Extending the Reach of Ad hoc Networks using Layer 2 Tunnels

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1. Introduction

Ad hoc wireless networking has been an active research area for the past several years. Reachability has been one of the bigger challenges encountered in the design of an efficient ad hoc wireless network. One of the solutions towards improving the reachability of ad hoc networks is the usage of a hierarchical approach [1]. The authors of [1] suggest that instead of a flat homogenous ad hoc network (which suffers from poor scalability), an ad hoc network with Mobile Backbone Nodes (MBN) be used. They argue that a large scale ad hoc network suffers not only from the limitation of available bandwidth but also "many hops" paths are prone to break and cause numerous packet drops. The nodes that form an MBN network communicate over a separate radio frequency than the actual ad hoc network. In [2] another solution is proposed for improving the reach of ad hoc networks by considering the use of hybrid networks. The authors of [2] suggest a network that uses both ad hoc connectivity and access points (AP). Access points give mobile hosts (MH) access to the nodes that are outside their transmission range. These APs are joined together via a wired network. Using their proposed routing protocol, an AP maintains information about routes to all MHs within its own zone. It uses this information to entertain any Route REQuests (RREQs) coming from other zones. The routing protocol works differently for APs and MHs. In both [1] and [2], the solution completely relies upon the routing protocols. To expand the reach of ad hoc networks, these solutions either extend the existing routing protocol (LANMAR in [1]) or consider a new routing protocol [2]. In this paper, the authors examine the reachability problem of ad hoc networks with respect to layer 2 mechanisms. Two specific cases were considered for the current work: (1) Two ad hoc networks connected via two or more border gateways via an infrastructured network. (2) A single ad hoc network with the provision for an alternate path between ad hoc nodes via an infrastructured network.

2. Test Bed

A test bed shown in Figure 1 was setup at Wichita State University's Advance Networking Research Center (ANRC) to evaluate the various approaches employed to inter-connect ad hoc networks via an infrastructured network. The gateways (GW1 through GW3) and laptops (H1 through H4) were configured to run Red Hat Linux 9.0 (Kernel 2.4.18-3) operating system. Ad hoc On demand Distance Vector (AODV) routing protocol was employed in ad hoc domains, where as Routing Information Protocol (RIPv2) was employed in the infrastructured domain. For the IP cloud, two Cisco 3600 series and two Cisco 2500 series routers were employed.
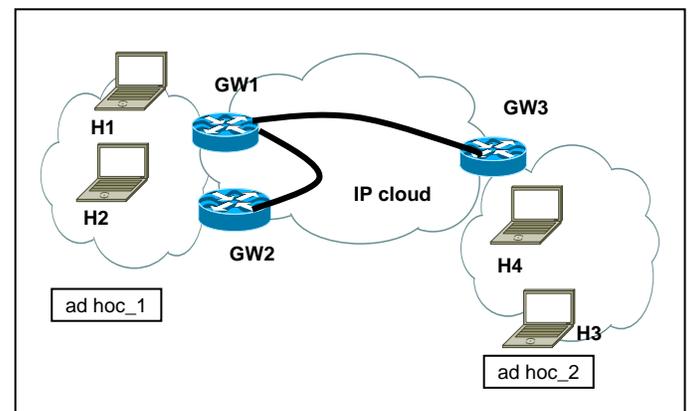

Figure 1: Test Bed

The gateways were configured to run Zebra [3]. Zebra is a freely available software package that manages TCP/IP based routing protocols on Linux. Code was written to redistribute the AODV and RIPv2 routes into each others routing tables. MobiEmu [4] was employed to emulate the mobility of the ad hoc nodes (laptops). MobiEmu operates employs a master/slave architecture. The *master controller* was run on a dedicated host outside the testbed network; a *slave controller* was run on each ad hoc node within the test-bed.

The gateways were configured to support two network interfaces: (a) *eth0* to connect to the infrastructured network, and (b) *eth1* to connect to the ad hoc network. The *eth1* interface of GW1 had an IP address of 130.1.1.10 while that of GW2 had an IP address of 100.1.1.20. Interface *eth2* of the gateways was employed to connect to the *master controller* to enable the control of the gateways by the *master controller* of MobiEmu. The ad hoc nodes H1 and H2 were configured with IP addresses of 140.1.1.11 and 150.1.1.12 respectively while nodes H3 and H4 were configured with IP addresses of 110.1.1.21 and 120.1.1.22 respectively.

The main aim of the research was to provide connectivity between nodes that are not in each other's transmission ranges. In order to achieve the goal the authors worked with a Layer 3 approach, i.e. Redistributing routes between ad hoc domain and infrastructured domain and vice versa. A code was written to accomplish this task and ran on the gateways. This method resulted in partial connectivity due to two reasons. First, the time taken to update a route learned from one ad hoc domain into another could lead to disruption in traffic streams within the ad hoc networks. The timers within RIP could be modified to accommodate a faster convergence time but this would lead to an increase in the "chattiness" of RIP over the infrastructured network. Second, and more importantly, the redistribution of routes is applicable to routes held by the gateways. If GW1 does not have a route to some ad hoc node within the ad hoc_1 domain, GW3 will not be updated of this route. Since a "On Demand" routing protocol (AODV) was used for ad hoc domains the gateways only knew the address that were used in previous communications or the nodes that are a hop away from gateway. Therefore the nodes from ad hoc_1 could not communicate with the nodes for which GW3 did not have the route entries. In order to have full connectivity Layer 2 tunnel approach was used which is explained in the next section.

3. Layer 2 Connectivity

The idea behind Layer 2 technologies was to create a secure virtual network for corporate's private use via an intermediate network (Internet Service Provider or ISP). This is a feasible solution compared to laying down a personal Local Area Network (LAN) or Wide Area Network (WAN) to connect, for example, remote corporate offices. Figure 2 shows ad hoc nodes (H1 through H5) connected to two different ad hoc domains via an L2TPv3 tunnel operating over an IP network. GW1 and GW2 are configured to support the L2TPv3 tunnel endpoints. Assuming H1 wants to communicate with H5. If H1 does not have a route for H5, it issues a RREQ. This RREQ travels towards GW1. Due to the presence of a layer 2 circuit between GW1 and GW2, the RREQ that GW1 receives is also transmitted over to GW2 (since RREQs are broadcast over the channel). The L2TPv3 enabled interface appends L2TPv3 header to the received RREQ frame, and forwards it to the other side of the tunnel. GW2 decapsulates the L2TPv3 header from the incoming packet and broadcasts the frame onto the ad hoc domain. Any node within the ad hoc domain (could be H4 or H5 itself) with an active route to H5 would respond to this broadcast RREQ by unicasting a Route REPly (RREP). This RREP travels towards H1 via the L2TPv3 tunnel after appropriate encapsulation and decapsulation operations are performed at the gateways. The network shown in Figure 1 was utilized to evaluate the inter-

connectivity of ad hoc domains over an L2TPv3 tunnel. Figure 3 shows the routing table on ad hoc node H3. As can be observed from Figure 3, all the routes appear on H3 and there is full connectivity between all the nodes in both the ad hoc domains.
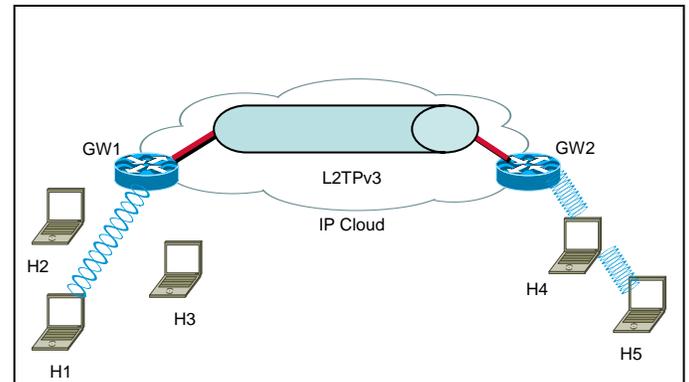

Figure 2: Ad hoc nodes connected via L2TPv3 tunnel

Figure 3: Routing table of H3 with a layer 2 circuit between the gateways

4. Conclusion

The problem of limited reachability of ad hoc nodes was considered in this paper. By utilizing the infrastructured network between the ad hoc domains, communication between ad hoc nodes from different domains could be enabled. The solution of using Layer 2 Tunnels across the infrastructured network was proposed in this research in order to connect the two islands. This method resulted in full connectivity between the nodes in either ad hoc domain.

5. References

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