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REDUCING ENERGY CONSUMPTION IN MANET USING A LAYER THREE ROUTING PROTOCOL

Alexandru Robert SIMION
Mid Sweden University, Holmgatan 10, Sundsvall, Sweden
alsi1400@student.miun.se

Abstract
Mobile ad-hoc network (MANET) is an autonomous system based on wireless links in which information is exchanged without having any centralized administration. In this paper, one of its main challenge, the limited battery power is treated. Based on the network layer information an energy reduction algorithm was proposed and the influence of reduced energy consumption over other metrics was studied. The paper pays a special attention to the effects of the hidden terminal problem in mobile wireless network.

Key words: ad-hoc networks, hidden terminal, OLSR protocol, energy consumption, NS-3

1. Introduction

MANETs [5] are self configuring mobile wireless networks in which the information is exchanged without having any centralized administration or special infrastructure (dedicated routers, base stations, etc). They are composed of mobile platforms or nodes which are free to move arbitrarily. Also these nodes act both as host and router, therefore they have an autonomous behavior.

Dynamic topology of MANETs is a consequence of node mobility [12] and spontaneous joining/leaving operations within network. This, together with the autonomous behavior of nodes, demand the existence of specific routing protocols in the network. More than that, when transmitter and receiver are outside radio range, these networks are capable of multi-hop routing.

There is a broad spectrum for this kind of networks [1][2]. Emergency/rescue operations: they do not require any network infrastructure and they have a rapid deployment, they could be used as an alternative solution in rescuing. Collaborative work: in business environments, information about a project could be exchanged in group meetings outside the office. Military battlefield: it's rapid and ease of deployment, can maintain an information network between headquarters, soldiers and vehicles.

Due to dynamic topology of MANET, certain special cases will exist when majority or a high amount of nodes will share the same area.

The main objective is to check if is possible to reduce the energy consumption in these particular cases using information from a layer three routing protocol.

Secondary objectives include studying the influence of reduced energy consumption over other metrics and issues that could appear, e.g hidden terminal problem [12].

2. Related works

In [7] the analysis of energy consumption between the proactive protocol, optimized link state routing (OLSR) and a reactive one, dynamic source routing (DSR), revealed several findings: in a dense network, the idle power and overhearing effects tend to consume the most energy; when traffic load is low is more suitable to use a reactive protocol and at higher traffic rates a proactive protocol can perform well with an appropriate refresh parameter. However an older version of the current network simulator was used, NS-2.

In [11] clustering technique is used in order to reduce the energy and bandwidth consumed by OLSR protocol in MANET. By dividing the network into smaller pieces and assigning them a cluster head, the complexity of proactive protocol is reduced. Selection criteria of the cluster head differ from most studies because node's residual energy is taken into account. One important aspect about this study is that it offers brief information about three mobility models as well with their energy consumption.

In [14] an adaptive routing protocol is proposed based on OLSR. They had a different approach than global optimization and took in consideration the fact that not all environmental changes in a MANET are the same at a given time. The proposed routing protocol allows a node to dynamically adapt its routing behavior based on a mobility metric called number of broken links. The most important things from this routing behavior was changing Hello interval and multipoint relay (MPR) selection. The first one is modified when the number of broken links in a given amount of time reaches a threshold and for the second one they introduced node states. It was concluded that adaptive OLSR can improve packet delivery ratio (PDR), packet latency and routing overhead, especially in high mobility scenarios.

A comparison of routing protocols used in MANET was done in [15]. It shows specific characteristics for studied protocols: ad-hoc on demand distance vector (AODV), distance vector (DSDV) and OLSR in terms of convergence time, memory and control overhead, time complexity of route discovery and maintenance. The comparison was studied on a real-world event in which there were 20 sender nodes and one receiver. Mobility model treated was Gauss-Markov.

Studies implying security were [10] regarding wormhole attack in OLSR and [13] regarding Black hole and Jellyfish attack on MANET.

3. OLSR routing protocol

OLSR [4] [11] is a proactive protocol of the IETF working group Mobile Ad-hoc Networks (MANET) [9]. It is an optimization of the classical link state algorithm designed to work in a distributed manner and independently from other lower layer protocols.

The key concept used in this protocol is the presence of MPRs. They represent elected nodes which forward broadcast messages during flooding process. Thus is well suited for large and dense mobile networks because of this technique that reduces the message overhead. It is a totally different approach than classical flooding mechanism where every node retransmits each message as it receive the first copy of the message.

Link state information is generated only by these MPRs which unveils the second optimization: minimizing the number of control messages flooded in the network. More than that, MPR can chose to report only links between itself and its selectors.

Based on the above characteristics in they refer to OLSR as having three components: neighbor sensing, efficient broadcasting of control traffic, and diffusing sufficient topological information in the network for shortest path calculation. A demonstration of MPR flooding is available at [8].

4. Proposed energy reduction solution

In pursuing the main goal, reducing energy consumption, information about neighbors is retrieved from routing table made by OLSR. For each node, when the routing table is updated, the number of neighbors is being compared with a threshold. If the number of neighbors is greater than the threshold then transmit power is decreased by a factor of 2 (divided in half). This is empiric as well as the chosen threshold value of 8 (star points). Important to mention here is that only an upper threshold is used, after the energy is reduced there isn't any lower threshold for it to increase. This is because of simulation simplicity but it can be used in a future work.

For measuring saved energy, one test is performed without lowering the transmit power and one test with this modification enabled. Saved energy is the absolute difference of remaining energy on each node from both tests. Important to mention here is that on both tests node mobility remains the same, nodes paths don't change between tests.

5. Evaluation

Chosen layer three routing protocol is OLSR because is a table-driven or proactive protocol and the information about neighbor nodes can be extracted from the routing tables that it generates. In all tests WiFi standard 802.11b has been chosen due to it’s maximum data rate of 11Mbps which in my opinion is sufficient for MANET environment conditions (higher data rates are more vulnerable to noise). Also it is quite popular, it does not support MIMO capability nor orthogonal frequency-division multiplexing (OFDM) modulation and it is easier to use in simulations. For this standard, ad-hoc mode was selected which in current used network simulator NS-3, it does not include beacon generation, probing or association.

Simulation parameters for energy salvation test: simulation time: 16 seconds; number of nodes: 50; node speed: 10 m/s without pausing; number of traffic pairs: 10; quality of service (QoS): disabled; WiFi standard: 802.11b; operating mode: ad-hoc; modulation: direct-sequence spread spectrum (DSSS); data rate: 2Mbps; application data rate: 2 Kbps; area: 1500 m^2; propagation model: Friis; packet size: 64 bytes; node power supply voltage: 3V; initial energy: 100 J; transmission power: 8dBm; modified transmission power: 3dBm.

Simulation parameters for hidden terminal tests: simulation time: 9 seconds; number of nodes: 3, 5; node mobility: static; QoS: disabled; WiFi standard: 802.11b; operating mode: ad-hoc; modulation: DSSS; data rate: constant, without adaptation 2, 11 Mbps; application data rate: 366 Kbps; transport protocol: UDP; packet size: 1400 bytes; propagation model: everywhere 300dB loss except between each sender receiver pair, 50dB loss.

Table 1: Hidden terminal tests

Topology	Data rate (Mbps)	RTS/CTS
3 nodes: 2 senders, 1 receiver	2 and 11	on / off
5 nodes: 4 senders, 1 receiver	2 and 11	on / off

Some of the basic metrics used for tracing [3]:

timeFirstTxPacket, *timeLastTxPacket*: absolute time of first and last sent packet.

timeFirstRxPacket, *timeLastRxPacket*: absolute time of first and last received packet.

txBytes, *txPackets*: total number of transmitted bytes and packets.

rxBytes, *rxPackets*: total number of received bytes and packets.

lostPackets: number of packets that are assumed to be lost (not being received or forwarded within a period of time, default is 10 seconds).

timesForwarded: number of times a packet was forwarded, summed for all packets in the flow.

packetsDropped, *bytesDropped*: number of lost packets and bytes (without including losses) but discriminates the losses by a reason code. Reasons for dropping are: no IPv4 route found for a packet, IPv4 TTL field reached zero, bad header checksum detected.

delaySum: sum of all end-to-end delays for all received packets.

jitterSum: sum of all end-to-end delay jitter value for all received packets. Jitter of a packet [6] is defined as the delay variation relatively to the last packet of the stream.

$$Jitter\{P_N\} = \left| Delay\{P_N\} - Delay\{P_{N-1}\} \right| \tag{1}$$

Based on previous metrics other ones can be derived as:

mean transmitted bit rate:

$$\overline{B_{tx}} = \frac{8 \cdot txBytes}{timeLastTxPacket - timeFirstTxPacket} \tag{2}$$

mean received bit rate:

$$\overline{B_{rx}} = \frac{8 \cdot txBytes}{timeLastRxPacket - timeFirstRxPacket} \tag{3}$$

mean delay:

$$\overline{delay} = \frac{delaySum}{rxPackets} \tag{4}$$

mean jitter:

$$\overline{jitter} = \frac{jitterSum}{rxPackets - 1} \tag{5}$$

mean transmitted packet size:

$$\overline{S_{tx}} = \frac{txBytes}{txPackets} \tag{6}$$

mean received packet size:

$$\overline{S_{rx}} = \frac{rxBytes}{rxPackets} \tag{7}$$

mean hop count:

$$\overline{hopcount} = 1 + \frac{timesForwarded}{rxPackets} \tag{8}$$

packet loss ratio:

$$q = \frac{lostPackets}{rxPackets + lostPackets} \tag{9}$$

Regarding energy results, Figure 1 shows the amount of saved energy on four different nodes. It can be seen that energy salvation is low in the first five seconds due to the convergence time of the network using the OLSR protocol. In these five seconds the routing tables are being developed.

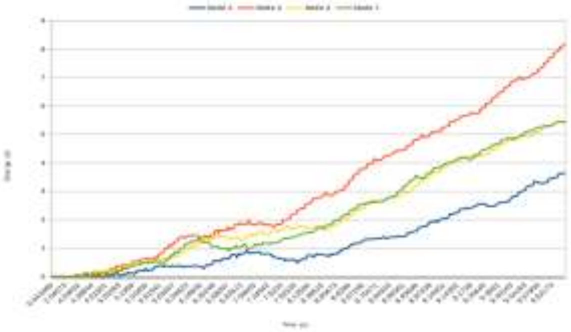

Fig. 1: Total saved energy from four different nodes

All results from hidden terminal tests, confirm that the number of packet collisions and retransmissions is lower when request to send (RTS) / clear to send (CTS) messages are used than the case in which they are omitted. This contributes to an increased number of received messages and an improved mean received rate as seen in figures 2 to 5.

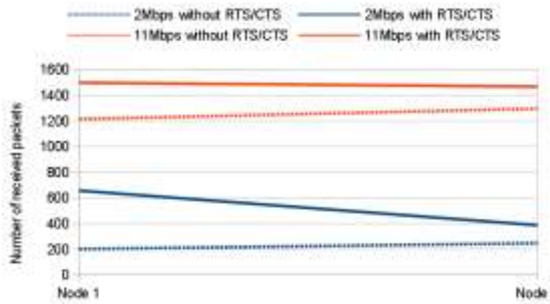

Fig. 2: Nr of received packets, hidden terminal test, 3 nodes

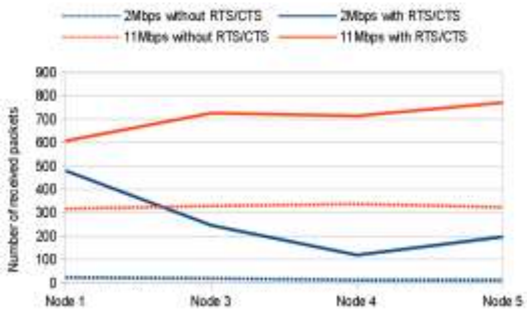

Fig. 3: Nr of received packets, hidden terminal test, 5 nodes

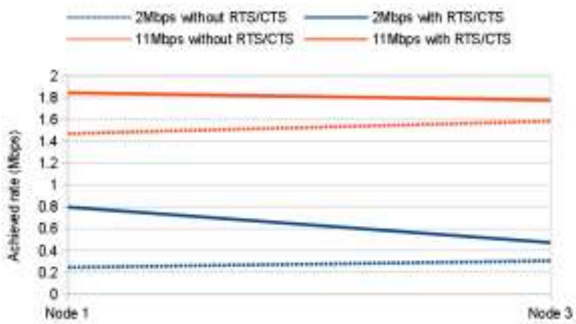

Fig. 4: Mean received rate, hidden terminal test, 3 nodes

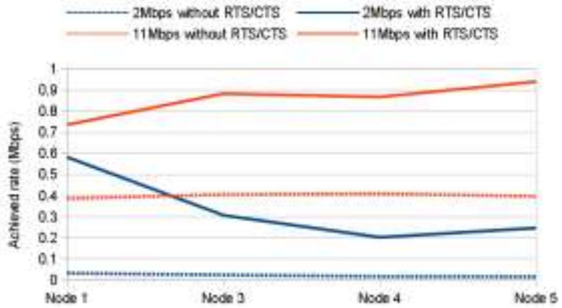

Fig. 5: Mean received rate, hidden terminal test, 5 nodes

In both cases, figure 2 and figure 3, *rxBytes* can be obtained by multiplying the number of received packets with packet size which is 1400 bytes.

Average delay was calculated as well but the results are not plotted because of similar values around 0.5 seconds. On tests with 11Mbps rate, this delay was around 0.48 seconds.

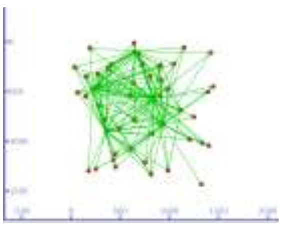

Fig. 6: *Python Visualizer

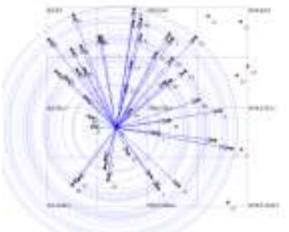

Fig. 7: *NS-3 Net Animator

*MANET network in energy salvation test as seen from Python Visualizer in figure 6 and from NS-3 Net Animator in figure 7.

6. Conclusions

It has been concluded that hidden terminal problem is indeed a major issue in MANET, causing retransmissions and low bandwidth as a consequence of packet collisions. With an increased number of hidden terminals, these aspects will only get worse. However, in military operations this can be used for benefits.

Regarding energy consumption, it is clearly possible to be aware of neighboring nodes by using routing tables and to apply a transmit power reduction in certain situations. This can lead to almost 1 Watt of power salvation in 10 seconds.

Because in this study a single upper bound was used as a threshold for applying energy correction scheme and it was an empirical value, as a future work a lower bound could be chosen as well and an analysis on how to choose these values can be done.

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