Heterogeneous Wireless Mesh Networks using Routing Protocol
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Abstract:
The heterogeneous wireless mesh technology provides an opportunity for higher network capacity, wider coverage, and higher quality of service (QoS). Each wireless device utilizes the different standards, data formats, protocols, and access the technologies. However, the diversity and complexity of such technologies create challenges for traditional control and management systems. This paper aims to propose a heterogeneous metropolitan area network architecture that combines an IEEE 802.11 wireless mesh network with a long-term evolution (LTE) network. In addition, a new heterogeneous routing protocol and routing algorithm based on reinforcement learning called Cognitive Heterogeneous Routing (CHR) are proposed to select the appropriate transmission technology based on parameters for each network. 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 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 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 the throughput compared with Wi-Fi-only networks or LTE-only networks.

I. INTRODUCTION

The INTERNET traffic is expected to increase over the couple of 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 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, the large areas or react to temporary changes in demand. The cost estimation is dependent on the number of required base stations and the cost to rent frequency bands. Interoperability is another confront as many devices use diverse 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 the developing next-generation wireless networks. LTE is an evolution of the 3G standard, which provides wide coverage and a peak the transmission rate ranging from 100 to 326.4 Mbps on the downlink (from base station to user kit) and 50 to 86.4 Mbps on the uplink (from user kit to base station) depending on antenna to configuration and modulation depth. Due to the advanced technologies working in LTE networks, it is used by major mobile operators around the world to hack it with the high traffic demands. However, LTE networks employ licensed the frequency bands, and so to provide more bandwidth, an extra cost is introduced to either buy more frequency bands (which may not be available in all regions) or invest in a higher density of the base stations.

II. RELATED WORK

This section reviews the advanced approaches to managing heterogeneous wireless networks and discusses the advantages and disadvantages of each approach. The management of heterogeneous networks involves employing different technologies that cooperate with each other in order to improve both the system performance and the metrics utilized to select the transmission technology. The proposed work employs on WMNs in the heterogeneous networks architecture, and therefore this review first highlights related work on WMN routing protocols and metrics. This is followed by a review of heterogeneous network architectures.

A. Routing Protocols in MNs

There are two type of routing protocol in WMNs. The first type consists of automatic routing protocols in which the route is created on demand by flooding the network with route requests. The route selection is maintained only for nodes that transmit traffic to a particular end. Examples of this type of routing are ad hoc on-demand distance vector (AODV) and dynamic source routing (DSR). Automatic routing causes some delay due to the fact that a route is created only when there is data ready to be sent. The second type of routing protocol consists of the proactive or table-driven routing protocols. They maintain a table of the whole destination in the network by periodically distributing an update of the routing table to all nodes. The Destination sequenced distance vector (DSDV) and optimized link state routing (OLSR) are examples of this type of routing protocol. The route table maintains the route the each destination; transmission begins with no delay if there are packets ready to be sent. However, a few overhead is added for distribute routing table information to among the nodes in the…
network. Some routing protocols, known as the hybrid routing protocols, combine reactive and proactive routing to reduce the overhead of route discovery by employing proactive routing for near nodes and the generating routes for far nodes using on demand routing.

B. Routing Metrics in WMNs

The most widely utilized metrics of the WMN routing protocols select the shortest path to the gateway based on the hop count, i.e. the number of nodes between the source and destination. However, the research has recognized the shortcoming of hop count metrics in WMNs because the shortest path metric results in a congested path. Therefore, many researchers employ quality-aware metrics, which dynamically evaluate link quality characteristics to improve network performance. Some of these metrics employ link loss ratio to select the path to the gateway. One of the most widely cited measures is expected transmission count (ETX), which estimates the required number of transmissions for successful data delivery between two nodes. ETX does not consider the bandwidth, packet size, or the link interference; therefore, the metric does not perform well with a network that has a high transmission rate and a large packet size. Expected transmission time (ETT) enhances ETX by considering the packet size and the link bandwidth in calculating the metric. However, this metric does not consider the load and link interference. Interference and channel switching (MIC) is proposed as an alternative metric to ETT. MIC is topology-dependent and selects paths with a minimum number of nodes that share the wireless channel. However, MIC fails to indicate whether the interference node has data to transmit, as the interferer cannot cause interference when there is no transmission.

C. Heterogeneous Network Architectures

If facilitates different types of transmission that used in the architecture and technologies in wireless networks. The heterogeneous network architectures are review according to the type of transmission technologies used varying in the heterogeneous networks (i.e. cellular networks and Wi-Fi devices). A Cellular/multi a hop Wi-Fi architecture is proposed to the relay data packets for clients that suffer from low channel quality, or to offload a packed cell by forwarding the traffic from this cell to other non-packed cells. These networks utilize the multi-hop Wi-Fi network as a secondary network to redirect traffic from one cell to another cell. Heterogeneous networks split data among broadband and Wi-Fi wireless networks to increase network capacity. One approach is to distribute traffic with networks fairly by employing load-balancing algorithms. Other architectures employ wireless characteristics to distribute data among networks. For instance, networks with better wall penetration are utilized for inside communication while networks with higher frequency bands are employed for outside communication. Traffic priority is employed to manage packets flow in heterogeneous networks in which only sensitive packets from the Wi-Fi network are forwarded through the cellular network to avoid unreliable links. Wi-Fi access points are also utilized to create Pico-cells to offload congested cells in cellular networks.

III. SYSTEM ARCHITECTURE

The proposed heterogeneous wireless mesh networks (HetMeshNet) consider the coexistence of multiple wireless technologies as well as a wired network. It employs the

Following types of nodes:

- Heterogeneous nodes (HetNode) - nodes with both Wi-Fi and LTE capability
- Mesh Gateway nodes - nodes with Wi-Fi and the wired connection
- LTE base stations - also known as evolved Node B (eNodeB or eNB)
- Wired network, and Client Nodes – used by end users or sensors.

Working of system:

Example of the proposed HetMeshNet architecture. It comprises the several types of network components. Firstly, the LTE network consists of a number of cells distributed in the region. An LTE base station is placed in each cell. Secondly, a number of HetNodes is deployed in the network, each of which is capable of utilizing multiple transmission technologies. The heterogeneous nodes (HetNodes) are the equipped with Wi-Fi and LTE network interface cards. The Mesh Gateway nodes are the third type of nodes, which connect the WMN to the Internet Gateway. The Internet Gateway acts as a server; it provides the Internet connection to both the LTE and WMN networks. Finally, the Client Nodes could be a human using a mobile phone, a laptop, or any other device connected to the Internet (e.g., a sensor sending data to the Internet).

IV. HETEROGENEOUS ROUTING PROTOCOL

- This section provides a detailed description of the proposed routing protocol of the heterogeneous wireless mesh network.
- The new routing protocols are proposed employs metrics from both networks to switch dynamically between transmission technologies.
The protocol consists of two main components: the heterogeneous routing tables and a routing algorithm. In a heterogeneous wireless network, the routing protocols want to employ metrics from all the technologies that might be utilized by a node.

A. Heterogeneous Routing Tables

Each type of node uses different transmission technologies and each transmission technology employs a different network address. In order to route packets between these different networks, each type of node maintains a routing table to forward data packets from different networks just as if they were sending from the same absolute network. Initially, the Internet Gateway node needs a routing table in order to forward data packets to and from the Internet for both WMN and LTE networks. Secondly, every node can maintain a table of one routes to the other nodes in the network as well as a list of available Mesh Gateways and the default Mesh Gateway to forward heterogeneous node data.

V. PERFORMANCE EVALUATION

In this section, the heterogeneous wireless mesh network is NS-3 LTE Module model.

The proposed network is compared in terms of throughput with LTE-only networks, Wi-Fi-only networks, and a random network (R) evaluating using the NS-3 simulator, which is a widely used tool for evaluating and validating wireless networks.

In particular, paper uses the LENA that randomly allocates LTE or Wi-Fi network for each node.

A. Simulation setup

The network parameters used in the simulation. Two types of scenarios are employed in instruct to evaluate and validate the proposed network. The first sequence consists of grid topologies on HetNodes are distributed in a grid with the 100 meters between each node.

The second sequence consists of random topologies in which all nodes are distributed randomly in a 1000 by 1000 meters area.

B. Evaluating and Validating Results

The activity of HetMeshNet is compared with LTE-only and random networks, using different no of radio resource blocks (RB), and Wi-Fi-only networks.

Two types of scenarios are employed to evaluate the proposed system: one to test the uplink and one to test the downlink.

In the uplink scenarios, the nodes (except the Mesh Gateway nodes) generate user datagram protocol (UDP) traffic with the same rate and the only destination is the Internet. This simulates the uplink traffic from customer terminals to the Internet.

The grid and random topologies are employed in the visual and other different loads are applied to the network using 19 and 30 nodes transmitting simultaneously to the Internet.

A second scenario is utilized to show how the algorithm adapts to the change of the load amount during the simulation.

VI. CONCLUSION

This paper 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 middle throughputs. Moreover, a new routing algorithm is proposed for the needs of the routing protocol, which estimates the cost of transmitting the traffic all the way through each network. The proposed algorithm considers the traffic load on the LTE network as a metric to estimate the cost of transmission over to 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 than throughput compared with Wi-Fi-only networks and LTE-only networks.

B. Cognitive Heterogeneous Routing Algorithm

The second part of the proposed routing protocol is an new algorithm developed, referred as Cognitive Heterogeneous Routing (CHR), which selects the most suitable transmission technology based on parameters from both of 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 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 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.

VII. REFERENCES


