Performance Evaluation of Routing in Mobile Hybrid Ad Hoc Robot Wireless Sensor Network Simulated with EG Based Protocol

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Abstract: Efficient, dynamic routing is one of the key challenges in mobile ad hoc networks. Wireless sensor in Hybrid Ad-Hoc Sensor Network (HANET) domain is presented, consisting of both mobile and stationary nodes has low-power, densely distributed, energy constrained stationary sensors which are able to form MAC level connections and network level multi-hop routes at runtime. However, in a large system with many mobile robots, it becomes difficult for all robots to exchange information at a time because of their limited communication capacities. In this present research, the EG based protocol to handle routing issues for packets associated with mobile nodes. As well as Mobility Models, the results shown here are separated in two parts, one using the random waypoint Mobility Model and another using intermittent model. This innovation can reduce energy consumption while maintaining a high quality of service.

Key words: HANET, MANET, NRTE, MAC level, Mobility Models

INTRODUCTION

A Hybrid Ad-Hoc networks are getting popular for their ease and speed in deployment, decreased dependence on infrastructure, being the only possible solution to interconnect a group of nodes. Nodes in these networks do not rely on any pre-existing routing infrastructure for communication but instead communicate either directly or with the help of other intermediate nodes in the network (Das *et al.*, 2003). As a consequence, new protocols must be designed to take advantage of these new network configurations while preserving key resources. Most importantly as the wired infrastructure is eliminated, these networks are free to support some degree of mobility in a subset or possibly all of the participating nodes. The research which will be presented here is concerned with the inclusion of mobile sensor nodes in a stationary ad hoc wireless sensor network, generating a HANET. Researchers assume that the stationary network has reached its steady state operation. That is the stationary nodes have been deployed (possible in a random dispersion), a link level architecture has formed, routing paths from any sensor node to a sink node have been established and each sensor node is periodically searching for new neighbours to incorporate into the network. Furthermore, the stationary sensors are assumed to be highly energy constrained. In the early robot wireless communications, infrared technology was applied in a large scale because of its low cost (Leighton and Rao, 1999). But infrared wave cannot pass through obstacles (e.g., wall) and infrared systems have poor communication rate and quality (rain effect) (Adachi and Nakagawa, 1998). Solution for wireless and mobile ad-hoc networks without infrastructure is to use the components of participants for networking, examples single-hop. All partners maximum one hop apart bluetooth piconet, PDAs in a room, gaming device, multi-hop: cover larger distances, circumvent obstacles Bluetooth scatternet, TETRA police network, car to car network. The design of ad hoc networks has focused on the development of dynamic routing protocols that can efficiently find routes between two communicating nodes (Li *et al.*, 2004). The routing protocol must be able to cope with the mobility of nodes which often changes the network topology drastically and unpredictably. The solution for this is EG based protocol which manages drop packets and shows the performance of other protocols. Recently there was a renewed interest in this field due to the common availability of low cost laptops and palmtops with radio interfaces.

MANET CHARACTERISTICS

The manifestation of mobility in HANETs is significantly different than that of MANETs and cellular networks. While mobile nodes are dominant in either

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of the other two network types, HANETs are comprised primarily of stationary nodes forming a network with its own protocols (i.e., multihop routing distributed bootup) and operational goals (Gomez *et al.*, 2001). The relatively few mobile nodes are later introduced into the network requiring connectivity support. The stationary nodes in HANETs are assumed to have limited energy supplies, requiring low-power protocols to be developed to increase the lifetime of the network (Camp *et al.*, 2002). The network often has a dynamic and unpredictable topology. Using protocols developed for MANETs and cellular networks may prove to be difficult due to the network goals and resource constraints. MANET is the collection of mobile nodes that form a temporary network (Chen and Nahrstedt, 1999). In such a network, there is no centralized administration or standard support services. Moreover, each host is as an independent router. Hosts use wireless RF transceivers as network interface. They have limited bandwidth, power supply and limited transmitter range. The network allows multiple radio hops but it lacks of symmetrical links. Ad hoc routing protocols can be broadly categorized into proactive and reactive protocols (Johnson and Maltz, 1996).

Proactive routing protocols have the characteristic of attempting to maintain consistent up to date routing information from each node to every other node in the network (Ko and Vaidya, 1998) (Fig. 1). In contrast to proactive ones, reactive protocols create routes only when desired. This means that an explicit route discovery process creates routes and this is initiated only on an as needed basis (Pottie and Kaiser, 2000). It can be either source initiated or destination-initiated. The reactive routing is highly dynamic network topology and

Fig. 1: 7-nodes network to illustrate alternate view of implicit visitation; a) time = t1; b) time = t2

device mobility plus varying channel quality and also the network possible is partitioning and merging. Another important consideration in reactive routing is risk of packet loss because of its asymmetric connections.

In conclusion, proactive routing protocols can be deployed in a small size and topology slowly changing network. The routing packets needed by protocols would not add too much load to the network under this situation. However, a reactive protocol may be more suitable for a large scale and fast topology changing network because the routing tables that are maintained at each node should be small compared to the size of the network to avoid requiring large caches. A large network can often be divided into some small subnets.

ROUTING IN MANET

Mobile Ad Hoc Networks (MANETs) are wireless networks consisting of entirely mobile nodes that communicate without using base stations. Nodes in these networks act as routers as well as communication end points. Rapid changes of connectivity, network partitioning, higher error rates, collision interference and bandwidth and power constraints together pose new challenges for this type of networks. In recent years, sensor networks have also received significant interest from the research community. Sensor network is a new family of wireless networks and is different from traditional networks like cellular networks or MANETs. A sensor network is composed of a large number of small sensor nodes and energy efficiency is a more important issue in this kind of networks. The lifetime of MANETs or sensor networks often depends on the node with minimum residual energy in the network. Minimum energy metric routing may not maximize network lifetime (Ye *et al.*, 2001). This is because the nodes' residual energy (remaining battery capacity) is not taken into account. That is some nodes on the minimum energy routes will suffer early failure due to their heavy forwarding load. The main problem in traditional routing algorithm is dynamics of the topology. This happens because of frequent changes of connections, connection quality; participant's limited performance of mobile systems. The periodic updates of routing tables need energy without contributing to the transmission of user data sleep modes difficult to realize. Bandwidth is limited in the system is reduced even more due to the exchange of routing information and the transmission quality changes because of links can be asymmetric. The major issue in traditional routing algorithm is distance vector where the periodic exchange of messages with all physical neighbors that contain information about who can be
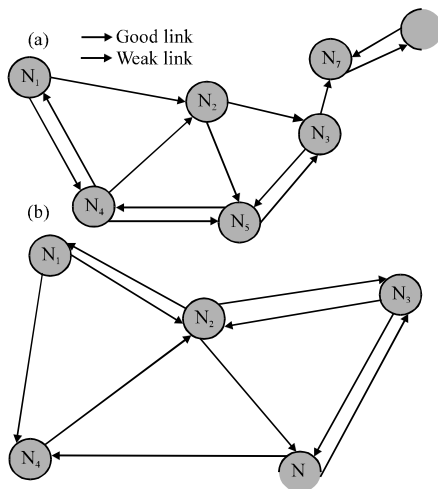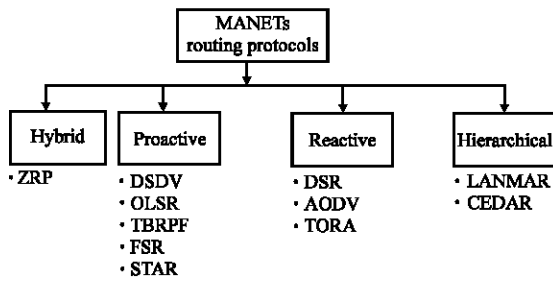
Fig. 2: Block diagram of MANETs routing protocols

reached at what distance, selection of the shortest path if several paths available (Royer and Toh, 1999) (Fig. 2)

Although, there are several existing surveys on multicast routing protocols over MANETs, they are either not up to date or mostly focus on the same technical trend such as tree, mesh and hybrid-based multicast routing protocols. The majority of applications for MANETs are in areas where rapid deployment and dynamic reconfiguration are necessary and the wired network is not available. These include military battlefields, emergency search and rescue sites, classrooms and conventions where participants share information dynamically using their mobile devices. Many multicast routing protocols are proposed for MANETs based on different design points of view to meet specific requirements from different application domains. There are two different ways to evaluate and compare the performance of multicast routing protocols for MANETs (Ferreira and Jarry, 2004).

Dynamic source routing I: This split routing into discovering a path and maintaining a path. This is applicable only if a path for sending packets to a certain destination is needed and no path is currently available. The main task to maintain the path only while the path is in use one has to make sure that it can be used continuously. No periodic updates needed.

Dynamic source routing II: In this concept the path discovery will broadcast a packet with destination address and unique ID if a station receives a broadcast packet. In case the station is the receiver (i.e. has the correct destination address) then return the packet to the sender (path was collected in the packet) if the packet has already been received earlier (identified via ID) then discard the packet otherwise, append own address and broadcast packet.

Mobile Robot Metworking Layered Model: Mobile robot wireless networks provide the networking infrastructure to support the Quality of Service (QoS) needs

(bandwidth, latency and reliability) of robot communications. They must support: quick reconfiguration (802.11, token ring), mobility management (mobile IP, AODV), Service Level Agreement (SLA) management and QoS (mobile Internet Protocol). A layered model of mobile robot networking is given:
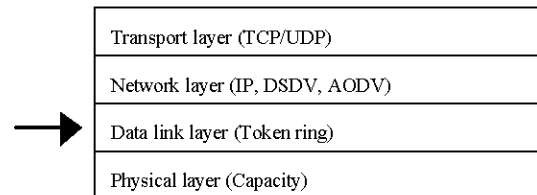
It has transport, network, data link and physical layers. In the system of cooperative multiple mobile robots, communications among them are critically important. Each robot should exchange the information collected through its sensors and negotiate its task scheduling with other robots. These robotic communications are executed through the random access telecommunication among mobile robots.

Experiments of robotic communication among several robots are reported using wireless LAN or infrared sensor systems (Chlamtac and Kutten, 1985). Wireless LAN devices that make use of spread-spectrum modulation and a UHF carrier (typically 2.4 GHz) offer the potential for high message data rates over a reliable physical layer implementation. However, the applicability of these systems to a large number of robots remains to be demonstrated. A modified cellular system for wide range robotic communication is proposed by Chlamtac and Kutten (1987). However, the communication service area is restricted by the positions of base stations. List of the major factors that particularly affect TCP performance in MANETs is provided. These factors are listed.

Mobility: The mobility of nodes causes routes to change and disconnect frequently which leads to low route stability and availability.

High Bit Error Rate (BER): The use of the wireless channel is vulnerable to errors due to weather conditions, obstacles and interference.

Unpredictability and variability: The time-varying nature of wireless channel quality creates uncertainty which causes substantial difficulty in measuring the RTT and estimating a proper timeout value.

Contention: The use of the shared wireless channel limits the ability of a node to send packets. Nodes within a local neighborhood have to compete for wireless channel access. Therefore, the bandwidth obtained by a node depends on the sending need of its neighbors.

SIMULATION RESULTS

The results are based in a simulation of an ad hoc network composed by wireless mobile nodes moving around, going to sleep a while and communicating with each other. As well as Mobility Models, the results shown here are separated in two parts, one using the Random Waypoint Mobility Model and another using intermittent model. Researchers focused the analysis in three main analyses:

Average throughput: The average number of packets received per amount of time by all nodes.

Ratio of dropped packets by no route (NRTE): Fraction of dropped packets by no available route per total number of sent packets.

Ratio of dropped packets by interface link queue overflow (IFQ): Fraction of dropped packets by link queue overflow per total number of sent packets. The EG protocol used in these experiments do not have any protocol overhead (there are no control messages since all nodes already have the EG of the whole network) hence researchers did not investigate the overhead metric.

Random Waypoint Mobility Model: Researchers are changing the pause time parameter in the random waypoint scenario. Low values of pause time means high mobility and high values of pause time means low mobility. As shown in Fig. 3, the EG protocol performance
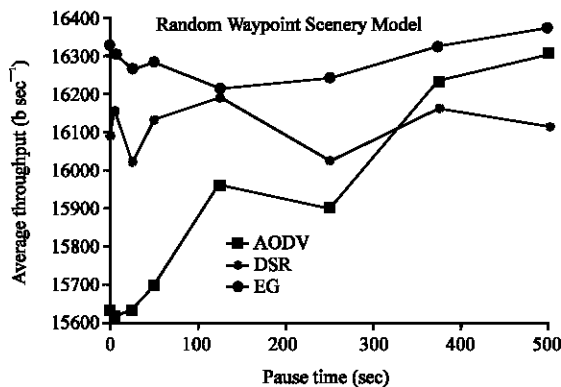
has better values of throughput for all pause times besides the fact that most protocols got very close values in this metric (researchers omitted the DSDV due to its very low values of up to 12000 b sec^{-1}).

The number of dropped packets for the EG protocol is almost zero for all pause times that is <0.5% of packet loss shown in the Fig. 4. The ratio of dropped packets for DSR is pretty good too, an average of 2.5% packet loss. It is surprising the fact of AODV did not perform well at high mobility values. Researchers attributed this behavior to the very low network load of the simulation (3 pkts sec^{-1} with 10 traffic sources) or to unknown adjust in algorithm parameters.

Intermittent mobility model: The intermittent mobility scenario is more realistic in the sense of FSDN networks on which the nodes have fixed position and their on/off dynamics can be more easily predicted. In the case of low dynamics, the values of throughput for EG decreases with the others protocols as the connectivity decreases (from 0-50% sleep probability). This EG protocol decline is a high number of inexistent routes as shown in the graph of Fig. 5 and 6. The high values of dropped packets
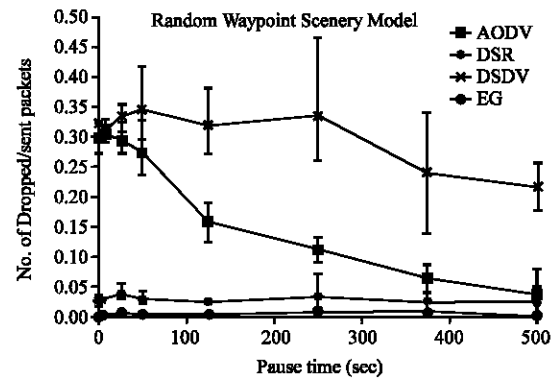

Fig. 4: Drop ratio as a function of pause time (mobility)

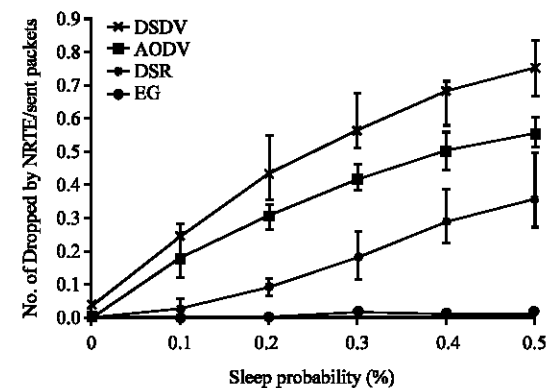Fig. 3: Average throughput as a function of pause time (mobility)

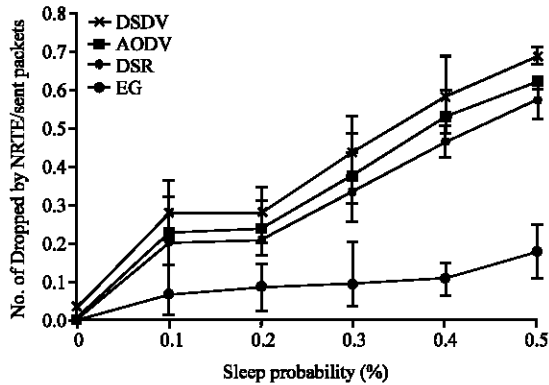Fig. 5: Intermittent Scenery Model for 15 sec

Fig. 6: Intermittent Scenery Model for 180 sec

by no available route (NRTE) means that a high number of nodes are disconnected therefore the throughput decreases.

When lot of packets are scheduled to be sent in same moment the intrinsic behavior of EG protocol to schedule packets to be sent when some node awakes arises the problem at its extent and the link Interface Queue (IFQ) does not hold that incoming traffic. To minimize this problem researchers increased the default length of IFQ from 50-500 packets. This characteristic appeared in the low connectivity and low dynamics scenarios of the intermittent model on which the nodes in the evolving graph remain disconnected for long time period. The values of EG protocol on the Fig. 4 shows that the number of dropped packets by NRTE using EG protocol is a lower bound value for all protocols, i.e. when EG Protocol drop a packet by NRTE, means that the requested path does not exist in any moment. Therefore, EG protocol can be used as a benchmark to measure how good the other protocols are performing.

CONCLUSION

Ad hoc mobile robot communications are a promising networking technology (Chlebus *et al.*, 2002). It should be noted that the high values of average delay is an inherent characteristic of the communication network dynamics. In an energy-constrained environment, protocols should pay more attention to energy consumption but for a real time image-sensing task, system throughput and bandwidth utilization are more important. Therefore, different protocols need to be developed to optimize different metrics for different applications. In the case of EG based protocols on which the foremost analysis are studied and minimum arrival date for a packet is also analyzed.

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