Comparison of Two Proactive Protocols: OLSR and TBRPF using the RNS (Relay Node Set) Framework

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Abstract: Past study of MANET routing protocols focused on designing new protocols, comparing existing protocols, or improving protocols before standard MANET routing protocols are established. Researchers have studied these protocols using simulations of arbitrary networks with certain traffic profiles. Due to the lack of consistent characterization of different MANET protocols, prior simulation experiments are not well designed. Some protocols that perform well, in terms of control overhead or throughput, in some scenarios may have poor performance under other conditions. Therefore, the conclusions based on these simulations cannot be generalized. These efforts can be aided by a framework that can characterize MANET routing protocols. We can describe MANET routing protocols with the RNS framework so that researchers can understand the protocols more easily. This framework characterizes different MANET routing protocols and highlights the internal relationships among different protocols. Quantitative models based on the RNS framework can be used to identify factors that affect control overhead for different MANET routing protocols. The framework allows comparison of routing protocols by analytical models coupled with network parameters and traffic profiles. Possible ideas for improving proposed MANET routing protocols can be found using the RNS framework. The RNS framework and the corresponding quantitative model can aid the design, evaluation, and validation of new MANET routing protocols with emphasis on control overhead. In this chapter, we concentrate on Comparison of Two Proactive Protocols: OLSR and TBRPF using the RNS (Relay Node Set) Framework. Based on the results and assumptions, OLSR usually has larger overhead in the maintenance module than TBRPF.

Key Words: RNS, MANET Protocols, Overhead, OLSR, TBRPF.

0.1 Introduction

The Optimized Link State Routing (OLSR) protocol [1] is a proactive link state routing protocol for MANETs. One key idea is to reduce control overhead by reducing the number of broadcasts as compared with pure flooding mechanisms. The basic concept to support this idea in OLSR is the use of multipoint relays (MPRs) [1], [2]. The latency for OLSR has the highest values from *1* to 10 hops, and generally the highest slope. This indicates that OLSR has difficulty scaling to hop count in this scenario. As a proactive protocol, we would expect OLSR to have lower average latency than a reactive AODV or DSR [3]. OLSR has fairly uniform control overhead, **as** expected from a proactive protocol. **It** trends downwards with sparse networks because there are fewer links to report. But since there are fewer links, route convergence takes longer[3]. The optimized link state protocol (OLSR) [4] utilizes a multicast-like mechanism (called "multipoint relay") to reduce the amount of traffic produced by the periodic topology updates. This has the potential for performing well on smaller ad hoc networks.

OLSR is designed to reduce duplicate retransmission in the same region. The routes are always immediately available when needed due to its proactive nature. Hop by hop routing is used in forwarding packets in OLSR, only nodes selected as MPRs forward control traffic that causes reducing the size of control message and minimizing the overhead from flooding control traffic.[5],[6].

The overall performance of OLSR was very good when mobile nodes movement was changing over varying time. OLSR has high control traffic as compared to TORA as it searches for routes to destination more frequently. Despite the other routing protocols, OLSR protocol showed increase in throughput even when the routing load was increased. We have analyzed that all routing protocol successfully delivers data when subjected to different network stresses and topology changes [7].

The Topology Broadcast Based on Reverse-Path Forwarding (TBRPF) protocol is another link state, proactive routing protocol for MANETs [8]. Each router running TBRPF computes a source tree to all reachable destinations based on partial topology information stored locally. The source tree is also known as the shortest path tree. To reduce overhead, routers in TBRPF only broadcast part of their source tree to neighbors. The partial source tree is called the reportable tree. The main idea of sharing reportable trees with neighbors comes from the Partial Tree-Sharing Protocol (PTSP) described in [9]. Basically, in the local copy of network topology, a link cost is equal to the actual value if this link is in the shortest path tree. Otherwise, the cost is equal to or greater than the real value. The procedure to generate a reportable tree at a router is as follows. Links that are in this router's shortest path tree are checked. If such a link is estimated to be in the neighbors' shortest path trees, it is added to the reportable tree. Note that the estimated results may not be correct, but they do include the correct link costs. TBRPF is said to work better in dense networks [8].

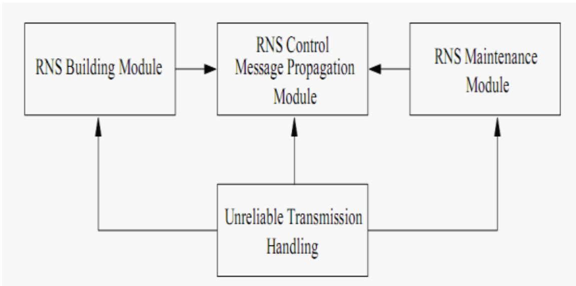

Fig. 1: Four Modules in RNS Framework

RNS Frame work has four modules, according to the four-module RNS framework, the total control overhead for a MANET routing protocol is formed by four overhead components: (i) the overhead to build or rebuild the RNS, (ii) the overhead to maintain the RNS, (iii) the overhead to propagate control messages in the RNS, and (iv) the overhead to handle unreliable transmissions.

Overhead is the number of packets generated by the routing protocols during the simulation, formally speaking it is:

$$overhead = \sum_{i=1}^{n} overhead_i \quad \text{..........(1)}$$

Where overhead *i* is the control packets number generated by node i. The generation of an important overhead will decrease the protocols performance. Although control packets are essential to ensure protocols functioning, their number should be as less as possible [10].

0.2 Analysis of OLSR with the RNS Framework

OLSR is a typical proactive routing protocol. OLSR uses periodic "hello" messages to exchange neighbor lists between neighboring nodes. An MPR node set is a small subset of neighboring nodes that covers all of the center node's two-hop neighbors and may rebroadcast any control message generated or forwarded by that center node. Information about MPR sets is also sent to neighbors via the "hello" messages. All nodes generate their own MPR selector (MPRS) sets. The MPRS set for a node is the set of neighboring nodes that select this node as a member of their MPR sets. Only nodes with non-empty MPRS sets broadcast control messages containing their MPRS sets. Generally, a node re-broadcasts a first-received control message sent by its neighbor if and only if this neighbor selects it as one of the neighbor's MPR nodes. Note that in the propagation procedure, if a node i is in the MPR node set for another node, say node j, and node i already received the broadcast control message originated by a certain initiator from a third node, say node k, before it receives this message from node j, node i keeps silent. In other words, node i is not included in the RNS, which reflects the first-seen rule for OLSR. The procedure described above is the RNS building procedure in OLSR. Therefore, the RNSs in OLSR are associated with certain source nodes and multiple copies of RNSs associated with different initiators can co-exist at any given time.

The sizes of different RNS sets may not be the same. The reason that these RNS sets may have different sizes is due to the distributed selection algorithm of MPR nodes, which is performed by neighbor nodes and may not be consistent among neighboring nodes. Each node rebroadcasts control messages sent by nodes that are in its MPRS set which have not been seen before. Therefore, information about all MPRS sets can be propagated to all nodes in the network with a small number of retransmissions. The total overhead in OLSR is shown in Equation (2).

$$Overhead = O_{construction} + O_{maintenance} + O_{propagation}$$

$$O_{construction} = \sum_{i=1}^{Nhell0} \sum_{i=1}^{N} P_{i.j.hello}$$

$$O_{maintenance} = \sum_{i=1}^{Nm} \sum_{j=1}^{Ni.adjust} (P_{i.j.MPRS} \times S_{i.j.RNS})$$

$$O_{propagation} = \sum_{i=1}^{Nupdate} \sum_{j=1}^{Ni.MPRS} (P_{i.j.MPRS} \times S_{i.j.RNS}) \quad \ldots\ldots\ldots (2)$$

0.3 Analysis of TBRPF with the RNS Framework

TBRPF is also a proactive routing protocol that provides shortest path routing. Each node uses periodic "hello" messages to detect links to its neighbors. Based on the local link state database, each node first builds a shortest path tree to all possible destinations. A node decides whether or not to report links in its shortest path tree to its neighbors by an estimation algorithm based on its local link state database. Information that is shared with a neighbor is considered to be reportable. Basically, a neighbor node is added to a reportable node set if this node has at least one neighbor which is not connected to this neighbor. Links in the shortest path tree are added to a reportable link set if one end point is in the reportable node set or one adjacent link that does not connect to the center node and is included in the reportable link set. Therefore, the reportable link set in the shortest path tree form a reportable tree. Each node broadcasts its reportable tree. This is the RNS building module in TBRPF. For any link, there is a set of nodes that broadcasts that link to neighboring nodes. Therefore, an RNS is built for each link in TBRPF. The control messages sent in TBRPF are reportable trees. Nodes have enough information to build proper shortest path trees based on reportable trees from neighbors.

When the topology changes, the maintenance module uses online computation to update corresponding RNSs and the link state update is propagated to all related nodes in the associated RNSs. Similar to OLSR, TBRPF uses periodic broadcast messages to handle unreliable transmissions. The overhead for TBRPF is presented in Equation (3)

$$Overhead = O_{construction} + O_{maintenance} + O_{propagation}$$

$$O_{construction} = \sum_{i=1}^{Nhell0} \sum_{i=1}^{N} P_{i.j.hello}$$

$$O_{maintenance} = \sum_{I=1}^{Nm} \sum_{j=1}^{Si,RNS} P_{i.j.LS}$$

$$O_{propagation} = \sum_{I=1}^{Nupdate} \sum_{j=1}^{Ei} \sum_{k=1}^{S.i.j.RNS} Pi.j.k.LS$$

----------(3)

0.4 Comparison of Two Proactive Protocols: OLSR and TBRPF

We discuss using the RNS framework to compare two protocols in this section. There are some schemes proposed in the literature to improve MANET routing protocols in terms of control overhead. Those schemes can be derived from the analytical model based on the RNS framework. For example, Perkins, et al. describes an effort to reduce the range of the RNS built when a route request is sent [11]. Perkins, et al. [11] and Johnson, et al. [12] incorporate routing caches to reduce the propagation range of control messages. It can be seen from the analytical model that these approaches are trying to limit the size of RNS in the RNS construction operation. In other words, reducing the blind broadcast range reduces the control overhead. Moreover, this analytical model can also guide us to improve MANET routing protocols in other ways. Since little research has been done to improve proactive routing protocols in terms of control overhead, the following paragraphs give such an example with OLSR.

OLSR uses "hello" messages not only to detect link connections, but also to exchange MPR information. So the overhead of "hello" messages in OLSR is larger than that of TBRPF. The packet size of $P_{i\ j,MPRS}$ is formed by a header (MAC layer header and an IP header) and a data payload. Equation (4) illustrates the calculation of the packet size. Here, we assume that P_{unit} is the basic unit to describe a four-byte node ID. We can assume $P_{i,j,MPRS}$ equals the size of packet header (MAC and IP headers) plus several basic units to describe the MPRS. The link description packet used in TBRPF, defined as $P_{i,LS,}$, shares one header since a node broadcasts a reportable tree. Each link needs at most two IDs, each of size $P_{unit.}$. Some links with common nodes can lead to smaller packet sizes. This yields the upper bound shown in Equation (4).

$$P_{i.j.MPRS} = P_{header} + (|MPRS| + 1) \times P_{unit}$$

$$P_{i.LS} \le P_{header} / S_{reportable.tree.i} + 2P_{unit} \le P_{header} + 2\,P_{unit}.$$

……….(4)

In the RNS maintenance module, the overhead for OLSR, shown in Equation (2), equals the sum of products of $P_{i\ j,MPRS}$ and $S_{i,j,RNS.}$. Generally, if $P_{i\ j,MPRS}$ increases, $S_{i,j,RNS}$ will also increase. Therefore, we can assume that the covariance between these two variables is greater than zero. Now, we have the lower bound for the OLSR overhead for the RNS maintenance module, shown in Equation(5) Based on Equations (4)and (5), the upper bound of the overhead for the RNS maintenance module for TBRPF can be formulated as shown in Equation (5)

$$O_{maint,OLSR} \ge N_m \bullet \overline{N_{adjust}} \bullet \overline{S_{i,j,RNS}}$$
$$= [P_{header} + (|MPRS| + 1)P_{unit}] N_m \overline{N_{adjust}} \bullet \overline{S_{RNS,OLSR}}$$
$$O_{maint,TBRPF} \le N_m \sum_{i=1}^{S_{i,RNS}} (P_{header} + 2P_{unit})$$
$$= N_m (P_{header} + 2P_{unit}) \overline{R_{RNS,TBRPF}}$$

…..(5)

We used simulation to estimate the parameters for the size of the RNSs for these two protocols. Two nodes can communicate with each other if the distance between them is less than the given maximum radio range. The number of nodes ranged from 2 to 100. OLSR and TBRPF were simulated. The latest OLSR draft states that a node "should select an MPR set such that any two-hop neighbor is covered by at least MPR COVERAGE MPR nodes" [13]. We assume that the minimum MPR set is used in OLSR, i.e., MPR COVERAGE equals 1. We generated 1000 random connected topologies for each set of parameters and obtained the average size of RNSs. Results are shown in Figures 2,3,4 and 5 with radio ranges of 25, Note that we only show the average values in these figures. Since for a given number of nodes in a network, say N, the range for all possible RNS sizes is [0, N]. Therefore, the variance of results can be large. In other words, our comparison results only give an idea on the average performance and which protocol generates smaller RNSs really depends on the actual MANET application it applies to.

According to the simulation results, in most cases when the maximum radio ranges were 25 and 50, the average size of RNSs in OLSR is larger than in TBRPF. Therefore, based on these results and assumptions, OLSR usually has larger overhead in the maintenance module than TBRPF. According to the RNS framework, we can improve the first two modules in OLSR without increasing the overhead in the propagation module.

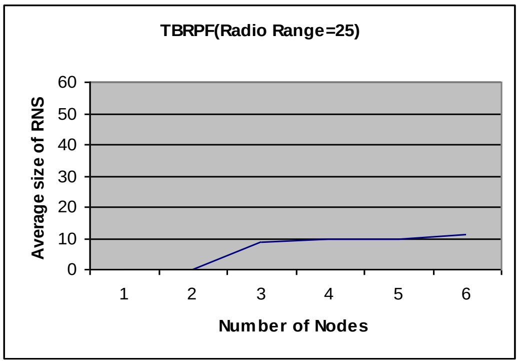

Fig 2: Average size of RNS versus number of nodes (Radio range=25) in TBRPF.

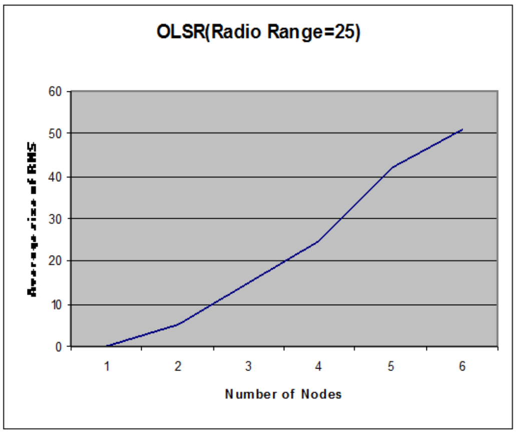

Fig 3: Average size of RNS versus number of nodes (Radio range=25) in OLSR.

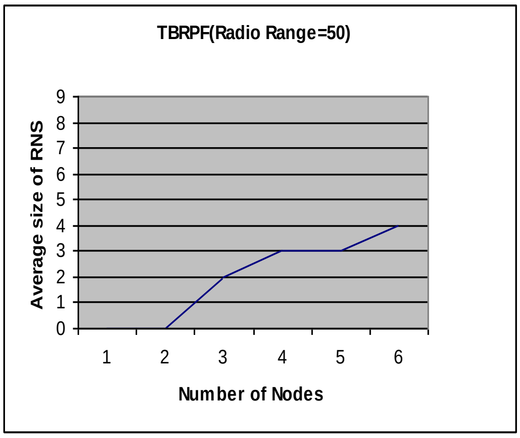

Fig 4: Average size of RNS versus number of nodes (Radio range=50) in TBRPF.

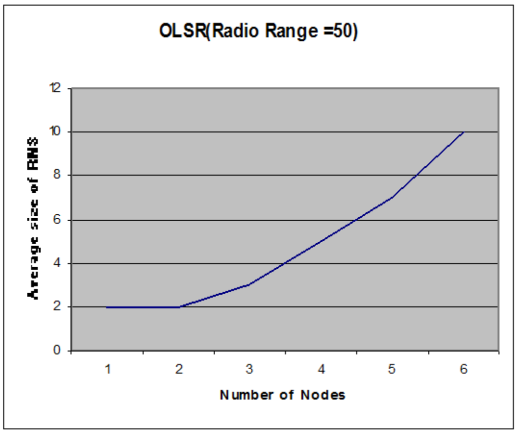

Fig 5: Average size of RNS versus number of nodes (Radio range=50) in OLSR.

0.5 Conclusion:

We presented a framework based on the concept of a relay node set that can characterize MANET routing protocols. We developed an analytical model with the RNS framework for control overhead for MANET routing protocols. Simple examples were used to show how we can compare and, possibly improve routing protocols using the RNS framework. There are some parameters defined in the analytical model that may not be measured directly for a MANET application. This is a limitation of using the RNS framework. One suggested approach is to use simulations or real-time measurements to estimate those values. This suggests a potential research topic for MANET routing protocols in which estimates of environmental parameters, including network and user application profiles, are used to adaptively choose different routing protocols or different sub-functions for one protocol. Here we compared OLSR and TBRPF using RNS. From the result we find out that OLSR usually has larger overhead in the maintenance module than TBRPF.

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