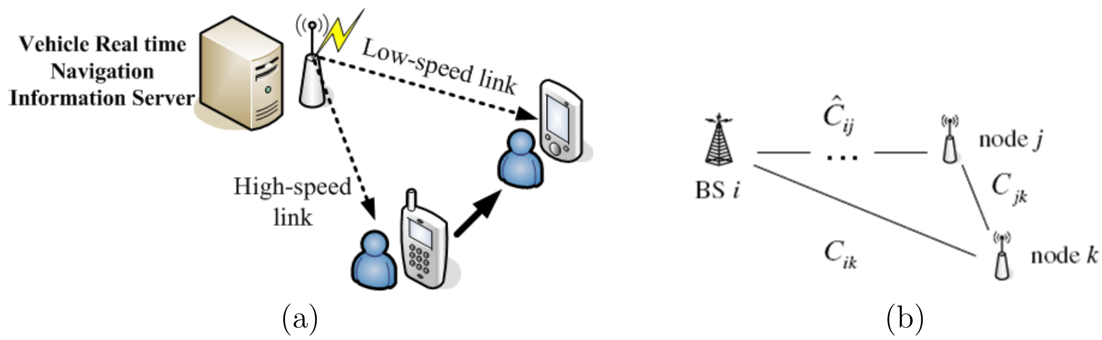

Figure 2. Wireless network two-hop-relay system and routing path

We used game theory to model the behavior of the selfish user in this type of network. When all users are selfish, Nash Equilibrium is an operating point where no user will benefit from deviating unilaterally from that operating point. Even without considering selfish user behaviors, the two-hop-relay system still requires a mechanism to allocate more radio resource to relay nodes. For instance, as shown in Figure 3, if the base station allocates the same amount of throughput to a directly-connected end user and to a relay node that serves two other end users (note that the relay node is also a traffic sink), the directly-connected end user is allocated three times of the throughput than that of the other two end users, who are connected via the two-hop-relay routes [8].

Cooperative transmission is an emerging communication technique that takes advantages of spatial diversity and broadcast natures of wireless channels to improve wireless channel capacity. In this paper, we can see that cooperative transmission has large performance gain over direct transmission after security problems are fixed by the proposed scheme. Multiple users system, such as MIMO, can create spatial diversity and therefore significantly increase wireless channel capacity. However, installation of multiple antennas

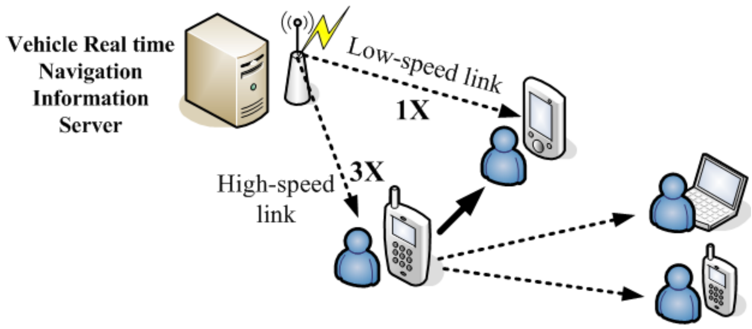

FIGURE 3. Throughput allocation in two-hop-relay network

on a wireless device may confront with many practical obstacles, such as increase in cost and size of hardware. In cooperative transmission, when the source node transmits a message to the destination node, some nearby nodes, which are overhead of this transmission, can serve as virtual antennas by transmitting replicas of the source's message.

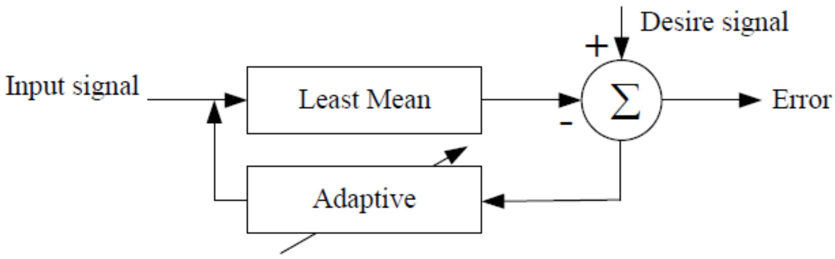

FIGURE 4. Adaptive LMS analysis model for V2V cooperative transmission

We proposed an adaptive inter-vehicle heterogeneous communication model in VANETs. Through the adaptive least mean square (LMS) analyze module, we can realize relation between the mean square error and the number of hops, As Figure 4, we consider two paths without correlations as shown Figure 5. For the case without correlations, Figure 5 shows the mean square error with respect to the number of hops, with the Poison packet arrivals, while the tow-hop two-path estimator of the deterministic packet arrival is a lower bound benchmark due to inherent deterministic information in each time slot.

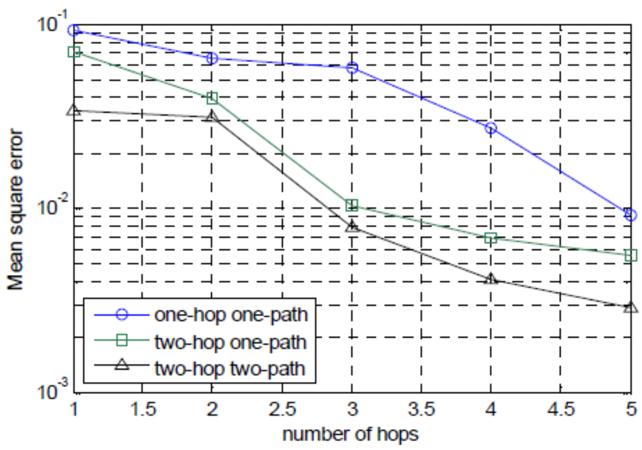

FIGURE 5. Number of hops with MSE

3.3. **Cooperative of game scheme.** The Game scheme provides a formal methodology to analyze the behaviors and the interactions among some rational agents (i.e., players). A game consists of several players who behave rationally. Each player has a set of strategies to be chosen. A player also has a utility function, which is a mapping function from a set of strategies to the corresponding real-number payoff of the player. A rational player will play the strategy that maximizes his/her utility function (i.e., user payoff). The Nash Equilibrium is an important concept in the game theory to model the selfish behaviors in multi-user games. The Nash Equilibrium is a strategy profile, including one strategy for each player, such that no player can gain benefit by changing his/her strategy unilaterally.

One important game theoretical concept is to identify Nash Equilibrium by finding dominant strategies among players. A dominant strategy of the player P is defined as a strategy that gives the player P greater payoff than the payoff of any other strategies under all circumstances. A dominant strategy solution of a game exists when every player in this game has a dominant strategy. The dominant strategy solution is the set of the dominant strategies. Since no player will deviate from his/her dominant strategy, the dominant strategy solution is Nash Equilibrium [10].

The game theory power allocation method [11] is a distributed system where each "player" or link controls its power based upon the utility (i.e. capacity) of a link and a penalty function for transmitting power. The utility of a link is the link capacity, C_l, which is a function of the squared singular value of the whitened channel, $\sigma_{l,i}$. The penalty or pricing function is then a function of the power amount of a link used, p_l, to prevent a link from transmitting unnecessarily high power. p_l is scaled by a pricing factor γ_l to enforce a minimum capacity per unit power. Therefore, the net-utility function can be expressed as $u_l = C_l - \gamma_l p_l$. With this net-utility function, the per-link objective function can be expressed as,

$$\max_{\mathbf{z}_l} \sum_{i=1}^{N_t} \log_2\left(1 + z_{l,i}\sigma_{l,i}\right) - \gamma_l \sum_{i=1}^{N_t} z_{l,i} \tag{15}$$

such that $\sum_{i=1}^{N_t} z_{l,i} \leq p_l$, which is the total power constraint, the value of γ_l must be selected.

4. **Heterogeneous Networks for Cognitive Radio System.** The cognitive radio network we considered consists of a set of N transmitting-receiving pairs of nodes, uniformly distributed in a square region of dimension $D^* \times D^*$. We assumed that the nodes are either fixed, or moving. The nodes measure the spectrum availability and decide on the transmission channel. We assumed that there are K frequency channels available for transmission, with $K < N$. By selecting a transmitting frequency distributively, the radio effectively constructs a channel of reuse distribution map with reduced co-channel interference.

The transmission link quality can be characterized by a required bit error rate (BER) target, which is specific for the given application. An equivalent signal-to- interference ratio (SIR) measured at the receiver j associated with transmitter i can be expressed as,

$$SIR_{ij} = \frac{p_i G_{ij}}{\sum_{k=1,k\neq i}^{N} p_k G_{kj} I\left(k, j\right)} \tag{16}$$

where p_i denotes the transmission power at transmitter i, G_{ij} is denotes the link gain between the transmitter i and the receiver j. $I(i, j)$ is denote the interference function which is characterizing the interference created by node i to node j and is defined as,

$$I(i,j) = \left\{ \begin{array}{ll} 1 & \text{if transmitters } i \text{ and } j \text{ are transmitting for the same channel} \\ 0 & \text{otherwise} \end{array} \right\} \tag{17}$$

Alternatively, the target SIR requirements can be changed (reduced or increased) by using different modulation levels and various channel coding.

5. Performance Results. Cooperative driving technology with inter-vehicle communication has increasingly attracted attention recently. It aims to improve driving safety and efficiency by using the appropriate motion scheduling of all of the encountered vehicles. The results indicate that in conditions when the vehicles are unable to communicate directly with each other, the availability of network nodes, infrastructure or vehicles, which can relay information, is crucial in such perceiving the environment is shown as in Figure 6.

In Figure 6, we assumed that in an inter-vehicle communication network, each vehicle utilizes different communication interface. This situation would not gain any satisfaction even if we have increased the performance. That is why there might be some differences for the proposed CN. Cooperative driving technology is able to support larger number of vehicles by enlarging communication range. This allows the vehicles to exchange information with each other, which also causes the increase of communication loading and prolong lifetime.

The multiple access interference (MAI) is the chief limiting factor in CDMA-based networks. Mobile terminals at the boundary of cells result in greater interference to neighboring cells. The relay node architecture minimizes the transmission of high power CDMA cellular signals and thus reduces the adjacent channel MAI interference in other cells, thus improving system capacity; it is shown in Figure 7. However, Figure 7 shows us the performance of cooperative transmission vehicle network utilized with cooperative driving technology. Bit error rate is much smaller than the correspond value from the performance result of direct transmission scheme.

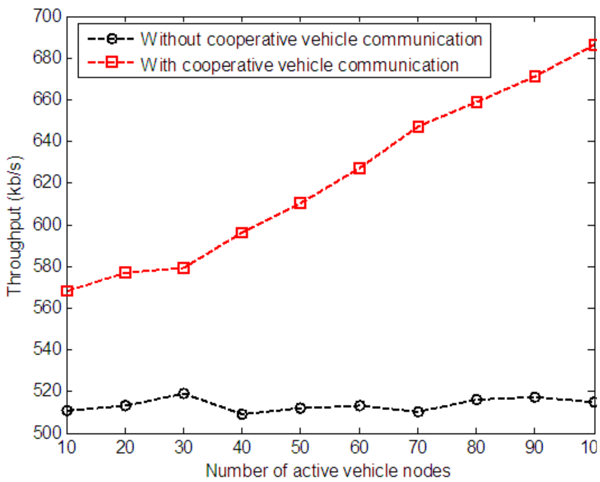

FIGURE 6. The performance of number of vehicle node and throughput

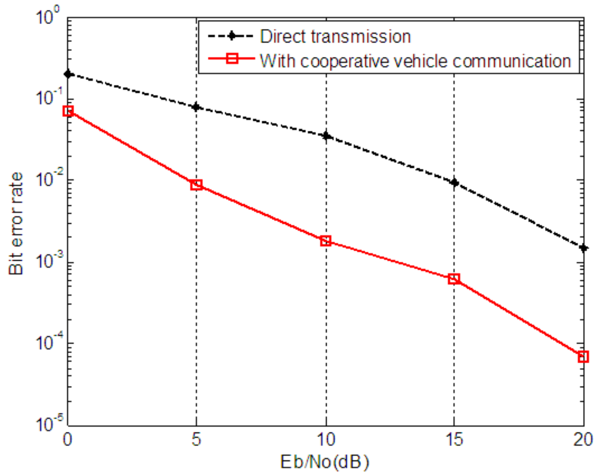

FIGURE 7. The performance of cooperative transmission vehicle network

This work used cooperative driving technology to increase the V2V data communication performance which BER is lower, and exchange the complete information with the shortest time we could get. Figure 8 demonstrates the relay node throughput in a CDMA-based system. As the simulated number of relay nodes with better signal quality increases, capacity gain increases. A relay node system has greater capacity with high mobile terminal density, long WLAN radio transmission range and variable radio channel conditions.

However, Figure 9 also shows the variance of lifetime of the cooperative communication scheme. Comparing cooperative and non-cooperative environment, there is an obvious difference for the value of lifetime. If it is a peer to peer communication, it would have decreased the lifetime due to inter-vehicle communication network environment and speed variance which cause the instability of communication quality. Therefore, it should be utilized with the cooperative mechanism as a complement for inter-vehicle communication network environment. Also, this work researched the result of round robin mechanism utilized with cooperative scheme.

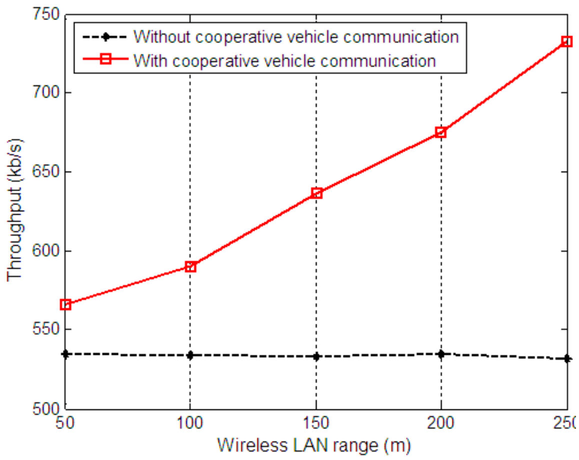

FIGURE 8. The performance of wireless LAN range and throughput

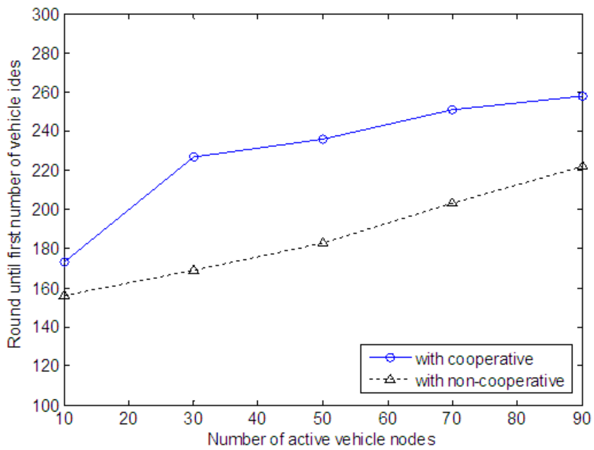

FIGURE 9. Lifetime of cooperative communication scheme

It is because no matter how is the quality of inner-vehicle communication, round robin mechanism causes each user acquires the same possibility. It is the fairest system.

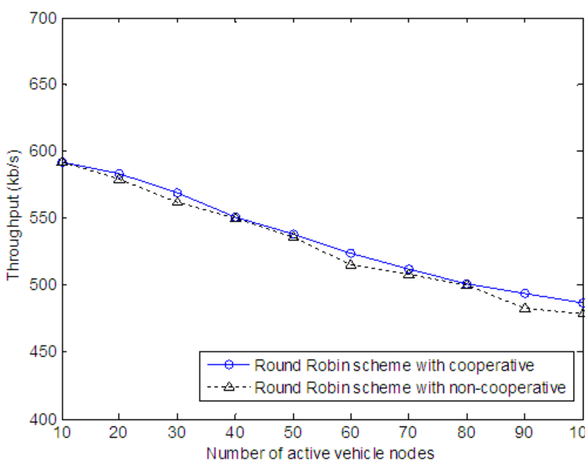

FIGURE 10. Vehicles throughput with the round robin scheme

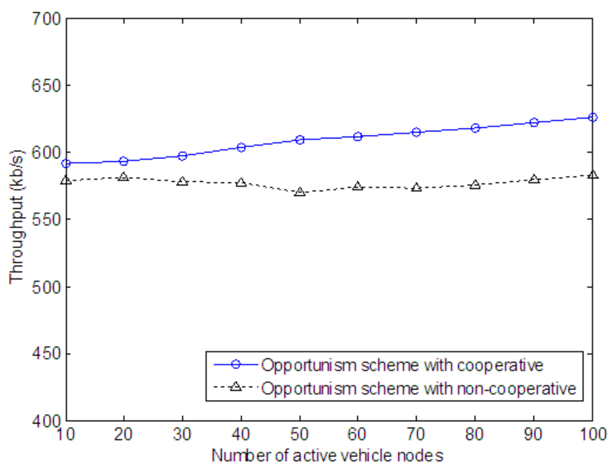

FIGURE 11. Vehicles throughput with the opportunism scheme

However, the communication decreases with the increase of the number of vehicle. Therefore the integration of cooperative and non-cooperative results an approximate performance which is shown in Figure 10. On the other hand, Figure 11 describes that we also researched opportunism scheme utilized with cooperative scheme. This combination of mechanism allows higher throughput for those vehicle which contain more information, but it sacrifices some fairness as a tradeoff. It results a higher throughput performance in cooperative scheme comparing to non-cooperative scheme, and the more difference for the performance when the number of vehicle increase.

6. **Conclusions.** In cooperative communication structure, Data transfer rate and the stability are influenced by distance of each car and communication environment. In order to enhance the stability and perform data receiving simultaneously, adaptive cooperative communication is quiet appropriate. In this paper, we proposed a cooperative inter-vehicle heterogeneous communication combined with the adaptive cognitive network in VANETs. In this work, the simulation results indicate that in conditions when vehicles are unable to communicate directly with each other, it is crucial for the availability of network nodes, infrastructure or vehicles, which can relay information in such perceiving the environment.

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