A Hybrid QoS Routing Strategy for Suburban Ad-Hoc Networks

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Abstract— **The suburban ad-hoc network (SAHN) aims to provide suburban area connectivity for local area networks at broadband speed with a low initial cost and zero service charges using wireless technology. There exists various QoS routing solutions for mobile ad-hoc networks. Some of the solutions can be employed in a SAHN with certain optimizations meeting its routing requirements. Network level security, bandwidth, latency and link stability must be considered to select suitable routes for data transmission. Though existing solutions consider bandwidth, latency and link stability to provide QoS routing, network level security is yet to be integrated. Major contributions of this paper are to propose an efficient routing algorithm for the SAHN, meeting above QoS requirements, and to compare it with two other non QoS solutions.**

I. Introduction

Commercially available broadband services require costly infrastructure and recurring charges. Mostly large educational institutions, governmental organizations, large companies and research groups are capable of bearing high expenses associated with these broadband services. Residential users can enjoy similar performance at relatively high cost provided they live in close proximity to the service providers. 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].

The 'Suburban Ad-Hoc Network' [3] or SAHN was proposed to alleviate these expensive, oversubscribed, area limited and low secured solutions. 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 can be regarded as feasible candidates 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. Without proper optimizations these 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]. Though proposals in [5],[6],[7] and [8] aim to provide QoS routing solutions in mobile ad-hoc networks, they need to be optimized before using in quasi static networks. Moreover, network level security is yet to be considered as a one of the QoS parameters in these solutions. Adrian Bickerstaffe has proposed an equation to incorporate bandwidth, latency, error rate and security to fulfill QoS requirements for SAHN specific traffic [2]. Real life experiments or at least simulation is needed to validate this proposal to be incorporated for routing in SAHN.

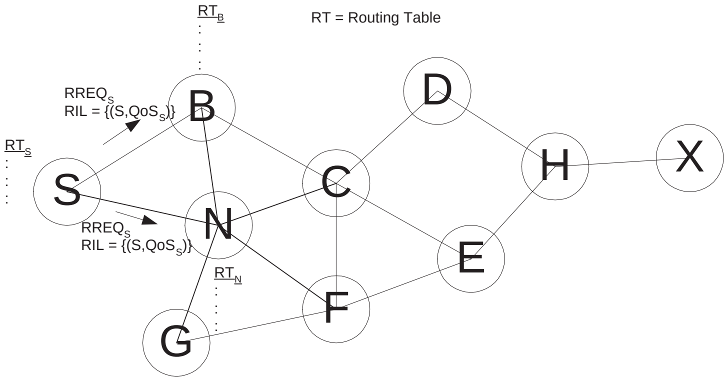
In order to minimize the aforementioned limitations of a single routing solution, we have proposed a hybrid approach (known as SAHNR) [4][9] primarily based on the principles of DSR, AODV and the initial works of Enes Makalic [2]. In this paper, we include more optimization of SAHNR in Section II. We also present some performance results in Section III, comparing SAHNR with two other ad-hoc routing protocols (DSR and AODV) with the help of GloMoSim.

II. SAHN Routing Protocol

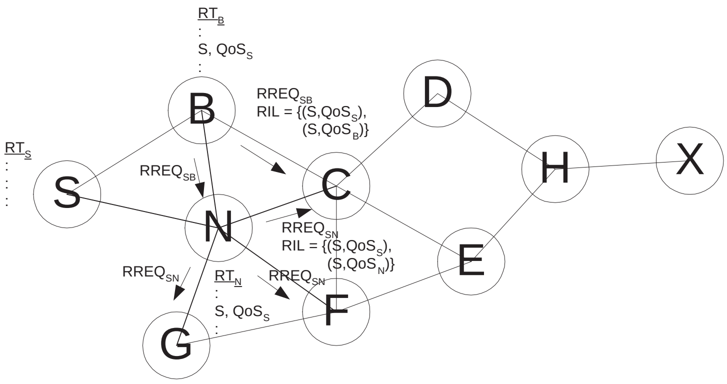
Preliminary specification of SAHN routing protocol in [4][9] involved hello and hello reply cycles to authenticate SHAN nodes. Exchange of network level encryption/decryption keys was also done in that cycle. In this paper both of these security mechanisms have been integrated in route discovery cycle. This optimization is believed to minimize control packet overhead and maximize network throughput without compromising the network level security outlined in [4] and [9]. The revised version of SAHN routing protocol (SAHNR) can be described as follows:

A. Node Authentication and Route Discovery

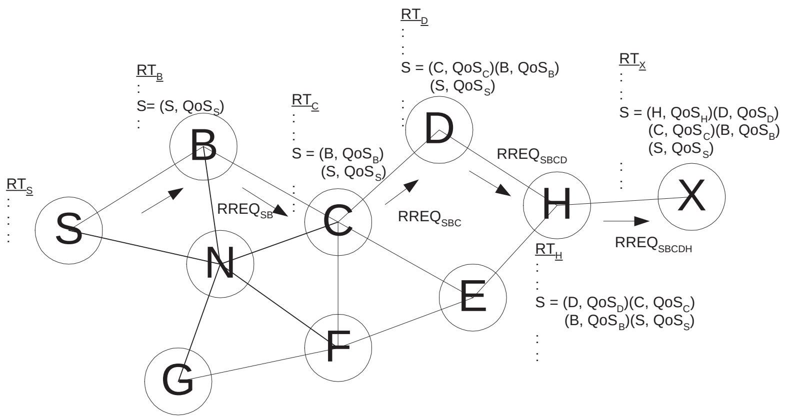
A node tries to discover routes to a destination if no route is found in its routing table or existing routes are unable to provide the required QoS. The route discovery process



(a)X broadcasts RREQ packets with its shared key in encrypted form



(b)B and N registers S as a valid SAHN node, updated their routing tables and rebroadcast received RREQs

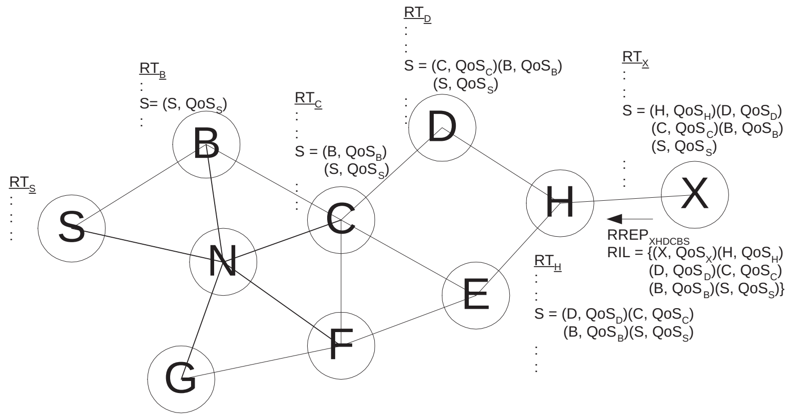


(c)Finally a RREQ reaches X from H. X registers H as valid SAHN node and update its routing table

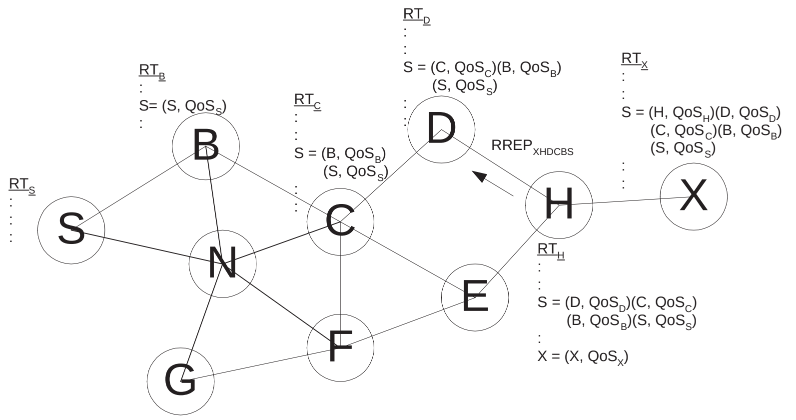
Fig. 1. Route request steps to find route from node S to node X

(Fig 1 and Fig 2)is accomplished with the help of with the help of route request (RREQ) and route reply (RREP) packets (Fig 3a). Node authentication and negotiation of shared key are also integrated in this stage with digital signature mechanism.

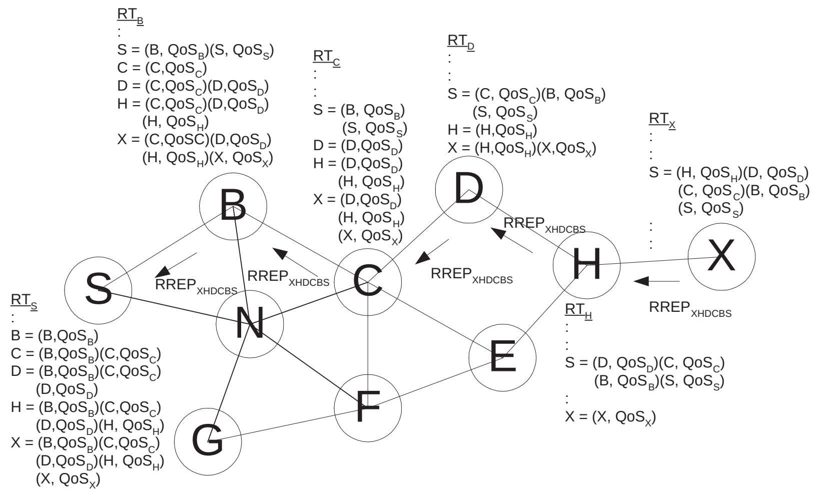
Before transmitting a RREQ packet, a SAHN node randomly generates a shared key for using as encryption key to transmit data to its neighbor. The shared key is encrypted using its own secret key to generate cipher text C1. Then C1 is encrypted using a public key (SAHN secret key), known only to valid SAHN nodes, to generate cipher text C2. Finally, C2 is added with rest of the RREQ packet and broadcast. A node receiving a RREQ packet from a neighboring node deciphers C2 using SAHN secret key to get C1. It searches its key database to get the neighboring node's public key to retrieve the encrypted shared key in C1. A successful retrieval of the shared key results in registering the neighboring node as a valid SAHN node. All upstream nodes towards initial source of RREQ packets perform the same tasks to register downstream neighboring nodes with



(a)For a RREQ from H, X encrypts its shared key, appends it with a RREP and unicasts it to H



(b)H registers X as a valid SAHN node, updateds its routing table and forwards it to D



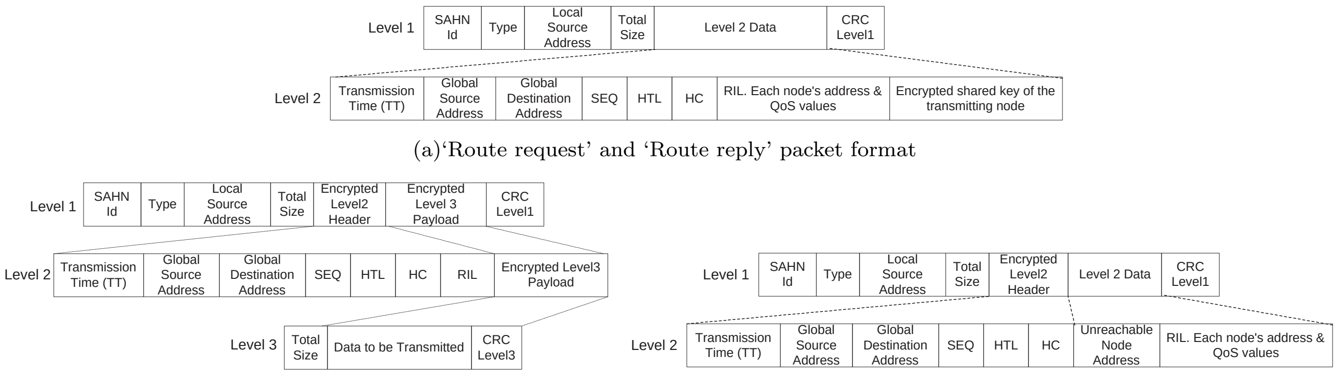
(c)Finally a RREP reaches S from X. S registers B as valid SAHN node and updates its routing table

Fig. 2. Route reply steps to find route from node S to node X

the help of RREP packets.

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

A RREP packet is generated whenever an intermediate node has one or more routes to the destination, or is the



(a)'Route request' and 'Route reply' packet format

(b)Data packet format

(c)'Route error' packet format

Fig. 3. Various packet formats in SAHNR

destination node itself. If the node is not the destination node but has a route to the destination, the RREP is constructed by joining RIL of the RREQ with the RIL 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 RIL. If the initiating source of the RREQ receives the RREP, route discovery is deemed successful. The source node then updates its routing table 'RT' with the unknown routes and corresponding QoS values from the RIL of the RREP.

B. Data Transmission

Whenever a source node wishes to send data packets (Fig 3b), routes with sufficient QoS are selected to transmit data. It should be noted that, data may be distributed along all feasible routes to provide load balancing.

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.

C. Route Maintenance

A SAHN node may not receive acknowledgement within a certain period of time for the transmitted packet to its neighboring node since that neighboring node may have disappeared. 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 (Fig 3c). When an intermediate SAHN node receives a RERR packet, it deletes the entries from the routing table and the 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 cache in the same way as the intermediate node. Then it tries to retransmit the data using an alternative 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 also checks the routing tables and the caches them for stale entries periodically. Moreover, the route maintenance module keeps its local QoS information database up-to-date.

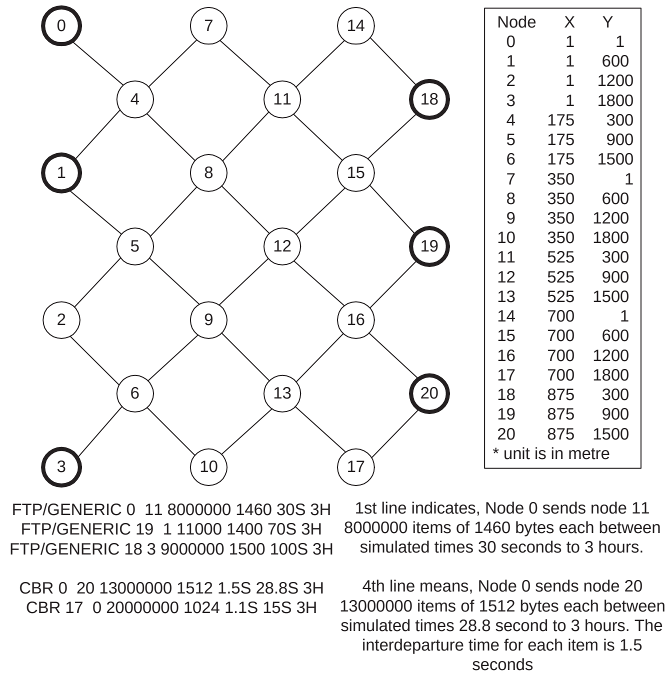
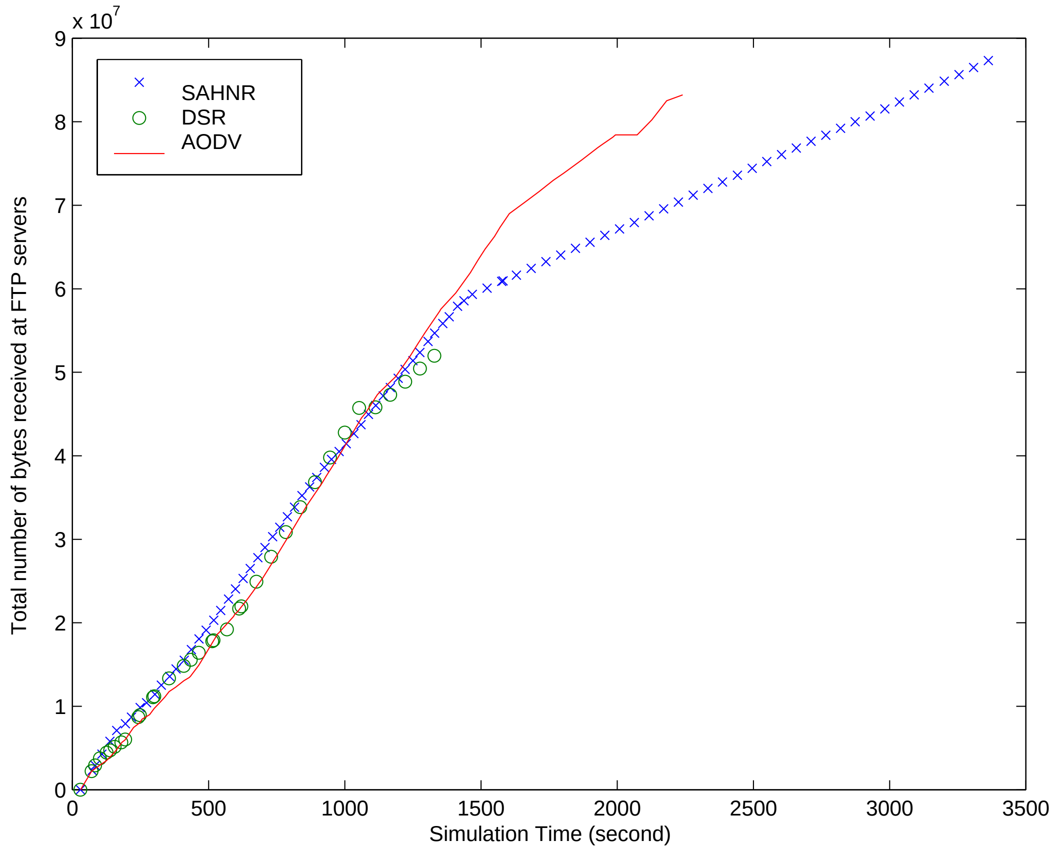


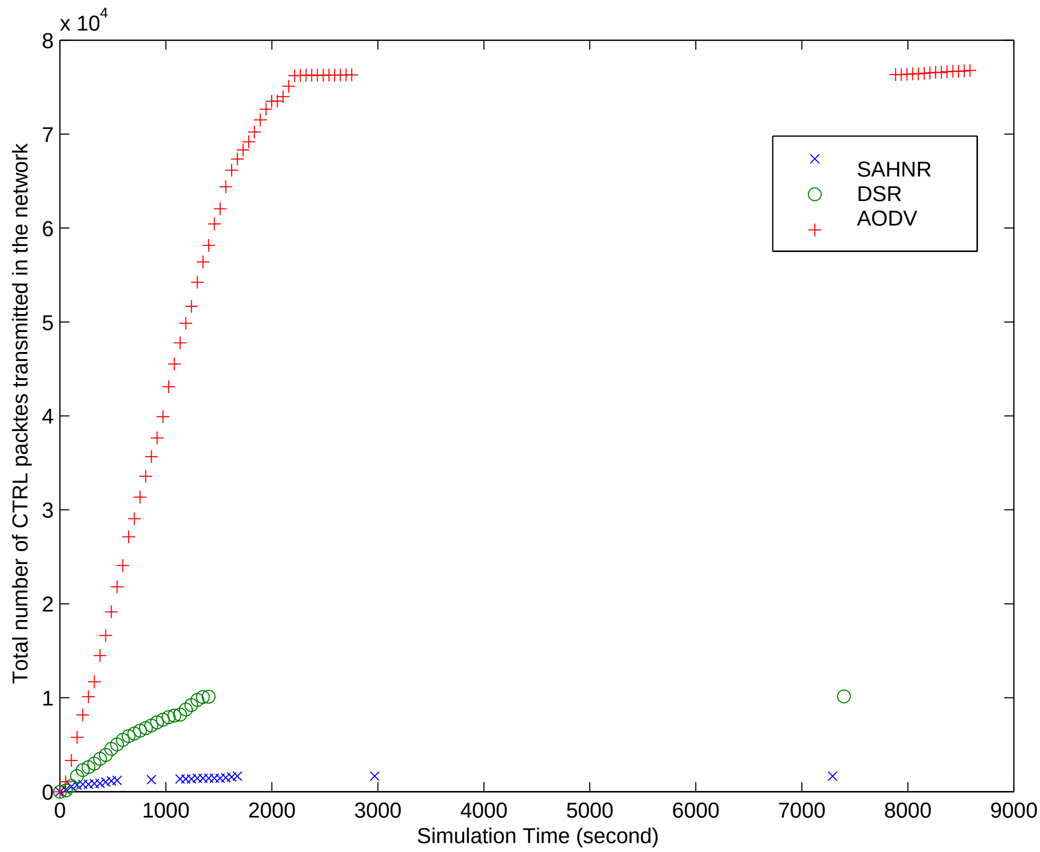
Fig. 4. Node placements for simulation

III. 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. Here we have integrated neighbor discovery process and security policies with the route discovery cy-



(a)Comparing data reception rates



(b)Comparing load of CTRL packets in the network

Fig. 5. Simulation result of network performance

cle. Bandwidth reservation was taken as the second QoS parameter. It was given priority over hop count metric. Remaining QoS parameters and provision for load balancing were not incorporated during this simulation.

This simulation consisted of 21 nodes in a physical terrain of 3 square kilometers. The nodes were placed as shown in Fig 4. 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 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.

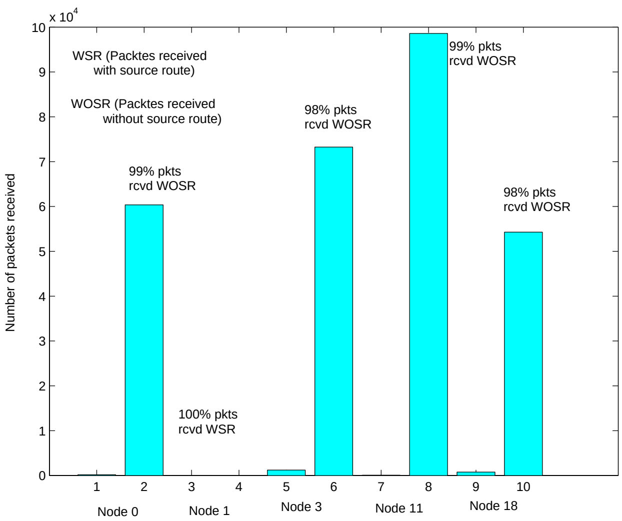


Fig. 6. Number of packets received at various nodes with and with out source routes using SAHNR

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. Fig 5a 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 (Fig 5b). Moreover, forwarding table in SAHNR reduced network load by excluding source route in each data packet (see Fig 6).

IV. Conclusion

In this paper, we have optimized our the routing solution (SAHNR) presented in [4] and [9]. Merging neighbor discovery, node authentication and negotiation of secret keys with route discovery cycle resulted in reduction in control packet overhead in the network. Though network level security and bandwidth reservation were considered as QoS parameters, latency and link stability in terms of error rate are yet to be integrated for simulation purpose. We are working on defining a suitable QoS equation for selecting suitable routes efficiently. 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.

Acknowledgments

Initial definition of the SAHN architecture was carried out by Adrian Bickerstaffe, Enes Makalic and Slavisa Garic in their computer science honours projects in 2001 at Monash University. They also implemented the testbed. The current project builds on their excellent work.

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