A NOVEL APPROACH TO DEVELOP A RELIABLE ROUTING PROTOCOL FOR WIRELESS MESH NETWORKS USING IEEE 802.11s AND LTE NETWORKS: A SURVEY PAPER

Sana Bari[1], Rajshekhar S A[2]

[1]*Student, Department of CSE, East West Institute of Technology, Bangalore, Karnataka, India*
[2]*Assistant Professor, Department of CSE, East West Institute of Technology, Bangalore, Karnataka, India*

Abstract
Wireless mesh networks (WMNs) have emerged as a flexible and low-cost network infrastructure, where heterogeneous mesh routers managed by different users collaborate to extend the network coverage. IEEE 802.11s standard was defined as a wireless mesh network which extends IEEE 802.11 MAC standard. The protocols introduced by IEEE 802.11s draft are divided into Proactive, Reactive or Hybrid categories. This paper aims to improve the routing process of HWMP: Hybrid Wireless Mesh Protocol defined by IEEE 802.11s standard by interworking 802.11s network with LTE network. Also, it aims to make the protocol more reliable by providing the QoS to the network. The pre-defined path selection metric is also enhanced to get more accurate information about the path quality. The proposed contribution aims to provide better performance to the 802.11s-LTE network and enhances the network with delay-aware routing. A simulation study will be conducted under NS-3 to observe the impact of the proposed protocol in offloading mechanism. Finally, the performance of overall contribution is compared to HWMP.

Keywords: Delay-aware routing, HWMP, IEEE 802.11s, Interworking, LTE, Multi-path routing, nALM metric, QoS and Wireless mesh networks.

--***--

1. INTRODUCTION

WMNs: Wireless Mesh Networks are becoming one of the core technologies for realization of next-generation networking technology. They provide high speed and reliable wireless transmission methods. In many cities, various forms of wireless mesh networks are already deployed and verified [6].

IEEE 802.11s is an amendment of 802.11 IEEE standards for mesh networking. Here the term 's' defines the task group. This standard defines how wireless devices can interconnect to create a wireless LAN (WLAN) mesh network. It extends the IEEE 802.11 MAC standard by defining an architecture and protocol that supports both unicast and multicast/broadcast delivery. This network provides high scalability and flexibility with low installation cost and maintenance cost [2]. Fig -1 shows the basic architecture of IEEE 802.11s network [7]. It is a wireless mesh network. There are Simple Stations (STAs) in the network, and also the Mesh Points (MPs). MPs serve as the wireless backbone for STAs. These MPs are interconnected according to mesh topology. Hence this wireless backbone is known as Mesh Basic Service Set (MeshBSS). Every MeshBSS has its unique Mesh ID. STAs do not implement networking functions, but the MPs do. MPs implementing networking functions are known as Mesh Access Points (MAPs). They provide network access to STAs. They also aggregate traffic to and from the legacy 802.11 stations. Last component is the Mesh Portal Point (MPP), it serves as a gateway and interconnects this network to other non-mesh networks.
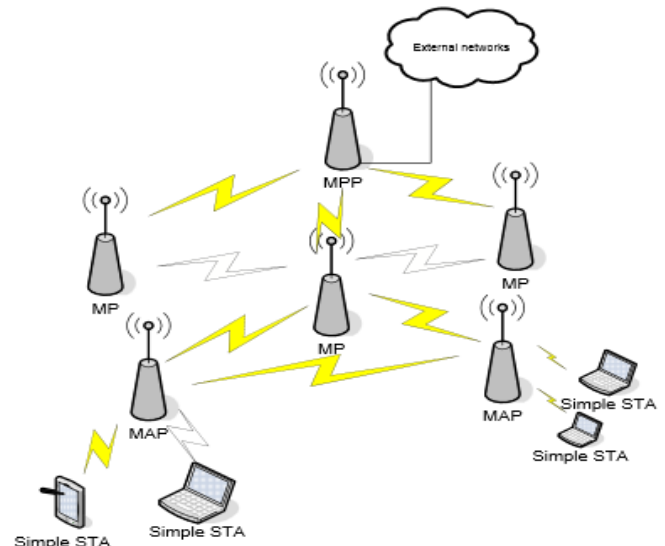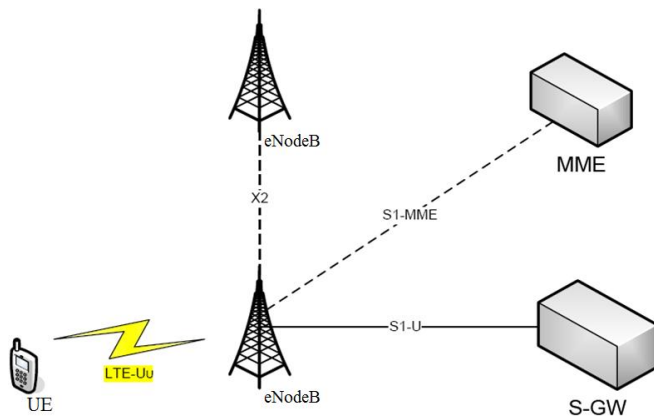

Fig -1: IEEE 802.11s Network Architecture

Fig -2: LTE Network Architecture

On the other hand, LTE is a Long-Term Evolution network, which is a well-designed technology that offers high data rate of 176Mbps and reduced latency of 10ms. It is defined as a Radio Access Network (RAN) 3GPP Release 8. It can interwork with different technologies [8]. In this paper, we are interworking it with IEEE 802.11s network. Fig. 2 shows the basic architecture of LTE network [7]. Here, UE is the User Equipment. LTE reduces the number of network elements in the radio part to only one element, which is known as evolved Node B (eNodeB). MME is the Mobility Management Entity, which establishes connection, provides security, authentication and processes signalling. S-GW is the Serving SAE (System Architecture Evolution) Gateway. It is the SAE component of LTE network, which is responsible for data management in the network. LTE defines a number of interfaces: LTE-Uu is the radio interface between eNodeB and the user equipment. X2 is the inter-eNodeB interface, which is used in handover co-ordination. S1-MME is the control interface between eNodeB and MME. S1-U is the pure user data interface, which connects eNodeB to several S-GW gateways.

The protocols introduced by IEEE 802.11s draft are divided into Proactive, Reactive or Hybrid Mesh categories. One key popular protocol is the HWMP: Hybrid Wireless Mesh Protocol [3]. It is a default routing protocol for IEEE 802.11s network. In this paper, an enhancement to this protocol is suggested in terms of good Quality of Service (QoS), path selection process and the routing process with delay-awareness. We first conduct a research on related papers, which describes motivation behind the enhancement. Then we describe our proposed idea to implement this enhancement. Later, we study impact of our proposed protocol in offloading mechanism. Finally, we conduct a simulation study under NS-3 [5] to compare our enhanced system with the existing one.

2. RELATED RESEARCH WORK

2.1 Performance Study of Hybrid Wireless Mesh Protocol (HWMP) for IEEE 802.11s WLAN Mesh Networks [1]:

This paper signifies that the IEEE forms a task group called IEEE 802.11s to develop an integrated mesh networking solution. HWMP and airtime metrics are set as default routing protocol and default routing metrics by the task group. Many simulation studies have been done to evaluate the performance of the HWMP with the assumption of unique type of flow with fixed packet size and fixed packet rate. However, real networks carry diverse applications like VoIP, interactive games, video, voice, FTP, Email etc with different characteristics such as packet size and data rate. In this paper, investigation and analysis of the performance of HWMP is done under such heterogeneous application characteristics [1].

2.2 Improving IEEE 802.11s Wireless Mesh Networks for Reliable Routing in the Smart Grid Infrastructure [2]:

This paper signifies that IEEE 802.11s network provides high scalability and flexibility with low installation cost and maintenance cost. It also signifies that the IEEE 802.11s standard provides an efficient form of multi-hop routing called HWMP. However, HWMP degrades the network reliability and throughput due to its route instability and poor route selection problems. It uses Air-time Link Metric (ALM), which does not take into account the different packet sizes. As a result, it does not take into account the different kinds of traffic and applications like VoIP and interactive games. Also, this paper does not guarantee optimal reliability where the packet delivery ratio also decreases when there is congestion in the network [2].

2.3 Q-HWMP: Improving End-to-End Qos for 802.11s Based Mesh Networks [3]:

This paper signifies that the HWMP is inadequate for multimedia applications, such as video conferencing, which often requires guaranteed QoS. QoS routing not only requires finding a best route from source to destination according to some criteria, but it also requires that the end-to-end QoS requirement is satisfied, often in terms of bandwidth or delay. This paper improves the native HWMP protocol by handling the QoS for real time applications, by increasing bandwidth utilization and by avoiding network congestion. However, this paper introduces five extra fields in PREQ to carry the QoS requirements: Maximum delay of transmission, QoSTag, desired throughput, desired packet size and the maximum path metric. The contribution of this paper fits the QoS requirements, but it induces extra overhead than native HWMP which reduces the performance of the IEEE 802.11s network [3].

2.4 Multi-Path Routing Challenging Single-Path Routing in WMNs [4]:

This paper signifies that the multi-path routing outperforms single-path routing in terms of network throughput, end-to-end delay and data drop. Also, it says that multi-path routing protocols increase the network reliability and capacity by increasing the rate of successfully delivered packets and throughput of the network [4].

2.5 Network Simulator-3 [5]:

NS-3 is a discrete-event network simulator, targeted primarily for research and educational purpose. The NS-3 simulation core supports research on both IP and non-IP based networks. However, the majority of its users are focusing on wireless/IP simulations which involve the models for Wi-Fi, WiMAX, LTE networks and a variety of routing protocols such as OLSR and AODV for IP-based applications [5].

NS-3 is not backward compatible with NS-2; it is built from the scratch to replace NS-2. It is written in C++, Python Programming Language can also be optionally used as an interface. This version of network simulator is trying to solve the problems present in NS-2. Compared to NS-2, there are a very limited number of contributed codes made with NS-3. Only the knowledge of C++ is enough for NS-3; whereas in NS-2, bi-language system makes the debugging complex. Thus, single-language architecture is more robust in the long term. It has an emulation mode, which allows for the integration with real networks. In 2009, NS-3 releases were downloaded around 14,000 times. In 2011, downloads have been risen to 86,014 times. As of NS-3.13 release, 93 people are listed as authors [5].

3. PROBLEM STATEMENT

The path selection mechanism and the routing process of Hybrid Wireless Mesh Protocol (HWMP) has to be modified and enhanced in order to adapt it to wireless mesh network environment in IEEE 802.11s-LTE interworking scenario.

4. EXISTING SYSTEM

The IEEE 802.11s uses HWMP as the mandatory routing protocol. The path selection mechanism of this protocol is based on the value of ALM (Air-time Link Metric) of the path [1, 3]. It is defined as follows:

Air-time Link Metric (ALM),

$$c_a = \left[O + \frac{B_t}{r} \right] \left(\frac{1}{1 - e_f} \right)$$

Where, O = Oca + Op
$Oca \rightarrow$ channel access overhead
$Op \rightarrow$ MAC protocol overhead
$Bt \rightarrow$ size of test frame
$r \rightarrow$ link transmission rate of test frame

$Bt/r \rightarrow$ transmission time
$ef \rightarrow$ frame error rate

In ALM metric, the transmission time (Bt/r) and frame error rate (ef) of adjacent links are estimated by broadcasting extra probe packets. This method of active information gathering is not well adapted to wireless mesh networks and it does not give accurate information. The estimated transmission time and frame error rate are based on a fixed frame size. This does not reflect accurate link quality [10]. Also, the ALM metric does not take into account different packet size. As a result, it does not take into account different kinds of traffic and applications like VoIP and interactive games. The routing process of HWMP uses single-path routing. Based on the investigation conducted on [4], multi-path routing outperforms single-path routing in terms of network throughput, end-to-end delay and data drop. Thus, the routing process of HWMP is also needed to be enhanced from single-path routing to multi-path routing.

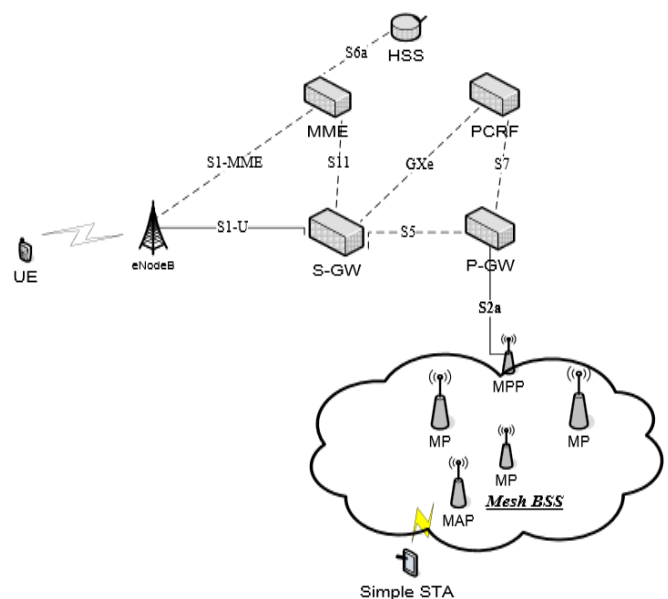## 5. PROPOSED SYSTEM

5.1 System Architecture

Fig -3: System Architecture

Fig. 3 shows the main architecture of our proposed idea. Here, we study the interworking issue between IEEE 802.11s and LTE networks. As we have described earlier that the MPP serves as a gateway and connects to other external networks, we are connecting it to the LTE network. IEEE 802.11s network is connected to the P-GW (Packet Data Network SAE Gateway) component of LTE network via S2a interface. The PCRF (Policy and Charging Rules Function) component connected to S-GW and P-GW is responsible for the control and management of policy of the data traffic [7]. It decides how data flow will be handled in terms of QoS and how it will be treated by its connecting components. HSS (Home Subscriber Server) contains the subscriber's information and performs authentication and authorization of the user. It is connected to MME of the LTE network.

5.2 Data Flow Diagram
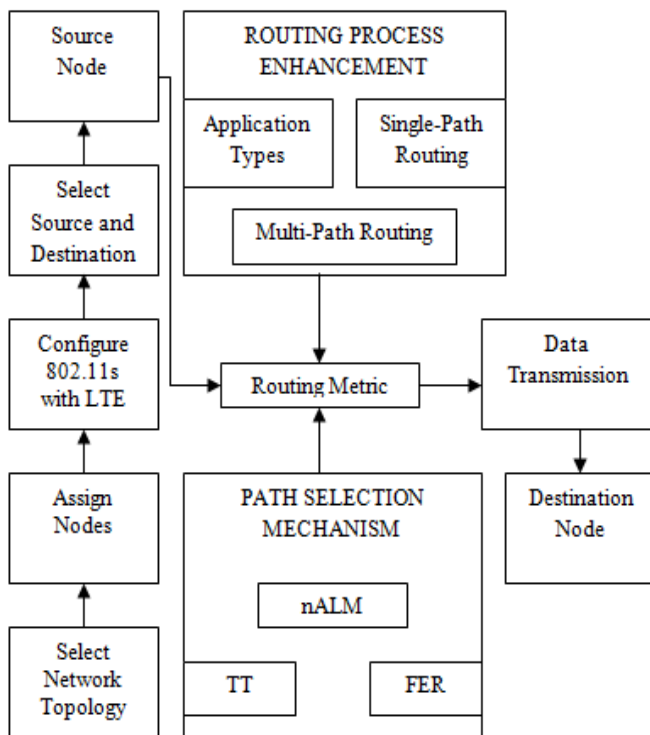
5.3 Path Selection Mechanism

To address the problem of ALM metric, we have decided to modify the methods of estimating 'transmission time' and 'frame error rate'. In this context, we redefine the transmission time as the sum of period of successful transmission, period of collision and the period of reception. Thus, the transmission time is redefined as follows:

Transmission Time,

$$TT = T_p S_p T_s + T_p(1 - S_p)T_c + R_p T_r$$

In the above formula, Tp, Sp and Rp are the probability of transmission, probability of successful transmission and the probability of reception respectively. Whereas, Ts, Tc and Tr are the times spent in transmission, collision and reception of the packets respectively. The frame error rate of the ALM metric is redefined as follows:

Frame Error Rate,

$$FER = \frac{\sum_i^{P_n} R_i * (1 - \frac{B_i}{B_{max} + B_i})}{P_n R_{max}}$$

Here, Pn is the number of packets to be transmitted by node n, Bi is the size of packet i in bits, Bmax is the size of biggest packet in the network configured to 1024 bits, Ri is the number of MAC level retransmissions of packet i and Rmax is the maximum number of retransmission allowed. Thus, we have modified the ALM metric as follows:

New Air-time Link Metric (nALM),

$$C_a = [O + TT](\frac{1}{1 - FER})$$

5.4 Routing Process Enhancement

To take into account the different QoS parameters for the applications during path selection process, we define three different application types according to the type of packets in the routing process at the MAC layer [11].
Type A: Critical delay sensitive applications
Type B: Non-critical delay sensitive applications
Type C: Non-error tolerant applications

Critical delay sensitive applications are the applications like VoIP, interactive games whose delay is so critical and sensitive that might cause the application to fail. Non-critical delay sensitive applications are the applications like video streaming whose delay is sensitive, but not critical. Non-error tolerant applications are the applications like file transfer whose delay is negligible. Below is the table that describes different QoS requirements for different type of applications.

Table -1: Qos Class Requirements

QoS Parameter	Application Type		
	Type A	*Type B*	*Type C*
Threshold Data Rate	4Kbps	16Kbps	20Kbps
Threshold Delay	150ms	400ms	4s
Threshold Packet Loss	3%	1%	0%
Threshold Jitter	1ms	1ms	Not Applicable

Now, taking into account all the QoS parameters and new Air-time Link Metric (nALM), we define the algorithm for multi-path routing. First, we discover three paths for the packets to transfer from source to destination. The best path is the path having minimum nALM metric based on the type of application.

Algorithm: Multi-Path Routing
Input: Packet, P
Output: Route, R
   1. find source & destination nodes
   2. select a packet to forward
   3. select three best paths from source to destination if available
   4. if (P ∈ Type A)
   5. R ← 1st Best Path
   6. else
   7. if 2nd and 3rd Best Paths are not available
   8. R ← 1st Best Path
   9. else if 3rd Best Path is not available
   10. use Weighted Round Robin method
   11. else if (P ∈ Type B) R ← 2nd Best Path
   12. else R ← 3rd Best Path

5.5 Advantages

The estimated transmission time and frame error rate of nALM metric reflects accurate link quality and also gives accurate information. Thus, it well adapts to WMN environment. The path selection metric is also able to address the load balancing issue. Also, this metric now takes into account different packet sizes. Multi-path routing process enhances the performance of the protocol, by taking into account different QoS parameters like threshold data rate, threshold delay, threshold packet loss and threshold jitter. It has made the routing protocol more stable against the path fluctuation. The application types define the type of packet to be transferred, which enhances the routing performance. Delay-aware routing enhances the QoS in the network in terms of end-to-end delay.

6. CONCLUSION

In this paper, we have suggested an enhancement to HWMP in terms of good Quality of Service (QoS), path selection process and routing process with delay awareness. To deal with this issue, we have interworked the two emerging networks viz., IEEE 802.11s and LTE. Firstly, we have conducted a research on related papers, which describes motivation behind the enhancement. Then, we described our proposed idea to implement the enhancement. Later, we will study impact of our proposed protocol in offloading mechanism. Finally, we will come up with a simulation study under NS-3 to compare our enhanced system with the existing system.

REFERENCES

[1] Bari.S.M.S.; Anwar.F and Masud.M.H, "Performance Study of Hybrid Wireless Mesh Protocol (HWMP) for IEEE 802.11s WLAN Mesh Networks."

[2] Ji-Sun Jung, Keun-Woo Lim, Jae-Beom Kim, Young-Bae Ko, Younghyun Kim and Sang-Youm Lee, "Improving IEEE 802.11s Wireless Mesh Networks for Reliable Routing in the Smart Grid Infrastructure," 978-1-61284-955-3/11/$26.00 ©2011 IEEE.

[3] J. Ben-Othman, L. Mokdad, and M. Cheikh, "Q-HWMP: improving end-to-end qos for 802.11s based mesh networks," in IEEE Global Telecommunications Conference (GLOBECOM), 2010, pp. 1–6.

[4] Pedram Ghahremanloo, "Multi-Path Routing Challenging Single-Path Routing in Wireless Mesh Networks," in Proc. of 5th International Conference on Application of Information and Communication Technologies (AICT), October 2011.

[5] "ns-3 Tutorial" Release ns-3.21, ns-3 project, @ http://www.nsnam.org , September 18, 2014.

[6] G. Vasilakis, G. Perantinos, I. Askoxylakis, N. Mechin, V. Spitadakis and A. Traganitis, "Business opportunities and considerations on wireless mesh networks," IEEE WoWMoM, 2009.

[7] Mariem Thaalbi, "University of Carthage DOCTORATE THESIS Elaborated in Ecole Supérieure des Communications de Tunis (Sup'Com)."

[8] Ayman Elnashar and Mohamed A. El-Saidny, "Looking at LTE in Practice: A Performance Analysis of the LTE System Based on Field Test Results," IEE vehicular technology magazine | September 2013.

[9] IEEE Std 802.11s-2011, IEEE Standard for Information Technology—Telecommunications and information exchange between systems—Local and metropolitan area networks Specific requirements—Part 11: Wireless Medium Access Control (MAC) and physical layer (PHY) specifications—Amendment 10: Mesh Networking, September 2011.

[10] Xiang Li et al., "Cross-Layer Routing Metric for Wireless Mesh Networks," in Information Computing and Applications Communications in Computer and Information Science, Vol.307, 2012, pp 523-530.

[11] ITU-T Recommendation G.1010: "End-user multimedia QoS categories", URL: http://www.itu-t.org