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Lifetime Analysis of MANET in Presence of Selfish Nodes

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Abstract *:* The MANETs are self-configuring and decentralized networks without having a fixed infrastructure. In such a network, each node acts as an end-system as well as a relay node (or router). Most of the routing algorithms designed for a MANET are based on the assumption that every node in the network is cooperative and takes part in routing of packets. But in practice, some of the nodes may act as the selfish nodes. Such nodes use the services provided by other nodes in the network and at the same time are reluctant in offering their services to other nodes. By doing so they are able to conserve their resources like CPU time, battery power etc. at the cost of other nodes. This certainly has effect on the overall performance of the network. In this paper, the objective is to study the impact of selfish nodes on the lifetime of the MANET. The adaptive fuzzy threshold energy based routing protocol (AFTE) is applied to improve the network lifetime. The experimentation has been done for different node densities and for different number of selfish nodes.

Key words : MANET, selfish node, residual energy, fuzzy threshold.

INTRODUCTION

Wireless networking has witnessed an explosion of interest shown by consumers in recent years for its applications in mobile and personal communications. A mobile ad hoc network (MANET) is infrastructure-less, self-organizing, rapidly deployable wireless network. These are highly suitable for applications involving special outdoor events, communications in regions with no wired infrastructure, emergencies, natural disasters, and military operations. Routing is one of the key issues in MANETs due to their highly dynamic and distributed nature. A MANET is a network that is set up spontaneously by a bunch of computing devices connected wirelessly. The devices participating in the network can unexpectedly move out or new ones may enter in their respective range of transmissions. Due to the lack of dedicated infrastructure and central control, the management of the MANET is the responsibility of each and every node in the network. Therefore, every host has to act as terminal as well as router in a distributed fashion. As a more formal relation, a MANET is a multi-hop packet radio network. As wireless networks have become an integral component of the modern communication infrastructure, energy efficiency has become an important design consideration in view of the limited battery life of mobile terminals. The power efficient mobile ad hoc networks aim at minimizing the power consumption of entire network and thus, maximizing the lifetime of ad hoc networks. A typical ad hoc network consists of nodes that are usually battery-operated devices which come together and spontaneously form a network. Energy conservation is a critical issue as the lifetime of these nodes depends on the life of the system. Since each node in a MANET works as a terminal node and a routing node as well, a node cannot participate in the network if its battery power runs out. Such nodes are declared as dead nodes. The increase of such dead nodes generates many network partitions and consequently, normal communication as a MANET will fail. The conventional protocols in MANETs such as WRP, DSDV, AODV and DSR assume that all the nodes are cooperative and, whenever a node receives a request to relay traffic, it always does so truthfully. As the time passes, there is a tendency in the nodes in a MANET to become selfish. The selfish nodes are not malicious but are reluctant to spend their resources such as CPU time, memory and battery power for others. The problem is especially critical, when the nodes have little residual power, with the passage of time, and want to conserve it for their own purpose. Thus, in a MANET environment, there is a strong motivation for a node to become selfish. Marti et al. [7] have defined the characteristics of selfish nodes as follows:

- Do not participate in routing process: A selfish node drops routing messages or it may modify the Route Request and Reply packets by changing TTL value to smallest possible value.
- Do not reply or send hello messages: A selfish node may not respond to hello messages. Hence, other nodes may not be able to detect its presence when they need it.
- Intentionally delay the RREQ packet: A selfish node may delay the RREQ packet up to the maximum upper limit time. It will certainly avoid itself from routing paths.
- Dropping of data packet: A selfish node may participate in routing messages but may not relay data packets.

The major reason for such a behavior is low residual battery power of a node. A selfish node is not malicious and doesn't intend to involve itself in the network damaging activities such as content alteration, spoofing, etc. It normally restrains itself from the activities of the other nodes, which do not bring any benefit to it. One immediate effect of node misbehaviors and failures in MANET is the node isolation problem due to the fact that communications between nodes are completely dependent on routing and forwarding packets. In turn, the presence of selfish node is a direct cause for node isolation and network partitioning, which further affects network survivability. Traditionally, node isolation refers to the phenomenon in which nodes have no active neighbors.

RELATED WORK

The limited energy resources coupled with the multi-hop nature of MANETs causes a new vulnerability that does not exist in traditional networks. To preserve its own battery, a node may behave selfishly. In the literature, there are many studies on the impact of the selfish nodes on the performance of the MANET. In [1], the effect of selfish nodes on the power consumption in MANET has been studied and it is observed that, as the number of selfish nodes increase, they save more energy as compared to the good nodes. This study has been done for both static and dynamic topologies. The investigation of several variants of selfish node behaviors that abuse the random choice of Contention Window in the 802.11 DCF MAC protocol is done in [2]. It shows that selfish behavior in the MAC layer can have devastating side effects on the performance of wireless networks, similar to the effect of DoS attacks. In [3], the selfish nodes do not participate correctly in routing function by not advertising available routes or by not forwarding route request packets. Consequently, such selfish nodes will not appear on packet forwarding path. In [4], a mathematical model to detect selfish nodes using the probability density function has been proposed. The proposed model works with existing routing protocols and the nodes that are suspected of being selfish are given a selfishness test. The effect of packet dropping on the throughput has been studied through analysis and simulation in [5]. A watchdog mechanism is used for mitigating the throughput degradation after detection of the attack. A survey of reputation based mechanism and credit based mechanisms for detection and isolation of selfish nodes is done in [6]. It also discusses about the advantages and limitations of each of the mechanisms. A global reputation based scheme is proposed for the detection and isolation of selfish node. Selfish nodes misuse the cooperative nature of other legitimate nodes, making network resources unavailable for them. A study about the evaluation of impact of selfish nodes on MANET, various detection methods and counter measures are studied in [8]. Discussion about two techniques, namely, Reputation based technique and Credit based technique which are used to detect selfish nodes in MANET is given in [9] and the two techniques are compared. In [10], a new routing algorithm for MANETs based on adaptive fuzzy threshold energy (AFTE), which conserves battery power of the mobile nodes and hence is able to extend the lifetime of the MANET has been proposed.

PROPOSED WORK

Though considerable study about the selfish nodes and their impact on the performance of MANET has been done, it is observed that very little work is done on the study of the impact of selfish nodes on the lifetime of MANET. In this paper, the objective is to study the impact of the selfish nodes on the lifetime of the MANET for various node densities (ranging from 50 to 300 in steps of 50) and also for various levels of selfish nodes (ranging from 10% to 50% of total number of nodes in steps of 10). That is, out of the total number of nodes in the MANET, 10% of the nodes are randomly chosen to be selfish and the number of nodes is increased in steps of 10. The basic routing algorithm AODV is used. The AFTE routing algorithm [10] is applied to the MANET with selfish nodes in order to see the impact of the presence of selfish nodes on the energy efficiency. The procedure to calculate the adaptive fuzzy based threshold energy is as follows:

Adaptive Fuzzy Threshold Energy (AFTE)

Let RE_i, i = 1,2, … , n , be the residual energies of the n neighboring nodes of a transmitter node. Let minRE = min{ RE_i} , maxRE = max { RE_i } and midRE = (minRE + maxRE) / 2. Let the three fuzzy subsets of these nodes with low, medium and high residual energy be defined with the membership functions, μ_{low}, μ_{medium} and μ_{high} , respectively, as given below (Fig.1).

$$\mu_{low}(RE_i) = \begin{cases} \dfrac{RE_i - midRE}{minRE - midRE}, & minRE \le RE_i \le maxRE \\ 0, & midRE \le RE_i \le maxRE \end{cases}$$

$$\mu_{medium}(RE_i) = \begin{cases} \dfrac{RE_i - minRE}{midRE - minRE}, & minRE \le RE_i \le midRE \\ \dfrac{RE_i - maxRE}{midRE - maxRE}, & midRE \le RE_i \le maxRE \end{cases}$$

$$\mu_{high}(RE_i) = \begin{cases} 0, & minRE \le RE_i \le midRE \\ \dfrac{RE_i - midRE}{maxRE - midRE}, & midRE \le RE_i \le maxRE \end{cases}$$

Then, the membership value μ_i of RE_i for the i^{th} node is given by:

$$\mu_i(RE_i) = \max\{\mu_{low}(RE_i), \mu_{medium}(RE_i), \mu_{high}(RE_i)\}$$

The defuzzification step is as follows:
Let RE_{Th} be the value of RE_i for which the membership value is minimum among the neighboring nodes, i.e.

$$\mu_{Th}(RE_{Th}) = \min_{1 \le i \le n}\{\mu_i(RE_i)\}$$

If there is a tie, it is broken by selecting the node with minRE among the nodes with the same minimum membership value. The, RE_{Th} obtained by this defuzzification process, is used as the threshold energy value, which is transmitted in RREQ packet to the neighboring nodes. If, for a neighboring node i, $RE_i > RE_{Th}$, where RE_i residual energy of node i, then the node i will forward the route request to its next hop, provided that the node i is not a selfish node. Otherwise, the node simply drops the route request packet. This process starts at source and continues till the destination receives the route request packet.

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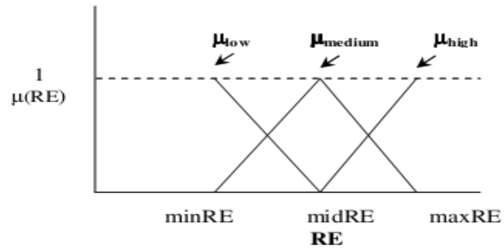

Fig 1: Membership functions for nodes with fuzzy RE levels

The lifetime of the MANET achievable by the proposed algorithm, in the presence of selfish nodes, is compared with that available in the following cases:

i. AODV without selfish nodes (AODV self)
ii. AODV with application of AFTE protocol
iii. AODV with selfish nodes
iv. AODV with selfish nodes with application of AFTE protocol.

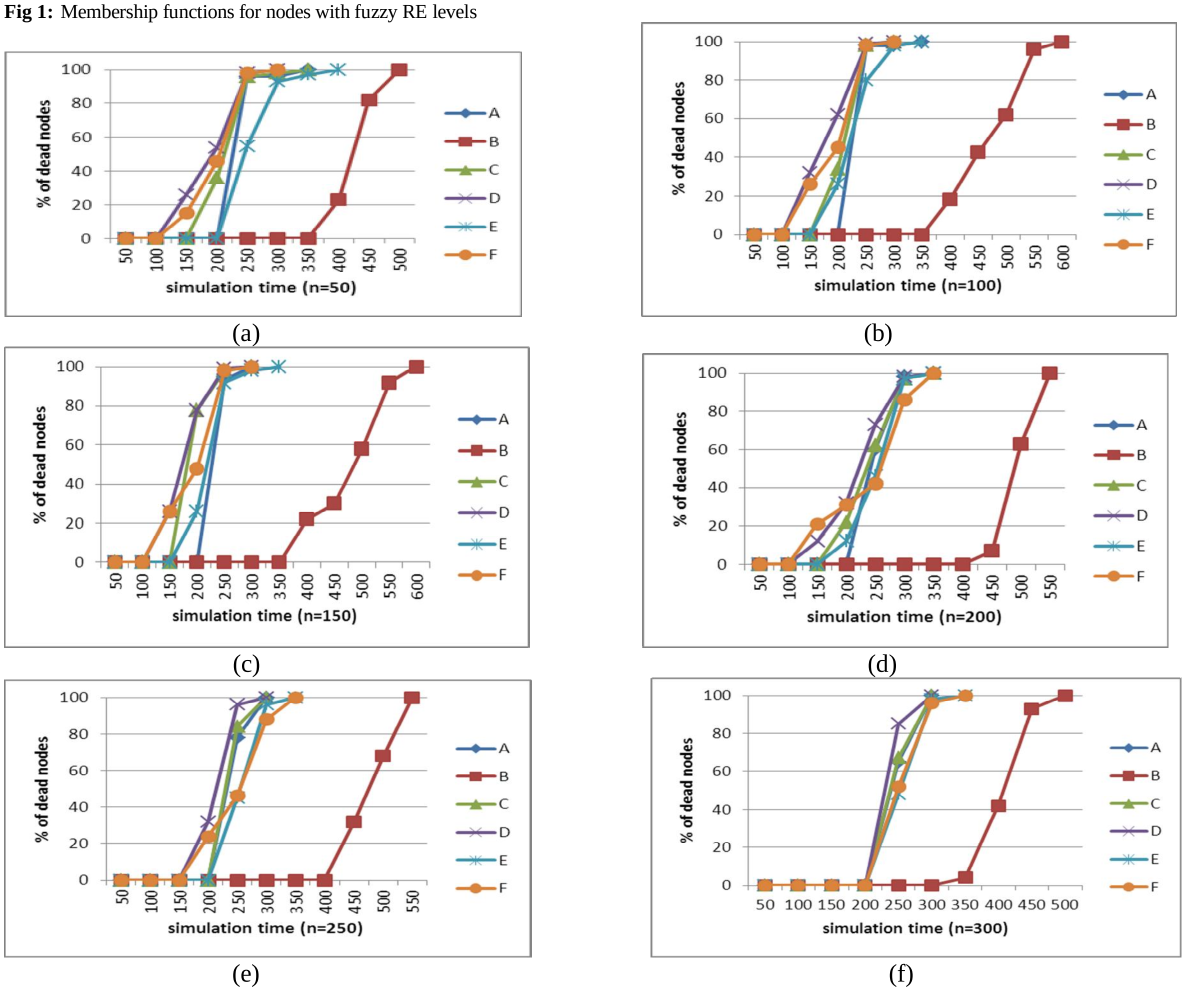

Fig 2: The % of dead nodes vs. Simulation time for (a) 50 nodes (b) 100 nodes (c) 150 nodes (d) 200 nodes (e) 250 nodes (f) 300 nodes. In the legend, A & B correspond to AODV & AFTE without selfish nodes, C & E to AODV & AFTE with 20% selfish nodes, D & F to AODV & AFTE with 50% selfish nodes, respectively.

Table 1: Simulation Parameters used

Parameter	Value
Simulation Time	50, ..., 600 sec.
Terrain Area	500 X 500 sq. mts
Number of Nodes	50,100,150,200,250,300
Node placement	Random
Propagation Model	RWP
Channel Frequency	2.4 G.Hz.
Routing Protocol	AODV, AFTE
Transmission Range	250mts
Initial Energy for each node	100 Joules

RESULTS AND DISCUSSIONS

The simulation experiment is carried out using NS2 simulator for different simulation times (50, …, 600), in steps of 50. In the experiment various node densities ranging from 50 to 300 in steps of 50 and various levels of selfish nodes ranging from 10% to 50% of total number of nodes in steps of 10% are used. The other simulation parameters are given in the Table 1. The results are shown in the graphical form in the Fig.2. To keep the graph simple, the results corresponding to only 20% and 50% of selfish nodes are presented.

Network partitioning is usually defined according to the following criteria [11]:

a. The time until the first node burns out its entire battery budget.

b. The time until a certain portion of the nodes fail.

c. The time until the network partitioning occurs.

In the simulation experiment carried out, the following three cases are considered:

a. Time when the first node fails.
b. Time when 50% of the nodes fail.
c. Time when all the nodes fail.

The results for the four protocols, namely, AODV, AFTE, AODV with selfish nodes and AFTE with selfish nodes are given in the Table 2. From the Fig.2, it is clear that as the simulation progresses, more and more nodes lose their energy and hence become dead. It shows that AFTE based routing protocols provide 15 to 50% more network lifetime as compared to AODV and other protocols. Thus, it is able to achieve higher network lifetime as compared to the other three protocols considered therein. Further, as the number of selfish nodes increases, there is a gradual reduction in the network lifetime. This reduction in the network lifetime is due to the fact that, as more and more nodes become selfish, the routing load on the good nodes increases. The good nodes keep losing their energy and hence become dead earlier. On an average, with 30% increase in the selfish nodes, the network lifetime reduces by 25%.

From the Fig.2, it can be seen that for a network with smaller node density, the impact of selfish nodes on the network lifetime is more. As the node density increases, this impact also keeps on reducing. This is because, with the increase in the node density, more nodes are available for sharing the routing load, excluding the selfish ones. An improvement in the network lifetime with the application of AFTE protocol can be seen from the Table.2. Considering only the first node failure, there is an improvement in network lifetime from 2 to 41%. Considering 50% node failure, there is an improvement in network lifetime from 2 to 16%. Considering 100% node failure, there is an improvement up to 14% in network lifetime.

Table 2: The time when 1st node fails, 50% nodes fail and 100% nodes fail in case of AODV & AFTE protocols without and with the presence of selfish nodes.

No. of Nodes	Time when first node's residual energy becomes zero						Time when 50% of nodes' residual energy becomes zero						Time when 100% of nodes' residual energy becomes zero					
	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
50	221	354	162	112	204	158	232	426	212	192	240	205	350	500	350	300	400	300
100	215	364	165	115	162	116	230	476	185	178	220	206	350	600	300	300	350	300
150	217	364	151	132	154	112	236	482	188	220	223	204	300	600	300	300	350	300
200	210	410	162	140	168	116	240	490	238	260	254	260	350	550	350	350	350	350
250	211	405	204	161	212	215	235	476	220	225	260	262	300	550	300	300	350	350
300	215	308	208	204	220	222	242	422	225	222	254	240	300	500	300	300	350	350

*A & B – AODV & AFTE without selfish nodes; C & E – AODV & AFTE with 20% selfish nodes; D & F – AODV & AFTE with 50% selfish nodes.

CONCLUSION

The nodes in MANET become selfish in order to conserve their energy for a longer period. But as more and more nodes become selfish, the routing load on the remaining good nodes increases. This leads to the usage of the same nodes again for packet routing, which ultimately leads to network partitioning. In this paper, we have simulated MANET with different node densities and different range of selfish nodes using adaptive fuzzy threshold energy based protocol and AODV protocol. It is found that as the number of selfish nodes increases, there is reduction in the network lifetime. The network lifetime can be enhanced 14 to 41% by the application of AFTE routing protocol in comparison with AODV protocol.

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