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Performance of Ad Hoc Network Routing Protocols with Environment Awareness

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Abstract: The present study has proposed an environment aware routing protocol. Environment awareness is incorporated by assuming that each node has the capability to understand its surrounding environment. As soon as a node smells the non-ideal environment it broadcasts a IN message and all the remaining nodes receiving this message will set the flag field for that node and do not use that node till the flag is reset by OUT message. The performance of this algorithm is analyzed by incorporating environment awareness to the existing protocols like DSR, AODV and NTP. The results indicate that all the algorithms show degraded performance under non-ideal environment and by incorporating awareness, the performance improves by about 10-15%.

Key words: Routing algorithms, mobile ad hoc network, non-ideal environment, ideal-environment, environment awareness

INTRODUCTION

Ad hoc network is a collection of wireless nodes, which form a temporary network without relying on the existing network infrastructure or centralized administration. Ad hoc network forms a multihop network where all communication is over the wireless channel, hopping over several mobile nodes. Nodes of this network function as routers, which discover and maintain routes to other nodes in the network. The nodes are free to move around randomly, thus changing the network topology dynamically. These types of networks have many advantages, such as self-reconfiguration and adaptability to highly variable mobile characteristics like the transmission conditions, propagation channel distribution characteristics and power level. Mobile ad hoc network are proposed for applications like military maneuvers, mobile robotics, sensor networks, disaster relief, home networking, conferences and for any instant infra structure. In certain applications like, military maneuvers, sensor network, disaster relief and areas under heavy shadowing, the environment in which the network is set up is not ideal. Each node in a network experience different environment conditions like chemical hazards, electromagnetic interference and other climatic conditions and also it is true that all the nodes participating in the network do not have same ideal setup. Some nodes may be initially ON and get turned OFF in between due to battery power level, or for any other emergency activity. All the current routing protocols like DSR[1,2], AODV[1,2], DSDV[2], SSA[2], ABR[2] and NTP[3] assume the environment to be ideal. The environment in which a mobile ad hoc network operates is unpredictable and sometimes unsafe. To our knowledge all the current routing algorithms suggested for MANET assume that every node in the network faces the same environment and all the nodes have the same ideal setup. In this work, we assume that the environment faced by each node in MANET is not the same, for example, in battle field operation as shown in Fig. 1, few nodes will be inside the non-ideal area and few in normal environment. Those nodes before entering the non-ideal area would have co-operated effectively to transmit data's for other nodes, but when they are inside the non-ideal region they fail to co-operate which may lead to black hole in the network and result in network failure. This situation is similar to the network set up in disaster relief, Sensor network and shadowing.

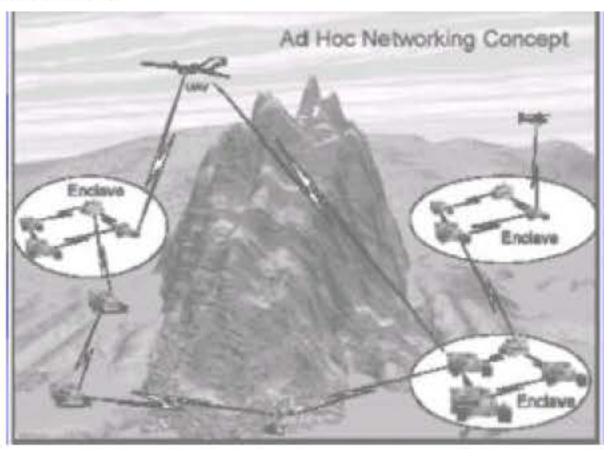

Fig. 1: Illustration of non ideal environment

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This nature of the network calls for special attention while designing the routing algorithms. The authors suggested a routing algorithm that generates warning signal when a node, which is in the path of routing, enters into the preemptive area[4]. The preemptive area is defined based on the signal strength in a normal wireless environment also this paper assumes that all the nodes face the same environment. But, the signal strength may get reduced due to various other reasons like fading, shadowing and environmental conditions. This algorithm does not include these situations and hence there may be situations of false alarm, which may lead to increased overhead and selection of paths with less capacity than the current one. Therefore, this study proposed an environment aware routing algorithm for a network of nodes working in different environmental conditions. The performance of this algorithm with respect to packet delivery ratio, control overhead and delay for the existing routing protocols like, DSR, AODV and NTP are studied.

NON-IDEAL ENVIRONMENT (NIE)

A non-ideal environment is defined as the propagation zones in which the nodes experience a high probability of failure compared to those outside. These zones can have any type of nature, which include areas with high electromagnetic interference, areas affected by flood, earth quack, chemical leakage and areas under heavy shadowing. In the environment aware routing algorithm, we assume that each node in the environment has the capability to understand its surrounding. To study the performance of this algorithm under non ideal environment, we randomly define some areas as non-ideal zones in the terrain area as shown in Fig. 2 which represents a 1000x1000 m terrain region of simulation environment with 3 non-ideal zones of 200x200 m squares each.

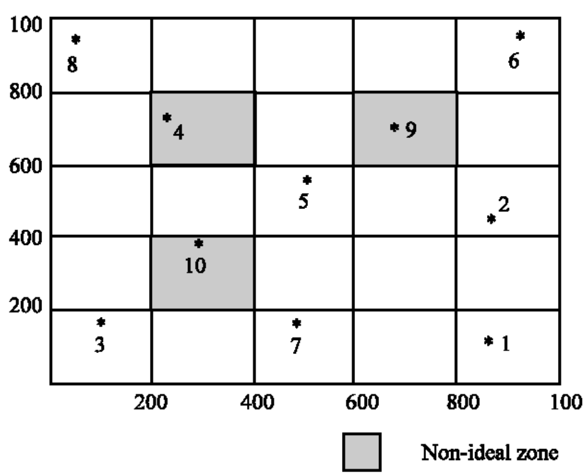

Fig. 2: Illustration of simulated non ideal environment

An active path in normal environment fails either due to the movement of the nodes out of transmission range or due to the drainage of battery power level at the node or due to intentional turn off of the mobile device. In addition to the above conditions the path may also fail when the node moves into the non-ideal environment. The cost of detecting a failure is very high since several retries have to be made before a path is pronounced dead. Therefore, the probability of link failure at time t is given by:

$$Pr_F\,(t)= Pr_T(t) + Pr_B\,(t)+ Pr_I\,(t)+ Pr_Z(t) \quad (1)$$

where, Pr_T (t) is the probability of link failure due to node moving out off transmission range, Pr_B (t) is the probability of link failure due to low battery power level of the node, $Pr_I(t)$ is the probability of link failure due to intentional turn off of the node and $Pr_Z(t)$ is the probability of link failure due to the movement of the node in to the non- ideal zone Z.

The analytical expressions for $Pr_T(t)$ can be obtained from link availability expression reported for random waypoint and random walk mobility models, respectively[5,6].

The probability of link failure due to low battery power level of a node can be written as[7,8]:

$$Pr_b(t) = 1 - Pr(P_L(t) > P_{th}) \quad (2)$$

where, P_L (t) is the battery power level at time t and P_{th} is the threshold power level, the minimum level required for the operation of the node. The probability of link failure due to intentional turn off of the node can be modeled as exponential distribution function as it is a memoryless operation and the probability of link failure due to movement of the node into non-ideal zones is one of the critical problems to be addressed. To our knowledge, this study is not carried out by any of the researchers.

Though, power aware and mobility aware routing algorithms are available in the literature[5-8], no algorithm with environment awareness has been reported so far. This study incorporate environment awareness in the routing protocol using a flag which is set or reset depending on whether the node is inside or outside non-ideal zone, respectively.

ENVIRONMENT AWARE ALGORITHM

In the environment aware routing algorithm, we assume that each node in the environment has the capability to understand it's surrounding. To study the performance of this algorithm under non ideal environment, we randomly define some areas as non-ideal zones in the terrain area as shown in Fig. 2 which represents a 1000x1000 m terrain region of simulation environment with 3 non-ideal zones of 200x200 m squares each. As soon as a node smells the non-ideal environment it broadcasts a IN message and all the remaining nodes receiving this message will set the flag field for that node and do not use that node till the flag is reset by OUT message.

The IN and OUT broadcast message of the critical nodes contain information such as Node id, the Sequence number, which is used for checking the freshness of the message and the packet type which is set as 0 for IN and 1 for OUT messages.

In conventional DSR, when the source node has data to transmit to a destination, it initiates route discovery by transmitting the RREQ packet. The nodes receiving this packet sends a reply if it has the path to the destination, otherwise, the RREQ is re-broadcasted. The destination node or any other node, which has a path to the destination, transmits the RREP to the source. When the RREP arrives at the source, it gets the path to destination through the nodes that are in the normal zone whose flags are set to zero. Similarly, in AODV and NTP routing algorithms, the routing table is created by initiating their corresponding route discovery process.

During data transfer, an active path may fail due to the intermediate node movement either out of transmission range or into the non-ideal zone. In the conventional algorithms, several retries have to be made by the node preceding the failed link before a path is pronounced dead and to send a route error packet RERR to the source node which in turn initiates a fresh route discovery process leading to extra control overhead and delay. In the environment aware routing algorithm, an intermediate node broadcasts a IN message just before moving into the non-ideal zone. The nodes, receiving this message set the flag to 1 for that critical node and rebroadcast the message. The source node on receiving this information reinitiates route discovery process. This mechanism of detecting a link failure due to non-ideal environment results in less control overhead and delay. When the critical node comes out of non-ideal zone it broadcasts OUT message to all its neighbours. The nodes receiving it reset the flag to 0 and transmits data packet through it once again if required.

SIMULATION AND PERFORMANCE ANALYSIS

The performance of environment aware routing for DSR, AODV and NTP algorithm is evaluated using GloMoSim simulator[9]. The GloMoSim (GLObal MObile information system SIMulator) provides a scalable simulation environment for wireless network systems. It has been designed using the parallel discrete-event simulation capability provided by Parsec (PARallel Simulation Environment for Complex systems). It is a C-based simulation language developed by Parallel Computing Laboratory at UCLA, for sequential and parallel execution of discrete-event simulation model. The parameters shown in Table 1, are used in the simulation and the performance of the algorithm is carried out for adequate number of times to obtain the optimal results.

Table 1: Simulation parameters

Number of nodes	100
Terrain range	1000x1000 m^2
Transmission range	250 m
Simulation time	600 sec
Node placement	Random
Mobility model	Random way point
Speed	0-60 kmph
Propagation model	Free space
Channel bandwidth	2 Mb s^{-1}
MAC	802.11
Packet size	256 bytes

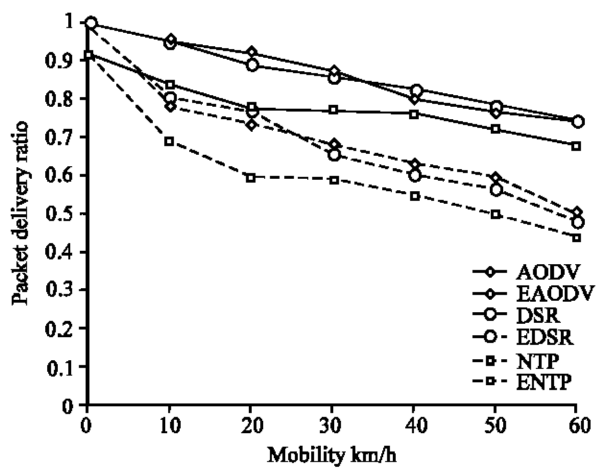

Fig. 3: Mobility Vs packet delivery ration

The effect of non-ideal zones inside a 1000x1000 m^2 of network area with 100 nodes moving with a maximum speed of 20 Kmph is studied for DSR, AODV and NTP protocols with and without awareness. The Table 2 shows the performance of DSR protocol with respect to PDR, control overhead and end-to-end delay. Similarly, Table 3 and 4 show the performance results of AODV and NTP protocols, respectively. From the results shown in Table 2 for DSR, it can be seen that as the percentage of non-ideal zones increases the packet delivery ratio decreases and it becomes zero when more than 70% of the area is non-ideal. The DSR algorithm with environmental awareness (EDSR) improves the PDR performance by about 5% for a particular case of 50% of non-ideal environment. Similarly, the environment aware EAODV and ENTP algorithms show PDR improvement of 16 and

Table 2: Performance of environment aware DSR routing algorithm under non-ideal environment

	EDSR			DSR		
Non-ideal environment %	PDR	Control overhead	End-end delay (m sec)	PDR	Control overhead	End-end delay(m sec)
5	93.4	0.132	6.87	84.98	0.156	8.32
10	89.23	0.102	6.94	76.72	0.128	8.46
20	72.016	0.098	7.008	68.67	0.1112	8.587
30	63.84	0.094	7.043	56.82	0.0994	8.632
40	57.23	0.0908	7.164	48.65	0.0983	8.792
50	42.98	0.0887	7.35	38.77	0.0918	9.002
60	32.42	0.0856	7.489	26.667	0.0874	9.0438
70	0	0.072	0.0000	0	0.072	0.0000
80	0	0.072	0.0000	0	0.072	0.0000

Table 3: Performance of environment aware AODV routing algorithm under non-ideal environment

	EAODV			AODV		
Non-ideal environment %	PDR	Control overhead	End-end delay(m sec)	PDR	Control Overhead	End-end delay(m sec)
5	97.38	0.4456	8.43	90.48	0.4832	9.42
10	92.11	0.4128	8.62	73.49	0.4246	9.456
20	83.54	0.36823	8.685	69.54	0.41732	9.843
30	71.23	0.3715	8.89	64.385	0.4056	9.921
40	62.41	0.3458	9.001	55.89	0.3826	9.987
50	58.487	0.29446	9.028	42.87	0.3024	9.994
60	43.64	0.20226	9.146	32.114	0.2482	10.008
70	0	0.200	0.0000	0	0.20	0.000000
80	0	0.200	0.0000	0	0.20	0.000000

Table 4: Performance of environment aware NTP routing algorithm under non-ideal environment

	ENTP			NTP		
Non-ideal environment %	PDR	Control overhead	End-end delay(m sec)	PDR	Control overhead	End-end delay(m sec)
5	82.667	0.4086	16.87	71.33	0.427	18.32
10	78.11	0.35907	16.94	59.667	0.38355	18.46
20	64.22	0.3308	17.008	39.778	0.38977	18.587
30	55.84	0.24544	17.043	24.77	0.34911	18.632
40	54.11	0.18977	17.164	20.44	0.33578	18.792
50	53.08	0.18677	17.35	18.674	0.27866	19.002
60	52.11	0.18667	17.489	16.84	0.2688	19.0438
70	18.6	0.1667	17.5003	11	0.20011	19.086
80	18.6	0.1667	17.5003	11	0.20011	19.086

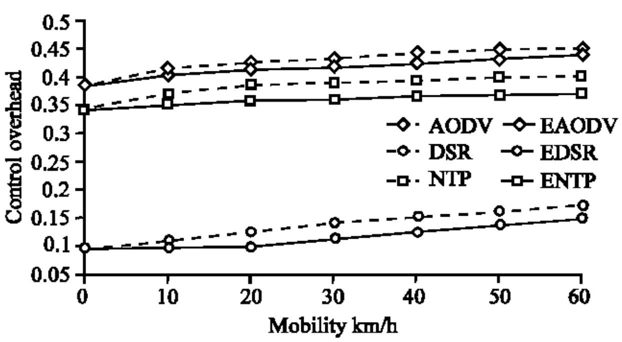

Fig. 4: Mobility Vs control overhead

34%, respectively. When the percentage of non-ideal zones is less than 5%, the packet delivery ratio of the NTP protocol is small compared to that of DSR protocol and AODV protocol, whereas at 70 and 80% of non-ideal environment DSR protocol and AODV protocol fail but NTP protocol still shows a PDR of more than 10% with and without environment awareness. This is because the NTP algorithm does not set the entire path to the destination but just finds its best neighbour and transmits the packet. Thus, the packets reach the destination through some path, which may not be the shortest, whereas DSR and AODV protocols first set up a path to the destination and if the path is not available, the packets are not delivered.

The control overhead for EDSR, EAODV and ENTP protocols is lesser than that for the corresponding protocols without environment awareness and it may be due to fact that more number of control packets are used to declare a path dead and hence to reinitiate route request. Also, it can be seen from the results that as the percentage of non-ideal zones increases, the control overhead reduces. Since the nodes inside the non-ideal zones cannot receive and rebroadcast any control packets. Flooding of RREQ and the search for new route contributes to the increased overhead in table driven AODV protocol. The DSR protocol uses less control packets than AODV and NTP, as it is a source-routed protocol but uses variable packet length. The control overhead for NTP is less than that of AODV because it uses stable routes.

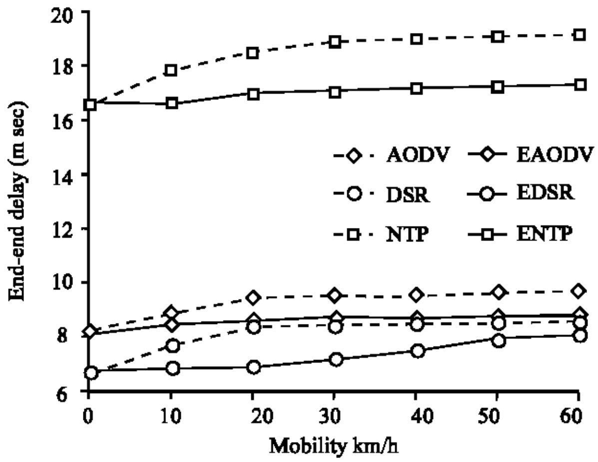

Fig. 5: Mobility vs end-end delay

The average end-end delay performance for all the three protocols for various percentages of non-ideal environments is given in Table 2-4. It can be seen from the results that as the percentage of non-ideal zones increases, the delay increases since the probability that a node enters into non-ideal zone increases and hence there are more link breakages, which lead to more number of new route requests to be initiated resulting in considerable increase in delay. By incorporating environment awareness, the end-end delay is reduced by about 16% in EDSR, 10% in EAODV and 16% in ENTP when the percentage of non-ideal zones is about 50%. Also, it can be inferred from the results that the end-end delay is less for EDSR compared to EAODV and ENTP as it is a source routed protocol and the delay is more for ENTP compared to other two protocols for the path selected may not be the shortest.

The packet delivery ratio, control overhead and delay of EDSR, EAODV and ENTP are evaluated with respect to mobility with 10% non-ideal environmental zones and the results are presented in Fig. 3-5 and it is observed that the environment aware algorithms perform better than conventional algorithms.

CONCLUSION

This study has presented the performance of existing routing algorithms like DSR, AODV and NTP in non-ideal environment such as PDR, control overhead and delay. All the current routing algorithms suggested for MANET assume that every node in the network faces the same environment and all the nodes have the same ideal setup. The concept of environment awareness in routing algorithm is proposed and the simulation performance of the environment aware DSR, AODV and NTP algorithms are presented in this work. From the results it may be stated that for the environments with less than 50% of non ideal zones, AODV protocol can be used as routing protocol for it has higher PDR, if control overhead and delay are not of utmost importance. For networks with stringent demand on control overhead and delay, the DSR protocol will best suite the requirement. For networks with more than 50% of non-ideal zones, the NTP protocol will be the best choice.

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