Throughput Computation of LTE-A Network for Urban Area

Kishor Pratap Singh, Pradeep Kumar Chopra

***Abstract*— LTE-A envisions a comprehensive all-IP-based solution, including voice, data, and streamed multimedia at much higher data rates and spectral efficiency. Emerging standards and technologies like LTE and WiMAX are actually leading towards this vision. In this paper, we implemented different frequency reuse schemes, MIMO mechanism for practical user throughput calculation in LTE-A network at different locations in macrocell and femtocell after removal of control signaling overhead.**

***Index Terms*—Fractional Frequency Reuse, MIMO, LTE-A, Throughput.**

I. INTRODUCTION

Wireless field in telecommunications is a very exciting field for research. The fast development of mobile telephone use, different satellite facilities and the wireless internet and lans are generating various changes in telecommunications. One of the recent steps in enhancing mobile telecommunication systems is the long term evolution of UMTS. This began with the conceptualization of the term cells by Bell Labs, USA. Usage of cells enhanced the capacity of mobile communication networks, by splitting the coverage area into small cells having their own base stations working on different frequencies. There are several generations of mobile communication systems depending on the technology that mobile communication networks have used. The first generation systems used analogue technology. The second generation system is GSM/GPRS/EDGE based on digital technology. Third generation is UMTS and its long term evolution. Fourth generation is LTE-Advanced. Our main focus is 4G that is LTE-Advanced also known as release 10. LTE-Advanced is high data rate all IP packet network in this network core network and radio access both are fully packetized network. LTE-Advanced standards development is going under 3rd generation partnership project (3GPP). LTE-Advanced provides spectrum flexibility for deployment, coexistence with legacy radio access technologies, and complexity [1]. Main features of LTE-Advanced are carrier aggregation, uplink multiple antenna transmission, enhanced downlink multiple antenna transmission, relaying, support for heterogeneous network deployments.

With regard to the peak data rates of mobile cellular systems [2], from the onset of the introduction of mobile cellular systems and until the mid-1991s the data peaked at approximately around 10 kbps. The peak data rate touched 160 kbps with the introduction of GPRS. Only few years later, the first WCDMA system supported peak data rates of 384 kbps. After that, HSDPA supported peak data rates from 7.2 Mbps to about 14.6 Mbps (by using adaptive modulation and coding with higher-order modulation and multicode transmission. HSPA-Evolved as specified by 3GPP Release 7 (Rel-7), the second phase of HSDPA, achieved data rates of up to 42 Mbps (assuming 64-Quadrature Amplitude Modulation (QAM)). In LTE technology, peak data rate is reaching 326 Mbps. In its advanced version, LTE-Advanced is pushing the peak rate to attain the huge throughput rate of 1Gbps. The evolution of the peak data rate from years 1991 to 2017 is shown in Fig. 1.1.

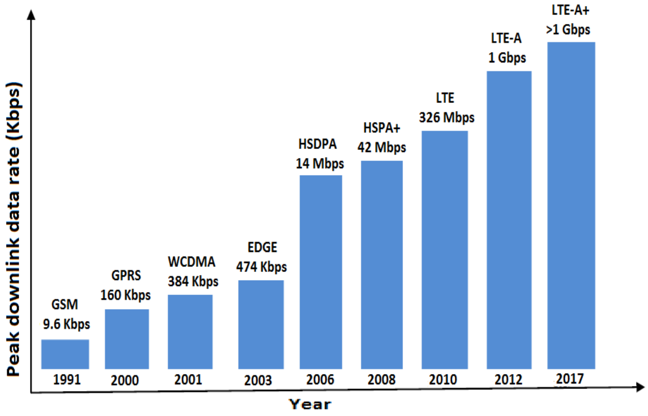

Fig. 1.1 Evolution of downlink peak rate from years 1991 to 2017

The paper is organized as follows. In Section 2, mathematical analysis of the work is done. In Section 3 simulator architecture is described. In section 4 results of the work are shown. Finally, the paper is concluded in Section 5, and future scope is discussed in Section 6.

II. MATHEMATICAL ANALYSIS

In order to estimate the signal to interference + noise ratio (SINR), first we have to calculate the distance and then the path loss between a macro base station (BS) and a User Equipment (UE) and between a femto base station (BS) and user equipment (UE). The path loss for the first case and for a macro user roaming outdoor in an urban area [3], can be determined as follows

$$\mathbf{PL\_MO\ (dB) = 15.3 + 37.6\ log_{10}\ D}$$

Whereas, for the case of an indoor macro user the path loss is given by:

$$\mathbf{PL\_MI\ (dB) = 15.3 + 37.6\ log_{10}\ D + L_{OW}}$$

where D is the distance between the transmitter (Tx) and the receiver (Rx) in meters and L_{OW} the penetration loss of an outdoor wall.

The path loss between a femto base station and a UE is calculated by the following equation

$$\mathbf{PL\_FO\ (dB) = 38.46 + 20\ log_{10}\ D + 0.7d_{2D,\ indoor} + 18.3n^{((n+2)/(n+1) - 0.46)} + q{*}L_{iw}}$$

where n is the number of penetrated floors, q is the number of walls separating apartments between the femto BS and the UE, and L_{iw} is the penetration loss of the wall separating apartments. Also, the term $0.7d_{2D,}$ indoor takes account of penetration loss due to walls inside an apartment and is expressed in metres.

Finally, we consider the case of an outdoor femto user associated to an indoor femto BS. In this case we also consider the outdoor wall loss.

$$\mathbf{PL\_FI\ (dB) = max\ (15.3 + 37.6\ log_{10}\ D,\ 38{:}46 + 20\ log_{10}\ D) + 0.7d_{2D,}\ indoor + 18.3n^{((n+2)/(n+1) - 0.46)} + q{*}L_{iw} + L_{ow}}$$

The channel gain is dominantly affected by path loss, which is different for outdoor and indoor scenarios. So, it can be expressed as:

$$\mathbf{GAIN = 10^{-\ PATHLOSS\ /\ 10}}$$

We also applied 8x8 MIMO in our work, which increase the user throughput. In an array of 8x8 MIMO base station power is divided between 8 parts, one part for each antenna. In MIMO we applied different MIMO schemes to users near base station and to users at edge. Users near base station get different data streams on each MIMO link, in this division of a single high SINR link takes place in to smaller SINR links with different data stream on each link. Users at edge get same data stream on each MIMO link due to which the SINR increased for edge users.

For ICIC different frequency reuse mechanisms are used such as co-channel, incremental frequency reuse (IFR3, where 3 is the factor of frequency reuse), Fractional frequency reuse (FFR), Soft frequency reuse (SFR). In co-channel operation all base stations use same bandwidth. In IFR3 bandwidth is divided in to 3 parts and used in a way that the adjacent base station will not use the same bandwidth. In FFR bandwidth is divided as in IFR3 and also equally in between center and edge of a cell i.e. in 4 parts but all at same power level. In SFR center part will get 1/3 part of bandwidth and edge part will get 2/3 part of bandwidth but in SFR frequencies for center get lower power level as compared to frequencies for edge of the cell. SFR shows a very high improvement in throughput. In these frequency reuse mechanisms interference only calculated from those adjacent places which uses the same frequency as used in the macro cell.

SINR_M is the SINR for a macro user which is calculated as:-

$$\mathbf{\mathit{SINR}\_M = \mathit{P\_M{*}GAIN}\_M\ /\ (\ \mathit{N}_O\ {*}\Delta \mathit{f} + sum\ (\ P\_M'\ {*}\ GAIN\_M'\ ) + sum\ (\ P\_femto{*}GAIN\_femto\ ))}$$

where P_M and P_M' is transmit power of serving macrocell M and neighboring macrocell M' on subcarrier k, respectively. GAIN_M is channel gain between macro user m and serving macrocell M on subcarrier k. Channel gain from neighboring macrocells are denoted by GAIN_M'. Similarly, P_femto is transmit power of neighboring femtocell F on subcarrier k. GAIN_femto is channel gain between macro user m and neighboring femtocell F on subcarrier k. N_O is white noise power spectral density, and Δf subcarrier spacing.

In case of a femto user f on subcarrier k interfered by all macrocells and adjacent femtocells, the received SINR can be similarly given by

$$\mathbf{\mathit{SINR}\_F = \mathit{P\_femto{*}GAIN}\_M\ /\ (\ \mathit{N}_O\ {*}\Delta \mathit{f} + sum\ (\ P\_M\ {*}\ GAIN\_M\ ) + sum\ (\ P\_femto'\ {*}\ GAIN\_femto'\ ))}$$

For 20 MHz, 100 resource blocks are available, each resource block have 12 subcarriers.

Having estimated the SINR, we can now proceed with the throughput calculation. The practical throughput of macro user m on subcarrier k can be given by the following equation for a subcarrier k on one MIMO link.

$$\mathbf{Throughput = \Delta f{*}log_2(1+\alpha\ {*}\ SINR)}$$

where, α is a constant for target Bit Error Rate (BER), and defined by

$$\mathbf{\alpha = -1.5/\ ln\ (5{*}\ BER)}$$

where, BER is set to $10^{-6.}$

After throughput calculation, 25% of the signaling overhead has been removed to get approximately the actual throughput.

III. SIMULATOR ARCHITECTURE

Firstly, User input is given in the form of the random location coordinates of femtocells, femto users, fixed macro cell coordinates, the number of expected users required, channel bandwidth, desired femtocell range, target SINR as shown in Fig. 3.1.

Based on the selection of user input, path-loss and gain are calculated.Then inter cell interference coordination (ICIC) is selected. They are of three types: incremental frequency reuse (IFR), fractional frequency reuse (FFR) and soft frequency reuse (SFR). Afterwards, depending on the interference technique chosen, the signal to interference + noise ratio (SINR) is calculated, followed by the throughput evaluation.

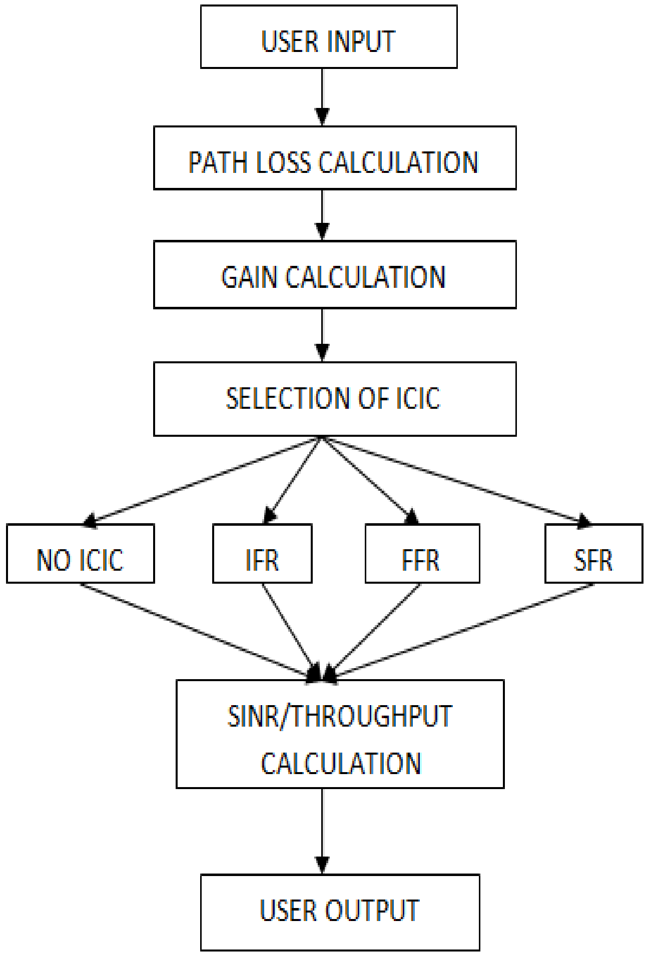

Fig. 3.1 Simulator flow chart

IV. RESULTS

A. THROUGHPUT FOR INDOOR MACRO USER

In this the interference experienced from macro user which is served by the macro base station that is located inside the building is examined by varying its distance from macro base station and by varying its distance from femto cell. In this the black line shows throughput for macro user by varying its distance from macro base station which is only 1 meter away from femto base station so it experiences very high interference so it get negligible throughput even after using MIMO.

Blue line shows throughput for macro user by varying its distance from macro base station which is located 10 meter away from femto base station due to which interference reduces in this case as compared to former case for this reason throughput is more in this case as compared to previous case. Red line shows throughput for macro user by varying its distance from macro base station which is located 20 meter away from femto base station, due to increase in distance of macro user from femto base station throughput is high because of very low interference from femto base station.

Throughput is decreasing in each case as we go far away from macro base station because of standard pathloss, the macro cell signal is further attenuated by the exterior wall of the building. The throughput of an indoor macro user decreases rapidly as the distance from the macro base station increases, especially for the first 100m from the macro base station. When the proximity of the user to femto cell base station is 1m, the user never reaches adequate level of service due to strong interference, even when close to macro cell antenna as shown in fig. 4.1.

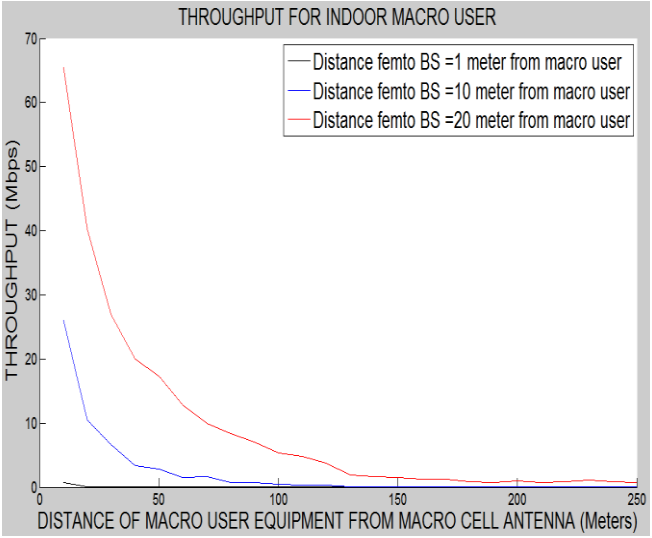

Fig. 4.1 Throughput for an indoor macro UE against the distance from the macro BS when femtocell interference exists

B. THROUGHPUT FOR OUTDOOR MACRO USER

In this there is no exterior wall between the macro base station and the user this means user is outside. Cross-tier interference will still exists when the user is 1m from femtocell base station and the user never has satisfying access to service as shown in fig. 4.2.

In this the black line shows throughput for macro user by varying its distance from macro base station which is only 1 meter away from femto base station so it experiences very high interference so it get negligible throughput even after using MIMO. Blue line shows throughput for macro user by varying its distance from macro base station which is located 10 meter away from femto base station due to which interference reduces in this case as compared to former case for this reason throughput is more in this case as compared to previous case. Red line shows throughput for macro user by varying its distance from macro base station which is located 20 meter away from femto base station, due to increase in distance of macro user from femto base station throughput is high because of very low interference from femto base station. In this the throughput is higher as compared to an indoor user throughput.

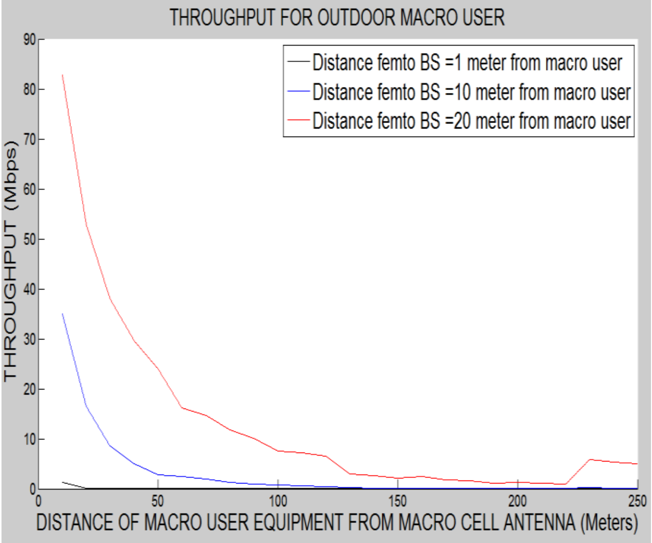

Fig. 4.2 Throughput for an outdoor macro UE against the distance from the macro BS when femtocell interference exists

C. THROUGHPUT FOR INDOOR FEMTO USER

In this the interference experienced from femto user which is served by the femto base station that is located inside the same building in which femto base station exist is examined by varying its distance from femto base station and by varying its distance from macro base station as shown in fig. 4.3

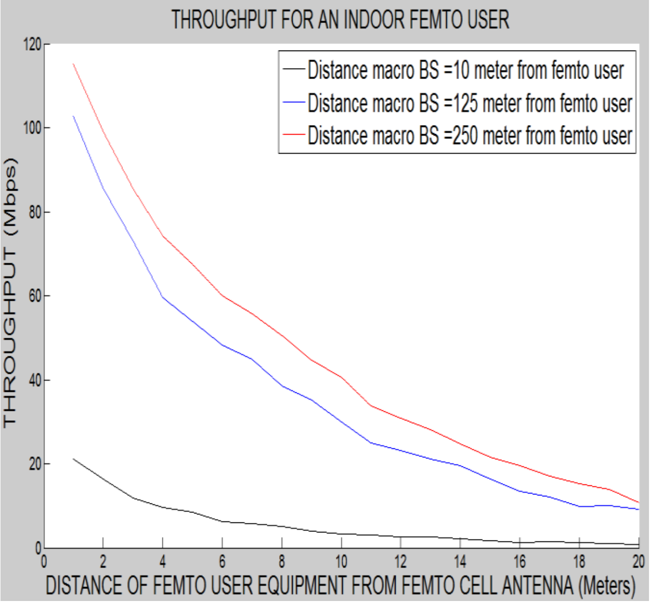

Fig. 4.3 Throughput for an indoor femto UE against the distance from the femto BS when macrocell interference exists

D. THROUGHPUT FOR OUTDOOR FEMTO USER

In this the interference experienced from femto user which is served by the femto base station that is located outdoor is examined by varying its distance from femto base station and by varying its distance from macro base station. This figure shows the user outdoor get very low throughput due to very high interference as shown in fig. 4.4.

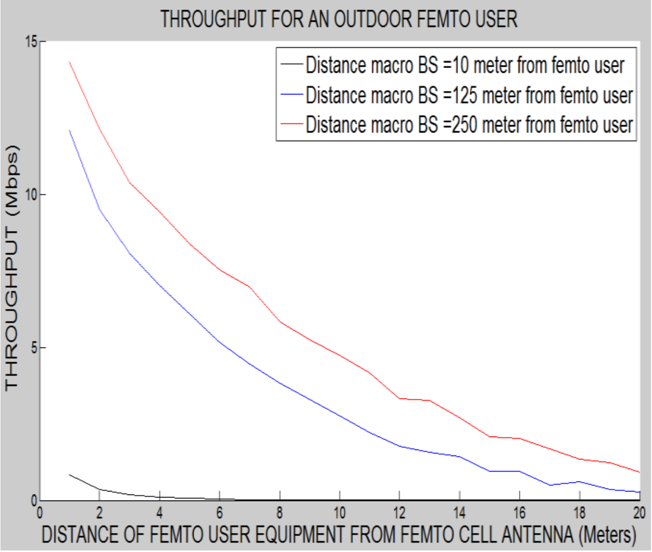

Fig. 4.4 Throughput for an outdoor femto UE against the distance from the femto BS when macrocell interference exists

E. AVERAGE THROUGHPUT PERFORMANCE FOR MACRO USERS INSIDE FFR RADIUS

Figure 4.5 shows average throughput for those macro users which are inside fractional frequency reuse radius (half of full macro cell radius) by varying number of femto cells under different frequency reuse schemes like co-channel, IFR, SFR, FFR. SFR is the best frequency reuse scheme because it uses a fraction of total allocated frequency inside ffr radius and the results are better than IFR, FFR and if given the full bandwidth inside ffr radius shows better result than co-channel.

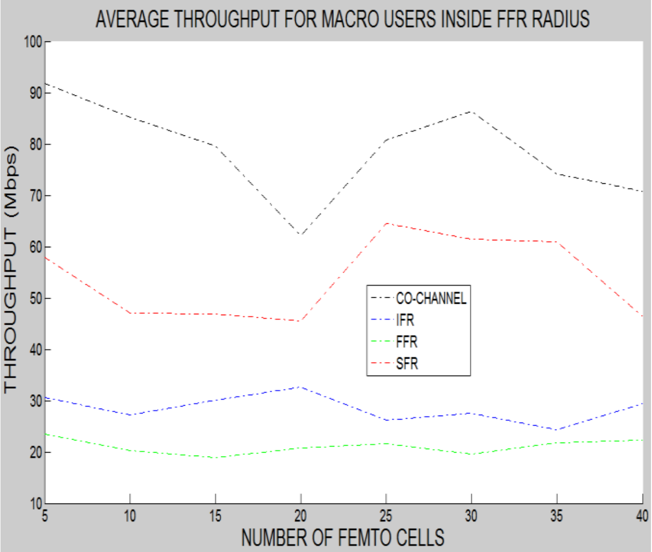

Fig. 4.5 Average throughput performance for macro users inside FFR radius

F. AVERAGE THROUGHPUT PERFORMANCE FOR MACRO USERS OUTSIDE FFR RADIUS

Figure 4.6 shows average throughput for those macro users which are outside fractional frequency reuse by varying number of femto cells under different frequency reuse schemes like co-channel, IFR, SFR, FFR. SFR is the best frequency reuse scheme because it uses a fraction of total allocated frequency outside ffr radius and the results are better than FFR and if given the full bandwidth outside ffr radius shows slightly better result than co-channel and far better than IFR.

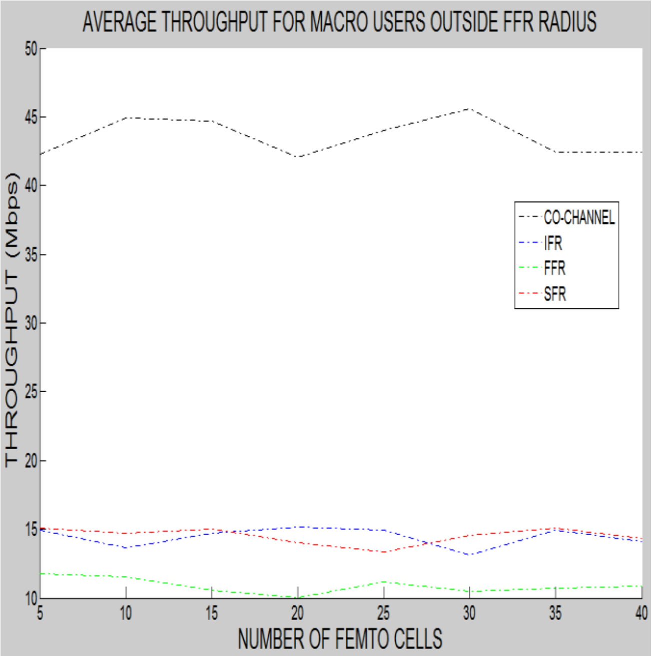

Fig. 4.6 Average throughput performance for macro users outside FFR radius

V. CONCLUSION

In this paper, analysis of LTE-A system has been done. This paper presented a simulator consists of combination of frequency reuse and MIMO techniques. This simulator takes into account most of the all major types of interference. With the use of SFR, MIMO user throughput gets increased due to reduction in interference.

VI. FUTURE SCOPE

With the current simulator consisting of frequency reuse, MIMO the throughput is increased to a large extent. For more enhancements in throughput, advanced power control algorithm and interference mitigation techniques can be used and for edge users COMP can increase throughput to a large extent. Also with the help of adaptive beam forming excellent data rates can be achieved.

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REFERENCES

[1] Christos Bouras, Georgios Diles, Vasileios Kokkinos, Konstantinos Kontodimas and Andreas Papazois, 2013 “ A Simulation Framework for Evaluating Interference Mitigation Techniques in Heterogeneous Cellular Environments”, *Springer Journal,* pp. 1 – 25.

[2] A. Z. Yonis, M.F.L.Abdullah, M.F.Ghanim, 2012 “Improving Peak Data Rate in LTE toward LTE-Advanced Technology”, *6th International Symposium on Advances in Science and Technology.*

[3] Christos Bouras, Vasileios Kokkinos, Konstantinos Kontodimas andAndreas Papazois, 2012 “A Simulation Framework for LTE-A Systems with Femtocell Overlays” , *Proceedings of the 7th ACM Workshop on Performance monitoring and measurement of heterogeneous wireless and wired network,* pp. 85-90.

Kishor Pratap Singh received his B.Tech degree in Electronics & Communication Engineering from Venkateshwara Institute of Technology (Gautam Budh Technical University, Lucknow) Meerut, U.P., India in 2011 and is shortly finishing his M.Tech degree in Electronics & Communication from Ajay Kumar Garg Engineering College (Uttar Pradesh Technical university, Lucknow), Ghaziabad, U.P., India. His interest areas are advanced wireless communication, digital signal processing.

Prof. Pradeep Kumar Chopra entered the field of education in the year 2004 after 24 years of exemplary service in the technical branch of the Indian Air Force, He earned his Bachelor’s degree in Engineering (Electronics) from Delhi college of Engineering in the year 1979 and Masters in Technology from IIT Delhi in the year 1985. He also has a Masters degree in Defence Studies from Madras University. While he was in the Indian Air Force he was part of, and headed a number of important technical projects. For his exemplary services he was awarded "Vishist Seva Medal" by the President of India in the year 1993. He took premature retirement from the IAF in the year 2004 and entered the field of education. He is the Dean and Head of Dept. (Electronics and Communication) in Ajay Kumar Garg Engineering College in Ghaziabad. AKGEC is rated as the No 1 Engineering College in U.P., Affiliated to Uttar Pradesh Technical University, Lucknow.