ISSN 2229-5518

Performance Analysis of Routing Protocols for Mobile Ad-hoc Networks

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Abstract:-This study is a comparison of three routing protocols proposed for wireless mobile ad-hoc networks. The protocols are: Destination Sequenced Distance Vector (DSDV), Ad-hoc On demand Distance Vector (AODV) and Dynamic Source Routing (DSR). Extensive simulations are made on a scenario where nodes moves randomly. Results are presented as a function of a novel mobility metric designed to reflect the relative speeds of the nodes in a scenario. Furthermore, three realistic scenarios are introduced to test the protocols in more specialized contexts. In most simulations the reactive protocols (AODV and DSR) performed significantly better than DSDV. At moderate traffic load DSR performed better than AODV for all tested mobility values, while AODV performed better than DSR at higher traffic loads.. Mobile ad-hoc networks have been the focus of many recent research and development efforts Combinations of wide range and short range ad-hoc networks seek to provide robust, global coverage, even during adverse operating conditions.

Index Terms- Destination Sequenced Distance Vector **,** Ad-hoc On demand Distance Vector, Dynamic Source Routing, Mobile ad-hoc networks.

1 INTRODUCTION

The notion of a mobile ad-hoc network used in this work is a network formed without any central administration, consisting of mobile nodes that use wireless interfaces to send packet
data. The nodes in an ad-hoc network can act as both In the commercial sector, equipment for wireless, mobile computing has not been available at a price attractive for larger markets. However, as the capacity of mobile computers increases steadily, the need for un-tethered networking is expected to rise as well. Commercial ad-hoc networks could be used in situations where no infrastructure (fixed or cellular) is available. Examples include rescue operations in remote areas, or when local coverage must be deployed quickly at a remote construction site. Ad-hoc networks between notebook or palmtop computers could be used to spread and share information among the participants of a conference. Short range ad-hoc networks can simplify intercommunication of various mobile devices (e.g., a cellular phone and a PDA) by eliminating the tedious need for cables. The latter case could also extend the mobility provided by the fixed network (e.g., Mobile IP) to nodes further out in an ad-hoc network domain. Since the network nodes are mobile, an ad-hoc network will typically have a dynamic topology which will have a profound effects on network characteristics. Network functions such as routing, address allocation, authentication, and authorization must be designed to cope with a dynamic and volatile network topology. Network nodes will often be battery powered, which limits the capacity of CPU, memory, and bandwidth. This will require network functions that are resource effective. Furthermore, the wireless (radio) media will also affect the behavior of the network due to fluctuating link bandwidths resulting from relatively high error rates.

1.1 Routing protocols for ad-hoc networks

This work focuses on routing protocols for mobile ad-hoc networks. Traditional routing protocols are proactive in that they maintain routes to all nodes, including nodes to which no packets are sent. They react to topology changes, even if no traffic is affected by the change. They are based on either link-state or distance vector principles and require periodic control messages to maintain routes to every node in the network. The rate at which these messages are sent must reflect the dynamics of the network in order to maintain valid routes. Hence, the use of scarce resources, e.g., power and link bandwidth, for control traffic will increase with increased node mobility. An alternative approach is reactive route establishment, where routes between nodes are determined only when explicitly needed to route packets, Several routing protocols for ad-hoc networks have been proposed, for instance but few comparisons between the different protocols have been published. Within the Internet Engineering Task Force (IETF), a working group named Mobile Ad-hoc Networks (MANET) has the charter to standardize an IP routing protocol for mobile ad-hoc networks. All the routing protocols listed above have been submitted to the MANET group as internet drafts. The work presented in is the most comprehensive comparison of ad-hoc routing protocols published so far. The study was done in the Monarch' project at CMU and aims at a fair evaluation based on quantitative metrics. Examples of other simulation results on individual protocols are and but as these used different metrics the results are difficult to compare. Three routing protocols are studied in this work, namely Ad-hoc on Demand Distance Vector (AODV), Dynamic Source Routing (DSR), and Destination Sequenced Distance Vector (DSDV). AODV and DSR were selected because they show the best performance in [2], but should be compared and evaluated further using additional metrics and scenarios. As opposed to DSR and AODV, DSDV is a proactive protocol and was included to illustrate the differences between reactive and proactive protocols. This work has been inspired by the simulations in [2], but extends those results further by introducing a new mobility metric and new network scenarios as well as presenting results on delays and byte overhead. First, a metric called mobility is introduced as a means to capture the relative motion of nodes in the network. Second, throughput and delay Mobile Networking architectures are measured for the analyzed protocols with mobility and offered traffic load as variables in a random network scenario. Third, three network scenarios are analyzed, denoted Conference, Event Coverage, and Disaster Area, respectively.They are intended to model a set of usage cases believed to be more realistic than a totally random motion pattern. In addition, the simulation tools were modified to include simple obstacles that shadow the coverage of nodes, which add to the realism of the latter scenarios.The models of DSDV and DSR used in the study were part of a simulation package from CMU ,while AODV had to be implemented independently at the time of this work. To clarify the differences to the work made in , a discussion on protocol implementations and protocol parameters are presented in conjunction with the protocol descriptions In all simulations presented herein, the link layer consists of a wireless LAN using a media access control (MAC) function based on the standard. This MAC function uses a random access algorithm denoted CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) that essentially operates as an Ethernet in the air without the collision detection part. The random access concept used in this protocol makes it relatively easy to form ad-hoc networks. The technology is commercially available, and there is an implementation of this link layer in the simulation environment used in this study. The paper is organized as follows.The brief descriptions of the studied protocols are given. Next introduces a mobility metric used throughout the study. In , simulation results for the random scenario are given and results for the three realistic scenarios are presented and discussed. Conclusions are drawn from the study and, finally, planned further work is listed.

2. Protocol Description

This section gives short descriptions of the three ad-hoc routing protocols studied in this work.

2.1 Destination Sequenced Distance Vector

DSDV is a hop-by-hop distance vector routing protocol. It is proactive; each network node maintains a routing table that contains the next-hop for, and number of hops to, all reachable destinations. Periodical broadcasts of routing
updates attempt to keep the routing table completely updated at all times. To guarantee loop-freedom DSDV uses a concept of sequence numbers to indicate the freshness of a route. A route R is considered more favorable than R' if R has a greater sequence number or, if the routes have the same sequence number, R has lower hop-count. The sequence number for a route is set by the destination node and increased by one for every new originating route advertisement. When a node along a path detects a broken route to a destination D, it adds 196 vertises its route to D with an infinite hop-count and a sequence number increased by one. Route loops can occur when incorrect routing information is present in the network after a change in the network topology, e.g., a broken link. In this context the use of sequence numbers adapts DSDV to a dynamic network topology such as in an ad-hoc network. DSDV uses triggered route updates when the topology changes. The transmission of updates is delayed to introduce a damping effect when the topology is changing rapidly. This gives an additional adaptation of DSDV to ad-hoc networks. The parameter values used for DSDV in the simulations are given in Table 1 .

Table 1: DSDV Simulation parameters

Periodic route update interval	15 S
Periodic updates missed before link declared 3 broken	3
Route advertisement aggregation time	1 S
Maximum packets buffered per node per destination	5

2.2 Ad-hoc On Demand Distance vector AODV-

AODV is a distance vector routing protocol, like DSDV, but it is reactive rather than proactive like DSDV. That is, AODV requests a route only when needed and does not require nodes to maintain routes to destinations that are not communicating. The process of finding routes is referred to as the route acquisition henceforth. AODV uses sequence numbers in a way similar to DSDV to avoid routing loops and to indicate the freshness of a route. Whenever a node needs to find a route to another node it broadcasts a Route Request (RREQ) message to all its neighbors. The RREQ message is flooded through the network until it reaches the destination or a node with a fresh route to the destination. On its way through the network, the RREQ message initiates creation of temporary route table entries for the reverse route in the nodes it passes. If the destination, or a route to it, is found, the route is made available by unicasting a Route Reply (RREP) message back to the source along the temporary reverse path of the received RREQ message. On its way back to the source, the RREP message initiates creation of routing table entries for the destination in intermediate nodes. Routing table entries expire after a certain time-out period. Neighbors are detected by periodic HELLO messages (a special RREP message). If a node x does not receive HELLO messages from a neighbor y through which it sends traffic, that link is deemed broken and a link failure indication (a triggered RREP message) is sent to its active neighbors. The latter refers to the neighbors of x that were using the broken link between x and y. When the link failure messages eventually reach the affected sources, these can choose to either stop sending data or to request a new route by sending out new RREQ messages. The implementation of AODV made within this study combines HELLO messages with information from the MAC layer to detect link failures, which results in quicker failure detection.DSR uses similar methods. The HELLO interval was also increased to 1.5 seconds (1 second in) since the protocol now gets additional information from the link layer. Moreover, the AODV implementation used in this study has a send buffer of 64 packets, which is not specified in . The send buffer, located in the sending node, stores outgoing packets until the route acquisition procedure obtains a route to their destination. The AODV specification does not require a send buffer, but it is needed to obtain a fair comparison with DSR which does specify a send buffer. The maximum time to keep packets in the send buffer was set to 8 seconds, which was a heuristically determined value based on a series of initial simulations. Some of the parameters used in the simulation was slightly modified compared to the ones used in and the ones specified by . The Route reply lifetime was set to match the Active route timeout value. The Time between retransmitted requests was set to fit the reverse route life time (3 Sseconds) since it should be possible to retransmit a request as soon as the reverse route has expired. To save bandwidth, the frequency of triggered RREP messages was limited to one every second. The parameter values used in the simulations are given in Table 2.

Table 2: Parameter values for AODV

HELLO interval	15 S
Active route time-out	300 S
Route reply lifetime	300 S
Allowed HELLO loss	2
Request retries	3
Time between retransmitted requests	3s
Time to hold packets awaiting routes	8s
Maximum rate for sending replies for a route	1/S

2.3 Dynamic Source Routing - DSR

Dynamic Source Routing (DSR) is a reactive routing protocol which uses source routing to deliver data packets. Headers of data packets carry the sequence of nodes through which the packet must pass. This means that intermediate nodes only need to keep track of their immediate neighbors in order to forward data packets. The source, on the other hand, needs to know the complete hop sequence to the destination. As in AODV, the route acquisition procedure in DSR requests a route by flooding a Route Request packet. A node receiving a Route Request packet searches its route cache, where all its known routes are stored, for a route to the requested destination. If no route is found, it forwards the Route Request packet further on after having added its own address to the hop sequence stored in the Route Request packet. The Route Request packet propagates through the network until it reaches either the destination or a node with a route to the destination. If a route is found, a Route Reply packet containing the proper hop sequence for reaching the destination is unicasted back to the source node. DSR does not rely on bi-directional links since the Route Reply packet is sent to the source node either according to a route already stored in the route cache of the replying node, or by being piggybacked on a Route Request packet for the source node. However, bi-directional links are assumed throughout this study. Then the reverse path in the Route Request packet can be used by the Route Reply message. The DSR protocol has the advantage of being able to learn routes from the source routes in received packets. When A finds a route to C through B, it will in the process learn a route to B, and C will learn a route to A. When data starts flowing from A to C, B will learn a route C. However, if the reverse path from C to A passes through B, B will learn a route to C already when Route Reply message passes through B. To avoid unnecessarily flooding the network with Route Request messages, the route acquisition procedure first queries the neighboring nodes to see if a route is available in the immediate neighborhood. This is done by sending a first Route Request message with the hop limit set to zero, thus it will not be forwarded by the neighbors. If no response is obtained by this initial request, a new Route Request message is flooded over the entire network. DSR may use the MAC layer to inform about link failures. Alternatively, it can use the Network Layer Acknowledgment feature as described in. In this study the MAC layer feedback is used only. In case of a link failure, a route error packet is sent back to the source node, which then removes the broken link from its route cache and all routes that contain this hop are truncated at the point of the broken link. Furthermore, an intermediate node that forwards the route error packet may also update its route cache in a similar manner. A DSR node is able to learn routes by overhearing packets not addressed to it (the promiscuous mode). However, this feature requires an active receiver in the nodes, which may be rather power consuming. In networks were nodes have limited power the aim is to shut down the transceiver as often as possible to conserve power. In order to investigate how DSR would operate in such an environment the promiscuous mode was not used in the DSR simulations. This decision was also motivated by simulation runs (not presented due to space limitations), comparing DSR with and without the promiscuous mode. In these simulations the use of the promiscuous mode did not give a significant improvement of network performance. However, more exhaustive simulations should be made to confirm this. The parameter values used in the DSR simulations are taken in Table 3 .

Table 3: Parameters for DSR

Time between retransmitted requests	500 ms
Size of source route header carrying n address	4n+4 bytes
Time-out for non propagation search	30 ms
Time to hold packets awaiting routes	8s
Maximum rate for sending replies for a route	1/S

3. Manet Routing Protocols

There are two types of Routing Protocols in Mobile Ad Hoc Networks: Reactive Routing Protocols and Proactive Routing Protocols.

3.1 Reactive Routing Protocols

Reactive protocols also known as On-demand routing protocols which takes the passive approach or lazy to routing which is different with proactive routing protocols. Router are identified and maintained for nodes that require sending data to destination this is done by routing discovery mechanism to find the path to the destination . This type of protocols find route by flooding the network with route request packets . The reactive protocols discovered when needed. In this source nodes initiate route discover broadcasting route request into the network. The discovered route maintained in the routing table however valid and kept and the old one are deleted after active route timeout. A serious issue for MANET occurs when the links are failure due to high node mobility. This is cause for increase in the traffic with link break make effects of intermediate nodes . AODV, DSR, ROAM, LMR, TORA, ABR, SSA, RDMAR, LAR, ARA, FORP and CBRP are the example of routing protocols. DSR-Dynamic source routing protocol comes under the category of Reactive protocol for Ad-hoc wireless network. It is not table-driven but instead of that it has the characteristics like AODV. This protocol is truly based on source routing whereby all the routing information is maintained (continually updated) at mobile nodes. It has only two major phases, which are Route Discovery and Route Maintenance. Route Reply would only be generated if the message has reached the intended destination node (route record which is initially contained in Route Request would be inserted into the Route Reply).This type of routing is different from table-driven and link-state routing in the form of decision making. AODV Ad-hoc On Demand Distance Vector is an on demand routing algorithm that builds route only when needed and also known as Source Initiated Routing Protocol. AODV works on the principle of Route Request (RREQ), Route Reply (RREP) and Route Error (RERR). Each node has its own routing table which contains the information about the route from source to destination. In AODV for route maintains nodes periodical send Hello Message to its neighbor .If in any case the node fails to receive three consecutive Hello Message from the neighbor it conclude that the link to that specified node is down and get a route error message from the lower stream nodes and then the other node have to discover new route.

TORA-The Temporally-Ordered Routing Algorithm is a highly adaptive scalable and efficient distributed routing algorithm which works on the principle of link reversal .In TORA the source initiate the demand for the route to send the packet to the destination and find many routes from source to destination then choose one from them. This protocols based on three function Route Creation for creating the route source to destination.Route maintenance maintain the session during the packet transfer Route Eraser use for ending the session of data sending and ensure that the occupied route is free. TORA maintains various routes to avoid the effect of topological change. In TORA we need not to maintain the update but the utilization of the bandwidth is minimized. TORA can be maintained with the help of DAG (Dynamic acyclic graph).

Table 4: Comparisons of AODV, DSR and TORA Routing Protocols

Protocols	Advantages	Disadvantages
AODV	Adaptable to high topology	Scalability Problem,Large Delay
DSR	Multiply Routes	Scalability Problem due to source routing & flooding
TORA	Multiple Routes	Temporary Routing Routes

3.2 Proactive Routing Protocols

Routing protocols are table-Driven protocols when each nodes maintain a route to old destination in its routing table . Proactive protocols also determine the route for various nodes in the network in advance, so that the route is already present whenever needed. Route overhead are larger in such schemes in compare to reactive protocols . DSDV, WRP, GSR, FSR, STAR, DREAM, MMWN, HSR, OLSR and TBRPF are some of example of proactive protocols. In case of route failure Route-error packet is sent by the source to destination nodes. All the route information is usually kept in numbers of different tables . Whenever the change occur these table updated according to change. DSDV-Destination sequence distance vector protocol is a table-driven routing scheme for ad hoc mobile networks based on the Bellman-Ford algorithm and developed by C. Perkins in 1994. This algorithm is used for calculating or finding the shortest path between the multiple paths and as the same suggest the source select the path which has minimum, distance from source to destination. The main contribution of the algorithm was to solve the routing loop problem. Each entry in the routing table contains a sequence number, the sequence numbers are generally even if a link is present; else, an odd number is used. The number is generated by the destination, and the emitter needs to send out the next update with this number. The update in the table can be done by two method one is full dump where node transmit their Routing table entry and other is incremental method where the node only forward newly updated entry. OLSR--The Optimized Link State Routing Protocol is a Proactive link state protocol . OLSR employs three mechanism for routing Hello message for neighbor sensing message Control packet using multi-point rely(MPR).Path selection using shortest path first algorithm. Each nodes using its two-hops by selecting MPR's such that all its two-hop neighbors are accessible .Basically the hello and topology control (TC) messages to discover and then broadcast link state information throughout the mobile ad-hoc network. Individual nodes use this topology information to compute next hop destinations for all nodes in the network using shortest hop forwarding paths

4. SIMULATIONS - RANDOM SCENARIOS

The simulation study was conducted in the Network Simulator (ns2) [5] environment and used the ad-hoc networking extensions provided by CMU [20]. All simulations were performed on a PC (Pentium-2, 400 MHz, 128 MB of RAM) running FreeBSD 2.2.6. In the random scenario, each node randomly selects waypoints in a square environment space (1 km x 1 km). At each waypoint a node pauses for a predefined time and picks the speed to the next waypoint from a uniformly distributed interval [&v-l. The simulations of random scenarios are similar to the approach in [2], where the area was instead rectangular, 15OOm x 300m. A square area does not "discriminate" one direction of motion like a rectangular area do. On the other hand, it limits the number of hops (from 6 to 4 for a transmitting range of 250m). Since Section 5 analyzes scenarios with many hops,the square area was chosen for this part of the study.

Delay and throughput were measured. In addition, to understand the protocol efficiency, the overhead imposed by the routing protocols was measured both in terms of packets and bytes. Two sets of simulations were run. First, the mobility was varied and the offered load was held constant. In the second set of simulations the offered load was varied as well as the mobility.

Table 5 Provides all the simulation parameters.

Transmitter range	*250 m*
Bandwidth	*2 Mbps*
Simulation time	*250 s*
Number of nodes	*50*
Pause time	*1 s*
Environment size	*1000x1000 m*
Traffic type	Constant Bit Rate
Packet rate	*5 packets/s*
Packet size	*64 byte*
Number of flows	*15*

In all random scenario simulations the implicit mobility value is controlled through the explicit maximum speed parameter,The mobility value is difficult to set exactly, so an interval of 0. I for each point was allowed. The mobility values used in the simulations are: 0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, and 3.5, where a mobility factor of 3.5 corresponds to a v-.of 20 m/s. In all the simulations the traffic was generated by 15 continuous bit rate (CBR) sources spreading the traffic randomly among all nodes. The packet size was 64 bytes and the packet rate was 5 packets/s in the first set of simulations. In the second set of simulations the rate ranged from 5 packets to
20 packets.

4.1 Delay

4.1.1 First set of simulations –

Varied Mobility The average packet delay increases with mobility for all three protocols, as shown in Figure 2. However, DSR has a lower delay than AODV at higher mobility values due to the way routes are detected in DSR. The route acquisition procedure in DSR allows more routes to be detected and cached than in AODV, which obtains a single route per RREQ. With DSR, packets wait less during route acquisition than with AODV. DSDV exhibits a low delay because only packets belonging to valid routes at the sending instant get through. A lot of packets are lost until new (valid) route table entries have been propagated through the network by the route update messages in DSDV. For DSR and AODV, on the other hand,

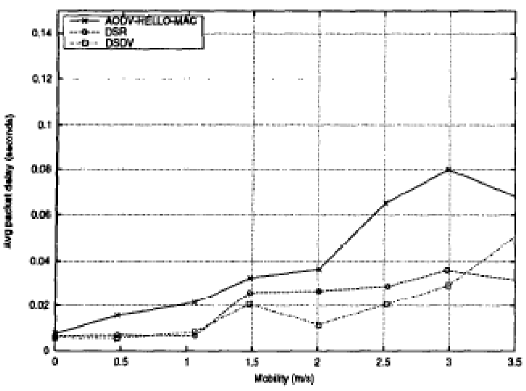

Figure 6:All Average delay with varied mobility

ISSN 2229-5518

the reactive route acquisition procedures manage to provide

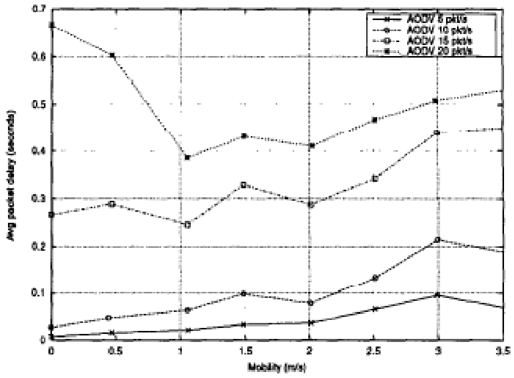

Figure 7:AODV Average delay with varied over traffic

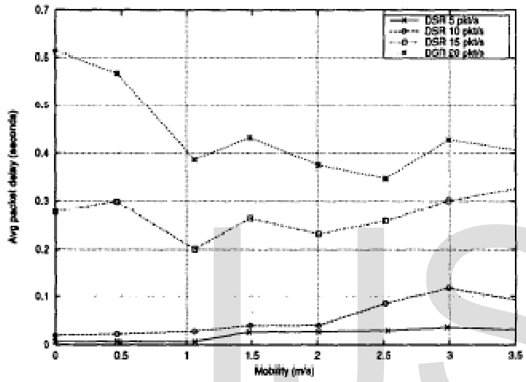

Figure 8:DSR Average delay with varied over traffic

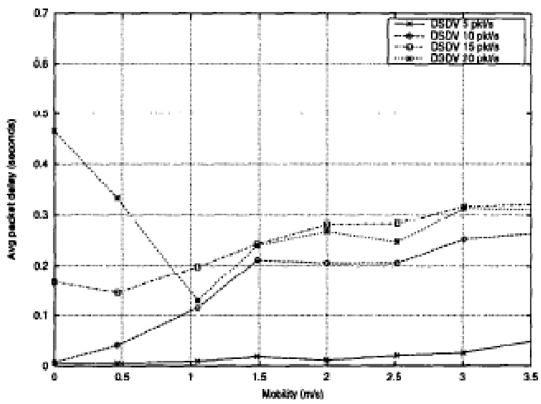

Figure 9:DSDV Average delay with varied over traffic

The results for AODV, DSR, and DSDV are shown in Figure 6, Figure 7,Figure 8 and Figure 9, respectively.

5. CONCLUSIONS

The simulations presented here clearly show that there is a need for routing protocols specifically tuned to the characteristics of ad-hoc networks. The mobility metric used throughout the study explicitly shows how the examined protocols behave for various degrees of relative node motion.The mobility metric is explicitly designed to capture the kind of motion important for an ad-hoc network – the relative motion of nodes. It can be used for any continuous node motion.

In networks with a dynamic topology, proactive protocols such as DSDV have considerable difficulties in maintaining valid routes, and loses many packets because of that. With increasing mobility, its strive to continuously maintain routes to every node increases network load as updates-become larger. This study clearly indicates that a reactive routing protocol is superior to a proactive one. The principle of focusing only on explicitly needed connectivity, and not all connectivity, seems to be excellent when the network consists of moving nodes. In addition, the protocol should be able to detect link failures as quickly as possible to avoid use of invalid routes. Overall, the proactive protocols under study (AODV and DSR) behaved similarly in terms of delay and throughput. On the basis of this study both should be considered suitable for mobile ad-hoc networks. However, a number of differences between the protocols do exist.The source routes used by DSR give increased byte overhead compared to AODV when routes have many hops and packet rates are high. DSR is, on the other hand, efficient in finding (learning) routes in terms of the number of control packets used, and does not use periodic control messages. Data packets in AODV carry the destination address only, and not source routes. Therefore, the byte overhead for AODV is the lowest of the examined protocols. The overhead is however high in terms of packets since AODV broadcasts periodic HELLO messages to its neighbors, and needs to send control messages more frequently than DSR to find and repair routes. The simulations in this work show that DSR performs better than AODV for low traffic loads, since it discovers routes more efficiently. At higher traffic loads, however, AODV performs better than DSR due to less additional load being imposed by source routes in data packets.

. FURTHER WORK

The work presented herein is the first of a series of simulation studies within the area of mobile ad-hoc networking. These studies will include

- additional analysis of other proposed protocols (e.g. TORA, ZRP and CBRP),
- measurements and estimation of power consumption and processing costs.
- other traffic than CBR (e.g., TCP transfers),
- inclusion of QoS mechanisms for real-time and non realtime traffic,evaluation of proposed multicast routing protocols.
- analysis of interworking functions for Mobile IP.

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ISSN 2229-5518