International Journal of Engineering & Technology, 7 (1.2) (2018) 135-140

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Power and resource allocation for MIMO based two-tier heterogeneous network using small cell clustering algorithm

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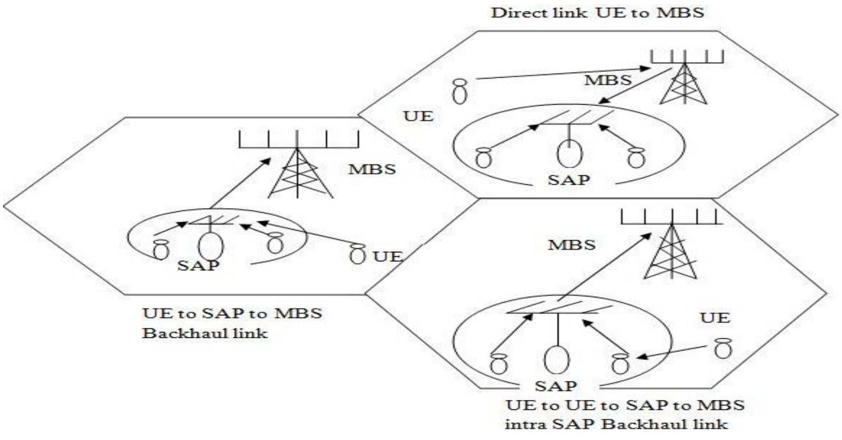
Abstract

Resource allocation problem in the two-tier heterogen eous MIMO network plays a vital role in avoidance of interference between the mobile users connected to the host directly and through the backhaul link. Two different frequency bandwidths are proposed to avoid the interference generated between the users placed in the interference region in the small cell. The mobile user frequency range is allotted for the link between small cell base station, macrocell base station and mobile user and millimeter frequency bandwidth is utilized between the small cell base station, small cell cluster heads and small cell users. The inter-small cell clustering helps the small cell base station node to select the number of antennas for communication and to send the request for allocation of bandwidth to eliminate the inter-cell congestion. The method was implemented in NS2 simulator, and the performance matrices were measured to analyze the efficiency and quality of service of the proposed topology.

1. Introduction

Increase in development of wireless communication devices, traffic generated in the communication medium increases rapidly in both rural and urban area. To manage network traffic and control congestion Multi Input Multi Output approach is implemented. MIMO helps the user to transmit data faster than the normal single antenna approach. MIMO antennas provide parallel communication by transmitting and receiving the data in multiple paths at the same time. This parallel approach reduces the communication time, which helps other users to use the channel without congestion in short time interval.

Utilisation of MIMO technique reduces the channel allocation time, the rapid increase in usage of wireless communication devices congestion of network increases in locations like public structures. To overcome this bandwidth shortage heterogeneous network is introduced. The network with different bandwidth was proposed which share the traffic between them in case of occurrence of congestion in particular bandwidth. The MIMO antennas are designed to access both the bandwidth efficiently to handle the congestion in the network.



The concept heterogeneous network introduces the new network connection namely backhaul network. This technique provides a private connection to the host rather than the regular direct connection. These backhaul networks are used to handle congestion in the communication network when the bandwidth is assigned low. An individual intermediate host is placed to regulate the traffic flow within the limited bandwidth. Many algorithms are implemented to handle connection in the backhaul network. Allocation of bandwidth for backhaul link based on a number of backhaul users and neighbor channel collisions and efficient handling network traffic is the important criteria's to handle in the backhaul based heterogeneous network with MIMO nodes. The methods in handling heterogeneous network were discussed in the related work chapter of this paper.

2. Related work

Due to the increase in communication devices providing the efficient connection between the hosts was made more critical. To provide efficient congestion free communication, many protocols have been implemented. The energy efficient connection is more important. The protocols involved in performing congestion free communication affect the energy utilization. Most of the wireless communication devices are battery powered, so energy efficiency plays the vital role in these communication networks. MIMO based cross-layer mechanism is introduced to handle the congestion and energy efficiency in the communication network. [1]

Many energy efficient algorithms are implemented in the cellular network to overcome the draining of energy in the mobile users. These energy efficient algorithms reduce the energy consumption but affect the quality of service in the network. The protocol must promote the dense frequency reuse in the presence of spectrum hole. To overcome spectrum densification problem, massive techniques like Multi Input Multi Output mechanism and soft cell approach is implemented. Beamforming approach is applied to perform MIMO concept in the soft cell network. The method satisfies both the energy constraint and Quality of service in the network. [2]

Traditional wireless communication networks are implanted to provide wider coverage and maximum load handling capability. Consumption of larger energy leads the monitoring nodes to become dead nodes. To replace these dead nodes new nodes are placed in the current location thus the dead node there becomes junk in particular locality. To overcome these effect energy efficient and environment free methodologies are introduced in wireless communication network. A green network is deployed based on the four the criteria they are: nodes placement & power efficiency, efficient spectrum allocation, bandwidth selection and delay handling. The network topologies are designed based on the above policies to develop an environment-friendly network. [3]

An extended wireless network is implemented using Multi Input Multi Output antennas in all the nodes and works in the line of sight propagation model. The number of nodes placed in the network determined the number of antennas, in each node. This method overcomes the zero data rate problems by regulating the multiple input and output through the line of sight propagation model. The antennas are equally split to perform transmission and receiving function. Two transmission strategies are implemented, Long-hop and Short hop. In long-hop strategy, the nodes are placed widely to meet the maximum transmission range. By sacrificing the multiplexing power, the gain in transmission is increased. In case of short hops, the nodes are placed nearer that the nodes will take maximum short hops to reach its destination. It gains the multiplexing power by performing shorter hops in the network. To hops, the efficiency of the antenna is relatively utilization. This method is used to perform back hole process in the network. [4]

A mathematical approach to finding the capacity of the backhaul network based on the multi-input multi-output concept. The number of antennas placed in the network user and base station node is determined by the size of the network. The arbitrary function is developed to identify the location of the nodes and number of antennas to be placed for transmitting and receiving process. To achieve maximum frequency in the smaller network, scaling of the antenna is used. Geometrical exponential stripping method is implemented to increase the channel gain and stability of the network. [5].

Increase in the demand of wireless communication network, future in the presence of will be implemented with multiple access points to cover the demand in the network. A decentralized approach is applied to perform densification and spectrum sharing management. Analysing the signal processing in distributed manner affects the performance of energy efficiency to overcome this problem three levels of distribution concept is implemented. In first a signal processing is performed between the nodes (hybrid) and in second level the processing is performed only at access points, and the third level is distributed form where the processing was performed in each individual nodes. The energy efficiency in distributed and centralized models are compared to find the suitable solution for the back hole network. [6]

A network framework for the green heterogeneous network is framed satisfying the energy efficiency, spectrum efficiency and quality of service. The framework also includes multilayer interference control and power management. The system is designed to manage all these criteria in unbalanced load condition in the 5G wireless communication network. [7]

Development in the wireless mobile communication results in the increase of higher data rate applications, which consumes much energy to achieve the quality of service in the network. The mobile devices are battery powered so that an energy efficient algorithm is needed to satisfy energy constrain sources and achieve the Quality of service in environment-friendly communication nature. The process should be executed in the background without disturbing the communication medium. To perform these process OFDMA based MIMO technique is implemented in the relay transmission network. It also handles the resource allocation in the sensor node to manage the signaling properties in the network. [8]

The rapid development in the wireless communication network demand for accessing the network was increased. The network devices are mostly battery powered. To handle the limited power resource, energy efficiency algorithms become major importance in both the communication devices. This operation drastically increases the communication cost in the wireless network. To overcome these limitations the heterogeneous network is introduced. It handles energy efficiency and Quality of service of the network by increasing the capacity of the network and shares the load between the different bandwidths of the network. Enhance inter-cell and macrocell architectures are proposed in the Heterogeneous network to handle energy efficiency in multi-RAT and Single RAT based heterogeneous network model. [9]

To improve the cost efficiency and energy efficiency in the network the density of the heterogeneous network was increased. The density of the communication channel increases the capability of the backhaul network to handle much higher traffic. Heavy, dense traffic created at backhaul link affects the performance of other mobile user connected directly to the host. So regulation of dense traffic by backhaul link should be monitored to provide balanced connection throughout the network. To overcome this problem a MIMO based two tire architecture was designed along with spatial multiplexing method and time division multiple access was proposed along with backhaul architecture. The backhaul architecture is more efficient tin two-tier system than single tire network. [10]

Computer network comprises of a huge number of network devices such as routers, switches and various types of intermediary devices such as a firewall which will also manipulate traffic though it is not for packet forwarding purposes. Many complex protocols are implemented on these intermediary devises. Network events and applications are managed by network administrators by configuring policies. This is done manually by transforming the high level-policies into low-level configuration commands which will adapt to the changing network conditions. For achieving these very complex tasks, very limited tools are currently at their disposals. Because of that, network administration and fine tuning of performance is quite challenging and thus error proneit gives an overview of programmable networks. The emerging field of Software Defined Networking (SDN) is examined and the history of programmable networks, from initial ideas to recent developments is studied. Network applications and services that have been developed based on the SDN paradigm are studied [11].

3. Methodology

The development of the wireless communication devices leads to the massive increase in the network traffic. In order to handle the traffic congestion effectively multi path heterogeneous topology was deployed which splits the traffic into multiple tiers. Two-tier heterogeneous network is used widely where an additional backhaul link was generated to handle the network users in highly dense environment. The backhaul link provides an individual connection between the host and user node. The heterogeneity is achieved when the user node enters a small cell region where an individual backhaul link is placed to handle the density of the network traffic.

To handle the network traffic and user density the network was deployed with Multi Input Multi Output capabilities and by increasing the network bandwidth. Only increasing these parameters is not sufficient. These methods fail at heavily dense regions and the edges of the network. To overcome the performance degradation issue, small cells are introduced. The small cells are coupled with the open macro network and help in sharing the load between the smaller cells and with the normal direct link. The small cells are developed in the area where the coverage link of the macro cell is weaker or at the highly dense regions. The small cells provided with low power base stations that help the user node to interface with the communication host. Figure 2 explains the position of small cells within the macro cell network.

The small cells are deployed to increase the capacity of handling the data load in the network. The small cells provide backhaul connection to the host by reducing the network traffic for the macro cell. The user node joins the backhaul network once it enters the small cell region. The network load was shared between the small and macro cells to avoid imbalance load in the network. To overcome transmission delay MIMO based antennas are placed in the base station of the network and micro access provider in the het-net small cells.

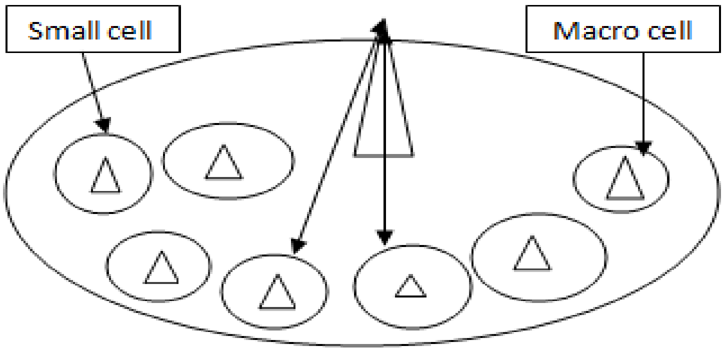


Fig. 2: Representation of Macro and Small Cells.

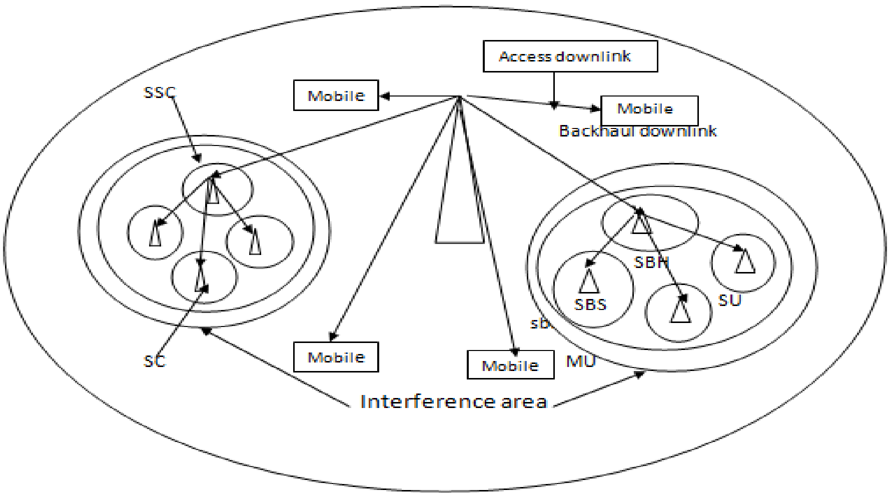


Fig. 3: Inter Clusters in Small Cell and Multi-Frequency Link.

In the heterogeneous network, the size of the cells will be varied and based on the size it is termed as the macro, small and Pico cells. Each cell size possesses its transmission power. Due to the placements of multiple small cells, interference between the nearer small cells is possible. The user node placed between the small cells posses three different signals one from macro cell and other from the corresponding small cells. To overcome this interference problem, inter-small cell clusters are introduced. Each inter cluster as its access point and the inter-cluster access points are grouped with the small cell base station. The backhaul network was framed between the small cell base station and the host node.

Two frequency bands are implemented in the heterogeneous network one with normal mobile frequency band and the other with millimeter wave frequency band. The mobile frequency band was applied to the macro cell, and the millimeter wave frequency band is used between the small cell base station and the small cell users in the inter clusters. This difference in the frequency handling provides interference avoidance between the macro node with the small cell nodes. Inter-cluster formation provides load balancing within the small cell area.

A small cell clustering algorithm is implemented to handle the inter-cell traffic within the small cell zones. The interference caused by the inter-cell and direct link mobile users are eliminated using block diagonalizing procedure. A transmit precoding procedure was framed to avoid the interference by the mobile user moving from direct link to small cell region and vice versa. This method is implemented in all the small cell nodes. At the initial state of the network, a number of users request for communication was submitted by the small cell base station. Based on the traffic rate the bandwidth for the small cell was allocated by the macro base station. The bandwidth was allotted based on the number of users requested directly and through the small cell base station. The procedure was repeated every time the user enters and exits the small cell. So the bandwidth and number of antennas involved are fixed before the communication starts. Moreover, the millimeter wave communication within the small cells provide additional security over the interference caused by the mobile user placed in the interference area which is moving from direct link to small cell zone.

The amount of bandwidth allocated for the small cell is calculated as follows

$$y^{m}_{ok} = h^{mm}_{0k} v^{m}_{ok} x^{m}_{0k} + \sum_{i!=k}^{Km} h^{mm}_{ok} v^{m}_{0i} x^{m}_{0i} + \sum_{i\epsilon B^{m}_{k}} \sum_{j=1}^{K_i} h^{sm}_{ik} v^{s}_{ij} x^{s}_{ij} + \sum_{i=1}^{c} \sum_{j=1}^{n} h^{bm}_{0k} v^{b}_{ij} x^{b}_{ij} + \sum_{i=1}^{c} \sum_{j=1}^{n} h^{bm}_{0k} v^{b}_{ij} x^{b}_{ij} + n^{m}_{0k}$$

Whereh^{mm}_{0k},h^{sm}_{ik},h^{bm}_{0k}, represents the maximum bandwidth requested by the small cell base station to the macro base station. $K_{m,}$Represents the total number of mobile users connected with the small cell cluster heads. $h^{mm}_{0k} v^{m}_{ok} x^{m}_{0k}$ Represents the total signal strength received by the mobile user from small cell, cluster access point and $\sum_{i!=k}^{Km} h^{mm}_{0k} v^{m}_{0i} x^{m}_{0i}$ is the interference generated by the mobile user within the macro cell. $\sum_{i\epsilon B^{m}_{k}} \sum_{j=1}^{K_i} h^{sm}_{ik} v^{s}_{ij} x^{s}_{ij}$ Is the inter tire interference which is caused due to the mobility of user nodes within the small cell network. The interface caused in backhaul link was denoted by $\sum_{i=1}^{c} \sum_{j=1}^{n} h^{bm}_{0k} v^{b}_{ij} x^{b}_{ij}$ these interferences caused in the communication link are very small, so these values are neglected in the calculation of loss in packets transferred due to this interference, but the values are added in bandwidth requirement to neglect the effect in the network. n^{m}_{0k} is the noise in the communication medium. The total bandwidth allocated to the small cell includes the smaller interference ranges and the noise value so that the effect due to these disturbances is neglected in the communication link.

4. Result and discussion

The small cell clustering based resource allocation algorithm was designed using NS2 simulator, and the performance of the network was measured using the performance metrics like packet delivery ratio, throughput, and energy consumption. The distribution plot and the CDF plots were generated to identify the mean and standard deviation for the measured values from the ns2 simulator. The basic information about the network framed in the NS2 simulator was listed in table 1.

Table 1: NS2 Parameters

Parameter	Value
Channel	Wireless
Propagation Model	Two ray ground
Queue Type	Drop Tail / PriQueue
Queue Length	200 Packets
MAC Type	802_11
Number of Nodes	100
Maximum X and Y values	2000, 2000
Simulation Time	15 Seconds
Routing Protocol	AODV
Receive Power	0.3 Joules
Transmit Power	0.6 Joules
Initial Energy	100 Joules

A measure to rate the amount of data transferred successfully within the network in the fixed amount of time is defined as throughput. The throughput plot explains the efficiency of the network at which speed the data are exchanged within the network. The Quality of service is measured using the plot of throughput. The figure 4 shows the throughput achieved by the proposed inters cluster method, and the performance is compared with Poisson method and hedonic regression method.

The throughput is calculated by measuring the time and amount of packets transferred in the network.

$$\text{Throughput} = \frac{\text{Amount of data transfered}}{\text{Network Time}}$$

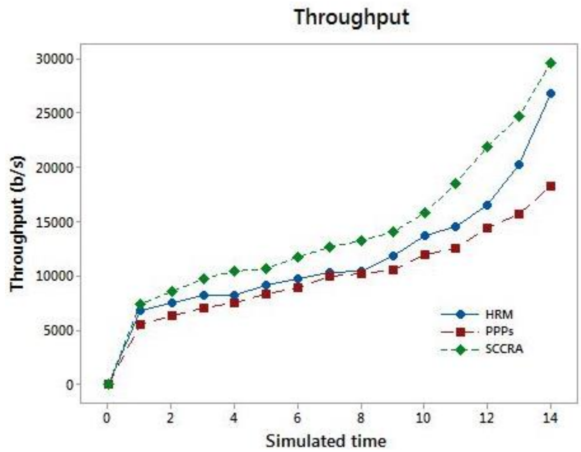


Fig. 4: Throughput.

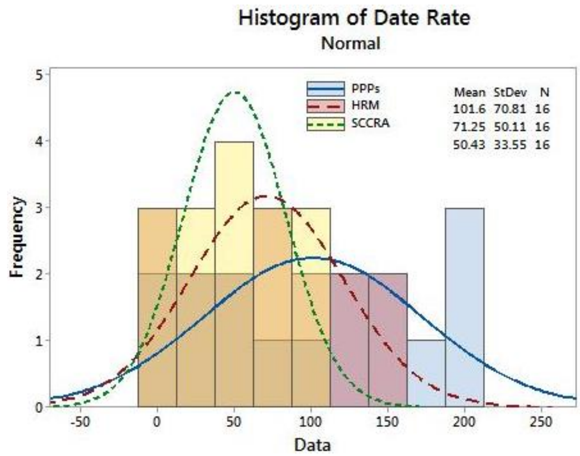


Fig. 5: Histogram for Throughput.

Figure 5, histogram plot shows the frequency of occurrence of transmission changes in the network. The mean and standard deviation values are generated and plotted as a histogram chart along with the normal distribution curve. The mean of Small Cell Cluster based Resource Allocation(SCCRA) is measured as 101.6 which is 60 percent higher than the existing methods.

The packet delivery ratio is directly proportional to the throughput of the network. The amount of successful packet transmission reduced will affect the rate of throughput of the network. The packet delivery ratio is measured by a number of packets generated with a number of packets delivered successfully in the network. Figure 6 represents the packet delivery ratio for the proposed model.

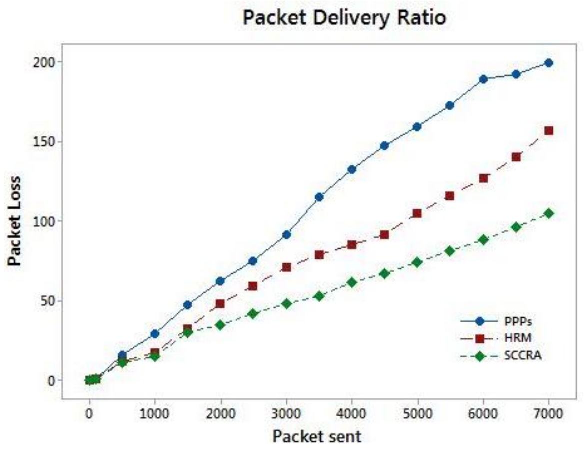


Fig. 6: Packet Delivery Ratio.

The Packet delivery ratio is measured using the formulae

$$\text{PDR}(\%) = \frac{\text{No of received packets}}{\text{No of generated packets}}$$

The percentage of packet delivery ratio is calculated, and the graph was plotted using the ratio of packet loss and packet sent in the network. Figure 7 compares the packet loss ratio with an increase in throughput of the network. The parameters namely packet delivery ratio, packet loss ratio, and throughput measure the quality of service achieved by the proposed method in the heterogeneous network with MIMO technology.

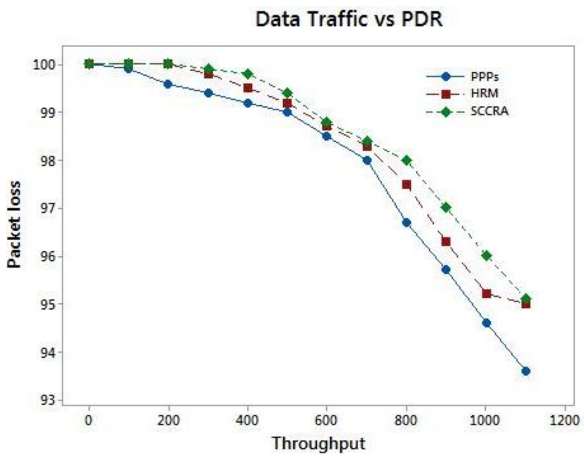


Fig. 7: Packet Delivery Ratio by Throughput Measured.

The packet loss ratio is the difference of packets generated by the amount of packets received by the nodes in the network. Increase in packet loss reduces the network performance.

The delay of the network was measured to analyze the time taken for routing data within the network. The end to end delay was measured by

Delay = received time – transmitted time

Total Delay = Total delay + delay[n]

Average Delay = Total delay / packet count

Figure 8 shows the generation of delay in the network for proposed SCCRA algorithm and existing hedonic model.

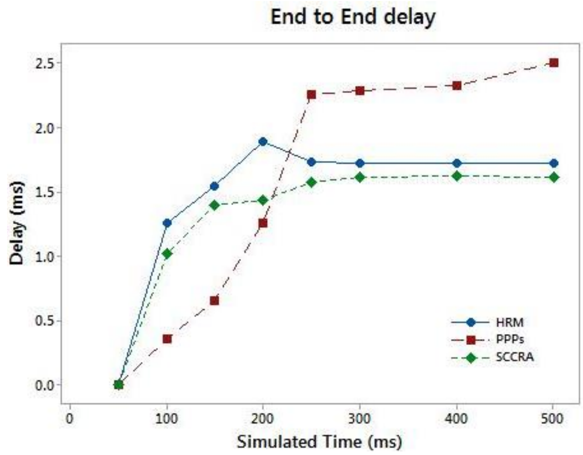


Fig. 8: Delay Measurement.

The cumulative distribution function is framed based on the amount of delay generated in the proposed network using comparative algorithms. The mean and standard deviation for cumulative distribution in the continuous state is measured. It shows the continuous distribution of values under the probability density function. Figure 9 plots the empirical Cumulative distribution plot and the plot provides the mean and standard deviation for the delay generated in the network the proposed SCCRA algorithm generates the least mean value for generation of delay in the network.

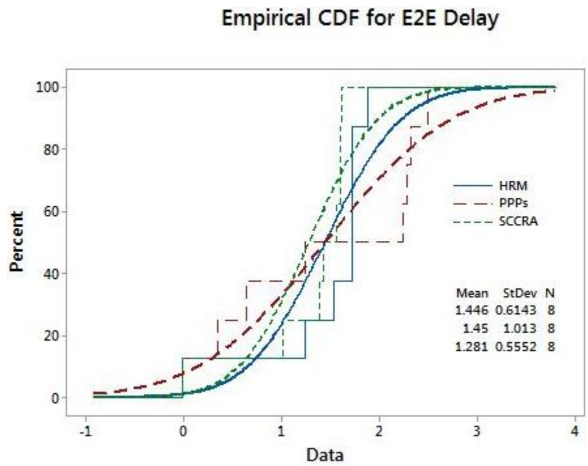


Fig. 9: Empirical CDF for Delay Generated in the Network.

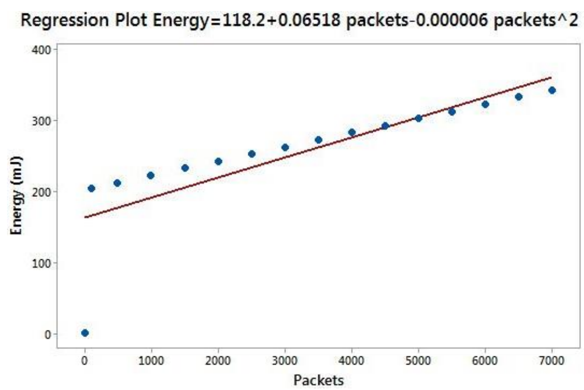


Fig. 10: Regression Plot for Residual Energy.

The energy consumed by the network for performing communication between the user node and the host node was measured as a regression plot. The regression plot determines the performance of the system by forecasting the projection of the performance of the system. The energy consumed by the node in the network was measured by

$$E_{node} = \sum E_{tx} + E_{rx} + E_{idle} + E_{sleep}$$

The total energy of the node is determined by the amount of energy consumed for receiving the data transmitting the data, and the system states idle or sleep. This energy requirement was reduced from the total allocated energy regularly for the fixed simulated time and during the transmission of the data in the network.

5. Conclusion

The interference problem and quality of service were handled in a heterogeneous network. A Backhaul link is generated using MIMO property, which increases the network performance in the two-tier heterogeneous network, but the congestion due to the macro user and small cell user was grater at interference region. To overcome this problem, small cell cluster based resource allocation algorithm is implemented in the heterogeneous network. The performance of the system is measured using NS2 simulator. The performance of the SCCRA algorithm was compared with the Poisson process and hedonic regression model. The proposed method achieves mean about 101.6 for throughput of the network that is 60 percent greater than the existing methodologies. The mean for delay generated is measured as 1.281. The performance of the proposed method is improved than the existing methodologies.

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