A Novel Approach to Improve the Quality of Service for the MAC Spectrum in Wireless Networks

N. KEERTHI
Assistant Professor,
Department of ECE,
CREC,
Tirupati, A.P. India
keerthi499@gmail.com

P. KRISHNA MURTHY
Assistant Professor,
Department of ECE,
CREC,
Tirupati, A.P. India
ecemurthy@gmail.com

A. MOUNIKA
Assistant Professor,
Department of ECE,
CREC,
Tirupati, A.P. India
mounikaallam36@gmail.com

V. THRIMURTHULU
Head & Professor,
Department of ECE,
CREC,
Tirupati, A.P. India
vtmurthy.v@gmail.com

Abstract**—***As the Fourth-Generation (4G) standards have been successfully deployed in all 4G-based wireless communications, mobile devices, research attention and the efforts of academia. The industry has already moved into fifth generation (5G) technologies. While the Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD) are widely used in 4G mobile wireless networks and they have their inherent deficiencies of low spectrum efficiency because FDD and TDD are both based on the half-duplex transmission mode. To overcome this, a novel approach for the wireless full-duplex transmission schemes in both the PHY and Media Access Control (MAC) layers of 5G mobile wireless networks has been done and to increase the spectrum efficiency. In particular, we first develop the wireless full duplex model for both bidirectional transmission and unidirectional transmission, respectively, taking into account self-interference mitigation. Using our developed wireless full-duplex model, we develop and evaluate the efficient full-duplex power allocation scheme at the PHY layer. According to the transmission (full-duplex) at the PHY layer, develop the full duplex MAC protocol at the MAC layer, to implement full-duplex over the 5G mobile wireless transmission. Through simulation experiments we show that our proposed schemes can significantly enhance spectrum efficiency, end to end dalays and bandwidth for 5G mobile wireless networks.*

Keywords— Frequency Division Duplexing, Multiple Input Multiple Output, Quality of Service, Wireless Networks.

I. INTRODUCTION

A fourth generation (4G) wireless communications and networks are becoming more mature and widely implemented in mobile wireless industrial and commercial products, fifth generation (5G) mobile and wireless communication technologies are rapidly emerging into research fields. While 5G mobile wireless networks create great potential and flexibility, supporting various advanced and high-data rate wireless communications, they also impose new challenges not encountered in 4G wireless systems. Because of 5G mobile wireless networks will need a combine of new system concepts to significantly enhance spectrum efficiency, power/energy efficiency, and advanced wireless network design technologies, which can be achieved by advanced wireless techniques, such as spectrum efficiency optimization, massive Multiple Input Multiple Output (MIMO), cooperative communications, and so on. Compared with the 4G systems and networks, several orders of magnitude higher wireless transmission rates/bandwidth are expected to support various statistical delay-bounded Quality of Service (QoS) provisioning [1-3] for the bandwidth rigorous and time-sensitive multimedia services over 5G wireless communications networks, which keeps spectrum efficiency maximization as one of the central issues in designing and implementing 5G mobile wireless networks.

To efficiently implement the wireless full duplex transmission mode in 5G mobile wireless networks, self-interference needs to be resolved at the PHY layer and the corresponding higher layer protocols, which can support the wireless full-duplex transmission mode, also need to be developed. In terms of self-interference mitigation techniques, a great deal of research has been performed, showing the significant feasibility of implementing full-duplex transmissions over wireless communications networks [11, 12]. These works either separately or jointly employ Propagation Domain Interference Suppression (PDIS), Analog-Domain Interference Cancellation (AIC), and Digital-Domain Interference Cancellation (DIC). PDIS endeavors to mitigate self-interference by avoiding the input of the RF amplifier being overwhelmed due to self-interference [12]. AIC attempts to cancel self-interference to avoid the input of the analog-to-digital converter (ADC) being overwhelmed by self-interference [11, 12]. DIC attempts to cancel residue, self-interference due to the non-ideal of the RF amplifier, the nonlinearities in the ADC, and the oscillator phase noise [12].

For presentation convenience, the combined AIC and DIC is denoted by ADIC in this article. However, only solving the self-interference mitigation problem does not warrant the implementation of full-duplex based 5G mobile wireless networks, because a large number of existing schemes/protocols at different protocol layers, such as the power allocation scheme at the PHY layer and the MAC protocol at the MAC layer, are already designed and implemented based on the corresponding FDD and TDD modes at the PHY layer [13]. Therefore, if the full-duplex transmission mode is only implemented at the PHY layer, spectrum efficiency cannot be effectively increased because of the constraint caused by the half-duplex transmission mode used in the MAC layer. As a result, we need to develop our full-duplex transmission mode framework across the entire protocol architecture through not only the PHY layer, but also the MAC layer to efficiently implement full-duplex transmission over 5G mobile wireless networks.

In this article we first analyze and show the superiority of the wireless full-duplex mode over the FDD and TDD modes. Then we develop the full-duplex power allocation scheme to maximize spectrum efficiency for the full-duplex based 5G mobile wireless networks. We show that full duplex power allocation follows a water-filling like algorithm when taking into account the impact of self-interference. The rest of this article is organized as follows. We start with a comparison of the wireless fullduplex mode with the FDD and TDD modes, showing the superiority of the former over the latter. Then we develop and evaluate the efficient full-duplex optimal power allocation scheme for full-duplex MIMO transmission at the PHY layer..

II. The Full-Duplex System Model For 5G Mobile Wireless Networks

In this article we consider 5G mobile wireless networks that use full-duplex transmission [14]. The Base Station (BS) is needed to centrally control the User Equipments (UEs) in 5G mobile wireless networks. Thus, we focus on full-duplex technique-based 5G mobile wireless networks, an example of which is shown in Fig. 1 with one BS and six UEs. As illustrated in Fig. 1, the BS communicates directly with the UEs. There are two types of transmissions in full-duplex technique- based 5G mobile wireless networks: the two-node (one of which is the BS node) full duplex wireless bidirectional transmission and the three-node (one of which is the BS node as the relay node) full-duplex wireless unidirectional executed between these two nodes each being equipped with one transmitter and one receiver, we call this type of transmission wireless full duplex bidirectional transmission (for example, BT-1 between two nodes and BT-2 between two nodes, as shown in Fig. 1). If the first node equipped with one transmitter sends its information to the second node equipped with one transmitter and one receiver while the second node transmits its own information to the third node equipped with one receiver, we call this type of transmission wireless full-duplex unidirectional transmission (for example, two UT-1s across three nodes and two UT-2s across three nodes, as shown in Fig. 1).

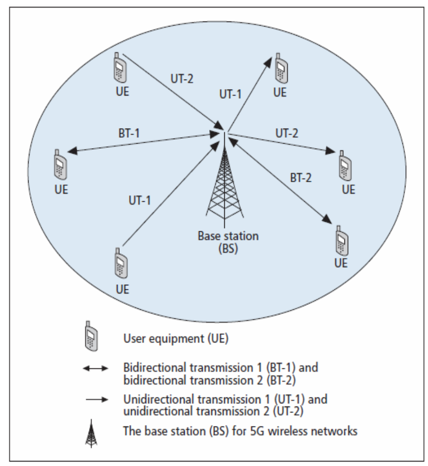

Figure. 1: An example of the full-duplex based 5G mobile wireless network.

All the full-duplex transmissions over 5G mobile wireless networks consist of wireless bidirectional full-duplex transmissions and/or wireless unidirectional full-duplex transmissions, and thus in the rest of this article we will focus on the wireless bidirectional and unidirectional full-duplex transmissions. Fig. 2a and 2b show the PHY layer connections for full-duplex wireless bidirectional and unidirectional transmissions, respectively, in 5G mobile wireless networks. Each UE has one transmitter and one receiver. The transmitter and the receiver can be equipped with a single antenna or multiple antennas according to the applied PDIS schemes [12]. We apply ADIC schemes at each node's receiver to cancel the residual self-interference after being processed by PDIS. As illustrated in Fig. 2a, nodes A and B transmit their data to nodes B and A, respectively, forming a two-node full-duplex wireless bidirectional transmission (as shown in Fig. 2a for nodes A and B's PHY layer connection which also corresponds to, for example, BT-1 and BT-2 in Fig. 1). As shown in Fig. 2b, nodes C and D transmit their data to nodes D and E, respectively, constituting a three-node full-duplex wireless unidirectional transmission (as shown in Fig. 2b for nodes C, D, and E's PHY layer connection which also corresponds to, for example, UT-1 and UT-2 in Fig. 1).

III. FULL-DUPLEX MULTIPLEXING MIMO BIDIRECTIONAL AND UNIDIRECTIONAL TRANSMISSIONS MODELS

We build a model for two node full-duplex wireless bidirectional transmission [2] and three node full-duplex wireless unidirectional transmission [1], as illustrated in Fig. 2, where nodes A, B, and D required to mitigate self-interference from the confined transmitter. The transmit power of different nodes A, B, C, and D for the ith singular value channel are denoted by Pa(i), Pb(i), Pc(i) and Pd(i) respectively. The novel approach proposed fullduplex multiplexing MIMO scheme with different nodes A, B, C, D, and E employ Nt transmit antennas and Nr receive antennas respectively (see Figs. 2a and 2b).

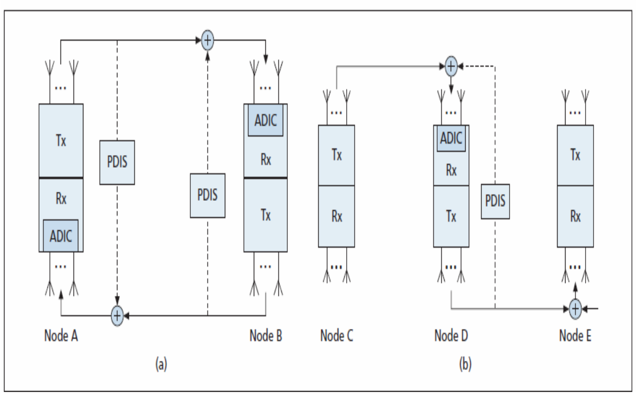

Figure. 2: The PHY layer connections for full-duplex wireless bidirectional and unidirectional transmissions, respectively in 5G mobile wireless networks.
a) The PHY layer connection for the two node full-duplex multiplexing MIMO bidirectional transmission in 5G mobile wireless networks
b) The PHY layer connection for the three-node full-duplex multiplexing MIMO unidirectional transmission in 5G mobile wireless networks.

IV. SELF INTERFERENCE MITIGATION MODELING

We define k ($0 < k < 1$) as the self-interference mitigation coefficient for the node with full duplex wireless transmission. The value of k depends on a number of factors, such as system bandwidth, antenna displacement error, transmit the signal amplitude difference, and so on [12]. When k approaches 0, it implies that self-interference causes large interference on wireless full-duplex transmission. When k approaches 1, it means that self-interference causes little interference on wireless full-duplex transmission. The self interference mitigation coefficients differentiate the outcome of self interference mitigation together using the propagation-domain Fig. 2. The PHY layer connections for full-duplex wireless bidirectional and unidirectional transmissions, respectively, in 5G mobile wireless networks. a) The PHY layer connection for the two node full-duplex multiplexing MIMO bidirectional transmission in 5G mobile wireless networks. b) The PHY layer connection for the three-node full-duplex multiplexing MIMO unidirectional transmission in 5G mobile wireless networks. ... Tx Node C Rx ... ... Tx Node E Rx ... ... Rx Node D Tx .. ... ADIC ... ... Rx Node B (a) (b) Tx ... ... Tx Node A Rx ADIC technique, the Analog-Domain Interference Cancellation (AIC) technique, and the Digital-Domain Interference Cancellation (DIC) technique. For example, if we jointly use the PDIS (30 dB self-interference mitigation), the AIC (25 dB self-interference mitigation), and the DIC (20 dB self-interference mitigation) techniques for full-duplex wireless transmission, the self-interference mitigation coefficient should be 1/(75 dB), which explicitly shows the entire effectiveness of self-interference mitigation by jointly using the PDIS, the AIC, and the DIC techniques.

V. THE OPTIMAL POWER ALLOCATIONS FOR FULL-DUPLEX MULTIPLEXING MIMO 5G WIRELESS NETWORKS

In contrast to the power allocation for wireless half-duplex transmission, the full-duplex wireless power allocation scheme needs to take into account self-interference, which is characterized by the self-interference mitigation coefficient. There exist some initial research works on optimizing transmit power to maximize the transmission rate in bidirectional [15, 16] and unidirectional [17, 18] full-duplex wireless networks. For bidirectional and unidirectional topologies, the authors of [15, 17] derived the bounds on the achievable transmission rate of bidirectional and unidirectional full-duplex transmissions under the standard isotropic Rayleigh-fading model for wireless signal propagation. For full-duplex wireless-powered communication networks, the optimal resource allocation can maximize the weighted sum-rate [16]. For cognitive-radio unidirectional full-duplex wireless networks, the optimal power allocation scheme (the outage constrained power allocation) can minimize the overall outage probability in the cognitive-radio unidirectional full-duplex networks without requiring the instantaneous CSI across the wireless links between the primary and secondary users [18]. However, these works mainly focus on specialized channel models. The optimal fullduplex power allocation scheme required for the more generic and more practical wireless channel models remains an open and challenging problem. We define the transmission rates for the twonode full-duplex wireless bidirectional (unidirectional) transmission as the sum of the transmission rates from node A (C) to node B (D) and from node B (D) to node A (E). Under our proposed multiplexing MIMO-based fullduplex 5G mobile wireless networks, we canderive the transmission rate for the two-node full-duplex wireless bidirectional transmission as

Rb = S_i=1 Nt [log2(1 + $k_a$gba (i) Pb (i)) +

log2(1 + $k_b$gab (i) P_a (i))] (1)

and the transmission rate for the threenode full-duplex wireless unidirectional transmission as Ru = Si=1 Nt [log2(1 + kdgcd (i) Pc (i)) + log2(1 + gde (i) Pd (i))], respectively, where Nt is the number of transmit antennas, Nr is the number of receive antennas, and i denotes the i^{th} transmit antenna (we suppose all channels are full rank, 1 £ i £ Nt, and Nt £ Nr), gba (i), gab (i), gcd (i), and gde (i) denote the power gains of the i^{th} singular-value channel corresponding to channels from node B to node A, from node A to node B, from node C to node D, and from node D to node E, respectively. Then we can formulate the spectrum efficiency optimization problem for the two-node full duplex MIMO wireless bidirectional transmission, denoted by P1, as follows:

$$P1: \max_{(P_a,P_b)} \{E_\gamma[R_b]\}$$
$$s.t.\ E_\gamma\left\{\sum_{i=1}^{N_t}[p_a(i)+P_b(i)]\right\} \le \bar{P} \quad (2)$$

Where i denotes the i^{th} transmit antenna, Eg{·} denotes the expectation over g, and P denotes the average transmit power constraint. Because full-duplex wireless transmission consists of different data flows from different nodes using the same frequency band at the same time, we use the average power constraint over multiple nodes. Using the powerful Lagrangian method, we can solve problem P_1 to derive the optimal power allocation scheme for the two-node full-duplex MIMO bidirectional transmission as follows

$$\begin{cases} p_a(i) = \dfrac{1}{\gamma_0} - \dfrac{1}{K_b \gamma_{ab}(i)} \\ p_b(i) = \dfrac{1}{\gamma_0} - \dfrac{1}{K_b \gamma_{ba}(i)} \end{cases} \quad (3)$$

where i denotes the i^{th} transmit antenna, k_a and k_b denote the self-interference mitigation coefficients of node A and node B, respectively, and g_0 is the cut-off SNR threshold and can be numerically obtained by

$$E_\gamma\left\{\sum_{i=1}^{Nt} P_a(i) + P_b(i)\right\} = \bar{P} \quad (4)$$

From Equation 2, we can observe that the optimal power allocations for the two node full-duplex bidirectional transmission still follows the tendency of a water-filling algorithm. However, the self interference imposed by kb affects the full-duplex transmission performance, which results in a decrease of the cut off SNR threshold and an increase of the power allocations in the high channel SNR region when kb decreases. The power allocation for node B follows a similar tendency as the power allocation for node A. Replacing Rb, Pa (i), and Pb (i) by Ru, Pc (i), and Pd (i) in problem P1, respectively, we can formulate the spectrum efficiency optimization problem for three-node full-duplex wireless unidirectional transmission. Then we can derive the optimal power allocation scheme for three-node full-duplex MIMO wireless unidirectional transmission as follows.

$$\begin{cases} p_c(i) = \dfrac{1}{\gamma_0} - \dfrac{1}{K_d \gamma_{cd}(i)} \\ p_d(i) = \dfrac{1}{\gamma_0} - \dfrac{1}{\gamma_{de}(i)} \end{cases} \quad (5)$$

Where i denotes the i^{th} transmit antenna and k_d denotes the self-interference mitigation coefficient of node D.

VI. THE FULL-DUPLEX MAC PROTOCOL

The optimal full-duplex power allocation can maximize the spectrum efficiency of full-duplex transmission at the PHY-layer. However, to minimize the collisions among all full-duplex transmissions in the full-duplex technique-based 5G mobile wireless networks, the full-duplex MAC protocol, which can significantly reduce the collision probability among all full-duplex transmissions in the full-duplex technique-based 5G mobile wireless networks, is also highly demanded [19, 20]. Jointly optimizing the full-duplex power allocation scheme and the full-duplex MAC protocol, the spectrum efficiency and throughput of full-duplex wireless networks can be maximized. The full-duplex MAC protocol needs to hold up not only bidirectional full-duplex transmissions, but also unidirectional full-duplex transmissions in full-duplex based 5G mobile wireless networks. Also, the traditional hidden terminal problem [13] in full-duplex based 5G mobile wireless networks needs to be resolved. To overcome these, the proposed algorithm has the RTS/CTS-based, full-duplex MAC protocol, called the RTS/full-duplex clear-to-send (FCTS) mechanism, to achieve the following goals:

- Both bidirectional and unidirectional transmissions can be supported.
- All hidden terminal problems in wireless full-duplex networks have been resolved.

We denote the first transmission (corresponding to the transmission from node A to node B in Fig. 2a, and the transmission from node C to node D in Fig. 2b, respectively) and the second transmission (corresponding to the transmission from node B to node A in Fig. 2a, and the transmission from node D to node E in Fig. 2b, respectively) in one time, full-duplex transmission by FD-T1 and FD-T2, respectively. Here the bidirectional and unidirectional transmission used to show the negotiation and transmission processes controlled by our proposed FD-MAC protocol in terms of the timing sequences as illustrated in Fig. 3a and b, respectively. As shown in Fig. 3a, if node A, which has the packet to be sent to node B, senses that the channel is idle, the node A starts broadcasting the RTS signal to its neighbors when its back-off counter reaches zero. As soon as the destination node B received the RTS from node A, node B will wait for a SIFS time and then broadcasts the FCTS signal to its neighbors. If node B has its packet to send to node A, the FCTS needs to be added to the destination address (node A) of the packet from node B and the length of the packet from node B to node A. The neighbors of node B will receive this FCTS and back off, according to the data length of the packet from node B to node A.

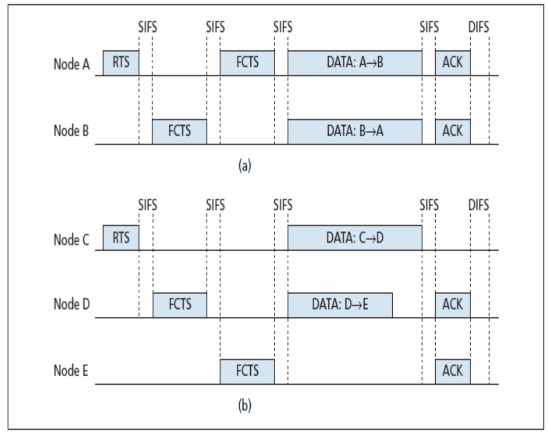

Figure 3: The timing sequences for the example cases of bidirectional and unidirectional transmissions controlled by our proposed FD-MAC protocol. a) The example of bidirectional transmission; b) The example of unidirectional transmission.

VII. RESULTS

As soon as node A received the FCTS, node A waits for a SIFS time and broadcasts another FCTS to notify the neighbors of node A that it will receive the packet from node B. Then, after a SIFS time, both node A and node B will transmit their packets to each other. The duration of the packet transmission will last for the longer time between the FD-T1 and the FD-T2. Then, after a SIFS time, the ACKs (from node A to node B and from node B to node A, respectively) will be sent and then the current bidirectional transmission ends.The case for three-node wireless full-duplex unidirectional transmission is shown in Fig. 3b, where node C first starts its transmitting to node D while node D also has its own data to be transmitted to node E. In this case, node C senses that the channel is idle, and when its back-off counter reaches zero, it starts to broadcast the RTS to its neighbors. As node D received the RTS from node C, it waits for a SIFS time and then broadcasts the FCTS to its neighbors, where the FCTS includes the destination address (node E), the length of the packet from node D to node E, and the length of the packet from node C to node D. The node E will receive the FCTS from node D. Then, after a SIFS time, node E will broadcast another FCTS to its neighbors. After another SIFS time, node C and node D will send their packets to node D and node E simultaneously. After the transmission of the data and a SIFS time, node D sends the ACK to node C, and node E transmits the ACK to node D, respectively. Please note that under the full-duplex MAC protocol, system synchronization is guaranteed through the three-way handshake protocol using one RTS frame and two FCTS frames. After the successful three-way handshakes, the two way transmissions (for the two-node bidirectional transmission, from node A to node B and from node B to node A; for the three-node unidirectional transmission, from node C to node D and from node D to node E) are synchronized at the end of the third SIFS of one full-duplex transmission. When the two way transmissions end, because all nodes "know" the long duration between the two way transmissions, after two SIFSs time periods and the ACK frame interaction, the two-way transmissions are synchronized.

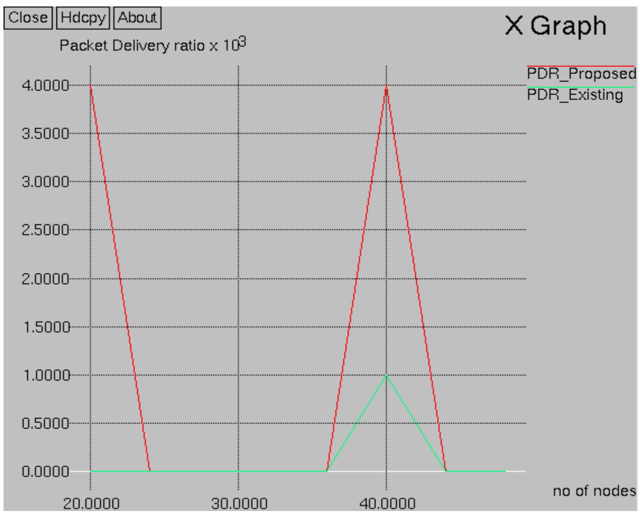

Figure. 4: Comparison of Packet Delivery Ratios

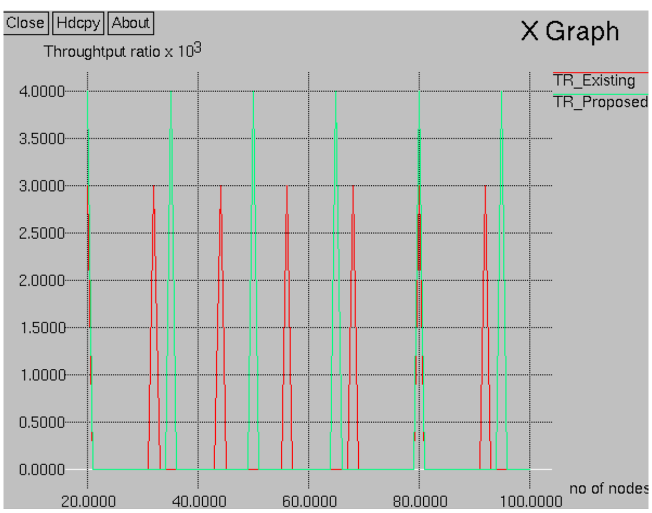

Figure. 5: Comparison of Throughput Ratios

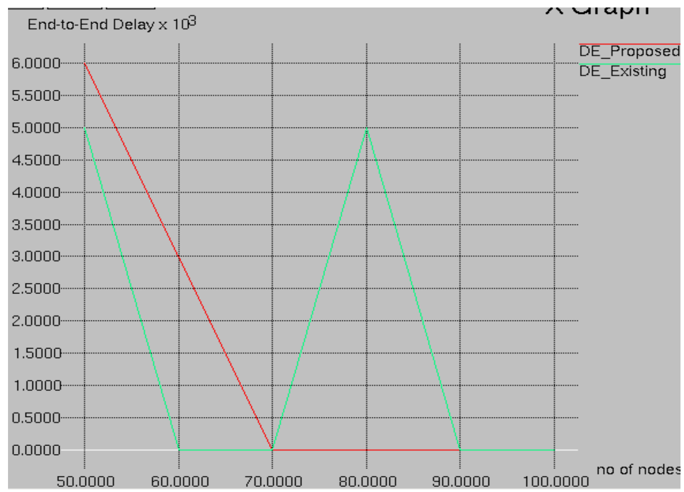

Figure. 6: Comparison of End to End Delays

VIII. CONCLUSION

We proposed to use the wireless full-duplex transmission mode to overcome the deficiencies of the half-duplex modes used in 4G systems and thus significantly increase the spectrum efficiency for 5G mobile wireless networks. The full-duplex mode has a number of significant advantages over the FDD and TDD modes. To implement full-duplex based 5G mobile wireless networks, we developed and analyzed not only self-interference mitigation schemes, but also a full-duplex wireless power allocation scheme and a full-duplex wireless MAC protocol. In particular, we developed a full-duplex wireless power allocation scheme and a full-duplex wireless MAC protocol to maximize the spectrum efficiency of 5G mobile wireless networks, respectively. The obtained simulation results show that our proposed full-duplex wireless power allocation schemes and full-duplex wireless MAC protocol can efficiently increase the spectrum efficiency for 5G mobile wireless networks.

REFERENCES

[1] W. Cheng, X. Zhang, and H. Zhang, "Full/Half Duplex Based Resource Allocations for Statistical Quality of Service Provisioning in Wireless Relay Networks," Proc. IEEE INFOCOM 2012, Orlando, Florida, USA, Mar. 2012, pp. 864-72.

[2] W. Cheng, X. Zhang, and H. Zhang, "QoS Driven Power Allocation over Full-Duplex Wireless Links," Proc. IEEE ICC 2012, Ottawa, Canada, June 2012, pp. 5286-90.

[3] W. Cheng, X. Zhang, and H. Zhang, "Heterogeneous Statistical QoS Provisioning over 5G Wireless Full-Duplex Networks," Proc. IEEE INFOCOM 2015, Hong Kong, April 26–May 1. 2015, pp. 55-63.

[4] W. Cheng, X. Zhang, and H. Zhang, "Optimal Dynamic Power Control for Full-Duplex Bidirectional-Channel Based Wireless Networks," Proc. IEEE INFOCOM 2013, Turin, Italy, April 14–19, 2013, pp. 3120-28.

[5] W. Cheng, X. Zhang, and H. Zhang, "Optimal Power Allocation for Full-Duplex D2D Communications over Wireless Cellular Networks," Proc. IEEE GLOBECOM 2014, Austin, Texas, USA, Dec. 8–12, 2014, pp. 4764-69.

[6] W. Cheng, X. Zhang, and H. Zhang, "Full Duplex Spectrum Sensing in Non-Time-Slotted Cognitive Radio Networks," Proc. IEEE MILCOM 2011, Baltimore, MD, USA, Nov. 7–10, 2011, pp. 1029-34.

[7] W. Cheng, X. Zhang, and H. Zhang, "Imperfect Full Duplex Spectrum Sensing in Cognitive Radio Networks," Proc. ACM MobiCom 2011–Workshop on Cognitive Radio Networks, Las Vegas, NV, USA, Sept. 19–23, 2011, pp. 1-6.

[8] D. W. Bliss, P. A. Parker, and A. R. Margetts, "Simultaneous Transmission and Reception for Improved Wireless Network Performance," Proc. IEEE Workshop Statist. Signal Process, Aug. 2007, pp. 478–82.

[9] 3GPP TSG RAN WG1 #60 R1-101659, "Text Proposal on Inband Full Duplex Relay for TR 36.814," 2010, San Francisco, USA.

BIBLIOGRAPHY

Mrs. N. KEERTHI received her B.Tech degree in Electronics & Communication Engineering from Narayana Engineering College, Gudur, JNTUA, Anantapur, A.P., and M.Tech. degree in Communication Systems in Srinivasa Institute of Technology and Management Studies,Chittoor, JNTUA, Anantapur, A.P. in 2012. Currently she is working as Assistant Professor in Department of ECE, Chadalawada Ramanamma Engineering College, Tirupati, A.P. She has 5 years of experience in teaching. She published 7 technical papers in various International journals, National and International conferences. Her current research interest includes Communication and Wireless Networks.

Mr. P. KRISHNA MURTHY received the B.Tech degree in Electronics & Communication Engineering from Sri Vidyanikethan Engineering College Tirupati, JNTU Hyderabad, A.P., and M.Tech. degree in Communication and Signal Processing in G Pulla Reddy Engineering College, Kurnool, JNTU Anantapur, A.P. in 2012. He worked as Assistant Professor in Department of ECE, G. Pullaiah College of Engineering & Technology, Kurnool, A.P. India. He pursuing his Ph.D. degree in Department of ECE at S. V. University College of Engineering, Tirupati, A.P. Currently He is working as Assistant Professor in Department of ECE, Chadalawada Ramanamma Engineering College, Tirupati, A.P. He has 6 years of experience in teaching, industry and research. He published many technical and research papers in various International journals, National and International conferences. His current research interest includes Radar signal processing and radar systems.

Mrs. A. MOUNIKA received the B.Tech degree in Electronics & Communication Engineering from JB Womens Engineering College, Tirupati, JNTUA, Anantapur, A.P., and M.Tech. degree in Digital Systems and Computer Electronics in SV College of Engineering, Tirupati, JNTUA Anantapur, A.P. in 2015. Currently she is working as Assistant Professor in Department of ECE, Chadalawada Ramanamma Engineering College, Tirupati, A.P. India. She has 2 years of experience in teaching. Her current research interest includes Image processing, Communication and Embedded Systems.

Dr.V.THRIMURTHULU received his Graduation in Electronics & Communication Engineering AMIETE from Institute of Electronics & Telecommunication Engineering, New Delhi in 1994 and Post Graduation in Engineering M.E specialization in Microwaves and Radar Engineering from University College of Engineering, Osmania University, Hyderabad in 2003. He done his research on Ad-Hoc Networks and received his Ph.D. from Central University in 2012. He is member of MIETE and MISTE. Currently he is working as Head & Professor, Department of ECE, Chadalawada Ramanamma Engineering College, Tirupati, A.P. He has 13 years of experience in teaching and 10 years in industry. He published more than 40 technical and research papers in various International journals, National and International conferences. His current research interest includes Antenna Designing, Microwave & Wireless Communication.