IP Reuse on GPS Mapped MAC for Multi-hop Mesh Network

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***Abstract*— We study the traffic overhead in TCP/IP network and propose the changes in IP address and MAC address for multi-hop mesh network. The proposed architecture describes routing protocol independent of subnet, hence omits the subnetting in the network architecture. The directional flooding (DF) is used in Wireless Mesh Networks with limited node mobility. The reduction in length of IP address and its reusability is discussed. The authors also focus on GPS mapped MAC address and its indexing. In the proposed approach, the IP address length is minimized by 6.25 percent and 53.125 percent in comparison IPv4- and IPv6-address respectively. In contrast, the length of proposed MAC address is 10 bytes for identifying the unique node globally.**

Keywords—DER, DGs, IP address, MAC address, Multihop mesh network, OSG

I. INTRODUCTION

The Global Positioning System (GPS) furnish the global coordinates (latitude and longitude) for locating a location with unique address. The authors focus on employing the GPS coordinates as MAC address in Wireless Mesh Network (WMN). In the proposed WMN, each node (device) is located at fixed location geographically. Hence, this article focuses on reshaping the MAC address based on GPS coordinates (GPS-mapped MAC). The length of GPS-mapped MAC address is 10 bytes. The routing protocol in network layer utilizes the GPS-mapped MAC address for routing the packets in the network. When MAC address is accessed in the network, it may refer to an outright GPS coordinate, or it can instead refer to physical address of the node. Thus, the GPS coordinates are used to access the node globally can also be used for communication among the nodes in the Mesh Network. Each Node examined the destination address. If the destination address of the received packet is analogous to the node address, the incoming packet will be further processed by the node. Otherwise, the packet will be forwarded on to the next node.

To accommodate the nodes in the network, the coordinates provided by the GPS server must be reserved for the node and must not be available for other nodes across the geographical region. The reservation of address (GPS coordinates) may be permanent, or temporary (as achieved via MAC Indexing).

MAC Indexing is a technique in proposed mesh network, used to increase the amount of usable MAC addresses beyond the amount directly addressable by the GPS server. It can be used to configure a node differently at different times.

IP address reuse is the process of using the same IP address (logical address) on different mesh nodes within a network region that are separated by sufficient distance to cause minimal address conflict with each other. The IP address reuse allows for a dramatic increase in the number of mesh nodes that can communicate within a geographic area on a limited address length (limited number of addresses).

In the proposed concept, logical address allocated to the mesh node is re-used in a regular pattern of network regions, called 'clusters'. It also ensures that the address conflict between mesh nodes does not exist. The neighbor node always uses different logical address. In fact, a set of C different logical address {A1, ..., AC} are used for each cluster of C neighbor nodes.

The rest of the article is organized as follows: the section II discusses the application context of proposed architecture. Section III focuses on protocol stack, section IV describes the header structure at network layer and link layer involved in communication. The section V elaborates the address allocation and routing mechanism. Finally, section VI concludes the work.

II. APPLICATION CONTEXT

In electrical networks, the Distributed Generation system (DGs) or an on-site generation (OSG) is the electrical generation and its storage by distributed energy resources (DER). The effective utilization of electrical energy has motivated researchers to fuse the DER with mesh network for sharing the data among various grid-connected devices. Each grid-connected electrical device is equipped with Internet of Thing (IoT). The IoT has limited computational and communication capability. The IoT is considered as Mesh Node in the network that computes relevant information from OSG/DER and communicates over the network. The Mesh node does not have mobility during communication and can communicate over wired/wireless path. The structure of distribution grid [1] in electrical networks resembles mesh topology [1] in computer networks. This article focuses on the promiscuous deployment of OSG for the efficient and balanced flow electrical potential in the distributed grid of electrical networks. The authors [2] propose an addressing scheme that uses a 10 byte IP address and discuss the features routing protocol including functionality. The article [2] also focuses on the payload structure for effective sharing of electricity over Wireless Mesh Networks (WMN). The work is extended by author [3] to propose the routing algorithm (proactive and reactive) in WMN.

The application context also includes the forecasting of power (electrical energy) availability and the power

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requirement at respective Mesh Node. The forecasting module comprises of:

A. Betz's law:

Betz's law indicates the maximum power that can be utilized from the wind, independent of a wind turbine design in open flow. According to Betz's law, turbine can capture maximum of 59.3% of the kinetic energy in wind. The Betz's law is defined by:

$$P_{available}= 1/2 \rho A V^3$$

(Src: https://www.raeng.org.uk/publications/other/23-wind-turbine)

B. The forecasting algorithm:

The samples are collected with suitable time interval. The correlation between obtained samples is computed (New_value) and is used to forecast the power availability at each DGs. The formulas used in forecasting are as below.

Algorithm: PREDICT NEW VALUE.
Step 1: start
Step 2: Let X, Y are the sample means average.
Step 3: B=(∑(x-x`)(y-y`))/∑(x-x`)^2
where x` is mean of x and y` is mean of y.
Step4: A=y`-B.x`
Step 5: New_Value= A+B.x
Step 6: stop.

III. Protocol Stack

The modules within a protocol suite are often planned for a unique function. This modularization makes design and evaluation simple and easy. Each protocol module usually communicates with two others and hence, imagined as protocol layers in a stack. The figure 1 depicts the protocol stack of proposed model.

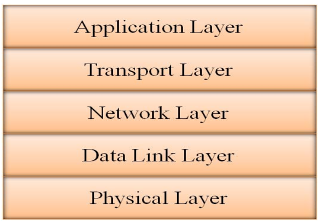

Fig 1. The Protocol stack.

The application layer is responsible for receiving/delivering the data from/to the application. The authors focus on the application context discussed in former section and explicate the payload structure [2] of packet.

The transport layer functionality in proposed stack is similar to that of transport layer in TCP/IP suite. However, in the context of this article, the UDP is best suited.

The network layer protocol makes use of logical address for locating a node uniquely. In IPv4 network, the address length is 4 bytes, and in IPv6 the address length is 16 bytes respectively. The authors propose 1-byte logical address. The packet header of proposed model is discussed in section IV.

The data link layer plays vital role in accessibility of medium for data exchange. Also, it adds the frame header and frame trailer (footer). The proposed frame structure differs from conventional frame structure in MAC address and its suitability for multi-hop network.

In this article, the dual antenna wireless medium is proposed so as to suit for communication between nodes separated by short and long distance.

The encapsulation of application data descending through the layers is depicted in figure 2.

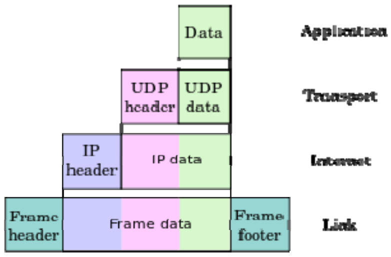

Fig 2. The data encapsulation by each protocol.

IV. Header Structure

In this section, the authors discuss the proposed header structures for network layer and data link layer.

Layer-3 header structure

The figure 3 depicts the packet header for proposed protocol. The fields in figure 3 are similar to the fields in IPv6 packet header. An additional field – *Destination Difference* (DD) is included in the header. The value of 'DD' is updated at intermediate node at each hop.

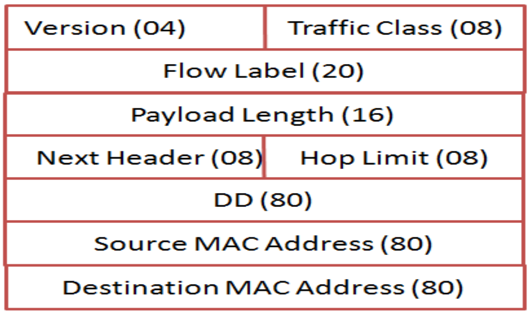

Fig 3. The proposed packet header.

The authors [2] propose the payload structure for application context discussed in section II. The routing strategies (proactive and reactive) discussed in article [3] are suitable for proposed model.

The figure 4 depicts the structure of proposed RTS frame. The fields: RA and TA indicate the 1-byte logical address of Receiver and Transmitter at each hop.

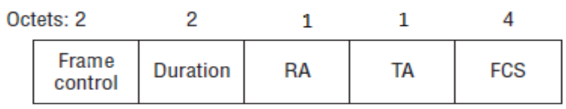

Fig 4. The proposed RTS frame.

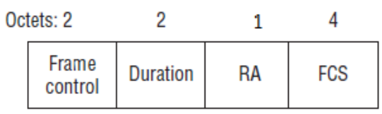

Fig 5. The proposed CTS frame.

The figure 5 depicts the structure of proposed CTS frame. The field 'RA' indicates the 1-byte logical address of Receiver in each hop.

Layer-2 header structure

In the proposed model, the mesh nodes communicate through wireless medium. Hence, the features of IEEE 802.11 frame format are necessary. However, authors propose exclusion of few fields so as to reduce size of frame overhead. The figure 6 depicts the proposed frame format.

Frame Control (2)	Duration ID (2)	Sequence Control (2)	Network Data (0-2312)	FCS(4)

Fig 6. The proposed frame format.

V. Address Allocation and Routing Algorithm

This section discusses the address allocation namely, MAC address and IP address and respective significance in routing the packets. The routing algorithm is responsible for efficient and effective routing of packet from source to the destination. The proposed architecture omits the use of subnet. Each node in proposed network is assigned a MAC address of 10 bytes. The MAC address comprises of two components namely: GPS coordinates (4 bytes of latitude, 4-bytes of latitude) and Index (2-bytes) and can be a physical address. However, the proposed IP address is of 1-byte and is logical address.

Node Initialization

A Mesh Node when initialized, send an Address Request (ADRQ) to Global Positioning System (GPS) server and receives the GPS coordinates (4-byte latitude, 4-byte longitude). The Mesh Node sends the Index Request (IRQ) to the Application- or Management-server. The Application- or Management-server replies with the 2-byte value representing index. The Mesh Node now possesses the 10-byte address and hive away as MAC address/physical address. The physical address of Source node and Destination node is involved in routing.

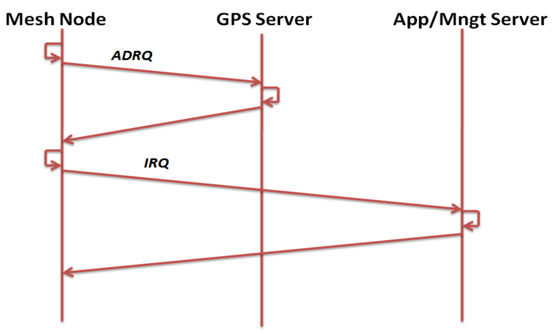

Fig 7. Physical Address allocation in mesh node (Sequence diagram)

4 Bytes	4 Bytes	2 Bytes

Fig 8. Format of proposed Physical Address

The figure 7 depicts the sequence diagram for obtaining physical address and figure 8 shows the fields of proposed physical address.

The 8-bit IP address (logical) is assigned to each Mesh Node. The value '0' (0x00) indicates that the node attempts to join network and the value '255' (0xFF) indicates that the routing table entries are exhausted.

Further, a node initially conforms '0' as the IP address. The node sends network JOIN request by broadcasting its MAC address and IP address to the neighbor nodes. The time elapsed till the node joins network is stated as *Joining Period*.

Throughout the *Joining Period*, the Mesh node receives the range of available IP address from each of its neighbors. It then identifies a unique value (say 'N') commonly available at most of the neighbor nodes. The unique value is then shared among the neighbors and gets connected to the network for updating the routing table. Hence, the routing table at the newly joined node is updated. The figure 9 depicts the process of obtaining logical address by mesh node.

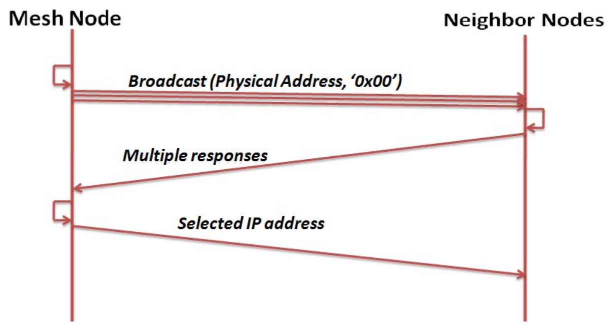

Fig 9. Obtaining Logical Address by mesh node (Sequence diagram)

Routing protocol

The routing protocol makes use of routing table built during initialization phase. As shown in figure 10, the routing table consisting of three entries: (a) the 1-byte IP address-logical (b) 10-byte MAC address-physical and (c) the 2-byte *difference*. The *difference* in routing table plays important role in determining the next suitable node for packet routing. The *difference* is computed as the actual difference between the MAC address of current node and the MAC address of respective neighbor node.

IP Address	MAC Address	Difference

Fig 10. The fields in proposed routing table.

At the source node, the destination MAC address is compared with self (source) MAC address and the *destination difference (DD)* is computed. The computed *DD* is placed in protocol header. When a packet is ready for transmission, the sender node reads the *DD* field in protocol header and a lookup is performed on its routing table. To perform *Directional Flooding* (DF), the next node is selected such that the absolute of deviation between respective *difference* and *DD* is nearly equal to Zero.

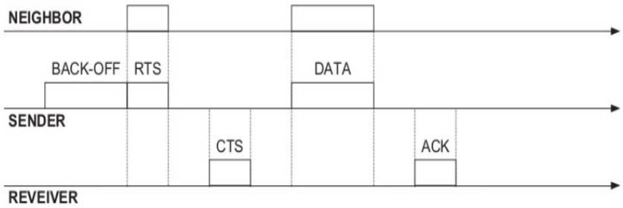

Fig 11. The fields in proposed routing table.

Once the next node is selected, the sender node issues a RTS (Request To Send) message using IP address (logical). In turn, the receiving node issues CTS (Clear To Send) message indicating the willingness to receive. By obtaining the CTS, the sender sends the packet. At each hop, the Acknowledgement (ACK) is given on successful packet transmission. A node is said to be destination iff the value of *DD* is Zero. The figure 11 illustrates the RTS-CTS-DATA-ACK scenario.

Density of nodes:

The nodes that actively transmit/receive data is said to be *participating node*. The density of nodes is defined as the total number of *participating nodes* accommodated in 1 square meter (Sq.mt.) of area. The survey has been carried out at various locations in India. During the survey, the 4 points (corners) namely A,B,C,D are chosen to form an area of 1 Sq.mt.. The readings obtained are tabulated in table 1.

Location	Points	Latitude	Longitude
Banahatti Rd	A	16.49501	75.18144
	B	16.49504	75.18137
	C	16.49509	75.18137
	D	16.49505	75.18136
Hanagandi	A	16.48674	75.07703
	B	16.48674	75.07704
	C	16.48674	75.07704
	D	16.48672	75.07698
Vijayapur City	A	16.84639	75.71161
	B	16.84644	75.71170
	C	16.84637	75.71152
	D	16.84648	75.71159
Vijayapur Rural	A	16.84670	75.79521
	B	16.84673	75.79523
	C	16.84678	75.79525
	D	16.84683	75.79526

TABLE I: GPS Coordinates sampled at various locations

The values of GPS coordinate are in floating point. Hence, we convert it to unsigned integer by multiplying with 10^5. The steps involved in computing the maximum density of *participating nodes* is as below:

i) At each given region in table 1, find the difference between maximum value and minimum value for latitude and longitude respectively (D_lat_{max}, D_long_{max}).
ii) Multiply D_lat_{max} and D_long_{max} of the given region. (P= D_lat_{max} x D_long_{max})
iii) The value for P indicates the maximum possible coordinates in the given region (1 Sq.mt.).
iv) Assign each GPS coordinate (latitude and longitude) to the node uniquely.

Location	D_lat_{max}	D_long_{max}	Available unique coordinates
Banahatti Rd	08	08	64
Hanagandi	02	06	12
Vijayapur City	11	18	198
Vijayapur Rural	08	05	40

TABLE II: Maximum Available GPS Coordinates within samples

The table 2 depicts the minimum density of *participating nodes* in a sample region as 12 and the maximum density of nodes as 64. Further, the density of *participating nodes* can be increased by appending the GPS-mapped MAC address with *Index*. This process is called as *MAC Indexing*. The length of *Index* in proposed approach is 2-bytes. Thus, the maximum density of p*articipating nodes* at each GPS-coordinate is 2^{16}.

Overhead incurred:

The overhead incurred at layer-3 address (IP address) and layer-2 (MAC address) in communication is discussed in this section. The advantage of proposed GPS-based MAC address and routing protocol architecture is also discussed.

In IPv4 network, the total overhead due to IP address is 8 bytes and the overhead due to MAC address is 24 bytes. Similarly, in IPv6 network, the overhead of 32 bytes is due to IP address and overhead of 32 bytes in WLAN frame header (MAC address).

The proposed protocol incurs the communication overhead of 20 bytes due to MAC address with 10 byte additional information (DD).

VI. CONCLUSION

In this article, the globally reusable logical address is proposed. The proposed logical address is 1 byte long. Also, the MAC address of 10-bytes is discussed. The suitability of routing mechanism [3] for preferred application context is highlighted by authors. Since the logical address (IP address) 1 byte is proposed, the reuse factor of proposed IP address is 0.0039. The routing protocol independent of subnet is discussed.

The traffic overhead due to IP address and MAC address in IPv4 network and IPv6 network is 32 bytes and 64 bytes respectively. However, the proposed protocol incurs overhead traffic of 30 bytes due to address. This ensures reduction of overhead by 6.25% and 53.125% in comparison with IPv4 and IPv6 network respectively.

The proposed model ensures the address space of at-least 65536 addresses per sq.mt. of area (assuming only one GPS coordinate per sq.mt.).

The proposed protocol can be simulated using the NS2/NS3, OMNET++ simulators. The traces from NS3 can be analyzed using wireshark.

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REFERENCES

[1] S V Vambase, S R Mangalwede, "A novel cross layer wireless mesh network protocol for distributed generation in electrical networks", IEEE, ISBN: 978-1-4799-6629-5, 2014, Pg: 885-888.

[2] S V Vambase, S R Mangalwede, "ATM based WMN architecture for Distributed Generation systems in electrical networks", IEEE, ISBN: 978-1-4673-7910-6, 2016, Pg:119-123.

[3] S V Vambase, S R Mangalwede, "WMN Routing Scheme to Reduce the Traffic Overhead based on GPS-Addressing", GRENZE, ISBN: 978-81-931119-9-4, 2017, Pg: 401-405.

[4] Rajkumar C. Shikkeri1, P. S. Khanagoudar2 and G. M. Patil3, "I-WMN: Intelligent System for Wireless Mesh Networks", ERCICA, ISBN: 978-93-510710-2-0, 2013, Pg: 332-337.

[5] Dong-Won Kum, Anh-Ngoc Le, You-Ze Cho, Chai Keong Toh, and In-Soo Lee, "An Efficient On-Demand Routing Approach with Directional Flooding for Wireless Mesh Networks", Journal of Communications and Networks, Vol. 12, 2010, Pg: 67-73.

[6] Wei-Liang Shen, Chung-Shiuan Chen, "Autonomous Mobile Mesh Networks", IEEE Transactions On Mobile Computing, Vol. 13, No. 2, 2014, Pg: 364-376.

[7] Seong Hoon Kim, Poh Kit Chong, and Daeyoung Kim, "A Location-Free Semi-Directional-Flooding Technique for On-Demand Routing in Low-Rate Wireless Mesh Networks", IEEE Transactions on Parallel and Distributed Systems, Vol. 25, No. 12, 2014, Pg: 3066-3075.

[8] Partha Dutta, Sharad Jaiswal, and Rajeev Rastogi, "VillageNet: A Low-Cost, IEEE 802.11-Based Mesh Network for Connecting Rural Areas", Bell Labs Technical Journal 12(2), 2007, Pg: 119–132.

[9] Lei Qin and Dongmei Zhao, "Channel Time Allocations and Handoff Management for Fair Throughput in Wireless Mesh Networks", IEEE Transactions On Vehicular Technology, Vol. 64, No. 1, 2015, Pg: 315-326.

[10] Xin Zhao, Jun Guo and Chun Tung Chou, "High-Throughput Reliable Multicast in Multi-Hop Wireless Mesh Networks", IEEE Transactions On Mobile Computing, Vol. 14, No. 4, 2015, Pg: 728-741.

[11] Greg Kuperman, Eytan Modiano, and Aradhana Narula-Tam, "Analysis and Algorithms for Partial Protection in Mesh Networks", J. Opt. Commun. Netw./Vol. 6, No. 8, 2014, Pg: 730-742

[12] Chun-Cheng Lin, Lei Shu and Der-Jiunn Deng, "Router Node Placement With Service Priority in Wireless Mesh Networks Using Simulated Annealing With Momentum Terms", IEEE Systems Journal, Vol. 10, No. 4, 2016, Pg: 1402-1411.

[13] Meng Li, Hiroki Nishiyama, Nei Kato, Yasunori Owada, And Kiyoshi Hamaguchi, "On the Energy-Efficient of Throughput-Based Scheme Using Renewable Energy for Wireless Mesh Networks in Disaster Area", IEEE Transactions On Emerging Topics In Computing, Vol 3, No. 3, 2015, Pg: 420- 431.

[14] Mohamad Sbeiti and Daniel Behnke, "PASER: Secure and Efficient Routing Approach for Airborne Mesh Networks", IEEE Transactions On Wireless Communications, Vol. 15, No. 3, 2016, Pg: 1950- 1964.

[15] Huang-Chen Lee and Hsiao-Hsien Lin, "Design and Evaluation of an Open-Source Wireless Mesh Networking Module for Environmental Monitoring", IEEE Sensors Journal, Vol. 16, No. 7, 2016, Pg: 2162-2171.

[16] Peng Yu, Bala Venkatesh, Amirnaser Yazdani and Birendra N. Singh, "Optimal Location and Sizing of Fault Current Limiters in Mesh Networks Using Iterative Mixed Integer Nonlinear Programming", IEEE Transactions On Power Systems, Vol. 31, No. 6, 2016, Pg: .4776- 4783.

[17] Ahmed Al-Saadi, Rossitza Setchi, Yulia Hicks and Stuart M. Allen, "Routing Protocol for Heterogeneous Wireless Mesh Networks", IEEE Transactions On Vehicular Technology, Vol. 65, No. 12, 2016, Pg: 9773- 9786.

[18] Shengyang Chen, Zhenhui Yuan, and Gabriel-Miro Muntean, "Balancing Energy and Quality Awareness: A MAC-Layer Duty Cycle Management Solution for Multimedia Delivery Over Wireless Mesh Networks", IEEE Transactions On Vehicular Technology, Vol. 66, No. 2, 2017, Pg: 1547-1560.

[19] Apostolos Apostolaras, George Iosifidis, Kostas Chounos, Thanasis Korakis, and Leandros Tassiulas, "A Mechanism for Mobile Data Offloading to Wireless Mesh Networks", IEEE Transactions On Wireless Communications, Vol. 15, No. 9, 2016, Pg: 5984-5997.

[20] Usman Ashraf , "Energy-Aware Gateway Placement in Green Wireless Mesh Networks", IEEE Communications Letters, Vol. 21, No. 1, 2017 Pg: 156-159.

[21] Pangun Park, Piergiuseppe Di Marco, and Karl Henrik Johansson, "Cross-Layer Optimization for Industrial Control Applications Using Wireless Sensor and Actuator Mesh Networks", IEEE Transactions On Industrial Electronics, Vol. 64, No. 4, 2017, Pg: 3250-3259.

[22] Hee-Tae Roh and Jang-Won Lee, "Channel Assignment, Link Scheduling, Routing, and Rate Control for Multi-Channel Wireless Mesh Networks with Directional Antennas", Journal Of Communications And Networks, Vol. 18, No. 6, 2016, Pg: 884-891

[23] Jie Hu, Member, IEEE, Lie-Liang Yang, Fellow, IEEE, and Lajos Hanzo, "Energy-Efficient Cross-Layer Design of Wireless Mesh Networks for Content Sharing in Online Social Networks", IEEE Transactions On Vehicular Technology, Vol. 66, No. 9, 2017, Pg: 8495-8509.

[24] Kostas Choumas, Ilias Syrigos, Thanasis Korakis, and Leandros Tassiulas, "Video-Aware Multicast Opportunistic Routing Over 802.11 Two-Hop Mesh Networks", IEEE Transactions On Vehicular Technology, Vol. 66, No. 9, 2017, Pg: 8372-8384.

[25] Ahmed Al-Saadi, Rossitza Setchi and Yulia Hicks, "Semantic Reasoning in Cognitive Networks for Heterogeneous Wireless Mesh Systems", IEEE Transactions On Cognitive Communications And Networking, Vol. 3, No. 3, 2017, Pg: 374-389.

[26] Fathollah Bistouni and Mohsen Jahanshahi, "Reliability Analysis of Ethernet Ring Mesh Networks", IEEE Transactions On Reliability, Vol. 66, No. 4, 2017, Pg: 1238-1252.

[27] Ashutosh Trivedi and Mukhtiar Singh, "L1 Adaptive Droop Control for AC Microgrid With Small Mesh Network", IEEE Transactions On Industrial Electronics, Vol. 65, No. 6, 2018, Pg: 4781-4789.

[28] Romain Favraud , Chia-Yu Chang , And Navid Nikaein, "Autonomous Self-Backhauled LTE Mesh Network With QoS Guarantee", Special Section On Mission Critical Public-Safety Communications: Architectures, Enabling Technologies, And Future Applications, Vol 6, 2018, Pg: 4083-4117.

[29] Canwen Xiao, Yue Yang And Jianwen Zhu, "A Sufficient Condition For Deadlock-Free Adaptive Routing In Mesh Networks", IEEE Computer Architecture Letters, Volume: 14, 2015, Pg: 111 – 114.