Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN : 2581 - 611X)
Volume 4- Issue 1, Paper 12, January 2021

HIGH SPEED RAILWAY COMMUNICATION USING MOVING RELAYS IN 5G

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Abstract— *In Today's scenario, Human utilize High-Speed Railway (HSR) transport system as it is more convenient to people, so the main importance is given to provide the reliable communication inside the High speed train. Due to the high mobility of train and frequent need of handoff to each communicating users, providing a reliable communication is a challenging task. To provide reliable communication and avoid individual handoff problems, cooperative communication technique using moving relays (MR) is implemented in the proposed system. The system model for non-cooperative and cooperative communication in heterogeneous network is proposed. Two different scenarios are considered and compared for High Speed Railway Communication, the direct communication without moving relay (MR) and using Multiple Moving relay(MR). The performance of system model is analyzed by coverage probabilities, transmission capacity and SINR. Thus the results shows that the Signal to Interference Noise Radio(SINR), coverage probability and transmission capacity increases as the number of Mobile relay increases due to cooperative communication.*

Keywords — *Cooperative communication, Moving relay (MR), High speed Railway, coverage probability, transmission capacity, Signal to Inference Noise Ratio (SINR).*

I. INTRODUCTION

Because of developing innovation, the travellers inside the train interested on using the fast web access and best voice quality. In this era, a few kinds of investigations are going on the rail route correspondence. Traditional worldwide framework for versatile communication is adjusted for the railroad specific application which is named as the Global System for Mobile Communication-Railway(GSM-R)[1]Yet, it is fruitful just for voice correspondence in the HSR correspondence not for information administration.[3]To remunerate the downsides of GSM-R Another innovation called Long-term advancement is created.

LTE offers significant improvement, in best organization accessibility and decreased handoff rate. However, as the traffic builds the LTE network can't give the adequate information rate to high versatility vehicles. In this way, there is the need of cutting edge remote organization which gives the sufficient information rate to high versatility vehicles moreover. Thus, helpful correspondence gives a champion among the most special approaches to bargain the limitations of existing remote organization and is depended upon to give a significant part in the arrangement of next ages of remote organizations [1].

II. EXISTNG SYSTEM

In cooperative heterogeneous wireless network, interference become a major issue. It combines the cloud radio access network with small cells which further increase the capacity of a Heterogeneous cloud small cell network. Another, to mitigate co-channel interference, coordinated multi-point communication is proposed. The advantage of using coordinated multi-point communication with heterogeneous cloud small cell network is the improved coverage and spectral efficiency. The drawbacks in this system are the Conventional Global System for Mobile Communication as it is successful only for voice communication in the high-speed railway not for data service [2].

To compensate the drawbacks of GSM-R, another technology Long-Term Evolution is developed. Long Term Evolution, more popularly known as 4G, which was further upgraded by 3GPP to LTE Advanced [3].The 3GPP technical report is further enhanced to release 13, named LTE Advanced Pro, to mark the evolution of 5G with enhanced bandwidth and improved latency. But as the traffic increases, the LTE network cannot provide the sufficient data rate for high mobility vehicles. It has several other limitations in handling such high bandwidth requirements and provide seamless communication across an HSR environment. Severe constrains in bandwidth and reduced handover success rate has posed significant challenges [4].

So, there is the need of next-generation wireless network which provides the sufficient data rate for high mobility vehicles. To enhance the data handling capability and seamless user experience in an HSR environment, a distributed mobile relay based approach is proposed and implemented which enhances the Quality of Service in an HSR communication environment. [10]

III. PROPOSED SYSTEM

In this system both the handoff and vehicle penetration loss problem are removed by using the moving relay through cooperative communication. It can be flexibly deployed for increasing the throughput and reducing the penetration losses and individual handoff. [8] Moving relays are placed on the top of the train and associated remotely with the base stations through backhaul link and with users by means of access links. It performs the handoff in a group which is also termed as group mobility. The concept of interference and noise is also considered. Here, in this paper, multi-tier heterogeneous environment is considered. The performance of system is analyzed in terms of handoff probability, outage probability and coverage probability and transmission capacity. [9]

A multi-tier heterogeneous network is one where each tier of heterogeneous network consists of three different class of Base Station such as one macro cell, many pico-cells and many femto cells.[1]Two different type of communications are considered: Non-cooperative and cooperative communication.[5] Here, the non-cooperative communication refers to the direct communication of train user to base station, while cooperative communication refers to the involvement of moving relay for communication to base station. In cooperative communication, three types of scenarios are considered: Cooperative communication using one Moving Relay, Cooperative communication using two Moving Relay and Cooperative communication using four Moving Relay.

The main issue in the High Speed Railway communication is Doppler shift, frequent handoff and vehicle penetration loss. [7] The problem of Doppler shift occur due to the relative motion of the train versus the serving base station and can be resolved by using the guard band. The second problem encountered with the High Speed Railway is the frequent handoff. The process of handoff from one network to another network happens when the selected base station does not provide the required quality of service for the specific application. It is the important parameter which improves the network performance by reducing the different parameters such as call drop probability, call block rate etc.[2] Due to the high mobility of trains, the handoff occurs frequently in the high speed railway which increase the burden to the base station and a mobile station. The third problem encountered in the high speed railway is vehicle penetration loss which occurs due to metallic body of the train. The problem of vehicle penetration loss can be removed by placing the moving relay on the top of the train. [6]

IV. SYSTEM MODEL

The BS across different tier may contrast regarding the transmit power, coverage area and spatial density. The MR operates in half-duplex where the total transmission time is divided into two slots. In the first time-slot, macro BS transmits signal to MR and in the next time-slot, MR uses amplify-and-forward protocol to amplify the received signal and forward it to the train users. Assuming that all non-vehicular users are randomly, independently, and uniformly distributed within the cell. [9] Thus, the interference intensity of a non-vehicular user is a random variable depending on its locations. Considering that the passengers inside the train using cellular connectivity are seated uniformly from each other in every carriage. The communication channel is assumed to experience path loss, Vehicle Penetration Loss (VPL) and Doppler shift. The proposed system model is outlined in two parts. The first part explains the model assuming there is no MR present in the network. So, all communication takes place directly and the train users suffer from VPL. In the next part, a MR is mounted on top of the train and the train users use this relay for communication with the macro BS.

A. Non-Cooperative Network

A non-cooperative communication is the classical multiple access channel, where users send directly to a common destination, without repeating for one another**.** The user directly communicates with the respective BS. As the modern trains are currently intended to be airtight to enhance the heating, air-conditioning and ventilation system, so trains are made by metal body. Due to airtight nature of the train and metallic body of the train, the user suffers from the problem of VPL in this non-cooperative communication.

B. Cooperative Communication Network

In the next generation wireless network, the cooperative communication is the promising key to increase the coverage area, reliability, power and spectral efficiency. It involves the third party i.e. relay nodes or MR as a cooperative agent to communicate with the related BS. Cooperative communications can be considered as a special case of relay channel, where in simple relay channel there are three nodes, transmitter, receiver and relay. The job of the relay is to receive signal from source and forward it to destination, like repeaters. On the other hand, in cooperative communications, the node acting as a relay, not only forwards other users' information but has its own information to send as well. In the same way source has its own information and acts as a relay for other user.

In this paper, two scenarios are considered under cooperative communication:

1. Cooperative communication using one MR
2. Cooperative communication using two MR and four MR

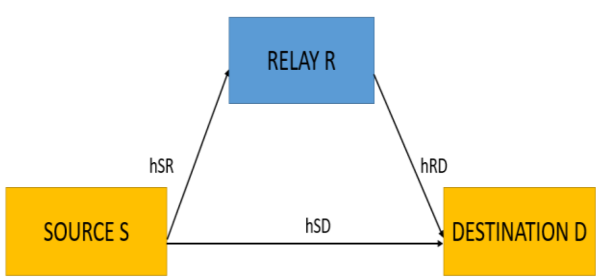

Fig.1: Relay Strategy

Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN : 2581 - 611X)
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1. Cooperative Communication using one MR

The MR is mounted on the top of the train and operate in the half duplex mode. It associated remotely with the BS through backhaul link and with users by means of access links. MR perform the handoff in a group which is also termed as group mobility. Firstly, MR receive the signal from the different train users and in the second slot, the MR amplify the signal with gain G and retransmit the amplified signal.

2. Cooperative Communication using two and four MR

With the worldwide increment in the quantity of mobile users, there is the requirement of more than the single antenna for efficient communication. It is not possible to place multiple antenna on mobile device so by considering this idea and concept of cooperative communication, the research moves towards the multiple relay. The scenario for cooperative communication using two MR. In this, two MR are used, first MR is called head MR and second MR is called back MR. Both the MR receive the signal transmitted by the train user and amplify the signal and then retransmit the signal. The MR amplify the signal with gain, G and retransmit the signal to the macro-cell. The signal received at the macro-cell BS via head MR.

C. Moving Relay System

In a relay system, sources first transmit data to the RNs. Each RN then processes and forwards its received data information to the destination nodes following some cooperation protocols. With the received signal from the RNs, the destinations decode the data from the corresponding sources. Some basic cooperation protocols are Amplify-and-Forward (AF), Decode-and-Forward (DF) and Compress-and-Forward (CF). In this paper Amplify-and-Forward protocol is used.

In this relaying protocol, every cooperating user or partner, after receiving the noisy version of the transmitted signal of its partner, amplifies and re-transmits it to common destination. The relay strategy used in this paper is shown in Fig.1. Fig.2 shows the relay network and Fig.3 shows how it can be implemented in HSR.

AF is also called non-regenerative relaying scheme and it is basically a processing method for analog signals. Compared with other schemes, AF is the simplest. Besides, as the destination node can receive independent fading signals from the source and relay nodes, full diversity gain and good performance can be achieved with this scheme. However, AF scheme is prone to noise propagation effect because the relay node amplifies the noise on the source-relay channel when the retransmitted signals are amplified in AF, the source-relay channel and the relay-destination channel are of the same importance because the relay node only amplifies and decodes, the information received from the source node; the incremental mode focuses on the source-destination channel

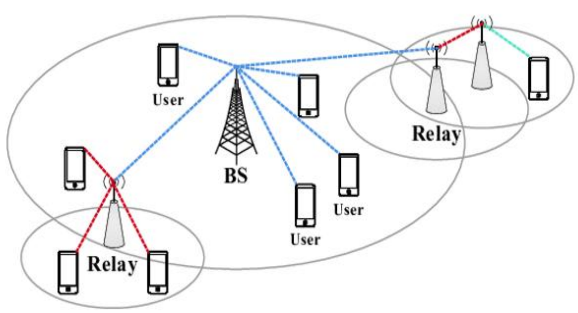

Fig.2: Relay Network

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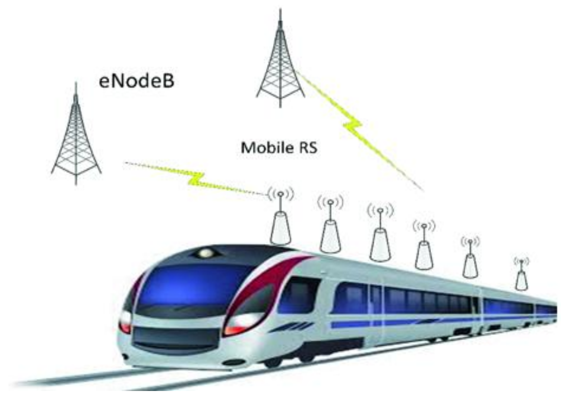

Fig.3: Relay Model in HSR

V. PERFORMANCE PARAMETERS

The performance of non-cooperative and cooperative communication is analyzed in terms of Bit Error Ratio (BER), Signal-to-Interference-plus-Noise ratio (SINR), coverage probability and transmission capacity.

1. SINR

In wireless communication, SINR is the most important parameter to measure the performance of any communication system. It is defined as the ratio of received signal power to sum of noise and interference power signal. In this work, only intra-cell interference is considered and interference from other cellular users is ignored.

Formula: $SINR = \ nErr/N * (nTx + nRx + nRe)$

2. TRANSMISSION CAPACITY

The transmission capacity is an important parameter that defines the performance of wireless network. The maximum average number of successfully transmitted data per unit area is called the transmission capacity. For successful transmission, it is necessary that the user should reside within the coverage area. As the user come out from the coverage area i.e. the call is disconnected from the previous base station and handoff or outage occurs. So, there is always a tradeoff between outage probability and transmission capacity.

Formula:

$$1/2 * max(log2(1 + (Relay\_i./Ns).* gama\_r\_s), log2(1 + (Relay\_i./Ns).* gama\_d\_s + (Relay\_i./Ns).* gama\_d\_r))$$

3. COVERAGE PROBABILITY

The coverage probability can be defined as a probability that the SINR is greater than the threshold for communication. It is the complementary Cumulative Distribution Function (CDF) of SINR.

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Formula:

Non-Cooperative: $1/n * 10log(1 + (norm(hsd).^2) * (P\_KL/(B/n)))$

Cooperative: $\frac{1}{n} * 10log(1 \left(\frac{(norm(hsr).^2)*(norm(hsd).^2+norm(hrd).^2)}{norm(hsr).^2 norm(hrd).^2}\right) * (P\_KL/(B/n)))$

VI. RESULT

Fig.4 a&b shows the graph of coverage capacity with 15 transmit and receiver values for Non cooperative and Cooperative relay 1, 2 and 4, x and y axis drawn for UE Throughput verses capacity. Similarly for different transmit receiver values graph is plotted in the next figures, Fig.5 a&b and Fig.6 a&b comparing Non cooperative communication and cooperative relays.

A. COVERAGE PROBABILITY

The coverage probability increases with the decrease in the threshold value and vice versa. It characterizes the average number of users which have the SINR greater than the threshold. The coverage probability is maximum at the BS and at the cell boundary, the received signal strength is small, so coverage probability decreases at that point. The coverage probability is maximum for the cooperative communication of two and four MR because of two amplify and forward.

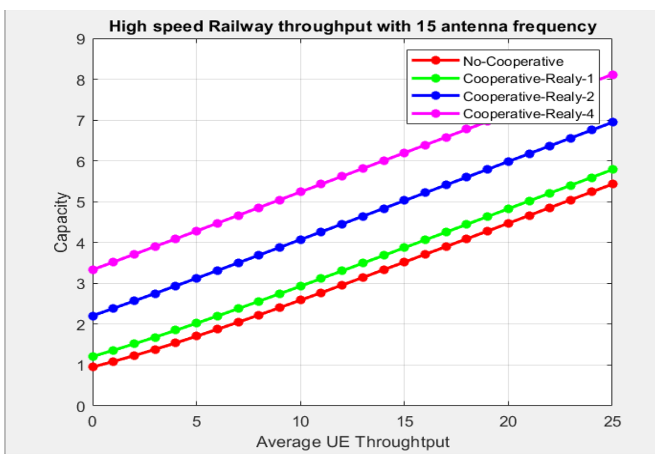

Fig.4.a: Coverage Capacity – 15

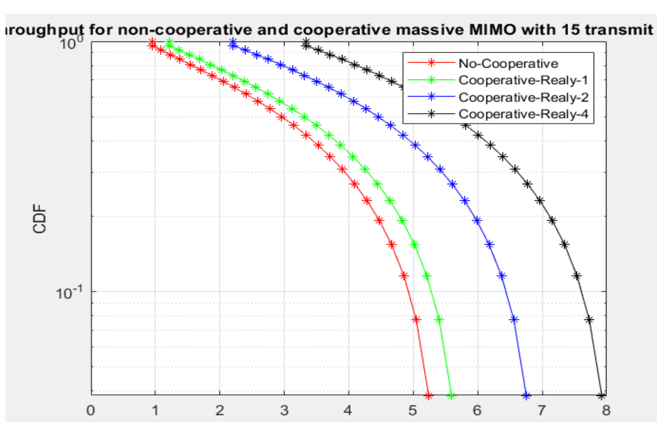

Fig.4.b: Coverage Capacity -15

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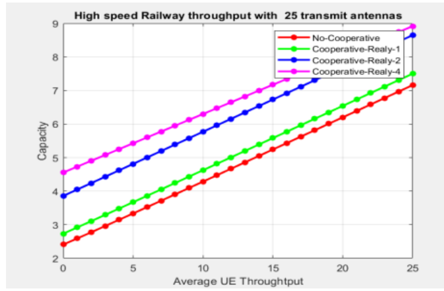

Fig.5.b: Coverage Capacity -25

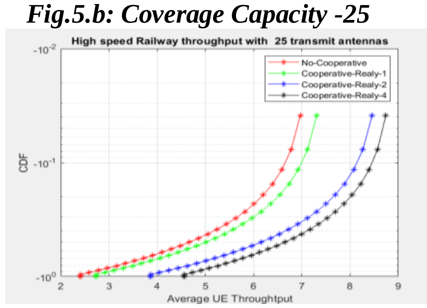

Fig.5.b: Coverage Capacity -25

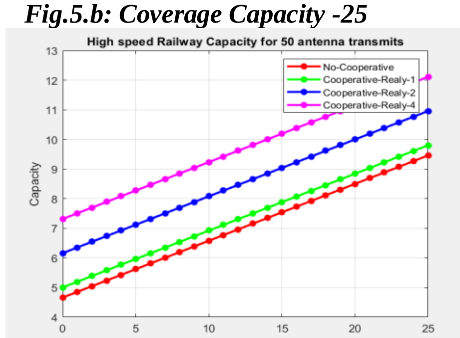

Fig.6.a: Coverage Capacity- 50

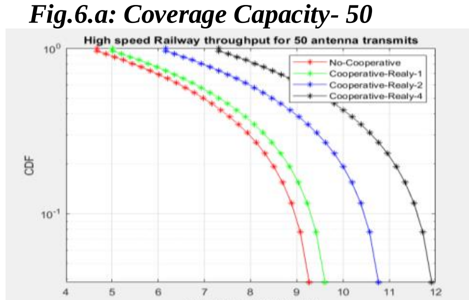

Fig.6.b: Coverage Capacity- 50

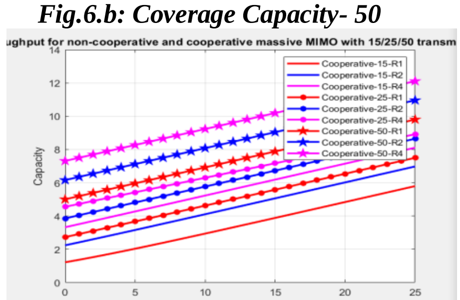

Fig.7.a: Coverage Capacity comparison 15/25/50

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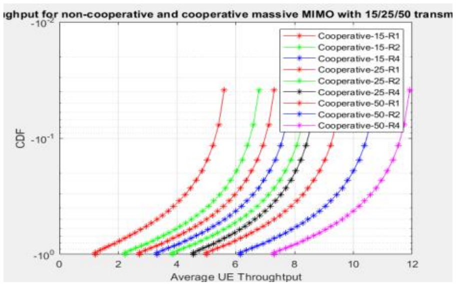
Fig.7.b: Coverage Capacity comparison 15/25/50

Above Fig.7 a&b shows the capacity comparison for all the transmit/receiver values determining which is the best value among them with the use of comparison table Table.1 below.

Table.1 Capacity Comparison Table

RELAY	X AXIS	Y AXIS	CAPACITY
MR-4 50	25	12.1088	302.72
MR-4 25	25	10.9581	273.96
MR-4 15	25	9.8010	245.02
MR-2 50	25	8.9153	222.88
MR-2 25	25	8.6478	216.20
MR-2 15	25	8.1082	202.70
MR-1 50	25	7.4999	187.50
MR-1 25	25	6.9804	174.51
MR-1 15	25	5.7988	144.97

B. TRANSMISSION CAPACITY

The transmission capacity simulation results are shown in Fig.8 for all the transmit/receiver values determining which is the best value among them with the use of comparison table Table.2 The four MRs have the greater transmission capacity as compared to the one and two MR due to more coverage area. The transmission capacity is the successful number of transmission per unit area. So, the larger transmission capacity means the more efficient model for data Transmission. Fig.9 shows the SINR.

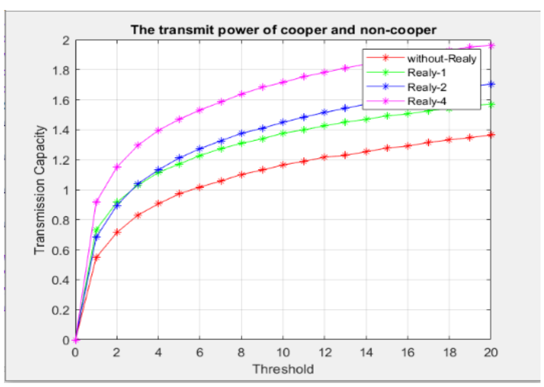

Fig.8: Transmission Capacity

Table.2 Transmission Capacity Comparison

RELAY	X AXIS	Y AXIS	TRANSMISSION CAPACITY
4	20	1.9618	39.236
3	20	1.7041	34.082
2	20	1.5689	31.378
NO RELAY	20	1.3646	27.292

C. SINR

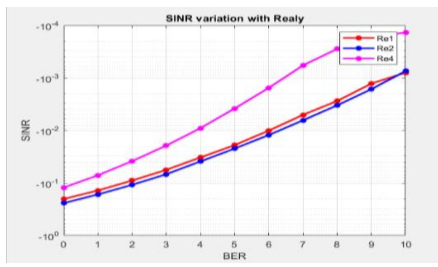

Fig.9: SINR

VII. CONCLUSION

In this paper, the effect of cooperative and non-cooperative communication for multi-tier heterogeneous network is investigated. The cooperative communication is possible with the help of MR by using the concept of group mobility. In the multi-tier heterogeneous environment of macro cell, pico cell and femto cell, the effect of one MR, two MR and four MR and without MR is tested. The system also proposes to use the MRs to cooperatively communicate with the stationary macro users that are in low coverage. Output shows that boundary macro users can improve the coverage by receiving signal from macro BS via a nearby MR. The proposed model in this work can be used to analyze and enhance the performance of users in heterogeneous cellular networks with the help of MRs.

The performance is evaluated in terms of coverage probability, transmission capacity and SINR. The cooperative communication with four MR enhances transmission capacity compared to one MR. The cooperative communication by using four MR proves best in terms of all parameters. In future, this can be further extended to various other forms of communication such as in aircrafts, mobiles, etc. Multiple and different types of MR will be analyzed in HSR communication**.**

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