International Journal of Scientific Research in Computer Science, Engineering and Information Technology
© 2017 IJSRCSEIT | Volume 2 | Issue 2 | ISSN : 2456-3307

Routing Protocol for Heterogeneous Wireless Mesh Network

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ABSTRACT

Heterogeneous metropolitan area network architecture is proposed that combines an IEEE 802.11 wireless mesh network with a long- term evolution network. In addition with this Cognitive Heterogeneous Routing proposed to select appropriate transmission technology based on parameters from each network. The introduction of heterogeneous wireless mesh technologies provides an opportunity for higher network capacity, wider coverage, and higher Quality of Service (QoS). Each wireless device utilizes different standards, data formats, protocols, and access technologies. However, the diversity and complexity of such technologies create challenges for traditional control and management systems. The proposed heterogeneous network overcomes the problems of sending packets over long paths, island nodes and interference in wireless mesh network and increases the overall capacity of the combined network by utilizing unlicensed frequency bands instead of buying more license frequency bands for LTE. The work is validated through extensive simulations that indicate that the proposed heterogeneous wireless mesh network outperforms the LTE and Wi-Fi networks when used individually. The simulation results show that the proposed network achieves an increase of up to 200% increase in throughput compared with Wi-Fi-only networks or LTE-only networks.

Keywords : Quality of Service, IEEE 802.11, Routing Protocol for Heterogeneous Wireless Mesh Network, Wi-Fi, LTE, WMN, MAN, WiMAX

I. INTRODUCTION

Recently, Wireless Mesh Network technology has become popular, especially for its low cost deployment in the areas of poor network infrastructure and terrain of difficult deployment. Wireless Mesh Networks have emerged recently as a promising technology for next-generation wireless networking to provide better services. INTERNET traffic is expected to increase three to five times over the next three years due to the growing number of connected mobile devices. The number of connected devices and machine-to-machine communications is expected to exceed the number of the population by a factor of two over the next three years. It is predicted that within the next decade, a more advanced Internet infrastructure will be required to support this increase in the Internet traffic.

Next-generation wireless networks need to address several challenges, including the cost to cover high-density areas, crowded events, large areas or respond to temporary changes in demand e.g large sporting events. The cost estimation is dependent on the number of required base stations and the cost to rent frequency bands. Interoperability is another challenge as many devices use different operating systems, protocols, and access technologies. Network reliability is also an important issue that needs to be addressed to ensure systems are able to tolerate faults in case of disasters. The internetworking of different wireless technologies, particularly Long-Term Evolution (LTE) and Wireless Local Area Networks (WLAN), is one of the key opportunities for developing next-generation wireless networks.LTE is an evolution of the 3G standard, which provides wide coverage and a peak transmission rate ranging from 100 to 326.4 Mbps on the downlink (from base station to user equipment) and 50 to 86.4 Mbps on the uplink (from user equipment to base station) depending on antenna configuration and modulation depth. Due to the advanced technologies employed in LTE networks, it is used by major mobile operators around the world to cope with the high traffic demands. However, LTE networks employ licensed frequency bands, and so to provide more bandwidth, an additional cost is introduced to either buy more

frequency bands (which may not be available in all regions) or invest in a higher density of base stations.
Another promising wireless architecture for the next generation of wireless networks is Wireless Mesh Networks (WMNs). The WMN is a paradigm developed to provide wide network coverage without using centralized infrastructure. Therefore, WMNs are a feasible choice to provide a backbone network for Metropolitan Area Networks (MANs). In such networks, gateways (wireless nodes with a high-speed wired connection to the external Internet) are employed to provide Internet connection to the mesh network. This architecture offers cost-effective ubiquitous wireless connection to the Internet in large areas through multi-hop transmission to the gateway and vice versa. However, the major drawbacks of using WMNs are their limitations in terms of capacity, system performance, and guaranteed wireless link quality. The causes of those problems originate in the multi-hop nature of the network.

II. LITERATURE SURVEY

2.1 Wireless mesh networks: a survey

Wireless Mesh Networks (WMNs) consist of mesh routers and mesh clients, where mesh routers have minimal mobility and form the backbone of WMNs. They provide network access for both mesh and conventional clients. The integration of WMNs with other networks such as the Internet, cellular, IEEE 802.11, IEEE 802.15, IEEE 802.16, sensor networks, etc., can be accomplished through the gateway and bridging functions in the mesh routers. Mesh clients can be either stationary or mobile, and can form a client mesh network among themselves and with mesh routers. WMNs are anticipated to resolve the limitations and to significantly improve the performance of ad hoc networks, Wireless Local Area Networks (WLANs), Wireless Personal Area Networks (WPANs), and Wireless Metropolitan Area Networks (WMANs). They are undergoing rapid progress and inspiring numerous deployments. WMNs will deliver wireless services for a large variety of applications in personal, local, campus, and metropolitan areas.

Despite recent advances in wireless mesh networking, many research challenges remain in all protocol layers. This paper presents a detailed study on recent advances and open research issues in WMNs. System architectures and applications of WMNs are described, followed by discussing the critical factors influencing protocol design. Theoretical network capacity and the state-of-the-art protocols for WMNs are explored with an objective to point out a number of open research issues. Finally, test beds, industrial practice, and current standard activities related to WMNs are highlighted. As various wireless networks evolve into the next generation to provide better services, a key technology, Wireless Mesh Networks (WMNs), has emerged recently. In WMNs, nodes are comprised of mesh routers and mesh clients. Each node operates not only as a host but also as a router, forwarding packets on behalf of other nodes that may not be within direct wireless transmission range of their destinations. A WMN is dynamically self-organized and self-configured, with the nodes in the network automatically establishing and maintaining mesh connectivity among themselves (creating, in effect, an ad hoc network).
This feature brings many advantages to WMNs such as low up-front cost, easy network maintenance, robustness, and reliable service coverage. Conventional nodes (e.g., desktops, laptops, PDAs, Pocket PCs, phones, etc.) equipped with wireless network interface cards (NICs) can connect directly to wireless mesh routers. Customers without wireless NICs can access WMNs by connecting to wireless mesh routers through, for example, Ethernet. Thus, WMNs will greatly help the users to be always-on-line anywhere anytime. Moreover, the gateway/bridge functionalities in mesh routers enable the integration of WMNs with various existing wireless networks such as cellular, wireless sensor, Wireless Fidelity (Wi-Fi), worldwide inter-operability for microwave access (WiMAX), WiMedia networks.

Consequently, through an integrated WMN, the users of existing network can be provided with otherwise impossible services of these networks. WMN is a promising wireless technology for numerous applications, e.g., broadband home networking, community and neighborhood networks, enterprise networking, building automation, etc. It is gaining significant attention as a possible way for cash strapped Internet Service Providers (ISPs), carriers, and others to roll out robust and reliable wireless broadband service access in a way that needs minimal up-front investments. With the capability of self-organization and self configuration, WMNs can be deployed incrementally, one node at a time, as needed. As more nodes are installed, the reliability and connectivity for the users increase accordingly. Deploying a WMN is not too difficult because all the required components are already available in the form of ad hoc network routing protocols, IEEE 802.11 MAC protocol, Wired Equivalent Privacy (WEP) security, etc. Several companies have already realized the potential of this technology and offer wireless mesh networking products.

A few test beds have been established in university research labs. However, to make a WMN be all it can be, considerable research efforts are still needed. For example, the available MAC and routing protocols applied to WMNs do not have enough scalability; the throughput drops significantly as the number of nodes or hops in a WMN increases. Similar problems exist in other networking protocols. Consequently, all existing protocols from the application layer to transport, network MAC.

Researchers have started to revisit the protocol design of existing wireless networks, especially of IEEE 802.11 networks, ad hoc networks, and wireless sensor networks, from the perspective of WMNs. Industrial standards groups are also actively working on new specifications for mesh networking. For example, IEEE 802.11, IEEE 802.15, and IEEE 802.16 all have established sub-working groups to focus on new standards for WMNs. WMNs consist of two types of nodes: mesh routers and mesh clients. Other than the routing capability for gateway/repeater functions as in a conventional wireless router, a wireless mesh router contains additional routing functions to support mesh networking.

To further improve the flexibility of mesh networking, a mesh router is usually equipped with multiple wireless interfaces built on either the same or different wireless access technologies. Compared with a conventional wireless router, a wireless mesh router can achieve the same coverage with much lower transmission power through multi-hop communications. Optionally, the Medium Access Control (MAC) protocol in a mesh router is enhanced with better scalability in a multi-hop mesh environment. In spite of all these differences, mesh and conventional wireless routers are usually built based on a similar hardware platform. Mesh routers can be built based on dedicated computer systems (e.g., embedded systems) and look compact, as shown. They can also be built based on general-purpose computer systems (e.g., laptop/ desktop PC). Conventional clients with Ethernet interface can be connected to mesh routers via Ethernet links.

For conventional clients with the same radio technologies as mesh routers, they can directly communicate with mesh routers. If different radio technologies are used, clients must communicate with the base stations that have Ethernet connections to mesh routers. Infrastructure/Backbone WMNs are the most commonly used type. For example, community and neighborhood networks can be built using infrastructure meshing. The mesh routers are placed on the roof of houses in a neighborhood, which serve as access points for users inside the homes and along the roads. Typically, two types of radios are used in the routers, i.e., for backbone communication and for user communication, respectively. The mesh backbone communication can be established using long-range communication techniques including directional antennas. Client WMNs. Client meshing provides peer-topper networks among client devices.

In this type of architecture, client nodes constitute the actual network to perform routing and configuration functionalities as well as providing end-user applications to customers. Hence, a mesh router is not required for these types of networks. In Client WMNs, a packet destined to a node in the network hops through multiple nodes to reach the destination. Client WMNs are usually formed using one type of radios on devices. Moreover, the requirements on end-user devices is increased when compared to infrastructure meshing, since, in Client WMNs, the end-users must perform additional functions such as routing and self-configuration. Hybrid WMNs architecture is the combination of infrastructure and client meshing as shown. Mesh clients can access the network through mesh routers as well as directly meshing with other mesh clients. While the infrastructure provides connectivity to other networks such as the Internet, Wi-Fi, WiMAX, cellular, and sensor networks; the routing capabilities of clients provide improved connectivity and coverage inside the WMN. The hybrid architecture will be the most applicable case in our opinion.

III. SYSTEM INFORMATION

3.1 Existing System

Destination-sequenced distance vector and optimized link state routing are routing protocols that maintains the route table for each destination; transmission begins with no delay if there are packets ready to be sent. Therefore, WMNs are a feasible choice to provide a backbone network for Metropolitan Area Networks (MANs). In such networks, gateways (wireless nodes with a high-speed wired connection to the external Internet) are employed to provide Internet connection to the mesh network. This architecture offers cost-effective ubiquitous wireless connection to the Internet in large areas through multi-hop transmission to the gateway and vice versa. However, the major drawbacks of using WMNs are their limitations in terms of capacity, system performance, and guaranteed wireless link quality.

The causes of those problems originate in the multi-hop nature of the network. When data packets traverse more hops in a large WMN, they may either fail to reach their destination or consume too many network resources. Moreover, in case of link or node failure, some nodes may become isolated from the network due to the lack of a path to the destination or gateway, and form what is known as an 'island node'. The use of heterogeneous technologies in wireless networks improves the overall network performance by distributing the load across different network technologies. However, switching from one transmission device to another presents challenges as each wireless device utilizes different standards and data formats. Furthermore, routing packets through a heterogeneous network requires a new mechanism to exchange control messages among the different networks.

3.1.1 Limitations

- Reactive routing causes some delay due to the fact that a route is created only when there is data ready to be sent
- Some overhead is added for distributing routing table information among the nodes in the network

3.2 Proposed System

The Heterogeneous Routing Protocol employs from both networks to switch between transmission technologies. It contains heterogeneous routing tables and a routing algorithm. In the case of mesh gateway nodes, the routing table maintains a list of the heterogeneous nodes for which it is responsible in order to connect them to the Internet. the proposed routing protocol is the new algorithm developed, referred to here as Cognitive Heterogeneous Routing (CHR), which selects the most suitable transmission technology based on parameters from both of the utilized transmission technologies. CHR employs the generated routing tables to select the best route to send the traffic demands. The CHR is responsible for selecting the best radio access network while the routing tables maintained by each node find the route to the Internet. In case a HetNode selects Wi-Fi device, it uses the routing table to send the packets to the next hop on the path of the selected Mesh Gateway.

CHR adopts a multi-rate Medium Access Control (MAC) protocol for 802.11 called Rate Adaptation Based on Reinforcement Learning (*RARE*). RARE was developed for a WMN only environment to consider the collision and interference in the neighboring nodes. It employs the transmission rate as a metric to measure the quality of the WiFi channel. RARE reduces the transmission rate when interference is identified on the link and increases it when the interference is low. Thus, the algorithm infers that the wireless channel quality is good when the transmission rate is high. This work employs IEEE 802.11a, which supports eight different transmission rates: 6, 9, 12, 18, 24, 36, 48, and 54Mbps. A core element of CHR is the new algorithm developed to estimate which transmission technology is the best to send the traffic. It is based on reinforcement learning and Q-learning.

3.2.1 Advantages

Increase the overall network capacity and enhance the average throughput.
Estimates the cost of transmitting the traffic through each network.

IV.CONCLUSION

This project introduces new heterogeneous network architecture in which LTE and Wi-Fi wireless devices are utilized in order to benefit from the bandwidth of each transmission technology. In addition, a new routing protocol for heterogeneous wireless mesh networks is developed, which selects dynamically the transmission technology in order to increase the overall network capacity and enhance the average throughput. Moreover, a new routing algorithm is proposed for the needs of the routing protocol, which estimates the cost of transmitting the traffic through each network. The proposed algorithm considers the traffic load on the LTE network as a metric to estimate the cost of transmission over LTE and uses transmission rate as a metric for the Wi-Fi mesh network. The simulation results show that the proposed network achieves up to 200% more throughput compared with Wi-Fi-only networks and LTE-only networks. The heterogeneous network architecture manages the different wireless devices as a part of single virtual network. The LTE network is utilized to avoid congested Wi-Fi nodes and high interference path in the WMN while the WMN offloads the load of the LTE network, reduces the cost of using more license frequency bands and forwards the data to another node when the LTE throughput is degrading. This work provides the foundation for future research on developing heterogeneous Wi-Fi / LTE mesh networks and using other wireless technologies as part of heterogeneous networks. The proposed routing protocol has the potential to be extended to support other wireless technologies by utilizing their parameters in the learning algorithm. The proposed architecture provides an easy way to expand the mobile network coverage and capacity and could contribute to the 5G infrastructure. Moreover, the heterogeneous networks could be used to connect the Internet of Thing networks and employed to provide the infrastructure for smart homes and smart cities.

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