

Modern Data Transmission for Vehicular Networks with Cooperative Schemes

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Abstract: The paper presents issues related to the cooperative transmission in wireless vehicular networks. Cooperative transmission involves the use of mobile terminals as relay stations to improve the transmission quality, improve network performance and reduce energy consumption. Instead of using two nodes, we are increased it up to 100 nodes. The paper presents the methods used to implement cooperative transmission and the types of cooperative networks.

Keywords: Cooperative Transmission; Mobile Terminal; Relay Station.

I. INTRODUCTION

Currently, mobile users can use mobile data services using cellular technology (e.g. LTE, UMTS, EDGE and GPRS) and low-range data transmission systems (e.g. Bluetooth, WIFI,) which enable a wide range of application in the vehicular environment. This application can be grouped into three types: road safety, traffic efficiency and infotainment. Various wireless communication systems also enable cooperative transmission.

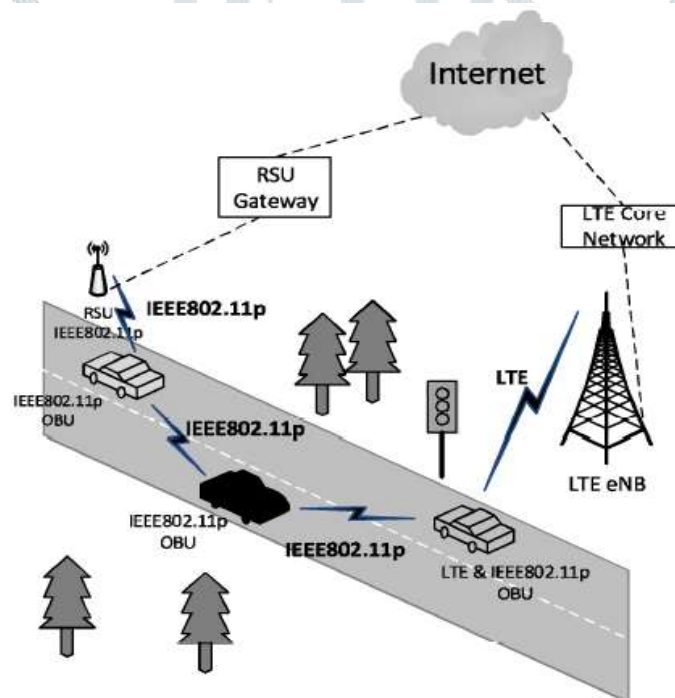


Fig.1. Example of vehicular network with IEEE802.11p and LTE.

Cooperative transmission uses terminals as relay stations to reduce power consumption of mobile terminals, resulting in longer operating times. Cooperative transmission can also increase the capacity, data rates and performance of wireless networks. In addition, it can contribute to increasing the transmission coverage area of both mobile networks and ad hoc networks [2]. As a result, the interest in transmitting on networks using the cooperation of various data transmission systems and relay station is steadily increasing. In the case of cooperative wireless transmission, we have to deal with mobile network or ad hoc network, in which users of mobile terminals can improve the quality of service measured, for example bit or block error rate. In this case, each mobile terminal can be both a data source and a relay station for another user's transmission. An example of cooperative transmission in vehicular network is presented in Fig.1. The network utilize IEEE802.11p and LTE (Long Term Evolution) networks. IEEE 802.11 p is an IEEE 802.11 based standard adapted for the vehicular networking environment. Interesting characteristic of the physical layer is the reduction to 10 MHz band width from 20 MHz, which provides data rates from 3 to 27 Mbps [1]. The IEEE 802.11p MAC is 802.11e Enhanced Distributed Channel Access with quality of service support. The physical and MAC layer allow ad hoc communication between On Board Units (OBUs) as well as OBUs and Roadside Units (RSUs) [3]. LTE standard offers superior performances in terms of throughput and lower latencies. Theoretically, downlink data rate of 150 Mbps and uplink data rate of 50 Mbps is achievable in 20 MHz spectrum. This is combined with the latency of less than 5 ms. The LTE base station eNodeB (eNB) comprises the radio access network of the LTE. The eNB is directly connected

with Evolved Packet Core which supports QoS handling, mobility management and interoperability with the 3GPP and non 3GPP access technologies [3]. The example shows IEEE 802.11 p based RSU connected via RSU Gateway to the Internet. On Board Unit (OBU) in black vehicle can connect via another OBU to RSU or to LTEeNB (via LTE & 802.11p OBU) and then to the Internet (Fig. 1). The purpose of the paper was the presentation of the methods used in the cooperative transmission. These methods have been described and presented in the figures.

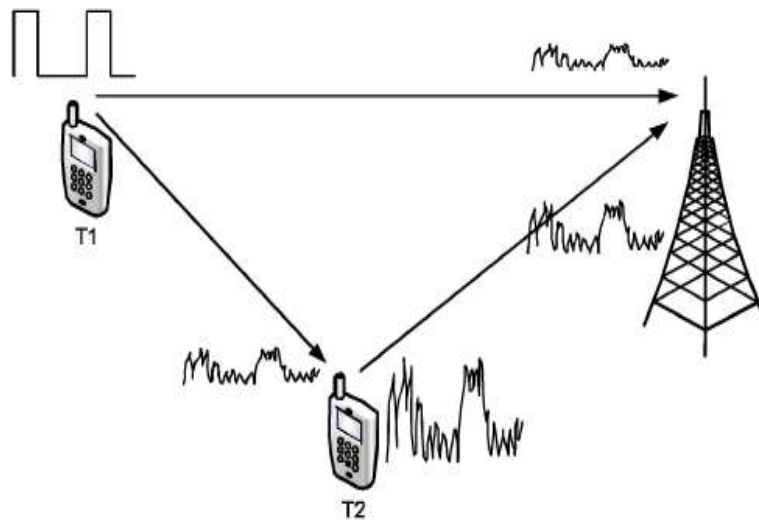


Fig.2. Amplify and forward method.

II. TYPES OF COOPERATIVE COMMUNICATION

For the implementation of the cooperative communication, the three methods are most commonly used: amplify and forward, decode and forward and coded cooperation methods [2] [5].

A. Amplify and Forward Methods

Each terminal in this method receives a noisy version of the signal transmitted by another terminal. According to the method name, the terminal, after receiving the signal from another terminal, amplifies it and then retransmits it (to the destination node of the transmission, e.g. the base station). The destination node combines the signal received directly from the sender and retransmitted by the relay and makes final decision on the transmitted data bits (Fig. 2) [5]. In this method, the signal is amplified with noise, but the situation that the destination receives two independently faded versions of the signal improves the detection of the information signal, improving the transmission quality. In this method it is assumed that the destination node knows the inter user channel coefficients to do optimal decoding. The mechanism of exchanging or estimating this information must be included into the final implementation [5].

B. Decode and Forward Method

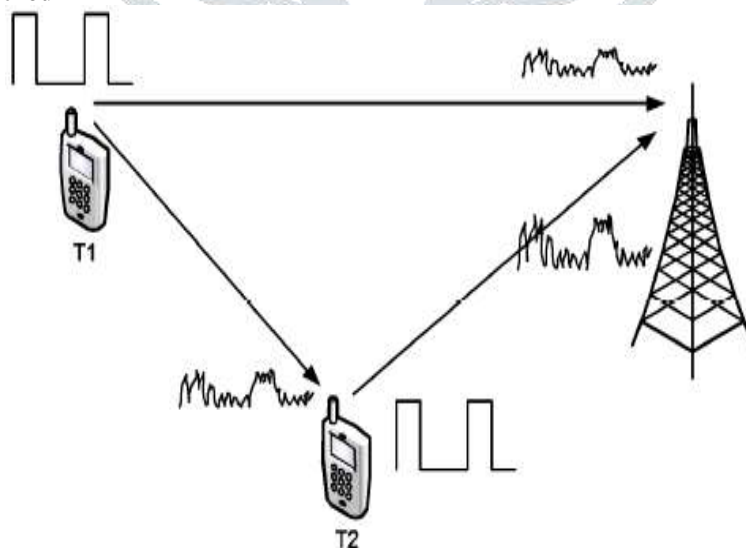


Fig.3. Decode and forward method.

In this method, the relay performs the detection and decoding of the received bits from the source and then retransmit those bits to the destination node (Fig.3). A more detailed description of this method can be found in [6] and [7]. These publications provide an example of an analysis of the use of this method in CDMA transmission. In this example, two terminals are connected

with each other to implement cooperative transmission. Each of them has a different spreading code $c_1(t)$ (terminal 1) and $c_2(t)$ (terminal2). Bits transmitted by both terminals can be labeled $b_j(n)$, where $j = 1$ and 2 are user numbers, n is the time index of the transmitted bit. The signals of both the terminals can be saved by the following formulas [6], [7]:

$$X_1(t) = [a_{11}b_1^{(1)}c_1(t), a_{12}b_1^{(2)}c_1(t), a_{13}b_1^{(2)}c_1(t) + a_{14}b_2^{(2)}c_2(t)] \tag{1}$$

$$X_2(t) = [a_{21}b_2^{(1)}c_2(t), a_{22}b_2^{(2)}c_2(t), a_{23}b_1^{(2)}c_1(t) + a_{24}b_2^{(2)}c_2(t)] \tag{2}$$

The a_{ij} coefficients in the formulas represent the amplitude of the signal. The signals $X_j(t)$ and $X_I(t)$ have a duration of three bits. Looking at formulas (1) and (2) we can say that during the first and second bits, each terminal transmits its own bits. They then detect the second bit, another user. The bit estimate of this user is denoted by the symbol h_i . During the third bit, a linear combination of its own second bit and a second bit of another user is transmitted over the terminal (Fig. 4) [7].

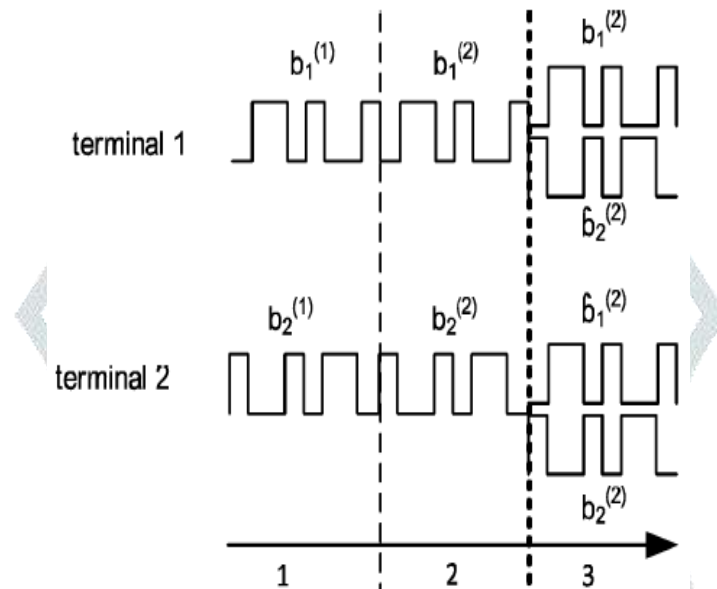


Fig.4. An example of cooperative transmission using the decode and forward method in a COMA network.

C. Coded Cooperation

If we assume that the wireless system uses a rate R channel code, the idea of coded cooperation is to use the same overall rate for coding and transmission, however, the coded symbols are rearranged between two users. In this case there will be no need for additional resources [4].

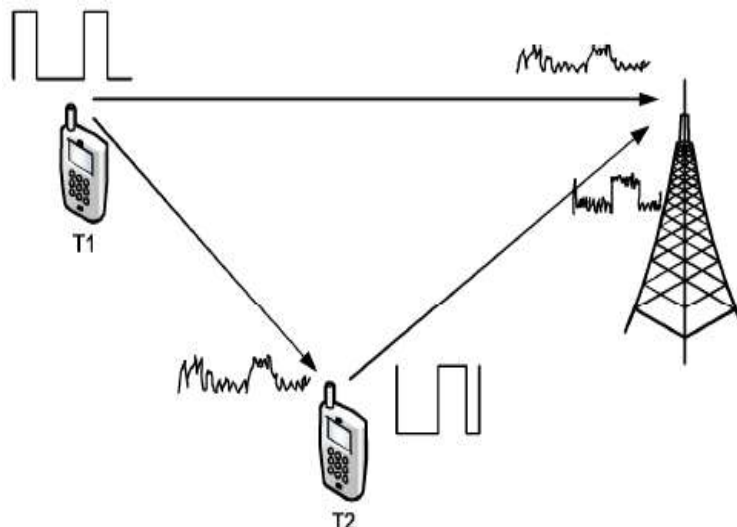


Fig.5. Coded cooperation.

If each user has K bit data block and N bit data block after channel encoding, coding rate $R = K/N$. We divide the N bit data block after encoding into two successive time frames, one with length $N/2$ and the other with length $N/2$ ($N/2 + N/2 = N$). In the first frame, the code rate is $R = K/(N/2)$ [5]. These data (frame) is broadcast by the user terminal are received by the second terminal and the base station (destination node) (Fig. 5). Each terminal will thus receive a noisy version of the coded information from the second terminal in the network. If the terminal 1 can correctly decode the information sent by the second terminal (using e.g. CRC coding) may send the data frame in a time slot $N/2$ (Fig. 6) [4]. If the terminal cannot correctly decode the data from the second

terminal, then its own data is sent in frame N2. Each terminal always transmits a total N bits per source block over the two frames. The overall code in this method may be block, convolutional or turbo code. The code bits for the two frames may be partitioned e.g. through puncturing [2]. 80th terminals transmit data independently, without knowing whether their own first frame has been correctly decoded. As a result, there may be four cases shown in Fig. 7 [4]. In the first case, both terminals correctly receive and decode the transmitted data, so they can send their neighbor's data in the second frame of their time slot. So this is a scenario full cooperative transmission. In the second case, none of the terminal does not receive and decode the data of your neighbor. Each terminal transmits only its data (bits N_1 and N_2).

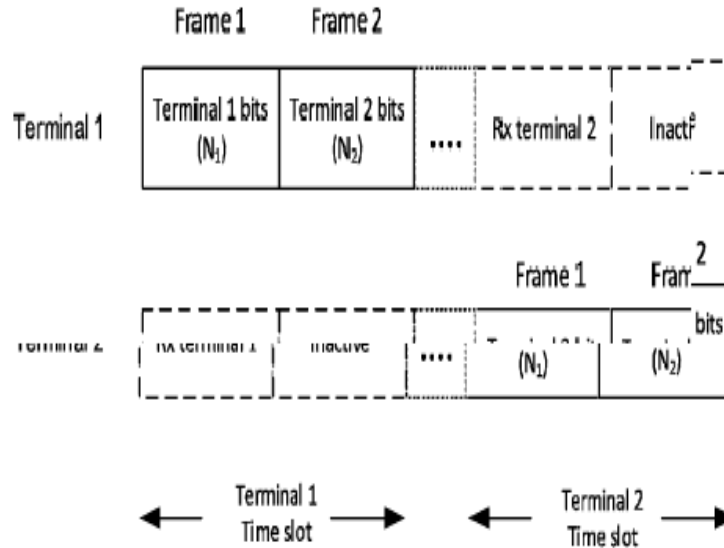


Fig.6. An example of coded cooperation in a TDMA network.

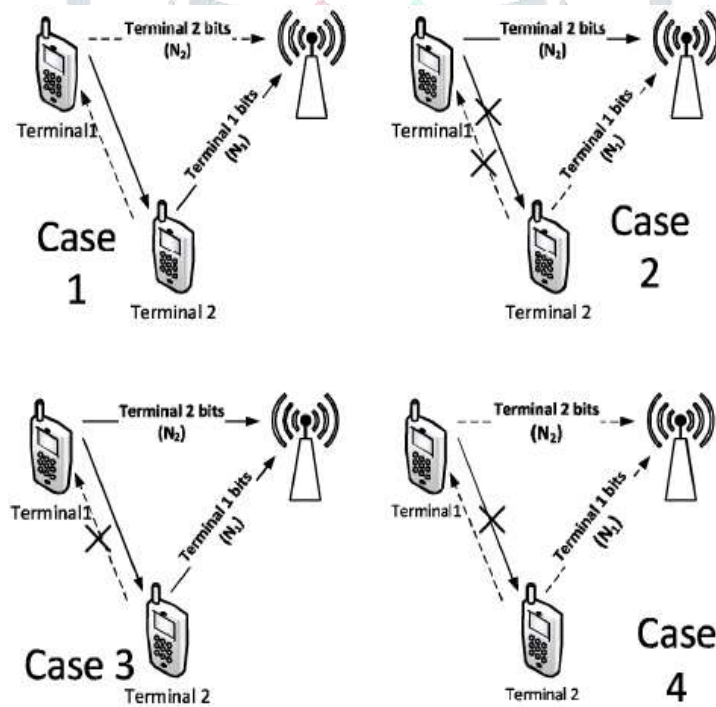


Fig.7. Four cooperative cases for second frame transmission based on the first frame decoding results.

In the third case, terminal 2 correctly receives and decodes data from terminal 1, but terminal 1 does not decode data from terminal 2. In this situation, there is no transmission of bits N_2 of terminal 2, and both terminals (1 and 2) transmit N_1 bits from terminal 1. In the fourth case, N_2 bits of terminal 2 are correctly received and decoded. Terminal 2 has not decoded N_1 bits sent by terminal 1. In this case, both terminals in the second frame transmit N_2 bits of terminal 2. A destination node to which both terminals send the data needs to know which of the four cases described took place, to be able to correctly decode the received data bits. One way is to check all 4 cases one by one until CRC decodes properly. Another method is to add one extra bit to the data transmitted by the terminal. This bit can indicate the state of the terminal i.e. whether it transmits only its data or data of the other terminal [4].

III. COOPERATIVE COMMUNICATION NETWORKS

In cooperative networks may be single relay (Fig. 8) or multiple relays (Fig. 9). In a single relay network, the data source terminal has only one option to relay its information to the desired destination [9]. In a network with multiple relays, the data source terminal has more than one relay available as option to forward its data to the destination node (Fig. 9) [8]. If the network is decentralized the terminal can independently select a relay that will retransmit the data to the destination node. In the case of a centralized network, the root node (e.g. base station, router) can help the terminal select a relay that will provide the most effective transmission. Cooperative networks can use single radio access technology or multiple radio access technologies for data transmission. When using only one transmission standard, both the data source and the relay use the same wireless transmission standard (Fig. 10). An example of such a network may be an ad hoc network [2]. When using multiple transmission standards for the cooperative transmission, the data source terminal may send data using one wireless standard, while the relay can send the data to the destination node using a different wireless transmission standard (Fig. 11) [10].

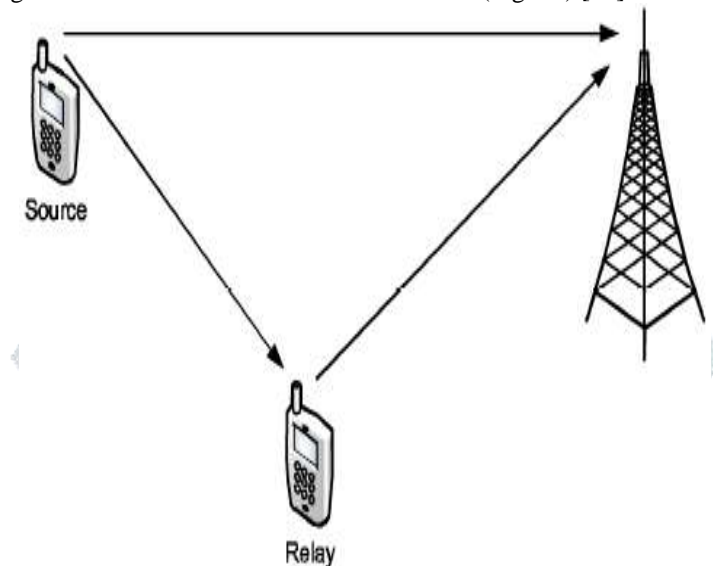


Fig.8. Single relay cooperation.

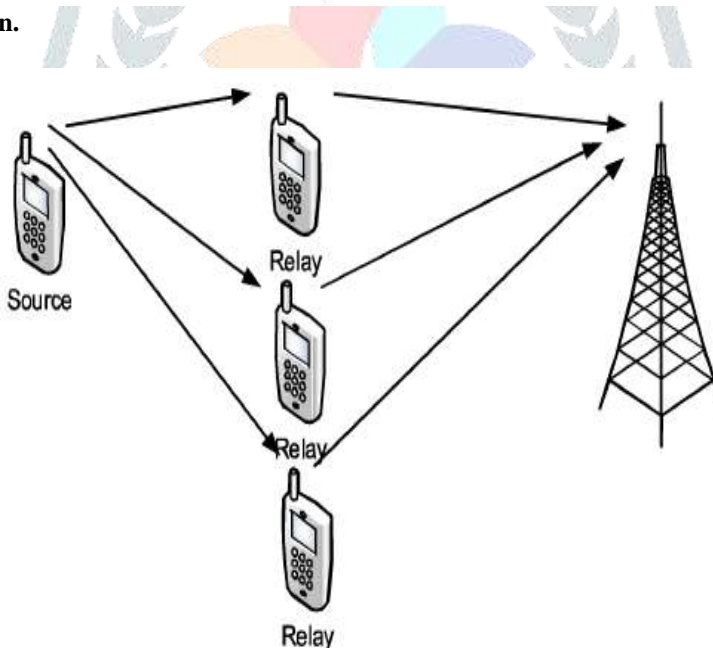


Fig. 9. Multiple relay cooperation.

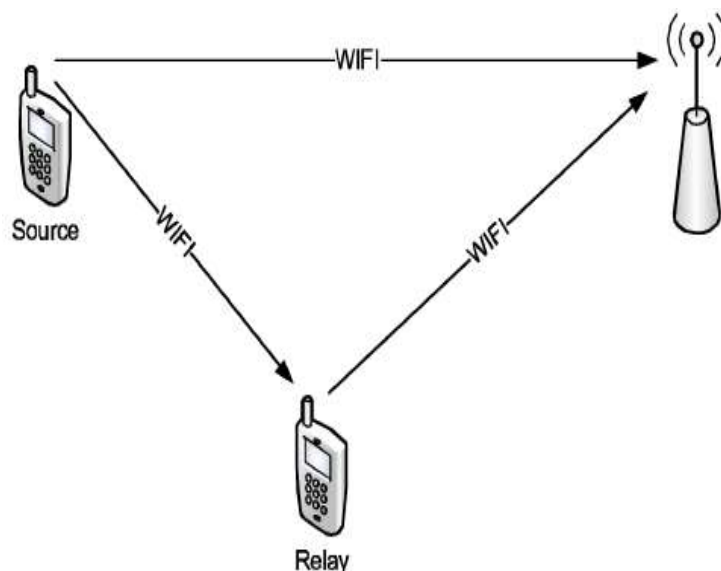


Fig. 10. Single radio access technology cooperation.

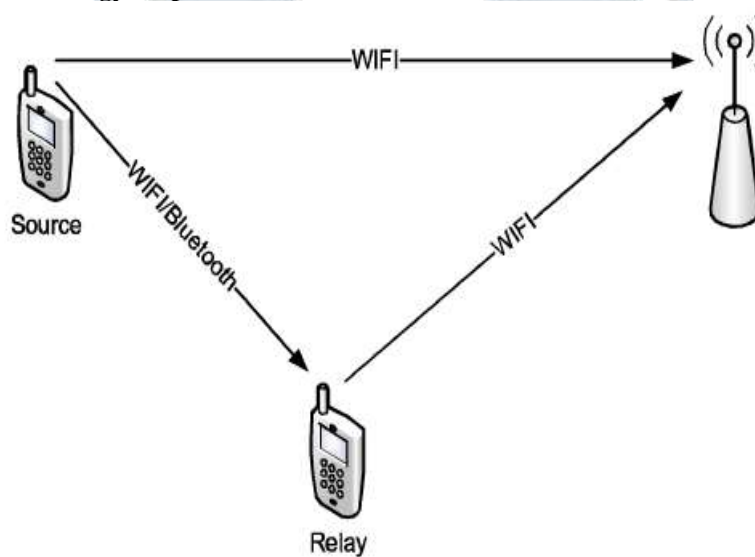


Fig.11. Multiple radio access technologies cooperation.

IV. SIMULATION RESULTS

Simulation results of this paper is as shown in bellow Figs.12 to 15.

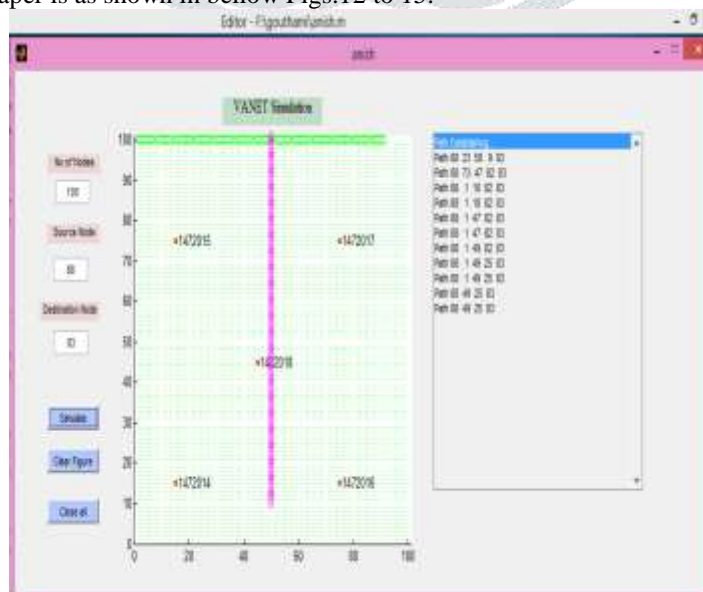


Fig.12. Path establishing during the simulation.

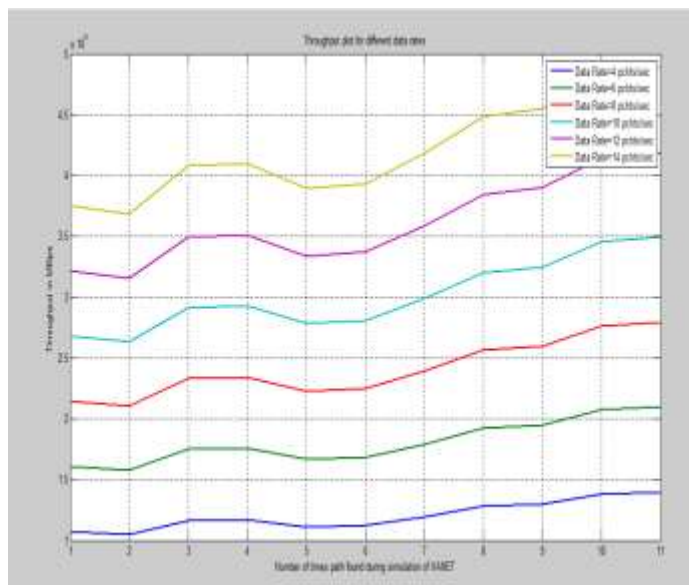


Fig.13. Throughput plot for different data rates.

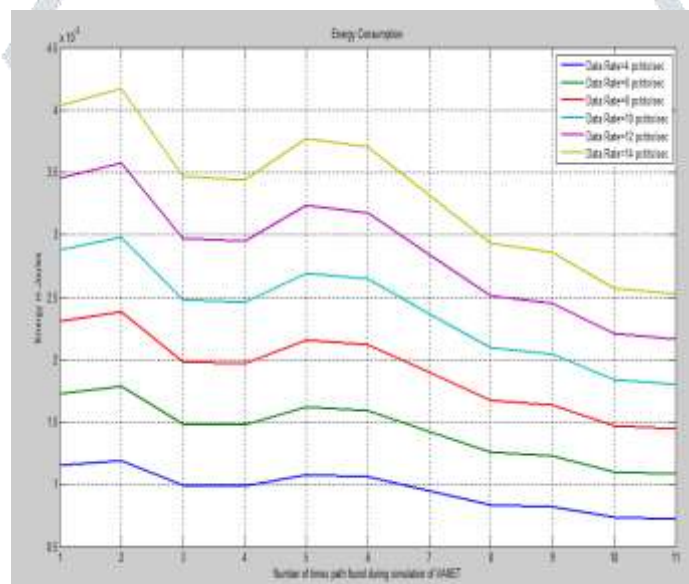


Fig.14. Plot for energy consumption.

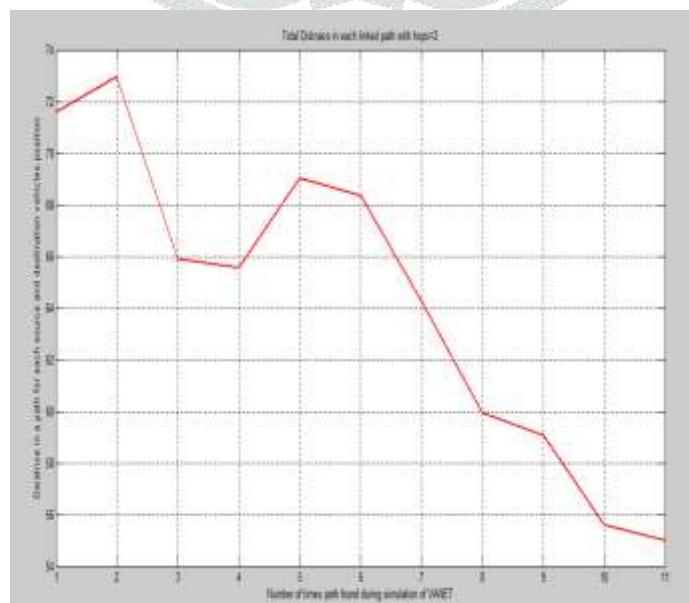


Fig.15. Plot for distance in a path for each source and destination in vehicles position.

IV. CONCLUSIONS

Cooperative transmission based on relay transmission is intended for use in 5G networks, particularly in "green" networks with high energy efficiency [11] and vehicular networks. The use of cooperative transmission allows you to reduce energy consumption, thus extending the working time of mobile devices. In addition, it is possible to improve the quality of transmission and to ensure high data rates by using several different wireless data standards. Presented in the paper, methods of implementation of cooperative transmission have varying degrees of sophistication and complexity. The LTE radio access technology offered superior network capacity and mobility support as compared with the IEEE802.11 p standard. Thus, we can conclude that the LTE technology is suitable for most of the applications of wireless vehicular network. The achievable delay satisfies most of the vehicular network application requirements, but you can observe a tendency of increase in the delay as the network load increases. As for IEEE 802.11p, the standard offers acceptable performance for sparse network topologies with limited mobility support. The performance is extremely sensitive to traffic load, larger vehicle densities, and vehicle speed [3]. Cooperation of the LTE and IEEE 802.11 p standard in wireless vehicular networks enables the use of the advantages of these two radio access technologies.

V. REFERENCES

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