Routing Protocols for Wireless Mesh Networks

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Abstract—Wireless Mesh Networks (WMNs) have emerged as a key technology for next-generation wireless networking. Routing in WMNs is challenging because of the unpredictable variations in the wireless environments. However, there is two ways to enhance the performance of routing protocol in WMNs. One way is to improve the metric used in the selection path; the second way is to modify the routing algorithms by considering new characteristics of WMN. In this paper, expected transmission time and interference aware metrics are used as the default metrics for single radio and Multi-radio AODV routing protocols respectively. The two routing protocols have been implementing in mesh wireless test bed consisting of up to 200 mesh nodes, using OMNeT++ Simulation tool. It has been demonstrated that multi-radio AODV routing protocol with iAWARE metric, gives better performance in terms of end to end delay, packet loss and throughput.

Index Terms— Reactive routing protocol, routing metrics, routing protocols, WMNs.

I. INTRODUCTION

Wireless Mesh Networks (WMNs) have emerged as a promising design paradigm for wireless networks. WMNs are comprised of two types of nodes: mesh routers, and mesh clients. Mesh routers have specific routing functions to support mesh networking. Mesh routers are not very mobile and they are considered as the mesh backbone for clients. Mesh routers have multiple wireless interfaces which can be built on either the same or different wireless access technologies. Mesh clients have additional functions for mesh networking and can also node operates not only as host but also as a router. Mesh client has only one interface [1]. WMNs combine concepts from a diverse set of existing and emerging wireless technologies, including cellular technologies, ad hoc networks, and sensor networks. The application of research results from these areas could greatly contribute to the development, implementation, and growth of wireless mesh networks. WMNs have low investment overhead and can be rapidly deployed. The wireless infrastructure is self-organizing, self-optimizing, and fault tolerant. It can extend IP connectivity to regions otherwise unreachable by any single access technology. Routing is an important factor to forward the data packet from source to destination node.

The choice of a routing protocol is highly dependent on the network size, node density, node mobility and traffic patterns. Therefore, flooding should be avoided if the network is large. Degree of mobility should be evaluated in order to design protocols adapted to the frequent change of routes. When the network is exposed to heavy traffic volumes, it is necessary to include load balancing techniques in the routing, in order to optimize network resource utilization and avoid congestion. The Wireless Mesh routing protocols can be divided into proactive routing, reactive routing and hybrid routing protocols. The processes of routing algorithm involve applying a routing metric to multiple routes, in order to select or predict the best route. A metrics is a property of a route consisting of any value used by routing algorithms to determine whether one route should perform better than another. To guarantee good performance, routing metrics must satisfy these general requirements are scalability, reliability, flexibility, throughput, load balancing, congestion control and efficiency. The routing metrics for mesh routing protocols are Hop Count, Expected Transmission Count (ETX), The Expected transmission time (ETT), The Weighed Cumulative ETT (WCETT), Metric of Interference and Channel-switching (MIC), Interference Aware (iAWARE), Modified ETX Metric (mETX), Sum of Motivated Expected Transmission Time (SMETT) [2]-[5].

In this paper, firstly, we present review of current Mesh routing protocols and its metrics, in order to provide a better understanding of the research challenges in WMN routing protocol. Secondly, ETT and iAWARE metrics are used as the default metrics for single radio and Multi-radio AODV routing protocols respectively. The two routing protocols have been implementing in mesh wireless test bed consisting of mesh nodes varying from 25 up to 200 nodes. The remainder of the paper is organized as follows. Section 2 provides a review of current routing protocols and its metrics. Section 3 simulation and results. Section 4 concludes this work.

II. REVIEW OF WMN ROUTING PROTOCOLS

Wireless Mesh Networks exhibit unique characteristics that differentiate them from other wireless and wired technologies. Therefore, existing routing protocols must be revisited in order to consider their adaptability to WMNs. The main differences relating to routing are: WMNs differ from wired networks due to the possibility of interference between disjoint paths. A fixed wireless backbone differentiates WMNs from other network types. WMNs differ from wired network as the link capacity can vary over time due to the very nature of wireless communications that are sensitive to surrounding interference. WMNs can benefit from the possibility of introducing channel diversity in the routing process, which is not possible in other wireless networks due to node mobility (MANETs) or energy constraints (WSNs). In WMNs, data transmission is primarily between the mesh clients and mesh routers. In general, the routing protocols may be categorized into proactive routing, reactive routing and hybrid routing.
protocols. In, proactive routing protocol; each node maintains one or more tables which have routing information to all other nodes within the network. Reactive routing protocol creates routes only when desired by the source node. The hybrid routing protocols combines both proactive and reactive routing protocols to transport the packets from the source to the destination. It takes both the advantages proactive and reactive routing protocols. Enhancing the performance of routing protocols can be achieved either by improving the metrics used in the selection path or modify the routing algorithms by considering new characteristics of WMN. Different studies have evaluated the performance of the various routing protocols [6]-[7]. Most of the works have focused on enhancing existing routing protocols with new routing metrics more appropriate for WMNs. The fixed wireless backbone allows a better estimation of the link quality through regular measurements. It is also possible to introduce channel diversity in the network infrastructure so as to reduce interference and increase overall throughput.

Some of the recently used WMN routing protocols are summarized. Dynamic Source Routing (DSR): The source will check in its route cache whether there is a valid route to the destination. If there is a route, the source uses this route. If there isn't the source then generates a route request packet. The routing metrics for DSR protocol is Hop Count. An advantage of this protocol is that it does not require any periodic update so the node can conserve power making it suited for low powered devices. However its shortcomings are that it has no mechanisms for handling congestion from high traffic load. Not scalable as delay increases with network size [7]. SrcRRT is a variation of DSR using the expected transmission time as a metric instead of the number of hops. The advantage of this protocol that it finds routes with high throughput rates. The disadvantage is that it is not scalable [8]. Link Quality Source Routing (LQSR): is an extension of DSR by adding some metrics to DSR. The metrics are Hop Count, Round-Trip Time latency, Packet Pair latency, expected transmission count. The advantage of this protocol is that it increases throughput since it considers the ETX metric. Its short comings are the same as its metrics overhead as the metrics use probe packets and not scalable. Multi radio-Link Quality Source Routing (MR-LQSR): The assumption is that if a node has multiple radios, they are turned to different non-interfering channels. It uses WCETT Metric instead of hope count as in LQSR. The protocol identifies all nodes in the wireless mesh network and assigns weights to all possible links. The link information including channel assignment, bandwidth and loss rates are propagated to all nodes in the network. Its advantages are similar to those found when using multiple radios: load balancing, tradeoff between delay and throughput as it considers channels with good quality. The disadvantage is that it is not scalable [9]. Ad hoc on Demand Distance Vector (AODV): Routes are set up on demand, and only active routes are maintained. It uses a simple request-reply mechanism for route discovery very similar to that of DSR. It uses the Expected Transmission Time (ETT) routing metric, which measures the expected time needed to successfully transmit a fixed-size packet on a link. The advantages of this protocol is that it reacts quickly to the topology changes and is loop free and avoids count to infinity problem. However is also has shortcomings such as, no routes are set up on demand, and only active routes are maintained. This reduces the routing overhead, but introduces some initial latency due to the on demand route setup. Also it is not suited for low powered devices. Furthermore packet delivery ratio drops dramatically when the number of connections increases [8]. Ad hoc On-demand Distance Vector-Spanning Tree (AODV-ST): uses a proactive strategy to discover routes between the mesh routers and the gateways, and a reactive strategy to find routes between mesh routers. AODV-ST supports ETT and ETX. The advantages of this protocol is that it reacts quickly to the topology changes However, its drawback, the packet delivery ratio drops dramatically when the number of connections increases [8] . Ad hoc On-demand Distance Vector- Multi Radio (AODV-MR): It is improved AODV to work in Multi-Radio wireless mesh network. It assumes that each node has at least one common channel with neighbor. AODV-MR increases the network capacity because it causes lower degree of interference and contention due to distributed traffic across multiple non-overlapping channels. However, AODV-MR uses IAWARE as router path metric [10]. Optimized Link State Protocol (OLSR): It is an optimization version of a pure link state protocol. Topological changes cause the flooding of the topological information. To reduce the possible overhead in the network protocol uses Multipoing Relays (MPR) by reducing the same broadcast in some regions in the network. The routing metrics for OLSR protocol is shortest path. The advantage is that it is suited for dense networks where the source and destination keeps changing constantly. The disadvantages are that bandwidth is wasted on topology control messages aggravated by increasing network size and no load balancing [7]. Destination Sequenced Distance Vector routing (DSDV): where each node maintains a routing table that contains the shortest path to every possible destination in the network and number of hops to the destination. The sequence numbers allows the node to distinguish stale routes from new ones and updates in the routing tables are done periodically to maintain table consistency. The routing table consisting of destination address, next node, metric (Hop count) and sequence number. The advantage of this is that DSDV guarantees loop-free paths and higher efficiency in route discovery as opposed to the latency experience in reactive protocols. The disadvantage is delivery ratio decreases with network size and does not provide load balancing [6].

III. SIMULATION AND RESULTS

The simulation work that has been implemented is done in Objective Modular Network Test bed in C++ OMNeT++ Simulation tool, by supporting of the INETMANET Framework [11]. INETMANET Framework supports wireless and mobile network simulation. The simulation implementation has been into three phases, Initialization Phase, Running Phase, and Simulation output and analyzing Phase. The purpose of the initialization phase is to setup the network based on a given Network Description (NED) file with support of Omnetpp.ini configuration file to configure
and assign or modify the network compound’s parameters and simple modulus’s parameters. Before the initialization phase is started, some parameters values should given, i.e. total number of mesh nodes, number of mobile hosts, number of radios, radio bit rate, radio sensitivity, the radio transmitter power, some UDP applications, simulation time, and the routing protocol type. By the end of this phase, the network is initialized. All mesh nodes took their positions uniformly as a grid in the simulation area of size 750m x 750m and whole system parameters are determined and preloads. These nodes are establishing connection with each other. There is no other background traffic. Both ETT and iAWARE metrics are used as the default metrics for single radio and Multi-radio AODV routing protocols consequently. There are two simulation scenarios that have been applied, one for Single radio and the other for Multi-Radio (2 radios) AODV routing protocol. For each scenario, different size of mesh nodes has been investigated (25, 75, 100 and 200 nodes). To evaluate the performance of WMN routing protocols, both qualitative and quantitative metrics are needed. Most of the routing protocols ensure the qualitative metrics. Therefore, we have used three different quantitative metrics to compare the performance. They are:
1) Average End-to-end delay: End-to-end delay indicates how long it took for a packet to travel from the source to the application layer of the destination.
2) Packet Loss: The fraction of packets sent by the application that are not received by the receivers.
3) Throughput: The throughput is defined as the total amount of data a receiver receives from the sender divided by the times it takes to receive the data.

Fig. 1 represents an average end to delay for Single Radio and Multi Radio AODV Routing Protocols. It’s clear that single radio AODV has greater delay than multi-radio AODV. Delay increases as the number of nodes increases. Fig. 2 shows the packet loss for both Single Radio and Multi-radio AODV routing protocols. Both of them face the problem of packet loss and it’s increased as number of nodes increases but multi-radio AODV protocol has less packet loss compared with Single radio AODV protocol. Since integrated metrics mechanisms assist to avoid congestion and increase network resource utilization, AODV-MR performed significantly better than AODV when number of nodes increases. Fig. 3 shows the variation of data throughput with grows number of mesh nodes. Multi-radio AODV has better throughput.

IV. CONCLUSION

WMNs are a promising technology for next generation wireless networking, the backbone of WMNs provides good solution for users to access the Internet anywhere anytime. In this paper, a review of WMN routing protocols and its routing metrics have been presented, highlighting their features and problems, in order to provide a better understanding of the research challenges. Well known AODV routing protocol operates in single radio and Multi-radio with their metrics have been implemented. The two routing protocols have been implementing in mesh wireless test bed consisting of mesh nodes varying from 25 up to 200 nodes. It has been demonstrated that multi-radio AODV routing protocol with iAWARE metric, gives better performance in terms of end to end delay, packet loss and throughput.

REFERENCES


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