HRP: A Hybrid Routing Protocol for Wireless Mesh Network

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Abstract

Wireless Mesh Network is a special type of MANET in which most of the nodes are static or have relatively fixed position. Most of the WMN solutions are provided using Hybrid Mesh, which consist of static router infrastructure and ad hoc components of mobile clients. Routing protocols for WMN face challenges in topology changes, asymmetric links and low transmission power. As both, reactive and proactive protocols seem to be inefficient under the circumstances, a hybrid approach is required. This paper proposes a hybrid routing protocol that combines the advantages of both reactive and proactive routing protocols to provide an efficient solution to the concerned problem.

1. Introduction

Wireless Mesh Networks (WMNs) [1] represent a good solution for providing wireless Internet connectivity in a sizable geographic area; this new and promising paradigm allows network deployment at a much lower cost than with classic wireless networks. In WMNs, it is possible to cover the same area, as compared to WiFi, with less wireless routers, which makes the use of WMNs a compelling economical case [2]; WMNs are thus suitable for areas that do not have existing data cabling or for the deployment of a temporary wireless network.

WMNs are extremely reliable, as each node is connected to several other nodes. If one node drops out of the network, due to hardware failure or any other reason, its neighbors simply find another route. Extra capacity can be installed by simply adding more nodes. Mesh networks may involve either fixed or mobile devices as shown in Figure 1. The principle is simple: data will hop from one device to another until it reaches a given destination. One advantage is that, like a natural load balancing system, the more devices the more bandwidth becomes available. Since this wireless infrastructure has the potential to be much cheaper than the traditional networks, many wireless community network groups are already creating wireless mesh networks.

Practical mesh network are not entirely mesh but partially mesh. A practical example to wireless mesh network is Hybrid Mesh. Hybrid Mesh consists of many ad hoc components compromise of many wireless clients. On the other hand, the router backbone is static in nature or has very limited mobility. Each ad hoc component is connected to one of the router present in the router backbone. Each Router manages its own ad hoc component, such as, providing addresses, routes to destination, authentication and secure communication to nodes present in its ad hoc region.

Since the nodes in ad hoc components can be highly mobile, the topology, within the ad hoc region, changes frequently and the nodes are dynamically connected in arbitrary manner. Moreover these wireless clients have low transmission power, limited power and small transmission ranges. The small transmission range limits the number of neighbor nodes, which further increases the frequency of topology change, due to node mobility. All these factors add up and make routing difficult.

2. Routing In WMN

In Wireless mesh networks (WMNs), nodes have relative fixed positions and communicate to the Internet through one or more gateways. While traditional ad-hoc routing algorithms, such as DSR [3] and AODV [4], can be used in WMNs, their performance is typically less than ideal [5]. The problem is that such algorithms make assumptions that are no longer true in WMNs, and those assumptions can have significant performance penalties in a mesh

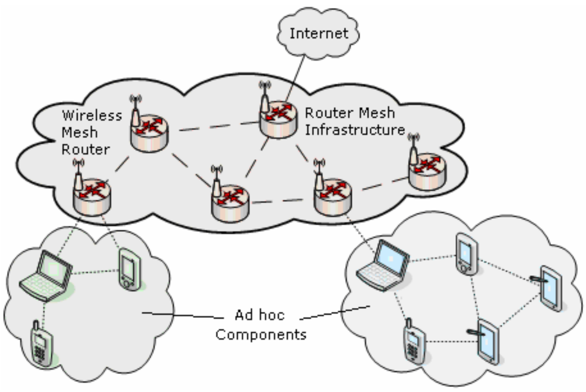

Figure 1: An example of Wireless Mesh Network (a Hybrid Mesh)

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environment.
A number of routing protocols [5] have been suggested for WMNs. These protocols can be classified as proactive protocols and reactive protocols.

2.1. Proactive Routing

Proactive protocols are table-driven and will actively determine the layout of the network. Through a regular exchange of network topology packets between the nodes of the network, a complete picture of the network is maintained at every single node [6]. There is hence minimal delay in determining the route to be taken. This is especially important for time-critical traffic.
However, a drawback to a proactive of protocol is that the life span of a link is significantly short. This phenomenon is brought about by the increased mobility of the nodes, which will render the routing information in the table invalid quickly.
When the routing information becomes invalid quickly, there are many short-lived routes that are being determined and not used before they turn void. Hence, another drawback resulting from the increased mobility is the amount of traffic overhead generated when evaluating these unnecessary routes. This is especially aggravated when the network size increases. The fraction of the total control traffic that consists of actual practical data is further decreased.
Lastly, if the nodes transmit infrequently, most of the routing information is deemed redundant. The nodes, however, continue to expend energy by continually updating these unused entries in their routing tables. Thus, proactive protocols work best in networks that have low node mobility or where the nodes transmit data frequently. Examples of proactive protocols include: OLSR [7], TBRPF [8], DSDV [7, 9], LANMAR [10], etc

2.2. Reactive Routing

Reactive protocols only find a route to the destination node when there is a need to send data [11]. The source node will start by transmitting route requests throughout the network. The sender will then wait for the destination node or an intermediate node (that has a route to the destination) to respond with a list of intermediate nodes between the source and destination. This is known as the global flood search, which in turn brings about a significant delay before the packet can be transmitted [11]. It also requires the transmission of a significant amount of control traffic. Thus, reactive protocols are most suited for networks with high node mobility or where the nodes transmit data infrequently. Examples of reactive protocols include: AODV [4], DSR [3], TORA [12] etc.

2.3. Hybrid Routing

Since proactive and reactive routing protocols each work best in oppositely different scenarios, there is good reason to develop hybrid routing protocols, which use a mix of both proactive and reactive routing protocols. These hybrid protocols can be used to find a balance between the proactive and reactive protocols. The basic idea behind hybrid routing protocols is to use proactive routing mechanisms in some areas of the network at certain times and reactive routing for the rest of the network [6].
Due to the dual nature of Hybrid Mesh, we propose such a hybrid protocol. Our protocol aims to provide an optimal solution for Hybrid Mesh Network by combining the best properties of both proactive and reactive protocols. Some of the others hybrid reactive/proactive routing protocols are Cornell's Zone Routing Protocol (ZRP) [13] and Scientific Research Corporation's Wireless Ad hoc Routing Protocol (WARP).

2.4. Multipath Routing

As one of the characteristics of a WMN is that it provides reliability and load balancing, hence, routing protocols proposed for WMNs can also be classified on the basis of paths between two nodes. These protocols are classified as single path, multiple disjoint paths [12] and multipath [15] routing protocols. Although single path routing is not fitting with the characteristics of mesh Networks, but in it, a path is selected on the basis of performance metrics. There has been a lot of discussion on the comparison between the single path, multiple disjoint paths protocols and multipath protocols [16]. In our proposed routing protocol architecture, either of these protocols can be used as long as there is compatibility in between the selected protocols.

3. Proposed Protocol

3.1. Motivation

Both proactive and reactive protocols have specific advantages and disadvantages that make them suitable for certain types of scenarios. Since proactive routing maintains information that is immediately available, the delay before sending a packet is minimal. On the contrary, reactive protocols must first determine the route, which may result in considerable delay if the information is not available in caches.
Moreover, the reactive route search procedure may involve significant control traffic due to global flooding. This, together with the long setup delay, may make pure reactive routing less suitable for real-time traffic. However, the traffic amount can be reduced by employing route maintenance schemes.
Purely proactive schemes use a large portion of the bandwidth to keep routing information up-to-date. Because of fast node mobility, the route updates may be more frequent than the route requests, and most of the routing information is never used. Some of the scarce bandwidth is thus wasted [17].
As we look at the architecture of Wireless Mesh Networks, we can conclude that both of these types of protocol faces problem in providing a solution [6]. A better solution

would be to use different routing protocols for the different parts of network. For the ad component, we can have a reactive protocol to counter the dynamic change in topology and the mobility of the nodes. A proactive protocol would be better suited for the static router infrastructure, so to provide immediate availability of routes in the router backbone. On the basis of this concept, we propose a hybrid protocol, which promises to provide a better problem to the routing solution.

3.2. Architecture

As discussed in the previous section, a hybrid mesh consists of several ah hoc components and a router infrastructure which works as a backbone in the network. Each ad hoc component is treated as a separate region. The router connected to this region is responsible of providing addresses to the nodes, routes to node of other regions and networks and management of that region.

Our proposed Routing protocol is consisted of three routing components, as shown in figure 2. These components are:

- Intra Region Routing Protocol – IRRP
- Router Infrastructure Routing Protocol – RIRP
- Region Gateway Routing Protocol – RGP

The router infrastructure uses the Router Infrastructure Routing Protocol. Because the router infrastructure has static mesh routers, RIRP is a family of wireless proactive routing protocols, as discussed in previous section. RIRP runs on each static router node and provide routes to the regions connected to the mesh routers. Routing tables are always up-to-date to provide immediate routes. This component does a very good job in reducing the delay in route determination.

In a specific region or an ad hoc component, the routes are maintained through a protocol component specified as Intra-Region Routing Protocol (IRRP). IRRP is a family of reactive routing protocols that offer enhanced route discovery and route maintenance services based on local connectivity within the ad hoc region.

The Region Gateway Protocol is used whenever a route between two ad hoc components or regions is required. It gets route information from the RIRP and IRRP and creates a complete route from source to destination and provides it to the source node. This is shown in Figure 2. When a node requires a route, RGP get information from RIRP and IRRP of both ad hoc regions and construct a route and send to both IRRP and RIRP.

Whenever a new mesh router node is added to the system or in a case of a link failure; RIRP needs to know about the event. For this RIRP make use of either Neighbor Discovery Protocol (NDP) [18] provide by Media Access Control (MAC) layer or provide this functionality itself. Each node sends Hello-packets to other nodes in the neighborhood, at constant interval. If the timeout occur and hello-packet is not received, then one can say that there is a problem within the link. Similarly, when a new node comes it can advertise itself by broadcasting a hello-packet.

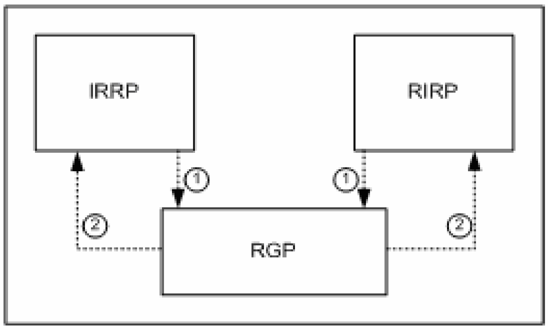

Figure 2: A conceptual architecture of the Proposed Protocol shows Packet flows between the routing components.

3.3. Routing

Whenever a node has to send some data to another node, it checks if it has the route to destination; if not it starts the route discovery phase. The route discovery mechanism has three phases: route request, route formation and route reply. In route request, a route query is send to the neighboring nodes using IRRP, if the neighboring nodes do not have the route to the destination, they forwards the request to other nodes. If no node has the route to destination, the request is sent to RGP running on the router connected to the ad hoc component. Here RGP tries to find the router connects to the destination ad hoc component using the RIRP. When the route to the router node is found, RGP use IRRP in the ad hoc region, in which the destination node is, to find the route to destination node.

After a route to the destination is found, the whole route from source to destination is formed by the RGP. This phase is called the route formation phase. When a whole route is formed, a route reply with the whole route is sent to the source node, which is the last phase of route discovery.

If the receiving node exists in the same region or ad hoc component as the sending node, only reactive routing is used. The IRRP discover the possible routes and data is send through the discovered routes.

If the receiving node and the sending nodes are not in a same region or ad hoc component then route discovery is done by using both reactive and proactive routing protocols. The route request phase is then further divided into two phases: the proactive phase and a reactive phase. The router node connected to the ad hoc region of sender node is responsible for the proactive phase and the router node connected to the ad hoc region of destination node is responsible for the reactive phase.

First the router node of the sender node discovers the route to the ad hoc region of the destination node by the help of RIRP. Then the router node at the receivers’ ad hoc region performs the reactive route determination using IRRP to find the route to the destination node. Region Gateway Protocol is responsible for creating a whole route from the two routes discovered through the RIRP and IRRP and send it to the source node.

3.4. Route Maintenance

The Route Maintenance protocol detects when the topology of the network has changed and decides if an alternative route can be used (if available) or if the Route Discovery protocol must be started to find a new path. Route maintenance is invoked when a link break is detected at time sender actively using the route. Intermediate node that detects next hop in the route is unreachable, sends route error packet back to sender. Sender after receiving route error may use different route or may perform route discovery.

The knowledge of network topology of a region can be used to provide better route maintenance. In Router Infrastructure, a multiple path routing will provide reliability, load balancing and better route maintenance with little delay and less control traffic.

In IRRP, due to the dynamically changing topology of mobile client nodes, route maintenance is very critical. Until a new route is discovered, the packets are dropped and as discussed earlier, a reactive protocol takes a longer time in determining a route. Therefore, a multipath routing protocol would be better that can come up with another link instead of finding a new path.

Cache can also serve to reduce the delay as well as the control traffic in finding the routes [19]. Each node can actively cache routes and thus reducing the frequency of route discovery. Broken path can be replaced by other paths locally and may not involve the whole ad hoc region. This new path will then be used to substitute the old broken path and a path update message can sent to the other nodes. If these repairs reduce the efficiency of the routes, a new route discovery phase can started after a certain number of local repairs.

3.5. Example

Suppose there is a network, as shown in Figure 3, in which we have two Ad hoc Regions and a single Router Infrastructure. The node ‘A’ has to send a packet to node ‘L’. ‘A’ would use IRRP to find the route to ‘L’, As it is not found in the region, a route request is issued using the RGP at the Router node ‘G’. Now, ‘G’ looks into its routing table for the route to the destination ad hoc region, which it has through RIRP. G has a route to destination ad hoc component through Router node ‘I’. So the route query is send to ‘I’. ‘I’ perform on-demand routing using IRRP and find the route to ‘L’. Now RGP running at ‘I’ would send this route back to Router node ‘G’. ‘G’ creates the whole route from source ‘A’ to destination ‘I’ and send route reply to node ‘A’. If multiple paths to the destination were available, then all paths would be sent to node ‘A’.

4. Analysis & Simulation

Our implementation of the proposed protocol is not final but it is mature enough to have some simulation with it. We used already proposed and used protocols as the modules of our protocol. For the proactive component of

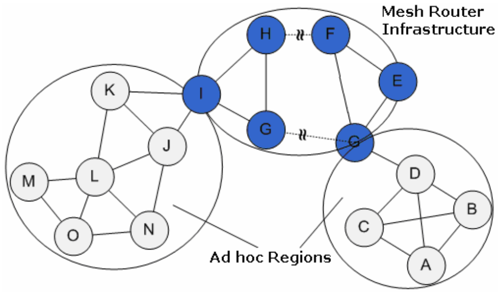

Figure 3: Routing Example

our proposal we use the Destination Sequenced Distance Vector (DSDV) [9] routing protocol to have route discovery in the mesh router infrastructure region. Similarly, to perform the route learning task in ad hoc regions, we used Ad hoc On demand Distance Vector (AODV) [4] routing protocol as the reactive protocol. We have a simple implementation of the Region Gateway Protocol, which computes the whole route and provide it to the requester node.

4.1. Simulation

We perform simulation of the proposed protocol in comparison to one reactive protocol and one proactive protocol. For proactive protocol we consider DSDV [7, 9] and for a reactive protocol we considered AODV [4]. So, that we can have a comparison that shows what is the improvement in our proposal.

We performed our simulation in ns-2.30 [20]. For the simulations, we used the ns-2 network simulator to include factors such as; Mobility in ad hoc regions and the 802.11 MAC layer.

We studied the AODV and DSDV routing protocols in comparison to our proposal. The implementation of these protocols was according to the modules provided in ns2.30 (all-in-one).

We performed our simulation using node mobility with speed 5m/s and l5mJs. We first compared the three protocols for the packet delivery ration and routing overhead with 10 sources for CBR traffic. We perform these tests on all three protocols sending 4 packets/s.

Figure 4 (a & b) highlight the relative performance of the three routing protocols on our traffic load of 10 sources. For little node mobility the packet delivery is very good, but as the pause time is decreased the delivery ratio is decreased. For AODV, the delivery ration is better than the other protocols, but our protocol work better than DSDV.

For the Routing overhead we observed that our protocol is better than AODV but DSDV is better than our protocol. As in real mesh network node mobility is not very much, so we think our protocol provide good trade off between the route overhead and delivery ratio.

5. Conclusion & Future Work

We compared the AODV and DSDV routing protocols in comparison to our proposed protocol. The simulation result shows that our proposed protocol’s performance is in

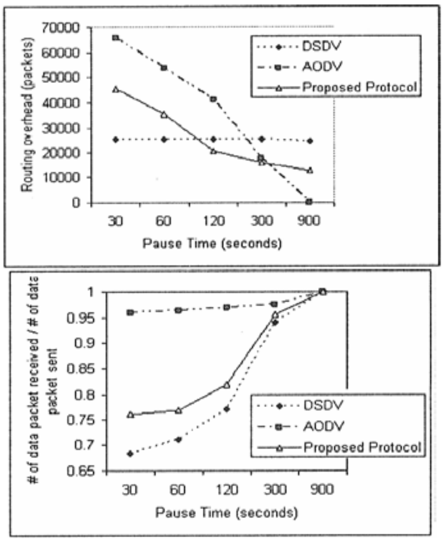

Figure 4. (a) Comparison between the 3 protocols of the # of route packet sent as a function of pause time. **(b)** Comparison between the 3 protocols of the packet delivery ratio as a function of pause time.

between the two reactive and proactive protocols. It uses the best properties of the both the routing protocols and provides better result for a mesh network.

Currently, we are working to mature our implementation of the protocol and in future we would be able to experiment it on a real wireless mesh network environment.

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