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Article

Wireless Mesh Network Routing Protocol Challenges -Traffic Engineering Solution

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Abstract: Wireless Mesh Network (WMN) is an evolving heterogeneous standard for multi-radio, multi-hop and multi-channel network technology. It has numerous potential, commercial advantages and is currently undergoing rapid research development and standardization. The growing need for adaptive and scalable routing protocol for heterogeneous mesh multi-hop network has enabled research into different areas of solutions. The high demand on the routing protocol for real-time multimedia traffics applications with its resultant high packet traffic, coupled with the inherent interference and scalability issues creates the need for a reliable routing protocol. In this paper, we studied the current solutions migration with more study emphasis on traffic engineering adaptation to Wireless mesh network routing protocol. This paper introduces a potential research opportunity in traffic engineering as a solution for path diversity, scalability, quality of service and security in WMN routing protocols.

Keywords: Wireless Mesh Network; Traffic Engineering; Multi Protocol label Switching

1. Introduction

Wireless Mesh Network (WMN) [1,2] as shown in Figure 1 consists of the quasi-static wireless mesh routers, nodes-access points and nodes-clients. The WMN routers acts as backbone to the wireless mesh architecture. These wireless mesh backbone routers can be interior or exterior gateway access to the internet protocol wireless cloud. The advent of WMN [3, 4] created a novel, low cost network, easily scalable over large networks. WMN is also a self-configuring, fast deployable and interoperable wireless network. Presently, using the different forms of the general architecture and structure, there exist infrastructure, non-infrastructure and hybrid types of WMN. The non-infrastructure WMN has no central hub, and so has the disadvantage of lower data traffic rates over multi-hop and heterogeneous WMN.

Nevertheless, its natural ease of self-configuration, self-healing and self-organization uses the decentralized architecture efficiently for interfacing and communicating with existing network protocol. WMN are infrastructure mobile networks. The network can either be connectionless or connect-oriented in operation during route discovery or in route establishment stages. The mesh clients run on batteries and have limited radio transmission ranges and traffic transmission to the next mobile nodes traverses the multi-hops node links through the Access Points (AP) to the backbone router infrastructure. Therefore, most wide area mesh architecture is hierarchal in topology. In WMN transmission operation, packets are forwarded to the upper layer AP the backbone gateways or bridge to the wireless cloud. These wireless mesh access techniques give the mesh networking added ease in integration through the inter-network interface connectivity with other wired networks and wireless standards like wireless local area network (WLAN), WIMAX (IEEE 802.16) and WIFI (IEEE 802.11n).

The unique structure of the WMN architecture, as shown in Figure 1 includes: its robustness, low cost, low battery power, reliability and ease of maintenance. WMN therefore can serve as access networks for wireless broadband, internet and other multimedia wireless networks. WMN is currently undergoing research development and standardization by the Internet Engineering Task Force (IETF) [5-7]. The technical developments are in research areas of increasing large network scalability, node mobility, security, Quality of Service (QoS), path diversity, transport and routing protocol. The WMN has other areas of improvement caused by the need for integration with other existing wireless or wired network standards. WMN will be a potential cheap access to community wireless broadband internet (IEEE 802.20).

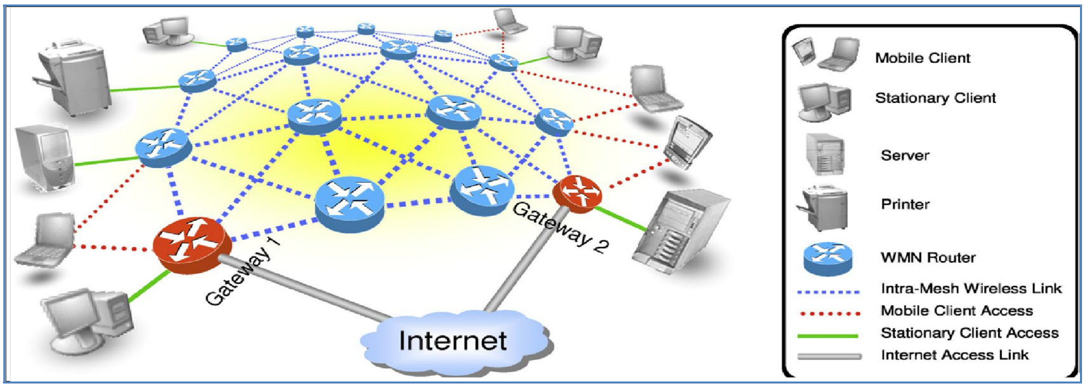

Figure 1: A WMN scenario with connected mobile nodes and routers

2. Traffic Engineering

The challenges in WMN routing protocol especially in traditional routing protocols: AODV, DSR, OLSR and DSDV, have created research opportunity for the resolution of scalability, link failures/recovery, path-diversity, bandwidth aggregation and network load balancing defects. The comparative analysis of using adaptation techniques and the challenges of partial solution, creates the need for a comprehensive approach to the problems in WMN routing Protocol.

The significant areas of research challenges such as load-balancing, path diversity, data transmission security, connectivity, congestion control and bandwidth aggregation as prevalent weakness in the routing protocol of WMN were highlighted. These weaknesses have resultant effects on route processing time, path determination and selection with the attendant processing overheads.

In view of the issues highlighted, we introduce Traffic Engineering (TE) [8-11] as a research opportunity and as a solution. It offers, unlike the older methods, Internet Protocol multi-addressing and comprehensive solution in achieving the resolutions of these challenges and imperfections in WMN routing protocol. Furthermore, it enables a traffic design approach for transmission mechanism in router to router and intermediate nodes with connectivity resolution which are avoided by the switched Labelled paths in the routing layer of the network.

Using analysis of the asymmetric flow communication in the WMN routing protocol, traffic transmission from the nodes to the gateway nodes then to the internet, we observe that the Internet Protocol cloud is usually the end destination of most data traffic. Internet Protocol addressing is a more effective mode of capturing the network topology and connectivity access. The route discovery and maintenance mechanism in the routing protocol stages requires each packet to carry the full addresses from the source node to the destination node for every hop in the network. This inadvertently means high control and processing overheads and high bandwidth over increasing network size (low scalability). The use of IP traffic engineering addressing and configuration lower the processing time and uses low overhead. IP addressing and quick capture algorithm converges faster than the older versions.

Most mobile nodes act as transceiver stations, their IP addressing are usually the best form for the resolution of link failures. Internet protocol Multiprotocol Label Switching (MPLS) virtual path network (VPN) creates a secure transmission path for notifications and acknowledgement of routing protocol traffic. It further directs the traffic data to the destination with reduced interference [8]. It also improves congestion control through connectivity using secured multi-path solution for traffic and data transmission in the Networks.

Routing layer research challenges such as scalability, connectivity, interference and congestion issues are better resolved using traffic engineering mechanism. Traffic engineering using MPLS technique creates additional multi-path route-redundancy for improved congestion control and link failure recovery [8]. It also improves the scalability of the networks by creating a high-connectivity environment. Alternate paths can be configured as access links in broadband and ISP for aggregation of multiple bandwidths in WMN routing protocol. This concept will be a technical departure from the typically adopted mechanism prevalent in most studies. Efficient designs of Traffic management techniques and algorithm are used as solution to achieve improved scalability with better load balancing, path-diversity and route connectivity solutions. Cooperative hybrid multi-path routing designs [10] such as the use of the MPLS layer 2.5 switching over routing on WMN routing Protocol are facilitating much needed solutions in WMN routing protocol.

The use of MPLS traffic Engineering (MPLS-TE) [9] have shown remarkable improvements on bandwidth aggregation and load balancing mechanism in the routing layer of the WMN. The Multi-Protocol Label Switching (MPLS) creates a path balance of packets transmission and flow of data. It further creates a pathway for message retransmission and failure notifications while transmitting acknowledgement in the routing protocol. The internet protocol addressing and design configuration of this tunnelling with respect to WMN delivers a high QOS in WMN [10]. The adapted improvement in computation of the configuration improves scalability, bandwidth aggregation, load balancing and reduced congestion delays. It also increases fault tolerance and stability of routes in WMN multimedia traffic transmission compared to other variants and traditional routing protocols as previously discussed.

In WMN routing protocol, the architecture and operation from our study shows that there exists an asymmetric traffic transmission starting from the peripheral node to the access point (AP) then further down to the routing protocol backbone/ Interior gateway to the wireless cloud. These traffic flows in the wireless mesh network routing protocol creates a traffic re-engineering solution which is a departure from the usual network infrastructure hardware resolution. It is analogical to solving traffic road congestion either by building new access paths to lessen traffic flow or putting in place traffic regulatory access lights to control traffic density and road usage. They are both good concepts depending on the traffic design and its mechanism of operation.

Wireless mesh network traffic engineering (TE) is the mechanism of achieving efficiency by traffic manipulation to fit the network resources. It can be configured by IP addressing, IP routing and configuration. In addition, traffic engineering can be achieved by changing the interface IP metrics in large wireless mesh networks; however, this may create huge overheads in a large network. Multi-protocol LAN switching (MPLS) between the layers 2.5 to layer 3 of the OSI layer model can resolve these issues by intelligent mapping of two or more divergent architectures, routing protocols, address spaces, signalling protocols, resource allocation and even enhanced bandwidth access.

3. MPLS Traffic Engineering and IP Tunnelling

Multi-protocol Label Switching (MPLS) enables the mechanism for traffic engineering in wireless mesh network traffic patterns that is independent of routing tables. MPLS is also independent of any routing protocol, resulting in less processing time and overhead. In the network, it can act as independent or combine with existing switching circuits' mechanism to provide routing services and gateway function sometimes when needed. This technique differentiates the bandwidth priority and access therefore improves the processing time and lowers overhead and latency.

As shown in the Figure 2, it works on the principle of assigning short label tags to network packets (data packets); this label tags are 20 bits unsigned integer, carrying detailed information on the mechanism of achieving end-to end transmission of data through the network. Traffic engineering techniques involve creating label switched-paths (LSP) among the mesh routers in the wireless mesh network. These switched paths are connect-oriented and provide an alternate path from source to destination packet traffic without going through the next node or sets of nodes hops transmission. The purpose of traffic engineering in a network layer is to deliver priority based and time sensitive traffic over the network in a shorter time. Furthermore, the encapsulation of these Label switched path in traffic engineering enables secure pathway for data transmission. Geo-position location proactive routing protocol can be tracked using IP addresses and the MAC address of the mobile stationery nodes in the WMNs. In the routing layer operation, the data packet transmit from one router to the next, an independent forwarding logical decision is made at each hop. The IP network layer header is checked, and the next-hop is chosen based on the metric and on the information on the routing table. In an MPLS operation, the analysis of the packet header is performed just once, when a packet enters the MPLS cloud [11]. This ensures less overhead and speed of convergence from source to destination in the WMN. The MPLS enabled wireless mesh network is highly scalable. In MPLS operation, the packet is assigned / tagged to a traffic stream identified by a label, which is a short (20-bit), fixed-length value at the front of the packet. These labels are mapped to the label forwarding table. This table stores information on traffic forwarding and the labels like class of service are used in packet prioritizing before transmission i.e. VOIP, Skype and MPLS.

In this research, we came to the summation that most challenges and problems with the routing protocol of the WMNs are transmission faults and the ineffectiveness of the algorithms/mechanisms. In some existing routing protocols, partial solutions for the weakness generate other challenges and weaknesses. In resolving these problems, evaluation of the solutions and their mechanisms was done on the existing routing protocols. Therefore, path diversity in packet transmissions will provide an effective solution in the WMN routing protocol. MPLS enables the multiple alternate transmissions and routing of the packets in WMNs. This mechanism, in operation within a wireless network, gives secure traffic transmission and path diversity in the network. In addition, it provides a secured path for data encapsulation and tunnelling for these packets, videos and voice traffics especially in IP VPN tunnelling. Furthermore, MPLS-TE gives good load-balancing and improved connectivity especially against drop calls in the routing layer of the WMN.

Label: Label value, 20bits

CoS: Class of service, 3bits (also known as experimental bits)

S: Bottom of stack, 1bit

TTL: Time to live, 8bits

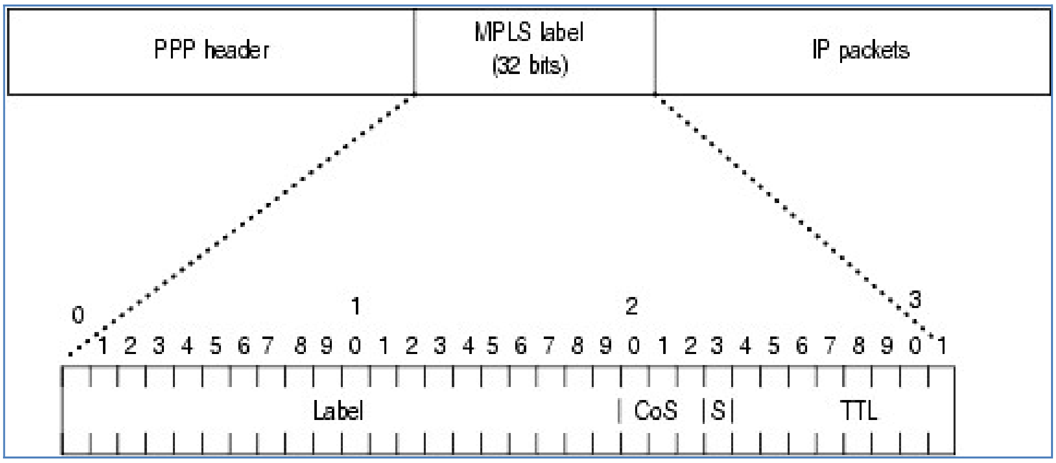

Figure 2: Label Allocation in MPLS Routers.

4. Advantages of Traffic Engineering

In multimedia and real-time type traffic environment, divergent multiple traffic streams with different service requirements as in Figure 2 contend for transmission access on a limited bandwidth; traffic engineering provides the class prioritization and efficient use of network resources. It provides administration and negotiated sharing and network bandwidth optimization.

In real-time network operations, high capacity utilization of service and fault resolution must be adopted for multiple link failure scenarios. Simultaneously, there must be mechanisms to efficiently and speedily re-route traffic through redundant link capacity. On recovering from the faults, optimization may be necessary to include the restored capacity of time-sensitive operations like traffic routing in multimedia video or online streaming television.

Traffic congestion and link-failures both occur when network resources are overwhelmed by the traffic during transmission and when the transmission is experiencing interferences/network problems. It may be due to hierarchal bottlenecks on the border gateway protocol access (BGP). This suggests that the network design or parameters are inadequate to accommodate traffic load. The design may be poor whereby traffic streams are not effectively mapped to available network resources resulting to the partial utilization of network resources. Congestion resolution can be improved using traffic engineering to effectively map network resources.

The challenges of intermediate nodes (router) in routing protocol are mostly with regards to the connectivity and processing time of routed traffics and packets. In addition, it addresses convergence, optimal routes selection in the route discovery stages and path determination in dynamic mesh routers. MPLS-TE provides direct alternate path to destination nodes bypassing intermediate nodes. The location, selection and determination of a route in the routing protocol and the eventual failure resolution of a link or node in WMN differs, depending on the metric, topology and architecture.

Qualities of MPLS-TE as a possible future solution for improved, low processing and less overhead high data transmission as obtained in multimedia traffics in WMN was identified. In addition, metrics and different algorithms in routing protocol were evaluated. We will not be discussing the implementation of the mechanism in WMN and techniques of MPLS-TE in this paper. Observation has shown that cross solution or comprehensive resolution of these challenges will provide the needed standard for routing protocol for WMN. A standard wireless standard will improve reliability, interoperability and integration with other wireless standards. It would provide standard platform for scalable meshing and multi-access in community broadband and enterprise wireless networks.

5. Results

We reviewed different IEEE 802.11 standard routing protocol algorithms and the alternative proposed algorithms stemmed from adaptations and modifications of the ad hoc network standard algorithms for both MANET and WMN. While the emerging IEEE 802.11s standard routing protocols are being considered and tested, more innovations are being proposed. There are also proposed improved-variants and hybrid WMN routing protocol versions. The routing protocols were reviewed based on packet transmission and connectivity issues. The study showed that diverse types of routing protocols have different attributes, strengths and advantages. Nevertheless, these proposed routing protocols also bring disadvantages and flaws, when used in diverse routing applications or network topologies. The routing flaws and challenges such as count-to-infinity, spoofing, delay location and speed of updates or failure recovery perform variably in different operations namely proactive or reactive. There is also a structural factor: cluster-based, hierarchical or flat architecture of the network transmission and also the routing table update mechanism. We deduced that mobility and randomness of the traffic at client-nodes are directly proportional to the network's traffic load and the load balancing. The transmitting spectrum of traffic may be multimedia, bidirectional or single way network traffics such as they can be constant, burst or periodic. The variation of the traffic has a limiting or sublime effect on the overall performance metric. Some IP traffics may be time-sensitive in data packets transmissions and such will require prioritization in WMN.

The traffic engineering technique is introduced as a research opportunity is a holistic and more comprehensive approach to achieving a routing operation which can work in different terrains and scenarios. MPLS being multi-layer path diversity and equally comprehensive solution is able to overcome most of the challenges and flaws analysed in the preceding sections. It will open an area of research opportunity in resolving routing protocol challenges by configuring secure tunnels and traffic paths using IP routing commands and addressing.

Transmissions using traffic engineering techniques can create path diversity for failed packets retransmission and facilitate faster routing table updates. This can enhance efficient connectivity, throughput and bandwidth in WMN routing protocol. Furthermore, the retransmission of data packets and acknowledgement of route requests may resolve the "looping" or counting to infinity problems in WMN routing protocol. Consequently, there will be faster routing protocol convergence and faster updates in short link-state route protocol information.

The traffic engineering label mapping tag technique reduces overhead and processing time. It also saves time in routing tables updating and speed of convergence. The IP configuration and addressing removes the instances of looping and count to infinity error challenges. The location management, GPS and directional based routing protocols all have high processing and overhead which increase latency, is resolved using IP addressing and intelligent configuration. IP addressing resolves mesh client node location. The comprehensive proposed research opportunity shows that even with the best metrics optimal routing is not only ensured but can be improved in a multi-layer optimization using TE. Research emulation test beds and evaluations have not been explored as of the time this paper is produced but a lot of works has been done on MPLS-TE routing protocol for WMNs.

6. Conclusion

In this paper, analysis and study was carried out on the WMN, the design migration and developmental trends in wireless mesh network routing protocol was done. Our study focus was more on the routing protocol layer. We highlighted many and divergent techniques the routing protocols capture the challenges of the traditional older ad hoc network routing protocol.

An open research opportunity on traffic engineering mechanism in synergy with the WMN was explored. The resolutions of existing routing protocol challenges were studied too. The numerous design-creative and adapted solutions to routing protocol network traffics were compared and objectively discussed. Furthermore, formulating comprehensive solutions through multi-faceted IP approaches to these major challenges offering the network resolution through traffic engineering - MPLS transmission engineering mechanism.

The proposed mechanism could improve path diversity, scalability, load balancing and security of the routed packets in routing protocol of wireless mesh protocol. This MPLS-TE can equally improve efficiency in bandwidth aggregating and connectivity especially in broadband networks. The advances in traffic engineering techniques using low-computationally overhead and low processing IP configurations and commands will further encourage potential commercial usage and adoption for faster forward switching routing protocol and the combined mechanism of traffic engineering and routing will promote faster data packet transmission in WMN. Traffic engineering mechanism also creates a secured packet traffic transmission over wireless mesh network.

TE also gives the administrator an enhanced flexibility approach in QoS and real time prioritization which in turn increases the scalability and load balance in WMN. TE addressing and intelligent configuration command can also increase the resultant throughput during transmission. These open research potentials will also generate a multi-protocol holistic standard for WMN. All these raised issues and possibility are open to further scientific research test and analysis.

REFERENCES

[1] F. Akyildiz, X. Wang, and W. Wang, “Wireless Mesh Networks: A Survey,” Computer Networks, vol. 47, no. 4, pp. 445-487, March 2005.

[2] J. Jun and M. L. Sichitiu, “MRP: Wireless Mesh Networks Routing Protocol,” Computer Communications, vol. 31, pp. 1413 – 1435, 2008.

[3] R. Bruno, M. Conti, and E. Gregori, “Mesh Networks: Commodity MultiHop Ad Hoc Networks,” IEEE Communications Magazine, vol. 43, no. 3, pp.

123-131, 2005.

[4] M. Bahr, J. Wang, and X. Jia, “Routing in Wireless Mesh Networks,” in Wireless Mesh Networking: Architectures, Protocols and Standards, Y.

Zhang, J. Luo, and H. Hu, Eds.: Auerbach Publications, 2007.

[5] B. Li, Q. Zhang, J. Liu, C. Wang, X. Wang, and K. Farkas, “Advances in Wireless Mesh Networks,” ACM Journal on Mobile Networks and

Applications, vol. 13, pp. 1-5, 2008.

[6] M. J. Lee, J. Zheng, Y.-B. Ko, and D. M. Shrestha, “Emerging Standards For Wireless Mesh Technology,” IEEE Wireless Communications, [see also IEEE Personal Communications], vol. 13, no. 2, pp. 56-63, 2006.

[7] IEEE Standards, “IEEE 802.11TM Wireless Local Area Networks,” The Working Group for WLAN Standards, Ongoing.

[8] C. T. Chou, “Traffic engineering for MPLS-based virtual private networks,” Computer Networks: The International Journal of Computer and Telecommunications Networking, vol. 44, no. 3, pp.319-333, February 2004.

[9] I. C.haieb, J-L. Le Roux, and B. Cousin, “A Routing Architecture for MPLS-TE Networks,” Proceedings of the fourth International Working Conference on Performance Modelling and Evaluation of Heterogeneous Networks (HET-NETs '06), September 2006.

[10] O.E. Muogilim, K.K. Loo, R. Comley, “Wireless mesh network security: A traffic engineering management approach”, Elsevier Journal of Network and Computer Applications, 2010. (IN PRESS)

[11] D. Adami, R. G. Garroppo, S. Giordano, L. Tavanti, Multi-Constrained Path Computation Algorithms for Traffic Engineering over Wireless Mesh Networks, First IEEE WoWMoM Workshop on Hot Topics in Mesh Networking (HotMesh), Kos, 15-19 June 2009