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Cognitive Communication in Link-Layer Evaluation Based Cellular-Vehicular Networks

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ABSTRACT The performances of data transmissions in vehicular network are investigated. In the vehicular network, the data transmissions are realized by the proposed transmission strategies. Under a cognitive way, the specific strategy is adopted in the corresponding transmission duration. In this paper, the vehicle-to-pedestrian, vehicle-to-vehicle, and vehicle-to-infrastructure/network transmission modes are adopted to implement the data transmission. In the data transmission durations, the transmission modes transit among one another based on the strategies decisions. A state transition model is proposed to describe the communication and evaluate the performances. The concept of effective capacity is adopted, and the mathematical expression of effective capacity is derived. Besides, the effective capacity under the parameter constraints is also demonstrated. From the specific simulations, it is shown that the effective capacity is the most sensitive to quality-of-service exponent. The pedestrian density and vehicle density also impose significant impact on the transmission performances. Besides, short transmission range of the infrastructures and vehicles is necessary to improve the effective capacity.

INDEX TERMS Cellular-vehicular network, cognitive radio, QoS, effective capacity, transmission transition.

I. INTRODUCTION

Wireless communication has grown rapidly to meet the demands of diverse communications. That leads to the scarcity of spectrum. One of the solution is to develop new technologies to use the spectrum efficiently. Cognitive radio, as a technology to the solution to the problem, becomes the research topic. Spectrum sensing, channel estimation and transmission power allocation of users as key technologies in cognitive radio draw attentions from the researchers [1]–[14]. Based on the individual research, cooperative communication and channel selection are also jointly investigated to improve the channel utilization. The evaluation metrics focus on the detection probability, false alarm probability, transmission rates, transmission delay and transmission durations. In some researches the optimization of such metrics are furtherly investigated.

However, that is insufficient. With the development of wireless communication and autonomous driving, the transmission process is more and more diverse. That leads to the result that the modeling of the channel is more complex. One of the prominent challenging is the quality-of-service (QoS) evaluation. The existing QoS support metrics usually require the accurate channel models. Under the complex transmission conditions, one needs to obtain an accurate estimation of the channel and extract the metrics of QoS from the channel model to use the existing QoS support metrics. The estimation and extraction is significantly complex and may lower the accuracies after some approximations. To address the issue, the researchers investigate the channel model based on the link layer for appropriate metrics. Effective capacity, as a metric to characterize the maximum throughput in the channel, is investigated and adopted. The metrics based on the link layer were once investigated and applied in wired communication. It is now being researched in wireless communication recently [15]–[21].

In autonomous driving, the communication is vulnerable to be interrupted and interfered. The position of the vehicles is not fixed. The vehicles need to contend with other systems randomly deployed for data transmission. Researchers have made much effort for the system modeling and security of vehicular network [22]–[32]. Based on the cluster-based routing method in [26], the overhead is studied with microscopic vehicle mobility. The privacy and security of vehicular communication is guaranteed by the improved

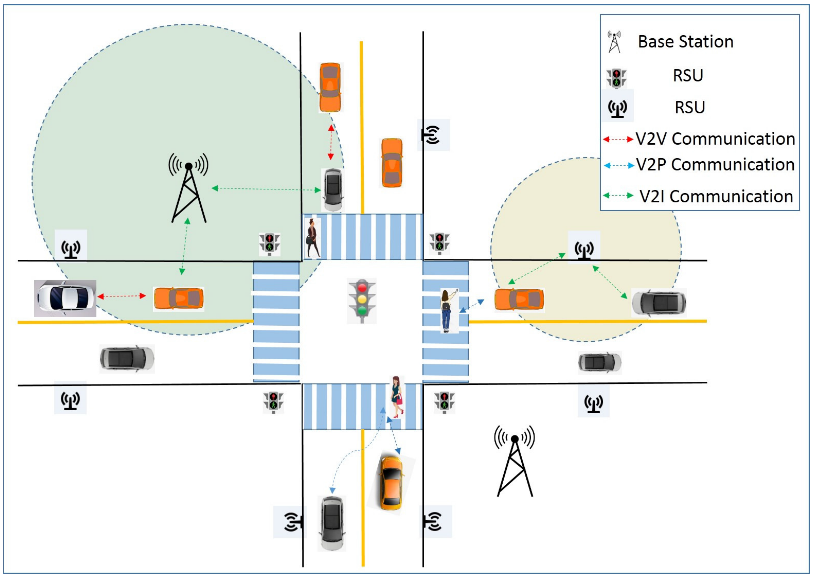

FIGURE 1. **Cognitive transmission model.**

dual-protected ring signature and artificial intelligence (AI) in [25] and [27] respectively. The Third Generation Partnership Project (3GPP) standardization group has specified vehicle-to-everything (V2X) communication in Release 14. For the interworking of cellular network to V2X (C-V2X) and V2X in communication, the further study is still done [33]. Besides, the research on the terminal vehicles is also conducted [34]–[37]. The complex communication conditions in autonomous driving also lead to the challenge in QoS evaluation. However, the study of such QoS is limited. The metrics study based on the link layer is a great need to meet the diverse demands in wireless vehicular networks. The demand of QoS in link layer is promising [21].

Based on the research and the new demands in diverse communication, the interworking of cellular network and V2X in vehicular network is investigated. The performances evaluation is based on link layer. Cognitive communication in vehicular network is studied in this paper. The main contribution in the paper is as follows: the analyses of data transmission strategy, new transition model and new evaluation metric in the network. In this paper, the transmission strategies are divided into three modes, vehicle-to-pedestrian (V2P) mode, vehicle-to-vehicle (V2V) mode and vehicle-to-infrastructure/network (V2I/N) mode. In V2P mode, the communication is among the vehicles and the pedestrians. In V2V mode, the communication is among vehicles and the information is directly transmitted to the receiving vehicles. In V2I/N mode, the communication is among vehicles and infrastructure. The information cannot be transmitted directly among vehicles. The communication among vehicles is realized via the infrastructure or the base station. A transition model is proposed to describe the transmission performances. The states can transit from one to another which means different transmission methods. The evaluation metric is based on the transition model and the actual transmission parameters. Furtherly, it is based on link layer, which was originally adopted in physical layer. To the best of our knowledge, the metric in link layer in vehicular network communication is still yet to be investigated.

The rest of the paper is arranged as follows. In section II, the system model description is presented. In section III, the transition model and the performance evaluation are investigated. We construct the transition model and derive the mathematic expressions of the metric. In section IV, the simulation is constructed and the performances are analyzed. In section V, the conclusion is presented.

II. SYSTEM MODEL

In this chapter, the system model is presented. The system model is shown in Fig.1. In the system, traffic participants consist of vehicles and pedestrians. During the autonomous driving, the information is transmitted in the vehicular network. However, there is a great amount of information. That means the information may be delayed even discarded because of transmission conflicts or other factors. In this paper the information is assumed to be transmitted in a cognitive way. And the information that is needed to be transmitted is assumed to be three kinds.

The first is the information transmitted among the vehicles and pedestrians, such as the temporary deceleration signal and the infotainment signal. The information that is only communicated among the neighboring ones is also included. The information is transmitted by individual vehicles and the communication mode is assumed to be V2P mode. The second is the information transmitted among the vehicles in a certain local area, such as local traffic jams. That means the vehicles in the area should communicate with one another. The communication mode is considered as V2V mode.

The last is the information that should be transmitted in a certain large area. The infrastructures and base stations are taken into consideration. When one vehicle obtains the information that is needed to broadcast, such as the security signal or a larger range of traffic control signal, the vehicle will transmit the information to the road side units (RSU) such as the base stations and the infrastructures. The communication mode is assumed as V2I/N mode. During communication, the transmission will transit to the failure transmission processing when transmission fails. The failure transmission processing is assumed to process the information in other methods and is not discussed in this paper.

It is assumed that the available bandwidth is B, the transmission power of the vehicles in V2P, V2V and V2I/N mode is P_1, P_2 and P_3. The channel noise power is N_0 for V2P, V2V and V2I/N transmission modes respectively. It is also assumed that the event probabilities of V2P, V2V and V2I/N transmission modes are P_{10}, P_{11} and P_{12} respectively, and $\sum_{i=0}^{2} P_{1i} = 1$. The transmission range levvels of V2P, V2V and V2I/N are r_1, r_2 and r_3.

In V2P mode, a vehicle is assumed to communicate with the pedestrian group around it and the interferences in the data transmission durations are from other pedestrians. The transmission is assumed to be successful when a certain percentage of pedestrians within r_1 can receive the information. The percentage is denoted by η_1. For the pedestrians within the transmission range, one is considered to receive the information successfully when the arrival signal to interference plus noise ratio (SINR) at the pedestrian, which is denoted by $SINR_1$, is larger than the threshold γ_1. The pedestrian density is denoted by ρ_P. The fading between the vehicle and pedestrians in terms of dB is as follows:

$$L_{V2P}(d,f) = 32.44 + 20 * lg(d(Km)) + 20 * lg(f(MHz)) \quad (1)$$

From the perspective in [38] and [39], the number of pedestrians is attributed to Poisson distribution with parameter $\lambda_1 = \rho_p \cdot r_1$ within r_1. For the one that receives the information from vehicles, the interference is from the individual pedestrians around it. The distance is from 0 to r_1. In this paper, we approximate the interference distance as $r_t = \frac{r_1}{2}$. The arrival transmission power from the vehicle is $P_{1d} = \frac{P_1}{10^{(L_{V2P}(r_1,f)/10)}}$. The interference power is $P_{1e} = \frac{P_e}{10^{(L_{V2P}(r_t,f)/10)}}$, P_e is the transmission power of a pedestrian.

$SINR_1$ can be expressed as:

$$SINR_1 = \frac{P_{1d}}{N_0 + P_{1e} \cdot N_k} \quad (2)$$

N_k is the number of pedestrians within r_1.

The probability that the vehicle succeeds in the data transmission is denoted by P_{V2P} . During the data receiving, we assume that the pedestrians have no impact on one another. The mathematical expression of P_{V2P} is

$$P_{V2P} = P\{SINR_1 > \gamma_1\}^{\eta_1 \cdot \lambda_1}$$

And

$$P\{SINR_1 > \gamma_1\} = P\{\frac{P_{1d}}{N_0 + P_{1e} \cdot N_k} > \gamma_1\} = P\{N_k < \frac{P_{1d} - \gamma_1 \cdot N_0}{\gamma_1 \cdot P_{1e}}\}$$

We notice that the number of pedestrians is a Poisson distribution. We can get

$$P\{N_k < \frac{P_{1d} - \gamma_1 \cdot N_0}{\gamma_1 \cdot P_{1e}}\} = P\{N_k \le \left\lfloor \frac{P_{1d} - \gamma_1 \cdot N_0}{\gamma_1 \cdot P_{1e}} \right\rfloor\} = \sum_{i=0}^{M} \frac{\lambda_1^i \cdot e^{-\lambda_1}}{i!}$$

where $M = \left\lfloor \frac{P_{1d} - \gamma_1 \cdot N_0}{\gamma_1 \cdot P_{1e}} \right\rfloor$.

P_{V2P} can be expressed as:

$$P_{V2P} = (\sum_{i=0}^{M} \frac{\lambda_1^i \cdot e^{-\lambda_1}}{i!})^{\eta_1 \cdot \lambda_1} \quad (3)$$

In V2I/N mode, the vehicle density is denoted by ρ_v. Similar to the V2P mode, we also assume the arrival number of vehicles is attributed to Poisson distribution. Besides, we also assume $P_1 \gg P_e$. The interferences from the pedestrians are negligible. The transmission is assumed to be successful when an RSU within the coverage range receives the information successfully. For the RSU within the transmission range, one is considered to receive the information successfully when the SINR at the RSU is larger than the threshold γ_3. The SINR is denoted by $SINR_3$, which includes the noise and the interference from the vehicles within the coverage range. The RSU density and transmission range are denoted by ρ_r and r_R respectively. Besides, the distance between the RSUs is considered to be $2 \cdot r_R$, as is shown in Fig.2. The fading expression between the vehicle and RSU is:

$$L_{V2I}(d,f) = (\frac{4\pi fd}{c})^2 \quad (4)$$

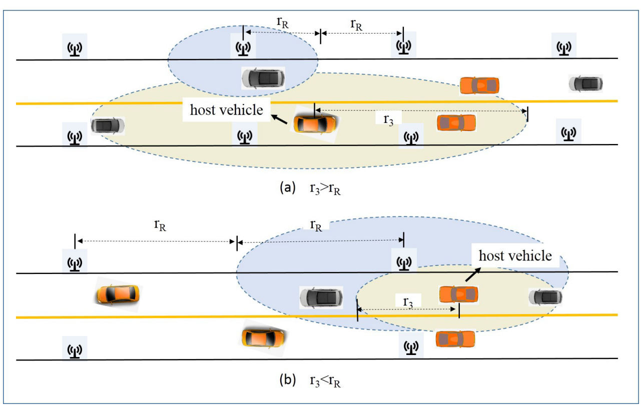

FIGURE 2. V2I/N transmission model.

d is the distance, f and c are radio frequency and radio speed respectively.

When $r_3 > r_R$, the case is shown in Fig.2(a). Within r_3, the number of the RSU is $N_R = 2 \cdot \left\lfloor \frac{r_3}{r_R} \right\rfloor$. In this case, the transmission is successful when at least one RSU receive the information successfully. For the interference from the vehicles, the fading range is 0 to r_R. We use the fading range as $\frac{r_R}{2}$ by approximation. The arrival power from the host vehicle at the RSU is $P_{3d} = \frac{P_3}{10^{(L_{V2I}(r_R, f)/10)}}$. The arrival power from neighboring vehicles is $P_{3I} = \frac{P_3}{10^{(L_{V2I}(r_R/2, f)/10)}}$. The number of vehicles within r_R is a Poisson distribution with the parameter $\lambda_3 = \rho_v \cdot r_R$.

The probability that the information can be transmitted successfully is denoted by P_{V2I}. The expression is written as follows:

$$P_{V2I} = 1 - P\{SINR_3 < \gamma_3\}^{N_R}$$

In the formulation above,

$$SINR_3 = \frac{P_{3d}}{N_0 + P_{3I} \cdot N_v}$$

N_v is the number of the vehicles within r_R.

After some mathematical derivations, we can get

$$P\{SINR_3 < \gamma_3\} = P\{N_v \geq \frac{P_{3d} - N_0 \cdot \gamma_3}{\gamma_3 \cdot P_{3I}}\} \tag{5}$$

For (5), it can be categorized into two types: 1) $P_{3d} - N_0 \cdot \gamma_3 \geq 0$ and 2) $P_{3d} - N_0 \cdot \gamma_3 < 0$. To get the solution in 1), we set $M_v = \left\lfloor \frac{P_{3d} - N_0 \cdot \gamma_3}{\gamma_3 \cdot P_{3I}} \right\rfloor$ and Eq. (5) can be rewritten as:

$$P\{N_v \geq \frac{P_{3d} - N_0 \cdot \gamma_3}{\gamma_3 \cdot P_{3I}}\} = 1 - \sum_{i=0}^{M_v} \frac{\lambda_3^i \cdot e^{-\lambda_3}}{i!} \tag{6}$$

For the type 2), we can get the result of Eq. (5) is 1. From (6), with $r_3 > r_R$ we can get

$$P_{V2I} = \begin{cases} 0 & P_{3d} - \gamma_3 \cdot N_0 < 0 \\ 1 - [1 - \sum_{i=0}^{M_v} \frac{\lambda_3^i \cdot e^{-\lambda_3}}{i!}]^{N_R} & P_{3d} - \gamma_3 \cdot N_0 \geq 0 \end{cases} \tag{7}$$

The case of $r_3 \leq r_R$ is shown in Fig.2 (b). In this case, the host vehicle is considered to be successful in the data transmission when the SINR is larger than γ_3 . The fading distance during the transmission of the host vehicle is r_3. The fading distance of the interference vehicles is approximated as $\frac{r_3}{2}$. The number of vehicles within r_3 is a Poisson distribution with the parameter $\lambda_3{}' = \rho_v \cdot r_3$. Within the fading distance, the arrival power from the host vehicle at the RSU is $P'_{3d} = \frac{P_3}{10^{(L_{V2I}(r_3, f)/10)}}$. And the arrival power from neighboring vehicles is $P'_{3I} = \frac{P_3}{10^{(L_{V2I}(r_3/2, f)/10)}}$. The probability that the information can be transmitted successfully is written as follows:

$$P_{V2I} = P\{SINR_3 > \gamma_3\} \tag{8}$$

Within the fading distance r_3,$SINR_3 = \frac{P'_{3d}}{N_0 + P'_{3I} \cdot N'_v}$. And Eq.(8) can be rewritten as:

$$P_{V2I} = \sum_{i=0}^{M'_v} \frac{\lambda_3'^i \cdot e^{-\lambda'_3}}{i!} \tag{9}$$

where $M'_v = \left\lfloor \frac{P'_{3d} - N_0 \cdot \gamma_3}{\gamma_3 \cdot P'_{3I}} \right\rfloor$.

From (7) and (9), we can get the expression of P_{V2I} as

$$P_{V2I} = \begin{cases} 0 & r_3 > r_R \text{ and } P_{3d} - \gamma_3 \cdot N_0 < 0 \\ 1 - [1 - \sum_{i=0}^{M_v} \frac{\lambda_3^i \cdot e^{-\lambda_3}}{i!}]^{N_R} & r_3 > r_R \text{ and } P_{3d} - \gamma_3 \cdot N_0 \geq 0 \\ \sum_{i=0}^{M'_v} \frac{\lambda_3'^i \cdot e^{-\lambda'_3}}{i!} & r_3 \leq r_R \end{cases} \tag{10}$$

In V2V mode, the transmission mechanism is adopted from [39], which is the LTE based transmission mechanism. The transmission range and awareness range are taken into consideration. The modulation mechanism is SC-FDMA in the LTE source. To keep the generality in the investigation of the performances in V2V transmission mode, only the shared channel is taken into consideration from the control channels, random access channels and shared channels. From Eq. (37)-(39), the probability that a host vehicle succeeds in the data transmission is

$$P_{V2V} = 1 - p_{out} \tag{11}$$

III. COGNITIVE TRANSMISSION MODEL AND PERFORMANCES EVALUATION

In vehicular network, the vehicles are assumed to have no channel side information when transmitting information. That means the data transmission rates at transmitter are fixed in a transmission process. A cognitive transmission transition model is constructed to describe the transmission in the transmission system by considering whether the transmission process is successful or not. In this section, we describe the cognitive transmission model in detail and derive the mathematic expressions of effective capacity under parameter constraints.

A. TRANSMISSION TRANSITION MODEL

Regarding the transmission performances, we can obtain the transition states and the transition model, as is shown in Fig.3. In the figure, there are 6 transition states. States 1 and 2 represent the transmission mode V2P. States 3 and 4 represent the transmission mode V2V. States 5 and 6 represent the transmission mode V2I/N. In states 1, 3 and 5, the transmissions are successful in the corresponding transmission modes. States 2, 4 and 6 means the transmission fails and retransmission will be triggered. The retransmission mechanism is not discussed in the paper.

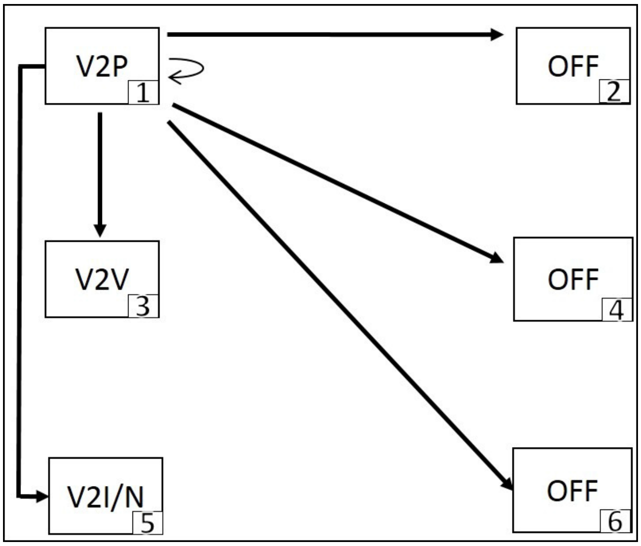

FIGURE 3. Cognitive transition model.

The transitions of the states occur among one and another with the probabilities $P_{i,j}$. In Fig.3, only the transition of state 1 is shown as the transition example. The other states transit in a similar way. As the channel condition transitions are independent from one to another. We can conclude the transition probabilities depend on the event prior probabilities only. Thus the transition probabilities $P_{i,j}$ can be mathematically expressed as follows:

$$\begin{aligned} p_{1,1} &= P_{10} \cdot P_{V2P} & p_{1,2} &= P_{10} \cdot (1 - P_{V2P}) \\ p_{1,3} &= P_{11} \cdot P_{V2V} & p_{1,4} &= P_{11} \cdot (1 - P_{V2V}) \\ p_{1,5} &= P_{12} \cdot P_{V2I} & p_{1,6} &= P_{12} \cdot (1 - P_{V2I}) \end{aligned} \quad (12)$$

Since fading conditions are independent from one block to another, we can further obtain

$$\begin{aligned} p_{i,1} &= p_{1,1} \\ p_{i,2} &= p_{1,2} \\ p_{i,3} &= p_{1,3} \quad i = 1, 2, 3, 4, 5, 6 \\ p_{i,4} &= p_{1,4} \\ p_{i,5} &= p_{1,5} \\ p_{i,6} &= p_{1,6} \end{aligned} \quad (13)$$

In V2P transmission mode, the transmission rate is R_1. While the transmission fails, the transmission rate is 0. The transmission rates are R_2 and R_3 in V2V and V2I/N modes respectively. In the failure mode, the transmission rate is 0. R_2 is calculated in [39], which is shown in Table 4 in the reference. The transmission rates of V2P and V2I/N are written as:

$$R_i = B \cdot \log_2(1 + SINR_i) \quad i = 1, 3 \quad (14)$$

B. PERFORMANCES EVALUATION

In this section, the transmission performances are evaluated based on link layer metric. In link layer, the concept of effective capacity is adopted from the physical layer to characterize the transmission performances. Wu and Negi [40] define the effective capacity as the maximum arrival rate that the channel service can support under the constraints requirement which is defined by the QoS exponent θ. The exponent θ is defined as:

$$\theta = - \lim_{Q_0 \to \infty} \frac{\ln P\{Q \geq Q_0\}}{Q_0}$$

Q and Q_0 is the buffer length of queue. For the overflow of the buffer, θ is also called the asymptotic decay rate of buffer occupancy. Besides, if the value of Q_0 is large enough, we can get the approximation: $P\{Q \geq Q_0^{\max}\} \simeq e^{-\theta Q_0^{\max}}$. Obviously, the larger the exponent is, the faster the decay rate will be. For the transmission strategy in the vehicular network, the effective capacity for one transmission process among the transmission modes that is normalized in terms of bits/Hz is defined as:

$$E(\theta) = -\frac{1}{\theta B} \ln E\{e^{-\theta r(t)}\}$$

In the expression above, $r(t)$ is the transmission service in terms of the number of bits.

With QoS exponent constraints and transmission mode changing, the effective capacity can be viewed as the maximization of the throughput [40]–[42]. The effective capacity satisfies:

$$-\lim_{n \to \infty} \frac{1}{\theta n} \ln E\{e^{-\theta s(n)}\} = -\frac{\Lambda(-\theta)}{\theta}$$

$\Lambda(\theta)$ is the logarithm of moment generating function of $s(n)$. $s(n)$ is the accumulated service process of time, and $s(n) = \sum_{i=1}^{n} s_1(i)$. $s_1(i)$ is the number of transmitted data in the vehicular network. In state 1, at time i, the service rate $s_1(i) = R_1 \cdot T_1$. Similarly, in states 3 and 5, the service rates are $s_1(i) = R_2 \cdot T_2$ and $s_1(i) = R_3 \cdot T_3$ respectively. $T_i \ (i = 1, 2, 3)$ is the corresponding transmission duration. In states 2, 4 and 6, the service rate is zero.

From the expressions in section III-A, we can get the transmission transition probability matrix, which is written as follows:

$$R = \begin{pmatrix} P_{1,1} & \cdots & P_{1,6} \\ \vdots & \ddots & \vdots \\ P_{6,1} & \cdots & P_{6,6} \end{pmatrix} = \begin{pmatrix} P_{1,1} & \cdots & P_{1,6} \\ \vdots & \ddots & \vdots \\ P_{1,1} & \cdots & P_{1,6} \end{pmatrix} \quad (15)$$

We can note the rank of R is 1. Besides, for a Markov modulated process, $\frac{\Lambda(\theta)}{\theta}$ satisfies the expressions [43]:

$$\frac{\Lambda(\theta)}{\theta} = \frac{1}{\theta} lnsp(\phi(\theta) \cdot R)$$

$sp(\cdot)$ is the spectral radius symbol, $\phi(\theta) = diag(\phi_1(\theta), \phi_2(\theta), \cdots, \phi_6(\theta))$ is a diagonal matrix with $\phi_i(\theta)$

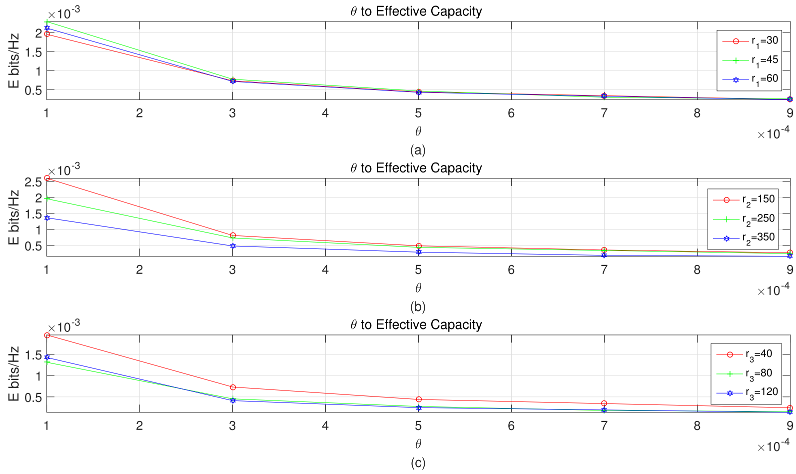

FIGURE 4. θ **vs. effective capacity.**

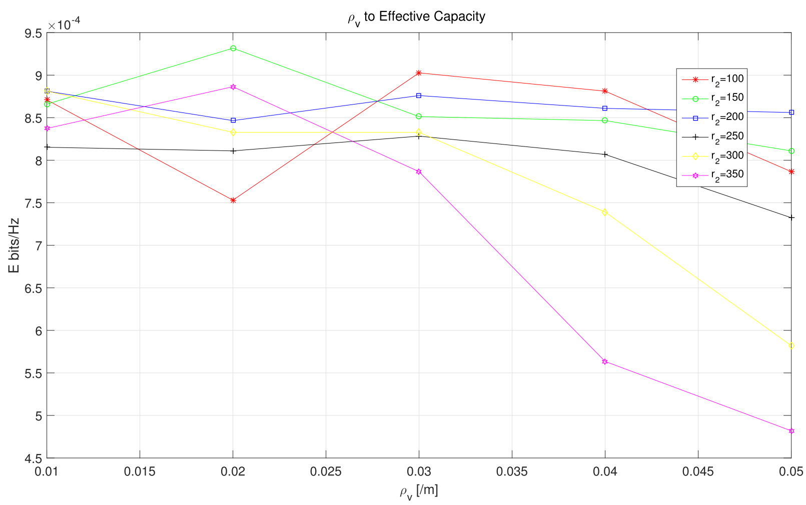

FIGURE 5. ρ_v **vs. effective capacity.**

($i = 1, 2, \cdots, 6$) being the moment generating function of the service process. In the proposed structure, with the 6 states, the moment generating function expressions are $e^{\theta R_1\, T_1}$,1,$e^{\theta R_2\, T_2}$,1,$e^{\theta R_3\, T_3}$ and 1 respectively.

Then we can obtain the expression as follows:

$$\phi(\theta) = diag(e^{\theta R_1\, T_1}, 1, e^{\theta R_2\, T_2}, 1, e^{\theta R_3\, T_3}, 1) \quad (16)$$

$$\phi(\theta)R = \begin{pmatrix} \phi_1(\theta)p_{1,1} & \cdots & \phi_1(\theta)p_{1,6} \\ \vdots & \ddots & \vdots \\ \phi_6(\theta)p_{1,1} & \cdots & \phi_6(\theta)p_{1,6} \end{pmatrix} \quad (17)$$

Since the rank of R is 1, we can conclude $sp(\cdot) = trace(\cdot)$, where the symbol $trace(\cdot)$ is the trace of the matrix . The spectral radius expression of $\phi(\theta)R$ can be written as:

$$sp(\phi(\theta)R) = trace(\phi(\theta)R) = \sum_{i=1}^{6} \phi_i(\theta)p_{1,i} \quad (18)$$

Thus the normalized effective capacity expression in terms of bits/Hz is:

$$\begin{aligned} E(\theta) &= -\frac{\Lambda(-\theta)}{\theta} \\ &= \max_{R_1,R_2,R_3>0} -\frac{1}{\theta B} \ln sp(\phi(-\theta)R) \\ &= \max_{R_1,R_2,R_3>0} -\frac{1}{\theta B} \ln(e^{-\theta R_1 T_1}p_{1,1} + e^{-\theta R_2 T_2}p_{1,3} \\ &\quad + e^{-\theta R_3 T_3}p_{1,5} + p_{1,2} + +p_{1,4} + p_{1,6}) \end{aligned} \quad (19)$$

IV. NUMERICAL RESULTS AND ANALYSES

In this section, the performances are substantiated based on the actual transmission parameters. In the vehicular networks, the transmission mechanism is based on the actual transmission. Especially in V2V transmission mode, the transmission mechanism is LTE based resource allocation and signal modulation. The radio beacon number, coding rate and the transmission rate are adopted from [39]. In V2P and V2I/N

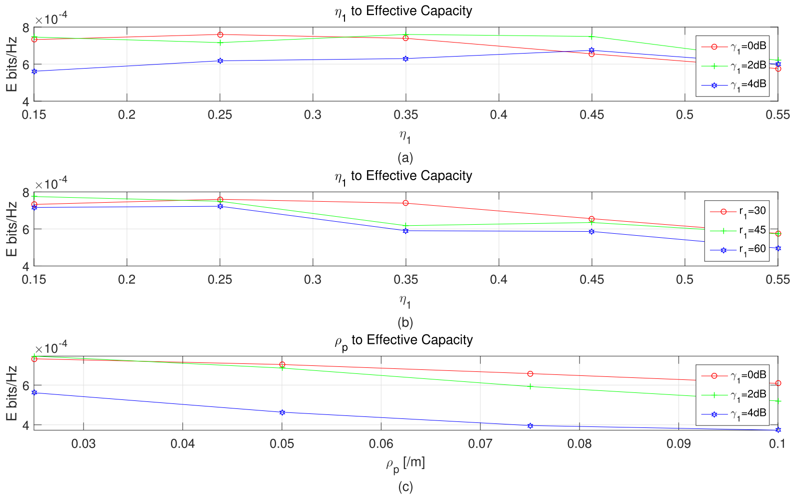

FIGURE 6. **Transmission performances in V2P mode.**

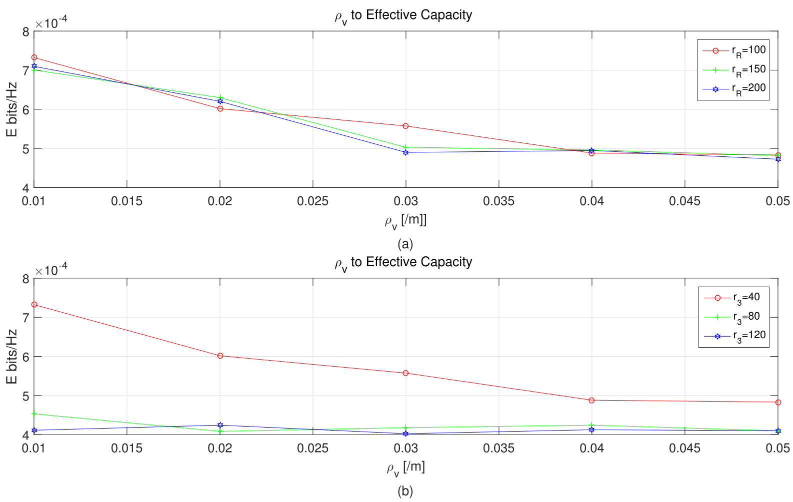

FIGURE 7. **Transmission performances in V2I/N mode.**

transmission modes, the elementary parameters are based on the actual application scenarios. In the paper, the parameters for simulation are set as $N_0 = -95dBm$,$B = 10MHz$, $P_{10} = 0.3$, $P_{11} = 0.45$, $P_{12} = 0.25$. Besides, the transmission durations are set as $T_1 = 10ms$, $T_2 = 10ms$ in V2P and V2V transmission modes. Under V2P transmission mode, the radio frequency for transmission is $f = 700MHz$, the transmission power of the vehicles and pedestrians are $P_1 = 3dB$, $P_e = -10dB$. Under V2V transmission mode, the radio frequency for transmission is $f = 5.9GHz$. Under V2I/N transmission mode, the radio frequency for transmission is $f = 2GHz$. The transmission power is $P_3 = 6dB$. The transmission duration is $T_3 = 20ms$.

The transmission performances in terms of effective capacity under QoS support θ are shown in Fig.4. In Fig.4 (a), we can note the effective capacity is the decreasing function of θ. For the different transmission range r_1, they impose limited impact on the effective capacity with r_1 increasing. In Fig.4 (b), at a fixed θ, the effective capacity decreases with r_2 increasing. However, the critical impact on the effective is from the QoS exponent. The similar conclusion can be obtained in Fig.4 (c), which is the impact from r_3 is limited and the overall performances are impacted by θ.

The impact of V2V transmission mode on effective capacity is shown in Fig.5. In the Figure, the performances are shown with $MCS = 17$, beacon frequency $f_B = 10Hz$. The transmission power of the vehicle is $P_2 = 3dB$. Under the V2V transmission mode, a larger value of ρ_v means a larger density of the vehicles, which in turn leads to a larger probability of conflicts in the data transmission. When r_2 increases, the average number of the arrival vehicles increases under the Poisson distribution . Both of the parameters show the negative impact on the effective capacity, which is testified in the figure. From the Figure, we can note the effective capacity significantly decreases at a high level of ρ_v and r_2.

The transmission performances under V2P transmission mode are shown in Fig.6. Fig.6 (a) shows the effective capacity is a decreasing function of η_1. Moreover, with the γ_1 increasing, the effective capacity still decreases since the failure probability of the transmission increases. With the transmission range r_1 increasing, the fading loss of the transmitter increases, which results in the decrease of the effective capacity. And that is demonstrated in Fig.6 (b). Under the condition of η_1 increasing, the effective capacity still decreases, which is similar to those in Fig.6 (a). A greater density of the pedestrian leads to a serious interference and a greater value of γ_1 leads to more failing in the transmission. Those affect the effective capacity, which can be noted from Fig.6 (c).

The transmission performances under V2I/N transmission mode are shown in Fig.7. Fig.7 (a) shows the transmission performances with different levels of ρ_v and r_R . In Fig.7 (a), at the fixed level of ρ_v, there is little change in terms of effective capacity. We can conclude that the vehicle density impose greater impact on the effective capacity compared with transmission range of RSU. The impact is limited under different values of r_R. In Fig.7 (b), the impact on effective capacity, which is from the transmission range r_3, is a little greater than r_R at small values. While r_3 increases, the impact can be negligible. The effective capacity is once again affected by the vehicle density. From the performances in V2I/N transmission mode, we can conclude a smaller transmission range of the transmitter and density of vehicles can improve the effective capacity.

V. CONCLUSION

In this paper, we have investigated the performances of the cognitive transmission in the vehicular network based on the link layer. We also analyze the performances under diverse parameter constraints and get some conclusions. For future research, the optimization of the data transmission is promising. During the optimization, the deep learning method is also efficient and promising to control the transmission mechanism for a better performance.

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