The Monitoring of Ad Hoc Networks Based on Routing

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***Abstract*— An ad hoc network is a collection of mobiles nodes that communicate via multihop wireless link. In this environment, it may be necessary to collect information about network. This information may be used in routing with QoS, topology discovery or network management. The process of data collection must be efficient and distributed in order to respect ad hoc network constraints like limited battery and bandwidth. To ensure this goal, we present an extension of the routing protocol OLSR to collect some parameters from nodes in a wireless mobile ad hoc network. The primary goal of our application called OLSRM (OLSR monitoring) is the collect of information from the network with a minimum of overhead and bandwidth consumption. In this paper, we describe the mechanism of OLSRM to facilitate autonomous and distributed monitoring of an ad hoc network and demonstrate its capability via simulation by comparing our solution with another mechanism of monitoring in the ad hoc networks: RAIC**

I. Introduction

An ad hoc network is a collection of mobile nodes without the aid of any pre-existent infrastructure or centralized administration. An ad hoc network is used in a situation in with it is impossible to construct an infrastructure such as disaster relief, military application and conference events. In these environments, it may necessary to monitor the state of the network by collecting some information from nodes to maximize the efficiency and the productivity of the network. The parameters collected could have a great importance in different applications like topology discover, routing with QoS and network management.

The constraints of ad hoc networks, such as dynamic network topology, limited battery supply and constrained wireless bandwidth network make this process more challenging than fixed and wired networks. We need to collect information, however, we must introduce low overhead (received and transmitted messages) to conserve bandwidth. On the other hand, we may reduce power to the minimum acceptable level to maintain the network connected.

This paper is organised as follows. Section 2 presents some works related to network management. Section 3 presents the routing protocol OLSR. OLSR will be used to exchange information in the network. Section 4 explains the choice of OLSR to perform our solution. Section 5 explains all parameters that will characterize a node and that will be collected. Section 6 presents the implementation of OLSRM and explains the extension of OLSR to ensure the collect of information. Section 7 evaluates the performance of this solution and compare it with others mechanisms. Section 8 concludes the paper.

II. Related works

In the last few years, research on ad hoc networks mainly focuses on routing and power control issues. There are few algorithms of monitoring or management of ad hoc networks. The first algorithm is ANMP (Ad hoc Network Management Protocol) [11]. The protocol uses hierarchical model for data collection, since intermediate levels of the hierarchy can collate data before forwarding it to upper layers of the hierarchy. The lowest level of this hierarchy consists of individual managed nodes called agents. Several agents are grouped into clusters and are managed by a cluster head. The cluster heads in turn are managed by the network manager. ANMP uses a MIB to store information collected.

The second algorithm is Guerrilla [12]. The Guerrilla management architecture uses the concept of cluster-based management. Nodes are clustered into groups with at least one nomadic manager in each group. The nomadic managers collaborate autonomously to manage

the entire network. A problem, however, with utilizing a hierarchical approach in an ad hoc network is the cost of maintaining a hierarchy in the face of node mobility. The last algorithm is RAIC [5] (Resource Aware information collect). RAIC is a distributed, two phases (setup and capture) resource aware approach to sensing the state of an ad hoc network from a source node (sink). The first phase (setup) is based on a resource aware optimized flooding mechanism to create a backbone of relay nodes throughout the ad hoc network. The backbone is used in the second phase (capture) to relay replies from nodes in the ad hoc network back to the sink.
All of these algorithms introduce an additional overhead to maintain the hierarchy (cluster construction and cluster head election process) or to disseminate requests and collect replies. This overhead will increase energy consumption and decrease the available bandwidth.

III. OLSR

OLSR (Optimized Link State Routing Protocol) [1], [3] is a proactive routing protocol for mobile ad hoc networks. It periodically sends control packets to build and update topology. OLSR [8] is divided into two phases: neighbour sensing and topology discover. The first phase is performed with Hello messages. Hello packets are used to build the neighbourhood of a node and they are sent in broadcast at one hop. The second phase is performed with TC (topology control) message. TC packets are broadcasted in the whole network and they contain the list of neighbours of a node. OLSR uses many tables like neighbour table (stores information obtained from the HELLO about neighbour), MPR selector table (store information obtained from the HELLO about the neighbours which have selected this node as a MPR) and topology table (store topological information obtained from the TC message about the network).
The key concept used in the protocol is that of multipoint relays (MPRs). MPRs are selected nodes which forward broadcast messages during the flooding process [6]. The idea of MPRs is to minimize the overhead of flooding messages in the network by reducing duplicate retransmissions in the same region (Fig. 1). Each node in the network selects a set of nodes in its symmetric neighbourhood which may retransmit its messages. This set is selected such that it covers (in terms of radio range) all nodes that are two hops away.

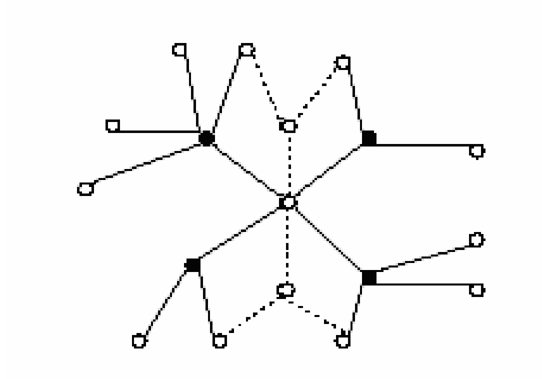

Fig. 1
MULTIPOINT RELAYS

IV. THE EXTENSION OF OLSR

To collect information from nodes, our solution is based on routing. We have used an existing routing protocol (OLSR) to propagate parameters in the network. We won’t introduce any new messages or applications. We have implemented an extension of the routing protocol to efficiently monitor the ad hoc network. We have choosen OLSR because it is a proactive protocol, thus it periodically sends control packets to maintain the knowledge of the network topology. In addition OLSR inherits the stability of a link state routing protocol and has the advantages of having the routes immediately available when needed due to its proactive nature. Also OLSR uses an MPR optimisation that can save a substantial part of the bandwidth and battery. It reduces the size of the control messages and minimizes the overhead from the flooding of control traffic. Our solution OLSRM has a good performance compared to others solutions because it used an existing application and doesn’t increase overhead or consumes ad hoc network resources such as battery and bandwidth. OLSRM is more suitable in ad hoc networks where routing (not managing) is the main priority.

V. COLLECTED PARAMETERS

To control the state of the ad hoc network, it would be interesting to collect some parameters that characterize nodes and links. These parameters are essentially delay between a source and a destination, battery consumption, and signal quality.

A. End-to-end delay

The end to end packet delay is the time from when the source generates the data packet to when the destination received it. The delay depends on the number of hope between a source and a destination, the available bandwidth and the propagation environment (signal attenuation). It is also constrained by the mutual interference of concurrent transmissions between nodes. A delay parameter will be calculated to describe the link between tow nodes.

B. Battery consumption

Mobile nodes rely on battery for proper operation. Since an ad hoc network consists of several nodes, depletion of batteries will have a great influence on overall network performance. Also, most ad hoc mobile devices operate on battery. Hence, an issue in the design and development of wireless nodes is power consumption. To maximize the lifetime of ad hoc mobile networks, the power consumption rate of each node must be evenly known and controlled. The power required by each mobile host can be classified into two parts, namely:

- Processing power : to execute algorithms
- Transceiver power : to communicate with the others nodes in the network

C. Signal quality

In wireless communication, a new radio transmission by a mobile host may affect existing communication link trough signal interference. Radio propagation can be modelled effectively with $1/d^n$ transmit power ($n = 2$ for free environment and $n = 4$ for closed environment). The SNR (signal to noise ratio) is the ratio between the signal power and the noise power. The SNR received at host n_j indicate if a transmission from a node n_i to node n_j is successful or not. If the SNR is greater than SNR-threshold the signal is received correctly.

VI. OLSRM IMPLEMENTATION

A. Parameters measure

In this section, we explain parameters that we will measure such delay between two nodes, battery consumption and signal quality.

To measure the delay between two nodes we implement the following algorithm described in [2]:

- Before that the OLSR layer sends a hello message, it includes the creation time of the message in Hello packet.
- When the OLSR layers receives a hello message, it gets the time stored in the hello message by the sender node, calculates the difference between such time and the current time that represents the delay. This information will be stored in the neighbour table and MPR selector table. Such measure will be done for all Hello messages without any additional message.
- When an MPR send a TC message it includes the delay between it self and the MPR selector.
- When a TC arrived to a node, a new tuple is recorded in the topology set including the delay between the MPR and the MPR selector.
- When a new route entry is recorded for the destination node $h + 1$ hops away in the routing table, we must add the old value of the delay (distant h) with the delay between the last destination and the new destination. This information is extracted from the topology table.

In order to achieve the delay information in the route calculation, a synchronized network is required [4]. We suppose in our scenario that all the nodes are provided with a global timing structure.

In our proposal extension; we will test if the node uses a battery or not and we will measure the instantaneous power consumption and the time to run before the expiration of the battery. If user knows the remained energy of distant nodes, he knows the nodes that going to switch of.

Also, we will measure the signal quality by calculating the SNR (signal to noise ratio). We will measure the signal received power (Pr) and the noise power (Pn) at a node [8]. The SNR can be calculated as:

$$SNR = -20 \log(Pr/Pn)$$

B. Parameters collection

We have introduced new fields in the hello message (Fig. 2) like creation time of the message , information about battery consumption (charge type, remaining energy percentage and remaining time before expiration of battery) and information about signal quality (signal level and noise level) to calculate SNR. A node that receives a Hello message will save parameters in the neighbour table and the MPR selector table. When a node sends a TC message it introduces, also, new fields (Fig. 3) to propagate information about nodes that select this node as MPR (MPR selector). These parameters are essentially the delay between the MPR and the MPR selector, the battery consumption and the signal quality for each MPR selector. These parameters will be saved in the topology table for every destination. When the local node calculates its routing table it will update new fields created to save parameters collected for all destinations in addition to old fields (destination, gateway and number of hops).

0	15	31
Paquet sequence		Mpr sequence number
Creation time		
Charge	**Battery**	**Remaining time**
Signal level		**Noise level**
Link type	reserved	Next type link
Neighbor Adresse		
……		
Link type	reserved	Next type link
Neighbor Adresse		
……		

Fig. 2
HELLO MESSAGE STRUCTURE

0	15	31
Paquet sequence number		Mpr sequence number
Tc hop count	reserved	
Originator adresse		
Mpr selector adresse		
Mpr selector delay		
Battery	**Charge**	**Remaining time**
Signal level		**Noise level**
.....		

Fig. 3
TC MESSAGE STRUCTURE

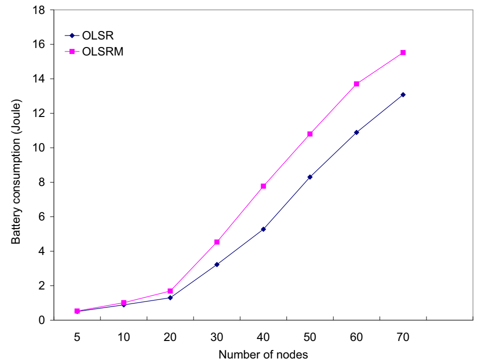

Fig. 4
TOTAL ENERGY CONSUMPTION

VII. PERFORMANCE EVALUATION

A. The simulation Model

We have used Glomosim [9], [7] (for Global Mobile Information system Simulator). Glomosim is a scalable simulation library for wireless network systems. In contrast to existing network simulator, Glomosim has been designed and built with the primary goal of simulating very large network using parallel simulation to significantly reduce execution time of the simulation model. It permits a rapid prototyping of protocols and a comparative performance evaluation of alternative protocols at each layer. Simulation generates a random topology of nodes. The simulation terrain has a size of $1000m * 1000m$. Nodes have a maximum transmission range of 100m. A first order radio model is assumed [10]. In this model the first order radio dissipates $E_{elec} = 50nJ/bit$ to run the transmitter or receiver circuitry and $E_{amp} = 100pJ/(bit\ m^2)$ for the transmitter amplifier. We also assume an r^2 energy loss due to channel transmission where r is the distance between transmitter and receiver (the transmission medium is error free). The cost of transmitting a k-bit message a distance d is:

$$E_{Tx}(k,d) = E_{elec} * k + E_{amp} * k * d^2$$

And the cost of receiving a k-bit message is:

$$E_{Rx}(k) = E_{elec} * k$$

We use the RTS/CTS scheme as access technique. Packets are sent at $2Mbit/s$. We have chosen a “random waypoint” mobility model. A node chooses a random destination within the simulated terrain and moves to that location based on the speed specified in the configuration file (between $0m/s$ and $10m/s$). After reaching the destination the node pauses for a duration that is also specified in the configuration file (2s).

B. Simulation of OLSRM with OLSR

We investigate simulation in order to evaluate OLSRM performance and to compare it with OLSR algorithm. In this scenario, we have defined a CBR (Constant Bite Rate) application for the two algorithms. We perform the evaluation of battery consumption and the number of collisions by varying the number of mobiles in a $1000m^2$ area network.

For instance, we suppose nodes without mobility. Figures Fig. 4 and 5 show difference between OLSR and OLSRM. In a network consisting of 70 nodes, the total energy consumed for OLSRM is 15% more than the total energy consumed for OLSRM. Also the total number

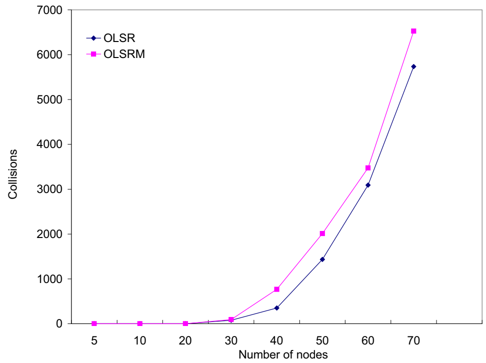

Fig. 5
TOTAL NUMBER OF COLLISIONS

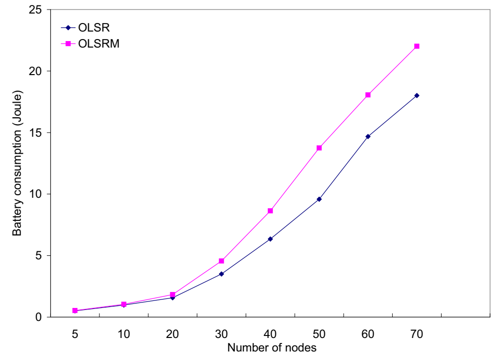

Fig. 6
TOTAL ENERGY CONSUMED (WITH MOBILITY)

of collisions induced by OLSRM is 19% more than the total number of collision induced by OLSR. The increase of battery consumption and the number of collisions are due to the extension of the header message. We notice that the difference between these two algorithms is little for small network (5 to 30 nodes). This difference increases with number of nodes (more packets received and transmitted) but it becomes nearly constant.
In a second step, we have studied the impact of our extension on OLSR but in mobile network. Mobility causes the degradation of performance in terms of delivered message. Also, mobility leads to more failures in routing. An important phenomenon appears when the route changes. When a packet is sent to a neighbour who no longer exist the IEEE 802.11 access schemes tries to send the packet until the maximum retry has been reached yet, the packet can not be acknowledged. This will lead to an additional load which can degrade performances.
Figures 6 and 7 show the simulation results of OLSRM and OLSR in a network with mobility. Also, in this situation, OLSRM doesn't cause an important degradation of OLSR. The difference between two algorithms is little for small networks and increases slowly for large networks (18% more energy consumed and 23% more collisions induced).

C. Simulation of OLSRM with RAIC

A simulation was investigated to evaluate the performance of our solution. We compare OLSRM with RAIC (Resource Aware Information Collect). RAIC [5] is a distributed, two phases (setup and capture) resource aware approach to sensing the state of an ad hoc network from a source node. An optimized flooding mechanism is used to both disseminate sensor request

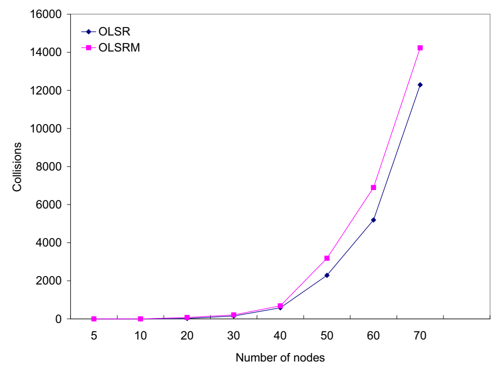

Fig. 7
TOTAL NUMBER OF COLLISIONS (WITH MOBILITY)

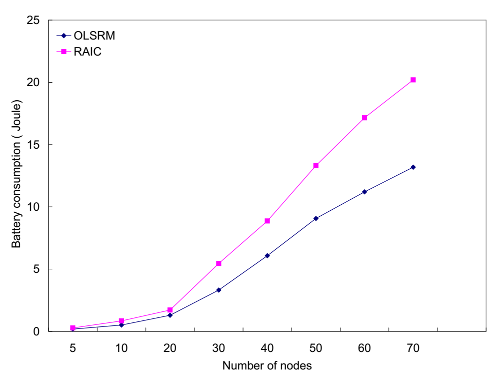

Fig. 8
TOTAL ENERGY CONSUMED

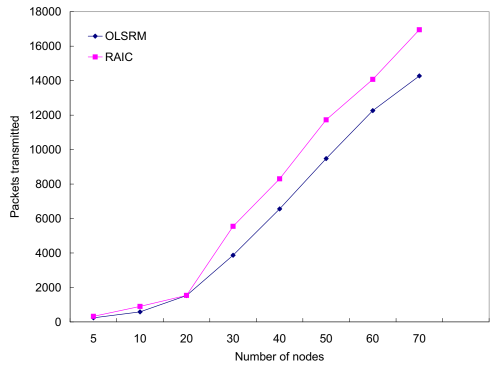

Fig. 9
TOTAL PACKETS TRANSMITTED

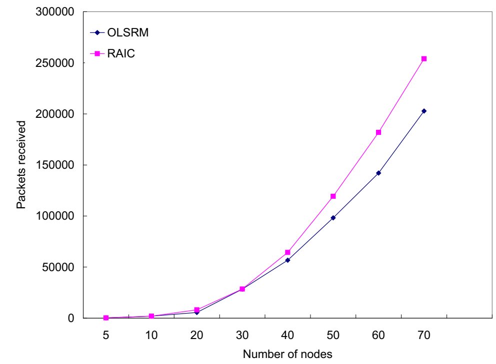

Fig. 10
TOTAL PACKETS RECEIVED

messages and setup a backbone of suitable nodes to relay replies. Utility Based Multipoint Relay (UMPR) flooding is an optimized flooding. It builds upon ideas from Multipoint Relay (MPR) flooding, with UMPR allowing for an optimized flood to be resource aware.
We have chosen RAIC because it uses an optimized flooding mechanism like the mechanism of MPR used by OLSRM. Also RAIC is used to collect information from nodes. OLSRM and RAIC have the same goal which is the collect of parameters that characterize a node in ad hoc network. In the simulation, RAIC is relying on OLSR but OLSRM is running on it own.
The idea is to show that OLSRM consume less resource (battery and bandwidth) compared to RAIC. We will compare the battery consumption, the overhead generates by the two algorithms and the numbers of collisions. Figures 8, 9, 10 and 11 show the simulation results for OLSRM and RAIC. In a network consisting of 70 nodes, a node using RAIC requires 35% more energy, 10.5% more packet transmission, 20.15% more packet reception and 33.3% more collisions than OLSRM. The energy consumed and the number of collisions increase since the number of transmitted and received packets growth. In this simulation, only one source that performs a single query (SREQ) message throughout the ad hoc network. The difference will be greater if more than one source that need to collect information.

OLSRM provides significant performances improvements over RAIC in term of battery and bandwidth conservation. In addition, OLSRM permit the availability of parameters that characterize each destination in the network like delay, battery consumtion and signal

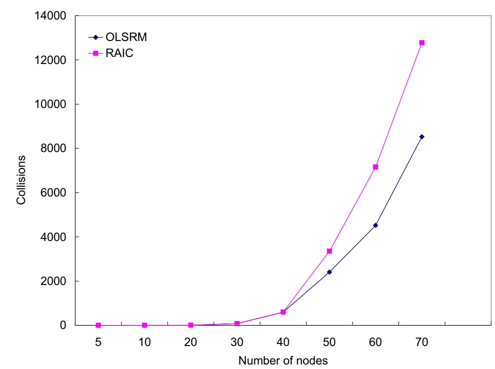

Fig. 11
TOTAL NUMBER OF COLLISIONS

quality. It attempts to maintain consistent up-to-date information from each node to every other node in the network. In the case of RAIC, when a node desires to know information about a destination, it will have to wait until a query can be send and a replay can be received. OLSR is more suitable for use in the situation where a node has a permanently need for information collect.

VIII. CONCLUSION

In this paper we have proposed OLSRM, an algorithm that collect monitoring information in ad hoc network. OLSRM is based on the routing protocol OLSR. Our purpose is to collect parameters from nodes without consuming ad hoc network resources. OLSRM greatly reduces problems associated with data collection in wireless network. We evaluated the performance of OLSRM and we compared it with RAIC. We have found that in term of energy consumption, received and transmitted packets, OLSRM have better results than RAIC. OLSRM used the routing messages to exchange information about nodes and it doesn't introduce any additional overhead. Moreover, we have compared OLSRM with OLSR to show that our solution doesn't influence the performance of the original routing protocol OLSR. The extension of the header of the routing message doesn't introduce an increase in collisions or battery consumption in ad hoc network with and without mobility.

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