A Survey on Telecommunication Technology Standards

Sandeep Singh Sengar[#], Alok Singh[*], Pramod Narayan Tripathi[*]

Department of Computer Science & Engineering[#], Department of Electronics & Communication Engineering*,
Motilal Nehru National Institute of Technology[#],
Sam Higginbottom Institute of Agriculture Technology & Science*
Allahabad, India

Abstract—Mobile Ad-hoc Network is a self configurable routing protocol. Nodes in MANET can shift freely from one place to another place and each node in MANET can take action as a transmitter, receiver and router. WiMAX is a telecommunication technology standard which provides fixed and mobile Internet access. Access Server Network (ASN) in WiMAX provides the layer 2 connectivity to the user equipments. HAAA server is used to offer security in the IEEE 802.16 standard. 3GPP LTE (*Long Term Evolution*) is the latest standard in the mobile telecommunication technology which makes available fastest service to the user by using System Architecture Evolution (SAE) and Mobility Management Entity (MME). In this paper we will analyze the architecture of MANET, WiMAX, LTE network, and handover as well as connection establishment mechanism between different networks.

Keywords- MANET; WiMAX; LTE; SAE; MIMO; SC-FDMA; GERAN; UTRAN.

I. INTRODUCTION

MANET is a routing protocol to establish a connection among the nodes. All the nodes can move freely and they can self create the link to another node. MANET uses RREQ (Route Request) and RREP (Route Response) message for set up the connection between two nodes but if any kind of error occurs to connecting the node then RRER (Route Error) message is sent by node. So in MANET node can works as a router, transmitter, and receiver.

WiMAX (Worldwide Interoperability for Microwave Access) is a telecommunication technology. It is standardized by IEEE 802.16 standard for both fixed as well as mobile network. WiMAX uses OFDMA (Orthogonal Frequency Division Multiple Access) and S-OFDMA (Scalable-OFDMA) multiplexing technique in Downlink (DL) and Uplink (UL) respectively. BPSK, QPSK, 16-QAM, 64-QAM modulation technique are used by IEEE 802.16 network. WiMAX uses ASN-GW (ASN-Gateway) to entrance in the network and CSN (Connectivity Service Network) is used to provide the network service to the user.

LTE (Long Term Evolution) network is standardized by 3GPP. It is a 3.9G technology and advance LTE is the part of 4G. LTE can work with 500 km/h vehicular speed. Speed of LTE is fast as comparison to WiMAX network. LTE uses QPSK, 16-QAM and 64-QAM modulation techniques in UL and DL both. LTE uses the OFDMA, SC-FDMA (Single *Carrier Frequency Division Multiple Access*) channel multiplexing technique for UL and DL respectively. Several users in LTE can transmit data simultaneously by using MIMO technique. The structure of this paper is as follows-

Section I describes about routing techniques of MANET. In Section II we will discuss different multiplexing technique, architecture functionality within WiMAX protocol stack. Section 3 deals with LTE architecture. Section IV concludes the paper.

II. MANET

A MANET is a self-governing collection of mobile devices linked by a wireless link. The devices are free to move randomly which eventually made MANET topology dynamic. MANET is an infrastructure less network with each node acts as a transmitter, receiver and router. A node forwards the message unrelated to its own use. All the network related routing functionality works on the top of link layer. Nodes within a MANET get internet

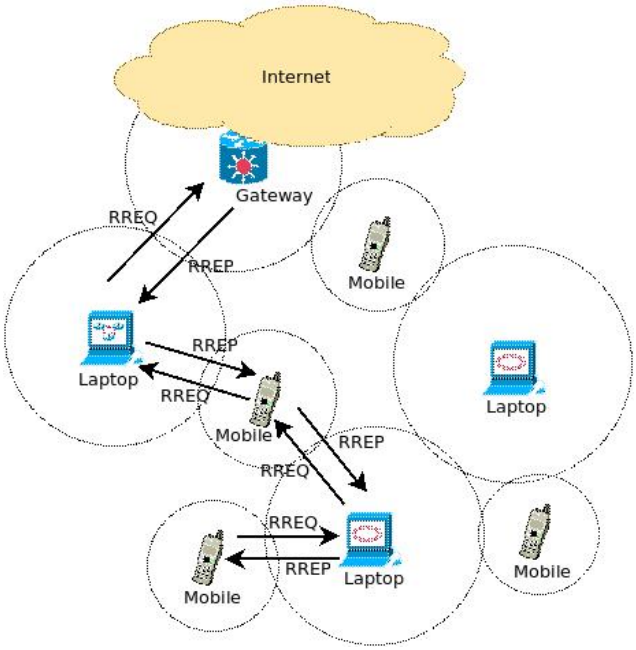

Figure 1. Architecture of MANET.

access through a gateway which is a normal mobile device. All the internet related data are traffic through this gateway node as shown in the fig: 1.

Mobile node sends the RREQ (Route Request) message to establish the connection with destination. When destination path is discovered then destination sends RREP (Route Response) to the source by using same path Dynamic nature of MANET leads to the mobile node to discovery instant but momentary topology. Data transfer between nodes occurs in multihop fashion. Nodes which are in communication range of each other transfer data directly whereas in case of destination being outside the communication range multihop policy is being adopted as shown in the Fig: 1.

Each node learns of its neighbor nodes and way to reach them. The routing protocols are basically divided into three categories.

A. Proactive Routing Protocols

Proactive routing are also known as table-driven routing protocols. As the name suggests, proactive routing protocols maintain route to all reachable destination in advance by sending the routing table amongst the routing nodes periodically. When a nodes join the network, it announce of joining the network by sending HELLO message in its vicinity. On getting the hello message neighbors node send their routing table to newly arrived node and at the same time update their routing table also. Proactive routing algorithms consume extra bandwidth which is rare in mobile device due to message overhead and may have lower latency since routes are maintained at all times.

B. Reactive Routing Protocols

The Reactive routing protocols establish a path when it is required. It basically consists of route discovery and route maintenance task. Route discovery process requires flooding of message. Since the route is determine reactively, it sometime leads to high latency when the size of network is large, however route maintenance task is less complicated as compare to proactive routing protocols. Advantage of reactive protocols is that it requires less bandwidth than proactive.

C. Hybrid Routing Protocols

Hybrid routing protocols combines the advantage of proactive and reactive routing protocols. Initially the route is established proactively then subsequently reactive policy is being followed.

.

III. WiMAX

WiMAX (Worldwide Interoperability for Microwave Access) is a telecommunication technology which is based on The IEEE 802.16 standard. Foundation of first WiMAX model was lay down in June, 2001 in the form of IEEE 802.16a. WiMAX provides fixed broadband wireless access services up to IEEE 802.16d (IEEE 802.16-2004). IEEE 802.16e and the entire standard after it support the mobility feature. Latest version of WiMAX is IEEE 802.16j which has developed in 2009.

A. WiMAX Protocol Layer

WiMAX network works on the following two layers.

1) Physical Layer: Physical layer in WiMAX performs modulation, signal mapping, MIMO Processing and Forward error correction coding. WiMAX contains BPSK, QPSK, 16-QAM, and 64-QAM modulation technique in DL, where 64-QAM is optional in DL and QPSK, 16-QAM, and 64-QAM mandatory techniques are used in UL. WiMAX uses two types of multiplexing technique in mobile WiMAX which are as follows.

a) OFDMA: OFDMA technique divides the bandwidth into multiple frequency subcarriers. OFDMA is the combination technique of FDMA (Frequency Division Multiple Access) and TDMA (Time Division Multiple Access). WiMAX uses OFDMA in DL MAP.

b) S-OFDMA: It is same as OFDMA but number of subcarrier in S-OFDMA may be chosen according to available bandwidth. It is used in UL MAP of Mobile WiMAX network.

2) MAC Layer: MAC Layer of WiMAX is divided into two parts

a) MAC Convergence Sublayer (MCS): MCS layer performs header suppression for upper layer protocol. Mapping of IP address from upper layer to several service identifiers is performed by classification block in MCS.

b) MAC Common Part Sublayer (MCPS): MCPS layer performs QOS, ARQ, Mobility Management, Radio Resource Management, Connection management, Security management, Physical Control.

All the layers in WiMAX are integrated with Service Access Points

B. WiMAX Network Model

WiMAX model is a combination of following logical parts

1) Mobile Station (MS): MS is generic mobile equipment used by the end user to providing wireless connectivity between subscriber equipment and the network. Mobile station may be movable or fixed terminal devices like cell phone, wireless laptops, PDAs etc.

2) Network Access Provider (NAP): NAP makes available radio access functionality. Some of the components included in the NAP are ASN, ASN-GW, base stations, foreign agent, which is used for QOS, policy enforcement, and to select a particular CSN. A NAP might have contracts with several NSPs. NAP may contain several ASN as shown in fig: 2.

a) ASN: The ASN may encompass one or more base stations and one or more ASN gateways that shape the radio access network at the edge. The ASN covers the set of functionalities that offers radio access connection to WiMAX subscribers. One or quite a lot of ASN, interconnected all the way through reference point R4.

The ASN provides Layer 2 connectivity to the WiMAX subscribers. In case of mobile network it offers paging and location management, Radio Resource Management mechanisms like handover control and execution. WiMAX subscriber's IP address allocation, AAA procedures, tunnelling of data and signalling between the ASN and the CSN provided though reference point R3. Multiple BSs may be associated with an ASN. ASN also includes many components which are explained below.

- **Base Station:** The BS is in charge to provide the air interface for the MS and also responsible for the arrangement of user and signaling messages exchanged with the ASN-GW through the R6 interface. Tunnel establishment, QoS policy enforcement, radio resource management, traffic classification, key organization, session organization, and multicast group organization functions are also component of base station. BS may be logically attached to more than one ASN-GW to permit load balancing and redundancy options.
- **ASN-GW:** The ASN gateway normally acts like a traffic aggregation point inside an ASN. Other functions that can be component of the ASN gateway comprise radio resource management, intra-ASN locality management, paging, QoS and procedure enforcement, admission control, caching of subscriber profiles, encryption keys, AAA user functionality, management of mobility tunnel with base stations, FA functionality in support of mobile IP, and routing to the selected CSN. The ASN-GW may be designed to offer redundancy and load balancing among different ASN-GW. The connectivity to numerous ASN-GW may be essential in the case of load balancing or redundancy purposes. The ASN-

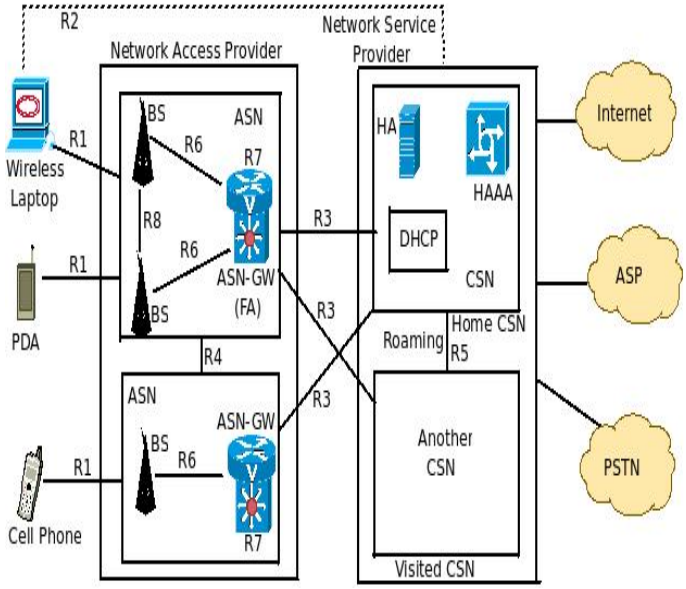

Figure 2. WiMAX Network Architecture

GW associated with the CSN through R3 for IP layer contacts as well as interactions with other ASNs by using R4 in bear of mobility.

3) Network Service Provider (NSP): NSP enables IP connectivity and services to WiMAX subscribers with established Service Level Agreements. The NSP organizes the CSN. IP connectivity to WiMAX subscribers are offered by CSN. At radio access network side WiMAX services are provided through contractual agreements with one or several NAPs.

NSP in a certain country may have roaming conformity with several other NSPs, which may be available in other countries. Therefore, a WiMAX subscriber may be linked to a Home NSP or to a Visited NSP, a NSP with whom its home NSP has a roaming agreement. Reference Model allows one NSP to have an association with multiple NAPs in one or different geographical locations. A NAP provides radio access infrastructure to one or several NSPs. Sometimes NSP may be the similar business entity as the NAP. NSP encompass many CSN as shown in fig: 2.

a) CSN: All the equipments which facilitate IP connectivity to WiMAX subscribers are provided by CSN. It grants connectivity to the Internet, Access Service Provider, Public Switch Telephone Network, and other public networks. The NSP offers The CSN which includes AAA (Authentication, Authorization, and Accounting) servers that support authentication for the devices, users, and services. IP address management, location management between ASNs, sustain for roaming among different NSPs, WiMAX subscriber billing QoS management, mobility support on mobile IP and roaming between ASNs also provided by the CSN.

It also supports for tunnelling based on IP protocol such as ASN-CSN tunnelling, inter-CSN tunnelling which is used for roaming. DNS/DHCP servers are used by CSN for IP address resolution and user IP address configuration. The CSN provides Firewalls for denial of service detection/prevention to the WiMAX network equipments by enforcing access and filter policies on the traffic to and from an external network. Home CSN is attached to another CSN in roaming by using reference point R5.

4) Internet: There may be access service provider, PSTN or other network to offer connectivity to NSP and internet substance to subscriber.

C. *Reference Points (RP)*

RPs is used for connect two functional entities. WiMAX network architecture consist six compulsory RPs from R1 to R6 and two revealing RPs R7 and R8. All the reference points in WiMAX are as follows.

1) R1: It represents the radio interface between the wireless device (Wireless laptop, PDA, cell Phone) and the base station. R1 carries both user traffic and user control plane messages. R1 provides all the physical and MAC features hold in WiMAX network.

2) R2: The MS and The CSN are connected to each other by logical interface of reference point R2. It includes all the protocols and other procedures that are occupied with authentication, service authorization and

IP host configuration management. IP host address management Protocol may be executed by the visited NSP in the case of roaming.

3) R3: It represents the logical interface between the ASN and the CSN. Traffic between the ASN-GW and the AAA server pass through R3.

4) R4: Reference point R4 connects two ASNs or two ASN-GW. It expresses both control and data plane messages during position modernize procedures in the idle mode or during the handover of a WiMAX user between ASNs/ASN-GWs.

5) R5: It represents the link between a CSN to another CSN. It consists of the set of control and data plane methods between the CSN.

6) R6: It represents the link between BS and the ASN-GW. It expresses data plane message information as well as control message like data path establishment, modification, and control with MS mobility.

7) R7: R7 reference point is an optional logical interface in the ASN-GW. It is used for internal communication within a gateway.

8) R8: R8 reference point present in ASN and it represents the logical interface between two base stations inside the ASN.

IV. LTE (LONG TERM EVOLUTION)

The LTE Technology was originally planned by NTT DoCoMo of Japan in November, 2004 as the international standard. First real system deployment of LTE was seen in 2010. The foundation of LTE network was lay down before few time ago of 4G so we can say that it is a 3.9 G technology. LTE is located as the next generation mobile wireless telecommunication technology which provides an improve path to 4G from 3G. The pre-4G standard is a step in the direction of LTE Advanced, a 4G of radio technologies designed to enhance the coverage as well as speed of mobile networks. LTE offers peak data rate of 100 Mbps for DL, 50 Mbps for UL channel and also support 1.4-20 MHz scalable bandwidth. It provides low-cost and low-complexity workstation in support of global exploit. LTE can support up to 500 km/h of vehicular speed. LTE provides the following benefit to network operators like High network throughput, Improve path from 3G networks, Low latency, Plug and Play architecture, All-IP packet based network, low operating costs.

LTE incorporate the development of the Universal Mobile Telecommunications System radio access through the Evolved UTRAN (E-UTRAN), it is escorted by a development of the non-radio aspects beneath the term System Architecture Evolution (SAE), LTE and SAE jointly comprise the Evolved Packet System (EPS). Routing IP traffic from a gateway in the PDN (Packet Data Network*)* to the UE is accomplished by EPS bearers. IP connectivity to a PDN for accessing the Internet and Voice over IP services is offered by EPS. LTE provides the following benefit to network operators like High network throughput, Improve path from 3G networks, Low latency, Plug and Play architecture, All-IP packet based network, low operating costs.

A. Multiplexing

The LTE physical layer is used for efficiently convey both data and control information between an enhanced base station (eNodeB) and mobile UE. LTE support both FDD (Frequency Division Duplexing) and TDD (Time Division Duplexing) approach. It works with two types of multiplexing techniques-

1) OFDMA: OFDMA is a downlink transmission scheme of LTE Standard. OFDMA is a basically hybrid of FDMA and TDMA. Users are dynamically allocated subcarriers (FDMA) in different time slots (TDMA). Available spectrum in OFDMA is divided into multiple carriers, called sub-carriers, which are orthogonal to each other. All of these sub-carriers are separately modulated through a low rate data stream. LTE offers three types of modulation scheme QPSK, 16-QAM, and 64-QAM in both UL and DL of physical layer.

2) SC-FDMA: The assignment of several users to a shared communication resource is provided via SC-FDMA. S-OFDM is used by WiMAX in UL but LTE uses SC-FDMA for UL because high PAPR (Peak to Average Power Ratio) of S-OFDM. SC-FDMA brings benefit of low peak to average power ratio (PAPR) as compared to S-OFDM, which makes it to suitable for UL transmission user terminal.

SC-FDMA is a novel hybrid modulation method that smartly merges the low PAR of single-carrier systems with the multipath resistance offered by OFDM. OFDM spread four modulated data symbols in parallel, one per subcarrier, but SC-FDMA transmits the four QPSK data symbols in series at four times the rate. SC-FDMA covered the bandwidth is alike multi-carrier OFDMA. SC-FDMA is having benefit in the form of robust resistance to multipath without the problem of high PAPR. The area of SC-FDMA is limited to UL because the increased time-domain processing would be a substantial load on the BS.

B. MIMO Technique

Multiple Input Multiple Output (MIMO) systems form a crucial part of LTE in order to accomplish the striving requirements for throughput and spectral effectiveness. MIMO refers to utilize of multiple antennas at transmitter and receiver area. LTE MIMO technique may be applied for both DL as well as for UL channel. LTE DL supports 4x2, 2x2, 1x2, 1x1 antenna configurations. Baseline configuration of LTE is a 2x2 configuration for MIMO which contains two transmit antennas at the BS (Base Station) and two receiving antennas at the terminal side. LTE UL MIMO is differ from LTE DL to acquire into account terminal complexity issues. UL supports 1x2, 1x1 antenna configurations. Numerous users' terminals may transmit concurrently on the similar resource block by using MIMO.

C. LTE Network Architecture

LTE model is a combination of following logical parts.

1) GERAN: GERAN (GSM EDGE Radio Access Network) is preserved by the 3GPP. The key element of GSM is GERAN which is used for combine the UMTS/GSM networks. GERAN encompasses the base stations and the base station controller. Packet data as well as phone calls are routed from and to the PSTN (*Public Switched Telephone Network*) and Internet to and from subscriber handsets by using GSM network.

2) UTRAN: UTRAN (**U**niversal **T**errestrial **R**adio **A**ccess **N**etwork) is a combined word for the Node B and Radio Network Controllers (RNC's) which create the UMTS network i.e. 3G. It can transmit numerous traffic types from Circuit Switched to IP based Packet Switched. The UTRAN permits link between the UE (User Equipment) and the core network. The RNC is used for controlling one or more Node B. Node B and an RNC do not physically separate, but logically implementations of both are deferent. More than one RNC may be present in an UTRAN. Lu interface is used for connecting the RNC to the Core Network (CN).

3) eNB: Node B is the base station in 3G. But it is eNB (Enhance Node B) in LTE standards and eNodeB connects to the UEs. Radio resource management and air interface support is accomplished by eNodeB. It offers functions like IP header compression, Selection of an MME at UE addition, data security, and routing the user data to the S-GW (Serving Gateway). Several operators can share the radio interface offered by eNodeB.

4) PCRF: Decision-making and flow-based charging Functionalities in the Policy Control Enforcement Function (PCEF) are controlled by PCRF *(*Policy Charging and Rules Function). PCEF resides in the P-GW. PCRF offered the QoS authorization to make a decision how a certain data flow will be treated in the PCEF and guarantee that this is in concurrence with the user's subscription profile.

5) HSS: HSS (Home Subscriber Server) User's SAE data likes the EPS-subscribed QoS report and any access boundaries for roaming is hold by HSS. Dynamic information like the identity of the MME to which the user is presently connected or registered is hold by HSS. The authentication centre (AUC) is also integrated by HSS which produces the vectors for validation and security keys.

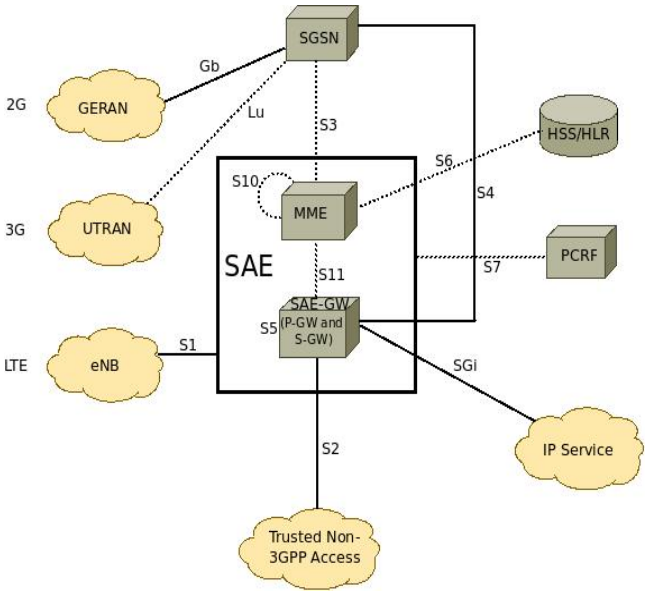

Figure 3. Architecture of LTE

6) SGSN: SGSN (Serving GPRS Support Node) offers Packet data services in the network. SGSN uses packet switched services for transfer the data. SGSN key liabilities are the release of data packets from and to UE within its environmental service region. Packet routing and transfer, logical link management and authentication and charging functions, mobility management is provided by SGSN. The location register of the SGSN contains location information as well as user profiles.

7) SAE: The main components of SAE (System Architecture Evolution) in LTE are as follows-

a) S-GW: S-GW (Serving Gateway) comes under SAE-GW. All users' IP packets are transported through the S-GW. When the UE travels amid eNodeBs then S-GW works as the local mobility anchor for data bearers. Information about the bearers is also keep by S-GW when the UE is in the inactive condition and it temporary buffers downlink data while the MME instigate paging of the UE to re-establish the bearers. The S-GW executes several decision-making functions in the visited network like as collecting information for charging and legal interruption. 3GPP technologies such as General Packet Radio Service (GPRS) and UMTS are also served by S-GW. It also provides the handover method with in eNodeB as well as in between 3GPP networks. Forwarding the data packets between the eNodeB and PDN Gateway is also performed by S-GW.

b) P-GW: P-GW (Packet Data Network Gateway) is in-charge for IP address distribution for the UE, as well as QoS enforcement and flow-based charging according to rules from the PCRF. Filtering of downlink user IP packets into the different QoS-based bearers is also performed by P-GW. The P-GW executes QoS enforcement intended for guaranteed bit rate bearers. It also provides interworking with non-3GPP technologies such as CDMA and WiMAX networks.

c) MME: MME (Mobility Management Entity) is the control node that progress the signaling amid the UE and the CN. MME performs the organization, maintenance and discharge of the bearers and is hold by the session management layer. MME set up the link and security between the network and UE and is hold by the connection or mobility management layer. It is used for take care of control plane, mobility management with 2G/3G nodes, and roaming. MME is also used for selecting particular SGSN to connecting with 2G/3G nodes.

V. CONCLUSION

In this paper we have seen architecture overview of different telecommunication technology standards like MANET, WiMAX and LTE. We have described modulation, multiplexing technique of WiMAX and LTE network. We have also discussed MIMO technique in LTE standard. GERAN, UTRAN, eNB, PCRF, SAE leads to LTE in 4G technique is also discussed in this paper.

REFERENCES

[1] A. Ghosh, R. Ratasuk, B. Mondal, B. N. Mangalvedhe, and N. T. Thomas, "LTE-advanced: next-generation wireless broadband technology", IEEE Wireless Communications, vol. 17, Issue 3, pp. 10 - 12, Aug. 2010.

[2] A. Munir, and Ann Gordon-Ross, "SIP-Based IMS Signaling Analysis for WiMAX-3G Interworking Architectures", IEEE Transactions on Mobile Computing, vol. 9, No. 5, pp. 733-750, May 2010.

[3] B. Clerckx, A. Lozano, S. Sesia, C. Rensburg, B. Papadias, "3GPP LTE and LTE Advanced", EURASIP Journal on Wireless Communications and Networking," vol. 2009, pp. 3, sep. 17, 2009.

[4] D. Ismail, M. Jaafar, "Mobile ad hoc network overview", IEEE Int'l Conf. Applied Electromagnetic APACE, pp. 1 – 8, 2007.

[5] Jim Zyren, "Overview of the 3GPP Long Term Evolution Physical Layer", Whitepaper, July 2007.

[6] K. WenigeK, M. Zitterbart, "Mobile ad hoc networks-current approaches and future directions", IEEE JOURNALS, vol. 18, pp. 6 - 11, 2004.

[7] LTE MIMO, http://www.radioelectronics.com/info/cellular telecoms/lte-long-term-evolution/lte-mimo.php.

[8] MANET, en.wikipedia.org/wiki/Mobile_ad_hoc_network.

[9] Mobile Ad-Hoc Networks, http://www.olsr.org/docs/wos3-olsr.pdf.

[10] Mobile Ad-hoc Network, http://www.sanog.org/resources /sanog13/sanog-13-mobile-adhoc-baber.pdf.

[11] Network Reference Model,http://etutorials.org/Networking/wimax+technology+broadband+wireless+access/Part+Four+Diverse+Topics/Chapter+13+WiMAX+Architecture/13.2+Network+Reference+Model/

[12] P. Iyer, N. Natarajan, M. Venkatachalam, A. Bedekar, E. Gonen, K. Etemad, P.Taaghol, "All-IP Network Architecture for Mobile WiMAX", IEEE int'l conf. Mobile WiMAX Symposium, pp. 54-59, April 2007.

[13] P. Mohapatra, Chao Gui, Li Jian, "Group communications in mobile ad hoc networks", IEEE JOURNALS, vol. 37, pp. 52-59, 2004.

[14] S. Abeta, "Toward LTE Commercial Launch and Future Plan for LTE Enhancements (LTE-Advanced)", IEEE int'l conf. Communication Systems (ICCS), pp. 146 – 150, 2010.

[15] S. Sesia, I. Toufik, M. Baker, "LTE – The UMTS Long Term Evolution: From Theory to Practice", Wiley, April 2009.

[16] S. Ahmadi, "An Overview of Next-Generation Mobile WiMAX Technology", IEEE Comm. Magazine, vol. 47, No. 6, pp. 84-98, June 2009.

[17] S. Dornal, "LTE Whitepaper", version 1.0, OCT 2009.

[18] 3GPP Technical Specification 33.401, System Architecture Evolution (SAE): Security Architecture (Release 8), Available: www.3gpp.org.

[19] WiMAX Forum, http://www.WiMAXforum.org.

[20] WiMAX Network Reference Model, http://www.juniper.n et/techpubs/software/aaa_802/sbrc/sbrc70/sw-sbrcadmin/html/WiMAX_Overview3.html.

[21] Wired n Wireless, http://wired-n-wireless.blogspot.com/2009/11/lte-dedicated-bearers-big-question.html.

[22] WiMAX Model, http://www.tutorialspoint.com/wimax/wi max_network_model.htm.

[23] WiMAX Overview, http://www.ietf.org/proceedings/64/sli des/16 ng-4.pdf.