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Routing Protocols for Wireless Mesh Networks: A Survey

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Abstract- In present the quickening pace of technological change development Wireless technology is growing in broad, there are many research issues arises in the wireless technology, the fundamental requirement in wireless is routing. Wireless mesh network is the emerging technology in which routing is the fundamental characteristic of the wireless network. Wireless mesh networks are very much capable of providing internet access anywhere anytime for stationary or mobile hosts at low costs both for network operators and customers. In wireless networks Routing is the necessary fundamental characteristics .In WMNs routing is the challenging research area due to the occurrence of unexpected changes in the wireless environments. There exist two different ways to enhance the performance of routing protocols in wireless networks. In wireless mesh network have to improve the metric used in the selection path , to modify the routing algorithms by considering new characteristics of the network and can apply cross-layer approach by merging the characteristics of two or more layers. This paper discussed about various types of routing protocols that are used in the wireless mesh networks along with metrics that are used in wireless mesh networks.

Keywords: Reactive Routing, Proactive routing, Routing Metrics, Routing Protocols, WMNs

I.INTRODUCTION

In the present wireless technology Wireless Mesh Networks (WMNs) is having an important role. Because of their low investment overhead and can be rapidly deployed, they can extend IP connectivity to regions of unreachable by any single access technology. The features of WMNs such as low-cost, easy maintenance, robust ness and reliable service. These features allow the networks to take more portion of wireless communication in future. A typical WMN consists of mesh routers and mesh clients [1]. All the mesh networks have a wireless infrastructure to provide a multi-hop internet access service for mesh clients. Mesh clients can be connecting to network over mesh routers and also through other clients. Routing in any wireless network is the important factor to forward the data packet from source to destination node. The selection of the routing protocol in wireless mesh network is dependent on the size of the network, node density, node mobility and traffic patterns. In wireless mesh networks the routing protocols divided into three different types they are proactive, reactive and hybrid routing protocols.

These networks are multi hop systems in which devices help each other in transmitting packets through the network [2]. In wireless mesh networks nodes are comprised of mesh routers and mesh clients. Each node operates as a host and also as a router, forwarding packets on behalf of other nodes that may not be within direct wireless transmission range of their destinations. In order to prove the networks performance it should satisfy some of the requirements such as scalability, reliability, flexibility, throughput, load balancing, congestion control and efficiency. The routing metric available for mesh routing protocols are hop count, blocking metrics, expected transmission count [EXT], the expected transmission time [ETT], the weighted cumulative ETT [WCETT][3].

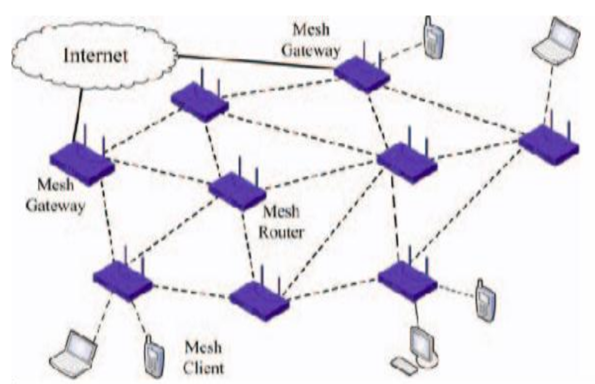

Figure 1: Architecture of Wireless mesh networks

The architecture of wireless mesh networks is as shown in the above figure. The architecture can be classified into three types. Wireless mesh architecture is a first step towards providing cost effective and low mobility over a specific coverage area. Wireless mesh network is built from peer radio devices that don't have to be cabled to a wired port like traditional WLAN access points (AP) do. Mesh infrastructure carries data over large distances by splitting the distance into a series of short hops. Intermediate nodes not only boost the signal, but cooperatively pass data from point A to point B by making forwarding decisions based on their knowledge of the network, i.e. perform routing by first deriving the topology of the network.

Wireless mesh networks is a relatively "stable-topology" network except for the occasional failure of nodes or addition of new nodes. The path of traffic, being aggregated from a large number of end users, changes infrequently. Practically all the traffic in an infrastructure mesh network is either forwarded to or from a gateway, while in wireless ad hoc networks or client mesh networks the traffic flows between arbitrary pairs of nodes. If rate of mobility among nodes are high, i.e., link breaks happen frequently, wireless mesh networks will start to break down and have low communication performance.

Other name of wireless mesh network is wireless ad hoc network or mobile ad hoc network (MANET), is a wireless network made up of radio nodes organized in a mesh topology. Each node forwards messages on behalf of the other nodes and each node performs routing. Ad hoc networks can "self-heal", automatically re-routing around a node that has lost power. Various network layer protocols are needed to realize ad hoc mobile networks, such as Distance Sequenced Distance Vector routing, Associativity-Based Routing, Ad hoc on-demand Distance Vector routing, and Dynamic source routing.

Wireless mesh networks are multi hop networks and provides much coverage range. Like if one node is failed or turns off then through other nodes message can be transmitted to destination nodes that function provides the redundancy in the mesh network. They have capability of self-healing and self-forming and self-organization and provide support for Ad Hoc Networking. As we have multi-hoping so it achieves higher throughput, and more efficient frequency re-use. They provide low cost for installation because the reduction of the number of access points to internet so the main advantages of WMNs is that easiness of deployment. Multiple type of network access like support for internet and p2p communication as well. Provide compatibility with existing wireless networks like WiMax, Wi-Fi, cellular networks. It has flexible network architecture.

Routing plays an important role in ensuring reliable communication. However, not all routing algorithms have optimal performance. Packet loss, energy efficiency, and forwarding time are still problems to be optimized for packet forwarding.

Rest of the paper is organized as follows, Section I contains the introduction of Wireless mesh networks, architecture of WMNs, Section II explains about different types of routing in WMNs, Section III gives brief details of different routing metrics used by WMN routing protocols, Section IV gives some of the applications of WMNs followed by different routing protocols of WMNs and finally Section V concludes the paper indicating the research problem can be solved by using cross layer design in routing.

The survey is done in order to know the routing problems associated with wireless Mesh networks and available routing protocols for the same and to design the appropriate method to increase the efficient routing.

II.ROUTING IN WIRELESS MESH NETWORKS

Routing protocols: WMN is a particular type of Mobile ad hoc network. WMN routing protocol design can be classified into several categories based on:

1. Routing topology:
   i. Flat routing protocol
   ii. Hierarchical routing protocol
2. Use of routing backbone:
   i. Tree based protocol
   ii. Mesh based protocol
   iii. Hybrid Topology protocol
3. Routing information maintenance approach
   i. Proactive(Table driven) protocols
   ii. Reactive (on Demand)protocols
   iii. Hybrid routing

There are more than 70 competing schemes for routing packets across mesh networks. Some of these include. AODV (Ad hoc On-Demand Distance Vector), B.A.T .M.A.N. (Better Approach To Mobile Adhoc Networking), Babel (protocol) (a distance-vector routing protocol for IPv6 and IPv4 with fast convergence properties), DNVR (Dynamic NIx-Vector Routing), DSDV(Destination-Sequenced Distance- Vector Routing), DSR (Dynamic Source Routing), HSLS (Hazy-Sighted Link State), HWMP (Hybrid Wireless Mesh Protocol), IWMP (Infrastructure Wireless Mesh Protocol) for Infrastructure Mesh Networks by GRECO UFPB-Brazil, Wireless mesh networks routing protocol (MRP) by Jangeun Jun and Mihail L. Sichitiu, OLSR (Optimized Link State Routing protocol), OORP (Order One Routing Protocol) (OrderOne Networks Routing Protocol), OSPF (Open Shortest Path First Routing), Routing Protocol for Low-Power and Lossy Networks (IETF ROLL RPL protocol, RFC 6550), PWRP (Predictive Wireless Routing Protocol), TORA (Temporally- Ordered Routing Algorithm), ZRP (Zone Routing Protocol) .

Traditional Routing Protocols:
DSR, DSDV and AODV are some of the on demand traditional routing protocols. They were maintaining routes under frequent and unpredictable changes in network connectivity, where packets are routed along paths with the shortest hop count [4].

III.ROUTING METRICS

The most widely used metrics in 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, prior research has recognized the shortcoming of hop count metrics in WMNs because the shortest path metric results in a congested path . 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, the 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 (EET) 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 interferer node has data to transmit, as the interferer cannot cause interference when there is no transmission.

IEEE 802.11 supports multiple transmission rates for each rate, there is a different transmission range and a different interference range. The simplest and most widely adopted algorithms in controlling the transmission rates are based on gathering the statistics of unsuccessful transmissions on the sender side to estimate the interference. The earliest algorithm in this category is the auto rate fallback (ARF), which sets a threshold based on the number of successful and failed transmissions to increase and decrease the transmission rate. Several enhancements to the ARF have been proposed, in order to avoid unnecessary updates in transmission rates. For example, Adaptive ARF (AARF) changes the threshold of switching the transmission rates adaptively. Mad Wi-fi ONOE enhances ARF by assigning credits to each transmission rate based on the loss rates and then selects the transmission rates with the highest credits. These rate adaptation algorithms are developed for infrastructure-based wireless networks and not for WMNs, and therefore they do not consider the competing nodes accessing shared channels. The recently developed rate adaptation algorithm based on reinforcement learning (RARE) sets the transmission rate based on the link quality of the neighboring nodes and the load on the Wi-Fi device. Thus, the transmission rate estimates the amount of interference and collision with other nodes and the load on the node. The best link quality is the one, which provides higher transmission rate. This algorithm is developed for WMNs and designed to work in highly congested multi-hop networks [5].

IV.APPLICATIONS OF WMNS

A WMNs can be deployed to render a wide variety of applications [6].

Building automation: Home or building automation can be done by mesh networks. Different electrical devices such as fans, lights, and air conditioners etc. can be monitored in a building. Usually wired networks are used for this purpose which is of expensive. By replacing wired network by wireless network can reduce the cost of the system and simplify the deployment.

Metropolitan area networks (MANs): WMNs s might also be useful in MANs. It provides the higher transmission rate at the physical-layer as compare to other networks such as cellular networks. Like the transmission rate of IEEE 802.11g nodes is 54 Mbps. Economically it is a best alternative for underdeveloped regions and broadband networking.

Enterprise networking: This type of networking can be of any scale. It can be a small office, a medium-sized company within a building, or a large-scale network with multiple buildings. Replacing access points with mesh routers can eliminate the necessity of Ethernet wires. Moreover, WMNs can easily expand with the size of the enterprise.

Broadband home networking: Similar to enterprise locations, broadband home networking is accomplished by using WLANs and the standard IEEE 802.11 protocols. Home networks using access points usually have zones with no coverage. Performing site surveys and installing multiple access points are expensive and impractical.

Community and neighborhood networking: In most cases, the architecture used in communities for network access uses cable or DSL connected to the Internet and at the end-user's side a wireless router is connected to any of these two options. Accessing the network in this way raises many issues.

All traffic must flow through the Internet which reduces network resource utilization significantly. Some areas in the neighborhood are not covered by wireless services. WMNs overcome all these limitations by providing flexible mesh connections between homes and communities.

Security surveillance systems: To deploy surveillance systems at public and private premises such as company buildings, shopping malls, and grocery stores etc., WMN is a more feasible solution than wired network. Due to the frequent transfer of images and videos, these systems demand high network capacity which can be efficiently managed by WMNs.

All these applications demonstrate the importance of WMNs in the real world. While these networks provide great benefits to the society but because of their diverse application and properties, they also bring forth security vulnerabilities which lead to several kinds of severe attacks on these networks.

Opportunistic Routing

More recently, researchers have proposed opportunistic routing for mesh networks. Opportunistic routing differs from traditional routing in that it exploits the broadcast nature of wireless medium and defers route selection after packet transmissions. This can cope well with unreliable and unpredictable wireless links. There are two major benefits in opportunistic routing. First, it can combine multiple weak links into one strong link. Second, it takes advantage of unexpectedly short or unexpectedly long transmissions [4].

Having these basics discussed, some survey related to routing protocols for wireless mesh networks is presented below:

[1] Adhoc On Demand Distance Vector Routing:

Charles E Perkins and Elizabeth M Royer presented a distance vector algorithm that is suitable for use with adhoc networks AODV avoids problems with previous proposals (notably DSDV). They simulated AODV using an eventdriven packetlevel simulator called PARSEC. The PARSEC language is suited to the simulation of dynamic topologies and routing algorithms AODV scales well to large networks and determining the optimal value for each of the necessary parameters. In this they have used number of metric (number of hops for the selected destination to select the alternative route) [7].

[2] SOAR: Simple Opportunistic Adaptive Routing Protocol for Wireless Mesh Networks:

Eric Rozner et al. proposed SOAR, a new addition to the opportunistic routing protocol design space. Different from the existing opportunistic routing protocols, SOAR explicitly supports multiple simultaneous flows by strategically selecting forwarding nodes and employing adaptive rate control. SOAR uses ETX as the underlying routing metric, but it is easy for SOAR to support any alternative routing metric [4]. They evaluated the SOAR routing protocol using NS-2 simulations and test bed experiments.

[3] Heat Routing Protocol for Wireless Mesh Networks:

Srivani. P presented Field based routing uses a little information to route the packets in the network. Due to this characteristic, field based routing algorithms are less expensive and mainly effective, but such algorithms also face different types of efficiency and scalable issues. Many existing unicast routing protocols like AODV are not well adapted in wireless mesh networks as the messages are flooded [8]. HEAT has two distinguishing features. Firstly, it considers both the length and the robustness of paths in the routing decision. Secondly, the field construction and maintenance mechanism of HEAT scales to the number of nodes and the number of gateways since it only requires communication among neighboring nodes.

The HEAT algorithm is a fully distributed, proactive any cast routing algorithm across large number of mobile nodes and a few access points with Internet connectivity [9].

[4] Destination-Sequenced Distance Vector (DSDV):

Guoyou He presented DSDV protocol for ad hoc networks, DSDV is a modification of the conventional Bellman-Ford routing algorithm. It addresses the drawbacks related to the poor looping properties of RIP in the face of broken links. The modification are adapted in DSDV makes it a more suitable routing protocol for ad-hoc networks. In this paper they have presented the review of DSDV protocol and verified its properties in ad hoc networks routing. The analyzed results of DSDV are compared with Bellman-Ford routing. The QoS with DSDV routing has substantial improvement in the routing results. The future work is for multi-path routing, QoS multicasting in DSDV and ad hoc networks [10].

Hemanth Narra et. al presented the implementation of DSDV routing protocol for MANETs. They have analyzed DSDV routing performance under various scenarios and compare its performance with the other protocols such as AODV and OLSR and implemented in ns-3. The cost metric used is the hop count, which is the number of hops it takes for the packet to reach its destination. In this paper. The evaluation of the DSDV routing protocol is done by considering these performance metrics: they are packet delivery ratio (PDR), routing overhead and delay [11].

[5] An Efficient DSDV Routing Protocol for Wireless Mobile Ad Hoc Networks and its Performance Comparison:

Khaleel Ur Rahman Khan et. al proposed Eff-DSDV) Protocol is for Ad Hoc networks. Eff-DSDV overcomes the problem of stale routes, and it improves the performance of regular DSDV. This protocol has been implemented in the NCTUns Simulator and performance is compared with regular DSDV and DSR protocols. Packet-delivery ratio, end-end delay, dropped packets; routing overhead and route length are the performance metrics considered for analysis of the proposed protocol. It has been found after analysis that the performance of Eff-DSDV is superior to regular DSDV and sometimes better than DSR in certain cases. The future work includes the performance comparison can be made between the proposed protocol and the other classes of the Ad Hoc Routing Protocols with different simulation parameters and metrics[12]. In this paper they have implemented the proposed Eff-DSDV protocol in C++ and integrated the module in the NCTUns Simulator. The future work of this paper includes the performance comparison can be made between the proposed protocol and the other classes of the Ad Hoc Routing Protocols with different simulation parameters and metrics.

[6] Orthogonal Rendezvous Routing Protocol for Wireless Mesh Networks:
Bow-Nan Cheng et. al introduced Orthogonal Rendezvous Routing Protocol (ORRP) for meshed wireless networks. It is a lightweight-but-scalable routing protocol utilizing directional communications (such as directional antennas or free-space-optical transceivers) to relax information requirements such as coordinate space embedding and node localization. The ORRP source and destination send route discovery and route dissemination packets respectively in locally-chosen orthogonal directions. Connectivity happens when these paths intersect (i.e., rendezvous). We show that ORRP achieves connectivity with high probability even in sparse networks with voids. ORRP scales well without imposing DHT-like graph structures (eg: trees, rings, torus etc). ORRP does not resort to flooding either in route discovery or dissemination. The price paid by ORRP is sub optimality in terms of path stretch compared to the shortest path; however we characterize the average penalty and find that it is not severe [13].

Orthogonal Rendezvous Routing Protocol (ORRP) is based upon two simple ideas: 1) local directionality is sufficient to maintain forwarding of a packet on a straight line, and 2) two sets of orthogonal lines in a plane intersect with high probability even in sparse, bounded networks. ORRP provides highly scalable routing under relaxed and unstructured global information for wireless networks with directional communications support. Future work includes the investigation of ORRP into a context of a hybrid network containing nodes with both directional antennas and Omni directional antennas. Other area of consideration is mobility and how to prevent routing loops and provide error correction.

[7] Scalable Location Update-based Routing Protocol: The protocol is based on a geographic location management strategy that keeps the overhead of routing packets relatively small. Nodes are assigned home regions and all nodes within a home region know the approximate location of the registered nodes. As nodes travel, they send location update messages to their home regions and this information is used to route data packets.

SLURP, is based on a combination of approximate geographical routing and a simple static mapping procedure to maintain approximate location information for nodes. In the remainder of this section we first describe the algorithm used to find the geographical location of a node and then we discuss the approximate geographic routing protocol used to route the packets to the destination [14].

[8] Mobility-aware hierarchical cluster based routing protocol: The authors were considered mobility and scalability as the two important criteria. The proposed scheme uses three input parameters to evaluate the output parameter i.e. the final score of individual node. The four input variables are: Node degree, Node Mobility, Node Residual Power, Distance between GH and MP. Hierarchical cluster based algorithms can give the good results in increased scalabilities. Our proposed method is based on the fact that the mobile nodes are not to be selected as CH in cluster based routing [15].

[9] Cognitive Heterogeneous Routing Algorithm: Cognitive Heterogeneous Routing (CHR), which is the mostsuitable transmission technology . 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 Wi-Fi 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 to estimate which transmission technology is the best to send the traffic. It is based on reinforcement learning and Q-learning [16].

[17] **Link Quality Source Routing Algorithm (LQSR):** Link Quality Source Routing Algorithm proposed by Microsoft Research Group. It is a Reactive routing algorithm. It is based on DSR algorithm by improving link quality metrics and other related metrics. To improve the link quality, and LQSR uses link cache instead of route cache. In LQSR, when a node receives a route request (RREQ) packet, it will adds link quality metric for the link over which packet had arrived. When a Source node receives route reply (RREP) packet, it includes link quality information and node information. For link state information, LQSR sends hello messages to adjacent nodes. These messages are used to measure the link quality at each node for the link on which this message was received. All these messages are based on piggybacked approach.

An Elliptical Routing Protocol: In the mobile adhoc routing environment, node can transmits R_REQ to its entire neighbor's in all directions, this type of route finding approach leads to unnecessary overhead due to sending of R_REQ packets in all directions unnecessarily instead of sending in right direction. The authors have addressed the an elliptical routing approach for sending R_REQ packets is addressed in order to minimize the overhead of R_REQ packets by sending these packets in a direction that is targeting to the required destination by assuming in ellipse towards the destination by selecting the next hop appropriately.

V.CONCLUSION

The above survey shows the working of different routing protocols for wireless mesh networks in conventional layered mechanism. Using layered-protocol architecture cannot obtain the optimal performance for wireless mesh networks. By adapting the different method of optimizing the protocol stack can achieve optimal network performance in wireless networks. To obtain the optimal performance in wireless networks it needs a cross-layer design. The different features related to WMNs indicates the need cross-layer optimization across different protocol layers. The future research problem can be considered under cross layer design architecture for wireless mesh networks and to increase the scalability.

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