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Mimo and Network Coding for LTE/LTE-A: A Review

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Abstract: The main objective of the paper is to explore on the key technique MIMO for the latest communication networks LTE and LTE-A. Among the existing features for the LTE-A communication, MIMO is said to be the state of art. When the cellular networks with the relay nodes are exploited with the MIMO feature, it enhances the diversity of the system. The network coding technique increases the system robustness and minimizes the delay in the network sharing the resources. The natural harmony between the MIMO and network coding techniques provides a tremendous amount of improvement in the overall system capacity and performance.

Key words: LTE · LTE-A · Relay · MIMO · Network Coding

INTRODUCTION

With the various advancements in the era, the need for enhanced networking technologies is also increasing. As the networking communication almost becoming wireless, the requirement to make the communication robust and fast with good quality of service has become the keen focus for the research community.

Wireless systems which started with 1G, the first generation system in 1980's has now reached its fourth generation 4G so called the LTE, which stands for Long Term Evolution. The 1G analog systems' used FDMA technology and the 2G systems evolved with the TDMA and CDMA techniques. The text messaging service and the Multimedia Messaging Service has become popular with the 2G networks. Later , with the users' need to send larger data in the form of videos, music and other text files their rolled out the 3G communication with IMT international Mobile Telecommunications by the ITU. 3G mainly boosted the number of calls in a given cell using CDMA and HSPA technologies. For providing true high speed data services by March 2008, ITU-R has set the standards, on to a set of connection and speed for the 4G services. For the mobile nodes the link speeds should be at least 100 megabits per second for the immobile uses which include mobile hotspots, the link speeds should be at least 1 gigabit per second. These minimum speeds set by the ITU-R for the 4G communication were considered to be fictitious at the early period. There emerges the role of LTE which paved the path to achieve 4G speeds. Now, the new technologies and features are being established focusing on expansion of the capabilities of LTE, and to support trendy ways of deploying and operating network environments ensuring finest supply of services with LTE-A [1, 2].

The remainder of this paper is organized as follows: The introduction about LTE and LTE-A is provided in section II. The brief note on MIMO technique for LTE systems is given in section III. In section IV the literature survey on Network coding technique with the MIMO feature is represented followed by the conclusion in section V.

LTE / LTE-A: When the term 4G evolved, the minimum speeds which has been set for 4G by ITU-R, were quite unreachable, regardless of the good amount of investments made by the manufacturers .The technical designation for the 4G by the ITU's IMT could be met by the LTE-A , Long term Evolution- Advanced technology. The existing marketing requirements for the 4G are met by HSPA and LTE technologies. As the 3G systems coexists with the 2G systems, LTE systems are also said to exist along with the 2G and 3G systems. Now, LTE is said to be the solution for achieving 4G and 5G with its high spectral efficiency, lower delay and high throughput. A typical LTE-A network is shown in Figure-1.

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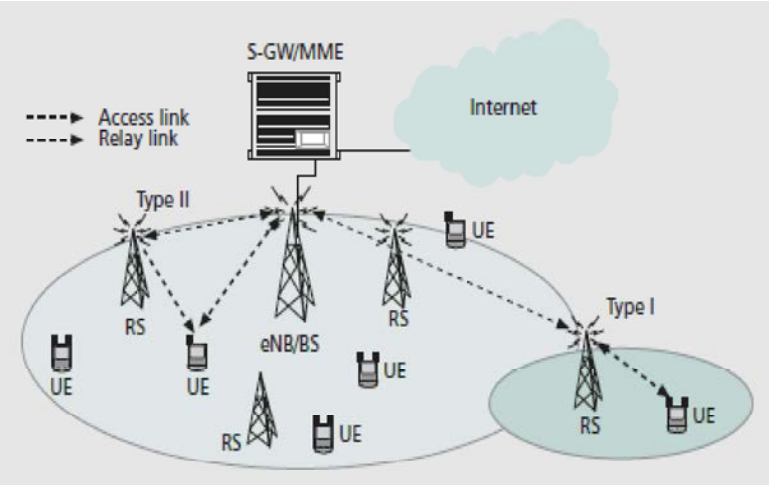

S-GW : Serving Gateway
MME : Mobility Management Entity
RS : Relay station
UE : User Equipment

Fig. 1: LTE-A network

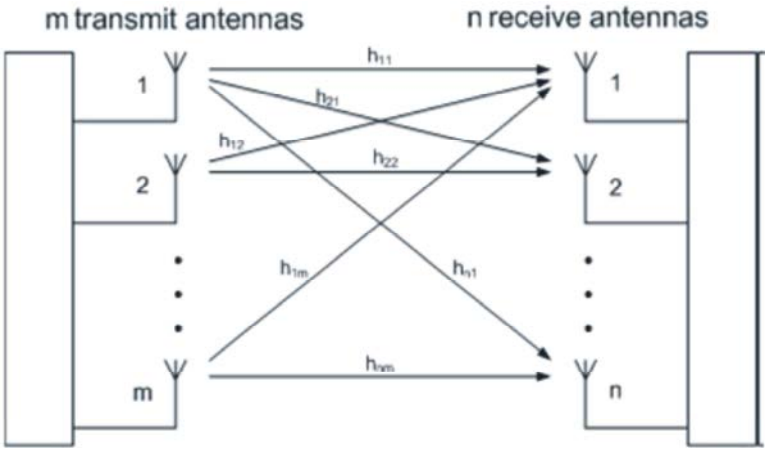

Fig. 2: MIMO system

The 3GPP 13 and 14 releases is said to be innovative with the LTE-A which includes following key features.

- Carrier Aggregation
- MIMO schemes
- Coordinated multi-cell transmission and reception
- Relaying
- Heterogeneous network

MIMO: MIMO, the acronym of Multiple Input, Multiple Output is the system with multiple antennas which improves the network's channel capacity and the data rate for the modern communications. It could be said that the heart of the LTE/LTE-A technology is the MIMO features with the help of the relay stations. These relay nodes have a reduced deployment cost than the deployment of the Base stations enhancing the spatial diversity of the system when selected optimally [3-5]. This spatial diversity is achieved with the multiple antennas at the transmitter and the receiver end increasing the system robustness.

A MIMO system with m x n links is said to consist of 'm' transmit antennas and 'n' receiving antennas is shown in Figure-2. With the same channel, all the antennas at the receiving side will be receiving the components anticipated for it, along with other unintended components i.e. the components meant for the other antennas.

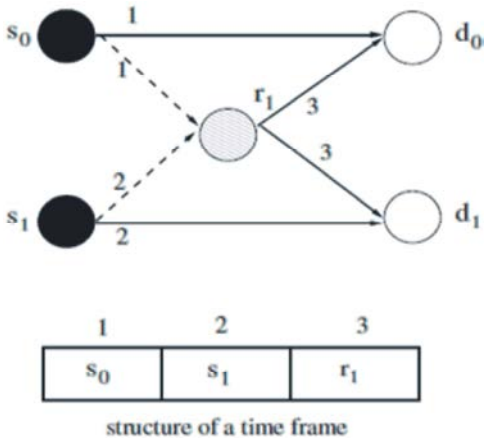

Fig. 3: Network coding

The direct connection from the transmitting antenna 'x' to the receiving antenna 'x' is denoted as h_{xx} and the indirect connection from the transmitting antenna 'x' to the receiving antenna 'y' is denoted as h_{xy}. So, the transmission matrix with 'm' transmit antennas and 'n' receiving antennas is given as follows.

$$H = \begin{bmatrix} h11 & h12 & h13.. & h1m \\ h21 & h22 & h23.. & h2m \\ : & : & : & : \\ hn1 & hn2 & hn3.. & hnm \end{bmatrix}$$

The diagonal elements h_{11}, h_{22}, h_{33}… h_{nn} are said to constitute the direct connections of the MIMO systems. The two methods of using the MIMO techniques are open-loop method and closed-loop method. In the open-loop method the receiver can also execute channel estimation with the help of a special section rendered for it during the transmission. In the closed-loop method, the receiver acknowledges the channel status to the transmitter by means of a special feedback channel [6].

With MU-MIMO, the multiuser MIMO where every stream is assigned to different users improves the capacity and speed of the system when blended with Network coding Techniques.2 x 2 and 1 x 2 MIMO are used in the low band LTE communications for the downlink and the uplink respectively. Similarly for the higher bands 2 x 2 MIMO on downlink and 1 x 4 MIMO for the uplink are used [7].

Network Coding with Mimo: Network Coding communication uses frame-by-frame mechanism, in which each frame is said to be divided into two time slots. In the first two time slot of each frame source nodes transmits its data which is overheard by the relay node. In the last time slot of each frame the overheard data by the relay nodes is transmitted to the destination nodes as shown in Figure 3.

Network coding (NC) is said to be the promising evolution of simple routing protocols which allows mixing of messages from different nodes before sending this mixture on shared links, instead of separate links for every messages. Hence, network coding will eventually increase the network's throughput by reducing the overall number of required links in the network. In other words, NC increases links' bandwidth efficiency. Each relay node stores the overheard data from multiple source nodes temporarily and broadcasts them to the destination nodes at final time slot [8].

The time frame structure with network coding is said to consist of only three time slots where in the time slot 1 s_0 transmits the data to the d_0 which is also overheard and captured by the relay node r_1.Similary in the time slot 2 s_1 transmits the data to the d_1 which is also overheard and captured by the relay node r_1 along with the data streams of s_0. Now in the final time slot relay node r1 multicasts the overheard data to d_0 and d_1. Without the network coding the time frame is said to consists of 4 time slots as s_0 - r_1, r_1 - d_0 , s_1- r_1 ,r_1- d_1. Thus with the network coding the transmission time is said to be reduced by one time slot along with increasing diversity and reliability. The required data at the destination nodes are obtained by XORing the packets received directly along with packets reached through the relay nodes. This could make the transmission of data from s_0 to d_1 or from s_1 to d_0 easily, if required.

There exist several issues with the implementation of network coding which includes the appropriate selection of the protocol stack layer in which the NC has to be implemented. The NC technique being implemented should also utilize and compatible with the existing technologies like Adaptive Modulation and Coding (AMC) and Hybrid Automatic Repeat Re-transmissions (HARQ). The TWRC, two-way relay channel is an inter flow NC implemented in the MAC layer considering it to be the most suitable layer. The NC implementation considers the AMC and the HARQ mechanism with the transmissions occurring between the between the eNB and the UE through the RS. The NC packets are broadcasted from the relay station using the OFDMA access technology. TWRC NC scheme is done for the multi users sharing the given relay node [9].

In random linear Network Coding (RLNC), the relay nodes create coded packets with the combining the block of coded or uncoded data packets with a random

coefficient. When the RLNC is implemented at the application layer it enables the packet level protection. The application layer- RLNC (AP-RLNC) implemented over the MAC layer improves the network performance without disturbing the functionality of LTE protocol stack. The eNB sends the encoded packets in the downlink till it receives an acknowledgment from the user equipment. This acknowledgment is done to notify the reception of required individual packets to continue the decoding process [10].

Cooperative Network Coded Decode-And-Forward, CNCDF is a relaying technique which comprises of two phases the broadcast phase and the relaying phase. The relaying technology is blended with the network coding technique to enhance the relay node performance in a MIMO environment. With a system of N sources nodes and a single relay node N receiving antennas are used in the uplink MIMO transmission. An open loop scheme is adopted, as the CSI information is difficult to be obtained at the transmitter practically. During the broadcast phase the data from the source nodes is transmitted to the base station as well as the relay station with the TDMA technology. And the antenna is selected randomly by the transmitter to transmit the signals. In the relaying phase for the NC operation N coding coefficients are randomly selected for the formation of a coding vector. The diversity gain achieved by this MIMO system with NC proven to be tremendous [11].

For the NC in the MIMO configuration the number of receiving antennas is said to be equal to or higher than the transmitting antennas. The zero force relaying technique requires all its diagonal elements to be zero in the permuted transmission matrix. The basic idea of the network coded relaying in the MIMO environment is not to force the diagonal elements to be zero as the self interference are known and it could be removed. For symmetric and asymmetric switch matrices, the corresponding matrices with nonzero diagonal elements are considered as network-coding switch matrix for relaying. In case of multiple nonzero diagonal elements in the matrix scheduling a set of switch matrices, each with a permutation can overcome the traffic problem [12].

MIMO-Physical Layer Network Coding MIMO-PNC scheme uses novel Eigen-Direction Alignment (EDA) precoding. The multiple users perform single-stream PNC for each associated corresponding channel simultaneously. Instead of completely decoding the multi-user's' individual messages separately the relay station recovers network-coded messages. During the downlink phase, the network-coded messages aggregated are re-encoded and broadcast. Finally, every user obtains the other user's data streams, with the help of the direct transmission of its corresponding messages. MIMO-PNC scheme is said to outperform the MIMO TWRC in the literature [13].

CONCLUSION

The paper gives an overview 3GPP LTE and LTE Advanced communications systems. The importance of MIMO technology in LTE-A network with has been discussed. The network coding techniques being simple increases the robustness of the system. Applying the novel network coding scheme with the MIMO configured systems enhances the systems efficiency. Evolving with different network coding technologies appropriate for various LTE-A system scenarios resolving the various issues is the trending research topic requiring an extra effort from the researchers.

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