ROUTING IN SUBURBAN AD-HOC NETWORKS

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ABSTRACT: *A suburban ad-hoc network (SAHN) aims to provide an inexpensive, secure, broadband, cooperative network using wireless technology. There exists a plethora of ad-hoc wireless routing solutions designed to route efficiently in mobile environments. Due to the quasi-static nature of the SAHN, existing solutions may not meet its requirements without proper optimizations. In this paper we have outlined an efficient routing solution suitable for the SAHN that considers (a) multiple routes to a destination, (b) QoS for route selection and data transmission, (c) load balancing among feasible routes and (d) security in the network layer. We have also presented some simulation results to show that our proposed approach can perform better than existing solutions in a SAHN.*

Keywords: *Suburban, Ad-Hoc, SAHN, QoS, Security*

1 INTRODUCTION

Commercial broadband facilities require costly infrastructure and recurring charges. Mostly large educational institutions, governmental organizations, companies and research groups are capable of bearing high expenses associated with these broadband services. Residential users can enjoy similar performance at great cost provided they live in close proximity to the service providers. With a view to provide inexpensive internetworking facilities to home users, many voluntary networking groups[1] have employed wireless technologies to build community networks. Though their services require low initial costs and almost no service charges, their solution are vulnerable to unauthorised intrusions. Moreover, dependance on centralised routing nodes for intercommunication results in performance bottlenecks as well as inefficient use of aggregate network capacity. As a consequence, these solutions are still less attractive than costly solutions provided by various commercial service providers. Nokia's broadband solution using wireless technology (Nokia RoofTop) can be considered as an alternative to expensive broadband solutions. However, it can be argued that Nokia RoofTop's optimized IP protocol stack may result in marginal performance in ad-hoc wireless networks [2].

To alleviate these expensive, oversubscribed, area limited and low secured solutions, a networking framework has been proposed termed the 'Suburban Ad-Hoc Network' [3] or SAHN. The inherent symmetric throughput in both upstream and downstream channels at reasonably high rates allows the facility to provide traditional costly broadband throughput at low cost. An efficient ad-hoc routing protocol at each node makes the network independent of any centralized gateway. The security scheme at the network layer is particularly appealing to security conscious business users. Additionally the wireless interconnecting property makes the SAHN suited to extend the Internet infrastructure to areas of inadequate wired facilities.

One of the important requirements of the SAHN implementation is to employ an appropriate routing solution. A number of existing ad-hoc routing algorithms for wireless environment have potential to be deployed in a SAHN. Dynamic source routing (DSR) and its variants, ad-hoc on demand distance vector routing (AODV) and its variants, temporally ordered routing algorithm (TORA) and signal stability routing are among them. Available solutions may not fulfill one or more of the following requirements of a SAHN : (a) finding redundant routes to a destination, (b) providing resource access control, (c) routing with guaranteed QoS, (d) balancing load among feasible routes and (e) incorporating security at the network layer [2][4]. Moreover, most of these routing approaches are not optimized for quasi static networks [2][4]. With a view to minimize the aforementioned limitations of a single routing solution, we have proposed a hybrid approach (known as SAHNR) [4] primarily based on DSR and AODV.

In this paper, we include more details of SAHNR in Section 2. We also present some performance results in Section 3, comparing SAHNR with two other ad-hoc routing protocols (DSR and AODV) in a simulated environment.

2 ROUTING PROTOCOL

Generally SAHNR has the following major responsibilities:

2.1 Neighbor Discovery

Neighbor discovery is a one-off procedure required when a node wishes to join the SAHN. The authentication procedure and negotiation of the shared key between a neighboring pair are performed in this stage (see Figure 1). Throughout this paper, if not mentioned explicitly, it will be assumed that all packets have been encrypted before their transmission according to the negotiated shared key. The same assumption will be applied to the packets being received.

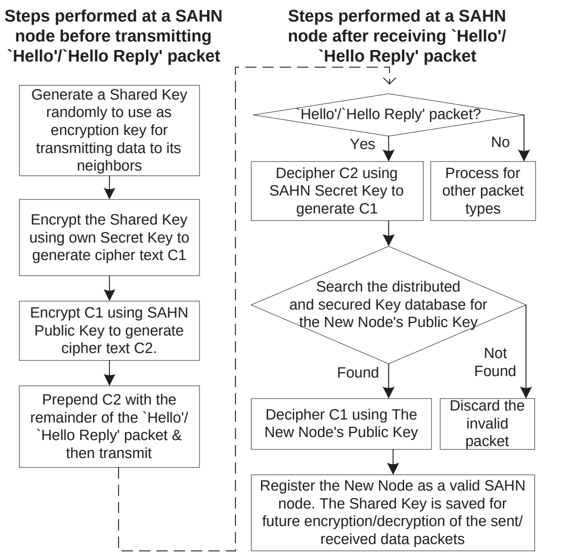


Figure 1: Authentication and negotiation of the shared key between neighbour nodes

SAHNR implements neighbor discovery procedure with the help of 'Hello' and 'Hello reply' packets (Figure 2). To minimize the network traffic overhead, these packets are kept as small as possible. QoS values (available bandwidth, error rate and delay) of the neighboring nodes are also exchanged with these 'HELLO' and 'Hello Reply packets'.

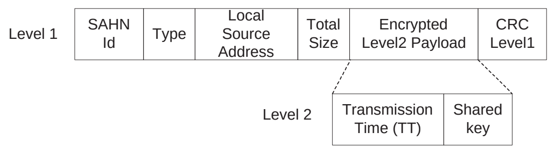


Figure 2: 'Hello' and 'Hello Reply' packet format

2.2 Route Discovery

A node tries to discover routes to a destination if no route is found in its routing table or existing routes are unable to provide the required QoS. The process of on-demand route discovery is accomplished with the help of route request (RREQ) and route reply (RREP) packets (Figure 3). A table called the 'routing table' (RT) is maintained to keep track of all valid paths to different destinations and their associated QoS values.

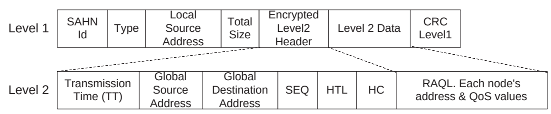


Figure 3: 'Route request' and 'Route reply' packet format

At each intermediate node, its address and local QoS information (available bandwidth, error rate) are appended in the RAQL (Route address and QoS information list) of the RREQ packets. Each entry in a RAQL can hold a node address and its QoS values. Before forwarding a RREQ packet, each intermediate node retrieves new routes and their QoS values from the RAQL.

A RREP packet is generated whenever an intermediate node has one or more routes to the destination, or is the destination node itself. If the node is not the destination node but has a route to the destination, the RREP is constructed by joining the RAQL of the RREQ with the RAQL of the route to the destination.

When an intermediate node receives a RREP, the node updates its routing table with previously unknown routes and QoS values contained in the RAQL. If the initiating source of the RREQ receives the RREP, route discovery is deemed successful. The source node then updates its routing table with the new routes and corresponding QoS values from the RAQL of the RREP.

2.3 Data Transmission

Whenever a source node wishes to send data packets (Figure 4) to its destination node, it first checks the cache of the neighboring nodes. If the destination node belongs to one of the neighboring nodes with sufficient QoS value, the data packet is unicast to it.

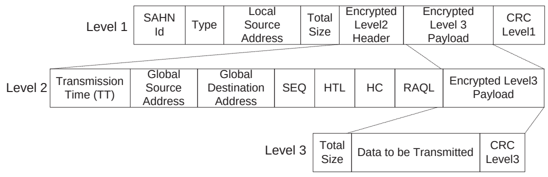


Figure 4: Data packet format

If the destination is other than any of the neighboring nodes, routes with sufficient QoS are selected to transmit data. It should be noted that, data may be spread across a number of feasible routes rather than one feasible route in order to distribute load to meet QoS requirements. The first data packet of any session contains complete route address list to the destination. When any intermediate node receives the first data packet of a particular session, it creates a row in its forwarding cache with the destination and next node address. Any subsequent data packet of that session no longer needs to carry the route address list. Fast forwarding is accomplished at each intermediate node by retrieving the next node address from its forwarding cache indexed by the destination address field of any data packet.

2.4 Route Maintenance

A SAHN node may not receive acknowledgement within a specified period for the packet transmitted to its neighboring node as that neighboring node may not be functioning. Sometimes it may receive a packet intended for a destination and the corresponding row is no longer in the routing table, as that row has been deleted for being idle for a long time. In any of these cases a SAHN node generates RERR packets (Figure 5). When an intermediate SAHN node receives a RERR packet, it deletes the entries from both the routing table and forwarding cache corresponding to the values of 'Unreachable Node Address' and 'Global Destination Address'. When the RERR packet reaches the global source, it updates its routing table and the

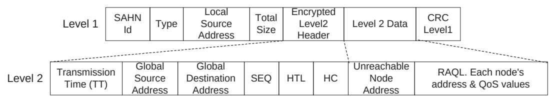


Figure 5: 'Route error' packet format

cache in the same way as the intermediate node. Then it tries to re-transmit the data using an alternate route contained in the routing table. If such route does not exist, it initiates a new route discovery sequence as described earlier.

The route maintenance procedure periodically checks the routing tables and the caches for stale entries. Moreover, the route maintenance module keeps its local QoS information database up-to-date.

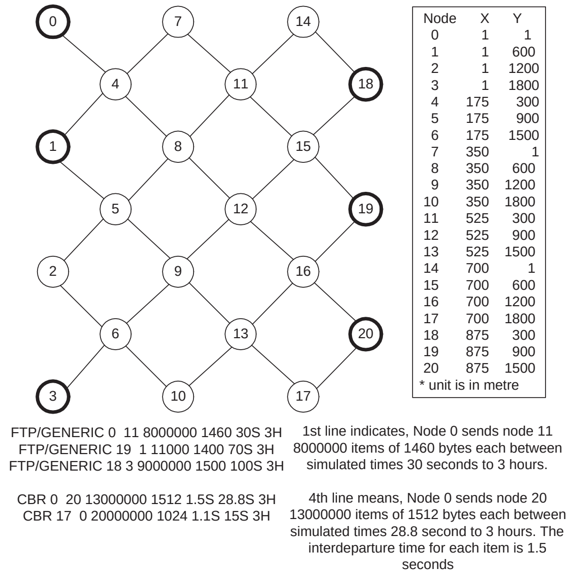
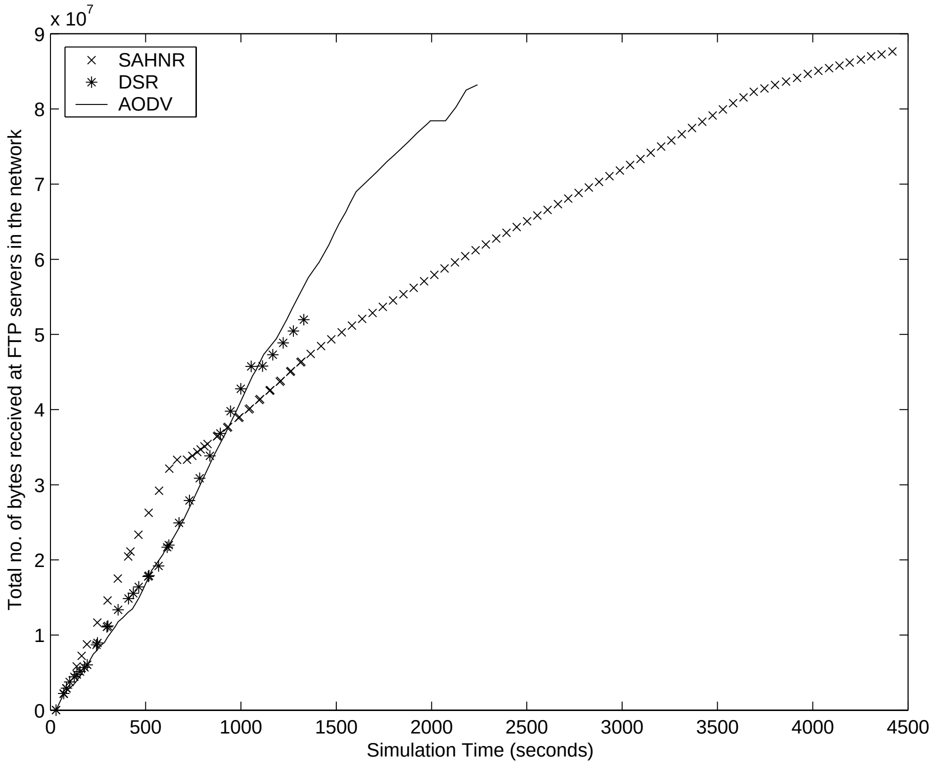


Figure 6: Node placements for simulation

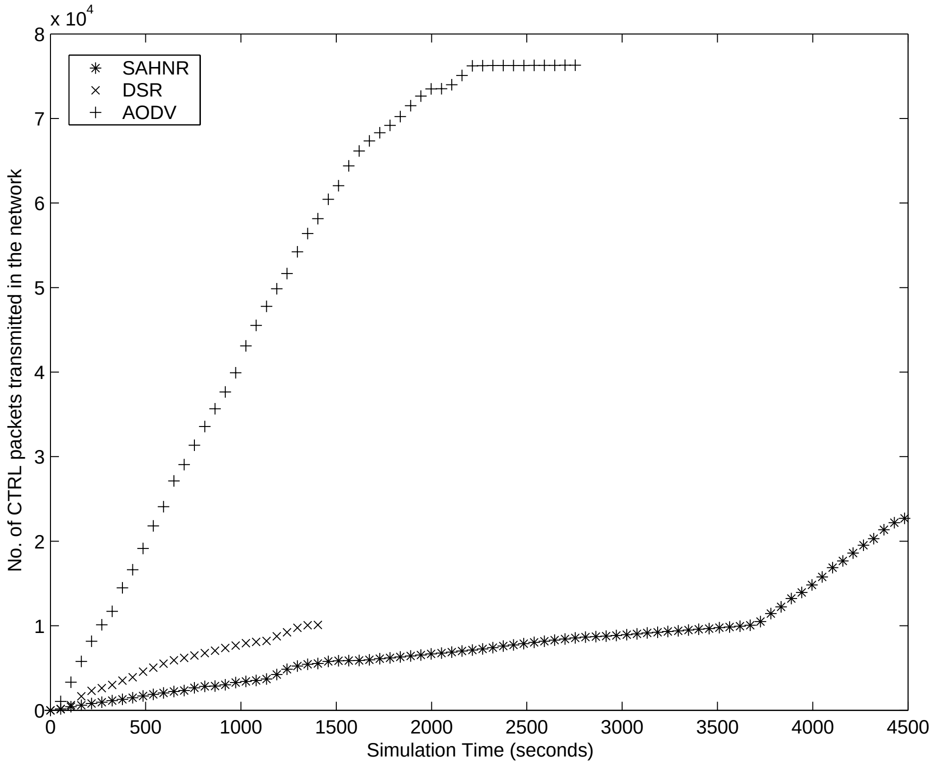
3 Simulation Results

We have used GloMoSim (version 2.03) to simulate our algorithm. The aim was to observe overall network performance using SAHNR, DSR and AODV in a densely connected graph. At this stage, neighbor discovery process, security policies and the load balancing facilities were not implemented.

This simulation consisted of 21 nodes in a physical terrain of 3 square kilometers. The nodes were placed as shown in Figure 6. A standard radio model was used to transmit and receive packets. Propagation limit was set to -111.0 dBm. The Two-Ray model represented propagation path-loss which uses free space path loss for direct links and



(a) Comparing data reception rates



(b) Comparing load of CTRL packets in the network

Figure 7: Simulation result of network performance

plane earth path loss for more distant links. Radio transmit power had a value of 15.0 dBm. Gain of the radio antenna was 0.0 dB. Radio reception threshold, sensitivity and SNR threshold were assigned with -81.0 dBm, -91.0 dB and 10.0 dB respectively. All these values of various radio parameters enabled nodes to face occasional link breakage. To investigate network performance with the IEEE wireless technology, we used 802.11 as the MAC protocol in 2.4 GHz frequency spectrum with 2 Mbits/sec bandwidth limit.

There were three FTP clients at node 0, node 18 and node 19 associated with three FTP servers at node 11, node 3 and node 1 respectively. With a view to saturate network links, we had also introduced a pair of constant bit rate (CBR) clients at node 0 and node 17 for a pair of CBR servers at node 20 and node 0 respectively.

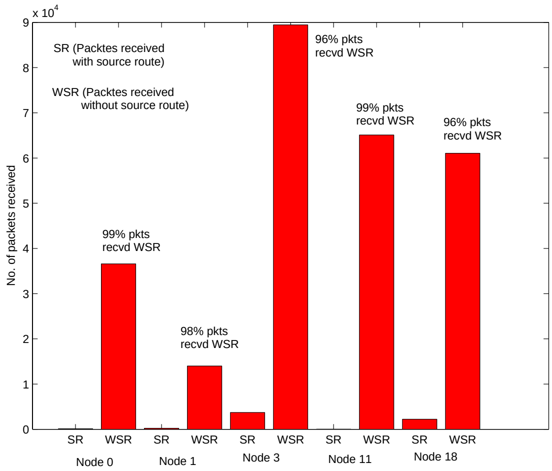


Figure 8: Number of packets received at various nodes with and with out source routes for using SAHNR

In SAHNR, selection of routes was based on QoS values associated with available routes to a destination. So, it can be argued that possibility of using more routes, instead of using overly congested routes repetitively, will be higher by SAHNR than DSR and AODV. As a result, SAHNR may receive more number of bytes than DSR and AODV within same duration. Our simulation result confirmed our views. Figure 7(a) shows that the total number of bytes received successfully at FTP servers was greater while using SAHNR than DSR and AODV. In terms of control packet generation and transmission, the SAHNR imposed less stress on the network than DSR and AODV (Figure 7(b)). Moreover, forwarding table in SAHNR reduced network load by excluding source route in each data packet (see Figure 8).

4 CONCLUSION

In this paper, we have given details of the routing solution (SAHNR) suitable for a SAHN with some simulation results. We are working on defining a suitable QoS equation for selecting suitable routes efficiently. We are also trying to incorporating all the features of SAHNR and compare it with existing solutions. We plan to design a suitable management module capable of detecting and handling noncooperative nodes. We have built a testbed with twenty desktop PCs to test our work in real environment. Each of these PCs acts as a SAHN node. After simulating complete SAHNR with GloMoSim, we will port it to our testbed where each of the PCs will have its own SAHNR module. Though we believe that more optimizations and changes may be required during prototype implementation and testing, the proposed solution can be adopted to many ad-hoc community networks.

Acknowledgements

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