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Using Energy Efficient Relative Neighborhood Graph for AODV Routing Protocol in MANETs

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Abstract— Mobile Ad-hoc Networks (MANET) are self-organizing networks composed of mobile nodes without any fixed infrastructure. The design and the implementation of efficient and scalable routing protocols constitute one main issue. However, routing protocols for MANETs are mainly based on computing the shortest paths and could not be energy efficient. Nodes failure based on power deficiency could affect the overall network lifetime. In our previous work, since in AODV, the processing time of packets stored in nodes queues increases as the number of packets increases, we have introduced an enhanced version, named QAODV[26], of the standard AODV (SAODV) protocol. In this enhanced version, we have included a technique to control the packet waiting time inside queues. Simulations have been conducted to compare QAODV protocol with SAODV in terms of network lifetime as well as packet delivery ratio. Simulation results showed that QAODV outperforms SAODV. In this paper, we further study the impact of using an efficient energy relative neighborhood graph (e-RNG) on the performance of QAODV in MANETs. Simulation results show that e-RNG provides better performance while decreasing the energy consumption.

1 Introduction

In the past years, various approaches have been proposed to address the problem of multi-hop routing in MANETs. When developing routing protocols, two main objectives have to be taken into consideration, *i)* energy reduction, which implies amelioration of the network lifetime, *ii)* the improvement of packets ratio, which implies the amelioration of the network throughput. However, finding the best suitable protocol that improves the throughput while minimize the energy consumption is still a challenging task.

In our work, we focus on enhancing the standard AODV. In fact, in this protocol the processing time of packets stored in nodes queues increases as the number of packets increases. In fact, an intermediate node relays a RREQ request if the available bandwidth is greater than the paths previously received or if the time is less than the paths previously received. If the time or bandwidth path fails to comply with any of these constraints the RREQ query is deleted. In the enhanced version of AODV, named QAODV, we have included we have included a technique to control the packet waiting time inside queues []. In this paper, we study the impact of using an efficient energy relative neighborhood graph (e-RNG) on the performance of QAODV in MANETs.

The reminder of this paper is as follows. First, in Section 2, we present the concept of RNG and how it is used to find an e-NRG. Simulations results are presented in Section 3. Conclusions and future work are presented in Section 4.

2 Related Work

According to previous studies, the energy consumption in an ad hoc network is a critical metric to control, new approaches have been proposed. The algorithms focused on reducing number of edges to reduce energy consumption. Relative Neighborhood Graph (RNG) used to reduce the number of links between a node and its neighbors [27]. An edge belongs to the RNG only if it is not the longest leg of any triangle it may form in the original graph. N.Li [28] proposed a minimum Spanning Tree based algorithm for topology control. LMST is a localized algorithm to construct MST based topology in ad-hoc networks by using only information of nodes which are one hop away.
In [29] Kenji proposed LTRT (Local Tree based Reliable Topology) which is motivated by LMST and TRT (Tree based Reliable Topology). LTRT can achieve nearly optimal performance at lower computational cost. Rajan [30] presented a semi-analytical approach to analyze topological and energy related properties of K-connected MANETs. In [31] authors have analyzed the optimal transmission power of nodes according the optimal number of neighbors, and proposed the optimal topology control algorithm based on virtual clustering scheme. Chen Wei et al [32] described an energy conservative unicast routing technique for multihop wireless sensor networks over Rayleigh fading channels. In Chen Wei model the assistant nodes transmissions can cause multiple packet reception at the receiving end and there by reordering requirement. In this model all the relay nodes are in-line so that they relay the same packet. So packets reach the destination in the same order. Jonathan et, al [33] focused on identifying the additional sensor placement for repairing and ensuring the fault-tolerance with k-connectivity. Present model is focusing more on reducing transmit power and thereby improving network life time while retaining connectivity. Martin [34] had presented a model identifying potential interference sources computing minimal interference path.
To the best of our knowledge, all topology control algorithms currently known only build balanced connections have in common that each node establishes a balanced connection to

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at least its nearest neighbor. Symmetric connectivity is achieved with the configuration of neighboring appropriate transmit power level. In other words to maintain connectivity, the transmission power of the neighbors are adjusted to an optimum level. However, in our model, we kept the transmission power of all nodes at the lowest possible level.

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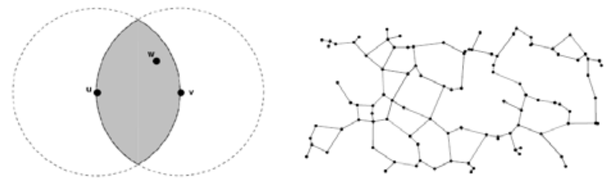
3 E-RNG COMPUTATION

In QAODV, each node needs to know the current state of the entire network. In dynamic networks, changes are performed frequently and information about network topology must be broadcast to all nodes. A message generated by a source node must be sent to all other nodes. However, performing this broadcasting process is too costly in terms of energy consumption and could create heavy contention, especially in dense networks. A node with a large number of neighboring nodes has the probability of packet collision than those with fewer neighbors. In order to minimize energy consumption while maximizing throughput, lowering broadcast messages is required. In the rest of this section, we study the impact of using an efficient energy relative neighborhood graph (e-RNG) on the performance of QAODV in MANETs. It's worth noting that the relative neighborhood graph (RNG) [21] was already applied for solving problems in wireless networks. For instance, [22] applied it to minimize the number of messages needed for broadcasting in one-to-one unit graph model. In [23] authors described the localized construction of RNG in details and proposed to use it as connected topology to minimize node degrees, hop diameter, maximum transmission radius and the number of connected components. However, [23] do not describe the use of RNG in solving any specific problem.

In order to shoe how RNG is used, let's consider V be a set of vertices and $G =(V,E)$ the induced graph with maximal range. The relative neighborhood graph of G [21] is denoted by RNG(G)=(V, E_{rng}) and is defined by :

$$E_{rng}=\{(u,v) \in G \mid \nexists\, w \in V\ (u,w), (w,v) \in V \wedge d(u,w) < d(u,v) \wedge d(v,w) < d(u,v)\}$$

This condition is illustrated in Fig. 1 (a), an edge (u,v) belongs to the RNG if there does not exist a node w in the gray area. The gray area is the intersection of two circles centered at u and v and with range $d(u,v)$. An example of an RNG is depicted in Fig. 1(b). In this example, and typically in general, the average degree of RNG is around 2.5. More information about RNG construction can be found in [22,23].



(a) (b)

Fig. 1. a) the edge (u,v) is not in RNG because of w, b) an example of an RNG

The e-NRG (see Figure 2) is computed as follows, each node processes the information related to its RNG 1-hop neighbors and selects the neighboring nodes with higher residual energy. Similar to the power law model presented in [24], [25], we use the following channel model: $P_{rec}=P_{tx}/rn$ (P_{rec} is the received power, P_{tx} is the transmission power, r is the transmission range and n is a positive real value, generally between 2 and 4). Each node, by observing the power indicator of the received signal (RSSI) from neighboring nodes, can determine the range of energy transmission that can be used.

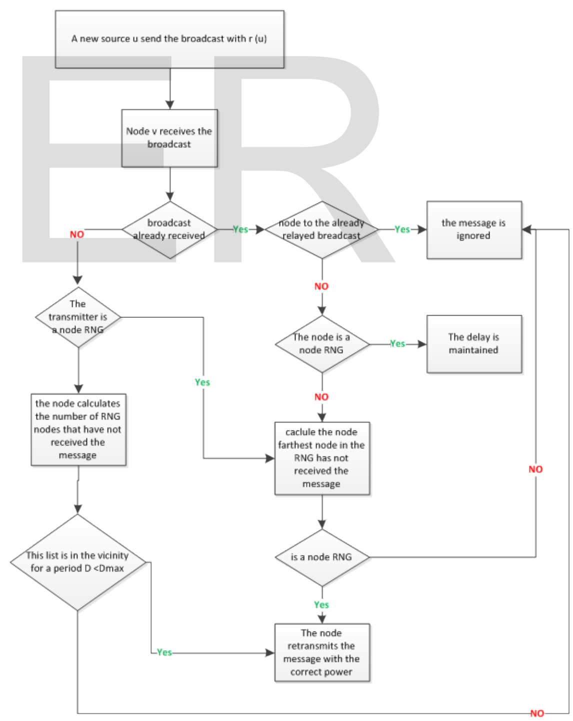


Fig. 2. e-RNG computation

4 PERORMANCE EVALUATION

In this section, the evaluation study is performed using the discrete-event simulator, ns2 [3]. Simulation parameters, mobility scenarios, and traffic that imitates the applications are presented. Performance metrics together with simulation results are also reported. In these simulations, each node uses

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IEEE 802.11 MAC protocol, operating at 2Mbps, to send and receive messages. We used two-ray ground model for radio propagation and the transmission range is 250m. All simulation parameters are described in Table 1.

Parameter	Value
Protocols	SAODV, QAODV
Number of Nodes	200 with 100 connections
Simulation Time	600 sec
Traffic Type	CBR
Routing protocol	AODV, QAODV-RNG
Transmission Range	250 m
Mobility Model	Random Waypoint
Simulation area	1000 * 1000 m
Node Speed	1 m/s, 10 m/s, 15 m/s, 20 m/s, 25 m/s
Pause Time	20ms
Interface Type	Queue
Mac Protocol	802.11Ext
Packet Size	512 MB
Queue length	50
Radio Propagation Model	Two Ray Ground
Energy	100j
pause time	20ms

Table 1. Simulation parameters

The performance of the QAODV is evaluated under different node speeds whith and without using e-RNG. The performance metrics we have evaluated are packet delivery ratio, packets loss, end-to-end delay and energy consumption.

Packet Delivery Ratio: is the ratio of number of packets received at the destination to the number of packets sent from the source. The performance is better when packet delivery ratio is high. We have also evaluated the packet loss (PL) to show its direct link to the throughput or packet delivery ratio as follows:

PL = (nSendPackets-nReceivedPackets)/nSendpackets, where : nSendPackets is the number of received packets and nReceivedPackets is the number of submitted packets. Fig. 3 (a) plots the packet loss as a function of nodes speed ranging from 1 m/s to 25m/s. It shows that when e-RNG is established fewer packets are lost because of less contention. We can

Packet delivery ratio		
Speed	QAODV Without RNG	QAODV With RNG
1	80.2	89.16
5	78.23	86.23
10	72.34	81.34
15	72.5	78.2
20	69.6	74.3
25	66.78	71.9

(a)

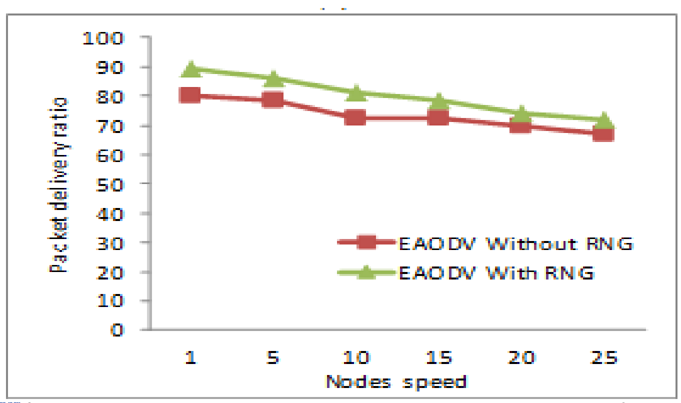
(b)

Fig. 3. A) Packet loss and b) packet delivery ration

Packet loss		
Speed	QAODV Without RNG	QAODV With RNG
1	501	112
5	53□	1□3
10	667	188
15	738	199
20	807	200
25	966	250

Average end-to-end delay: is the average time delay for data packets from the source node to the destination node. To find out the end-to-end delay the difference of packet sent and received time was stored and then divided by the total time difference over the total number of packet received gave the average end-to-end delay for the received packets. Figure 4 shows the broadcast end-to-end delay at various nodes speed. We can see that QAODV with e-RNG has lower latency values, by almost 15%, due to lower rebroadcasts that increases packets queuing time.

End-to-End delay		
Speed	QAODV Without RNG	QAODV With RNG
1	168.5	148.3
5	163.2	143
10	155.78	145



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15	153.3	133.3
20	149.49	119
25	146.58	106.58

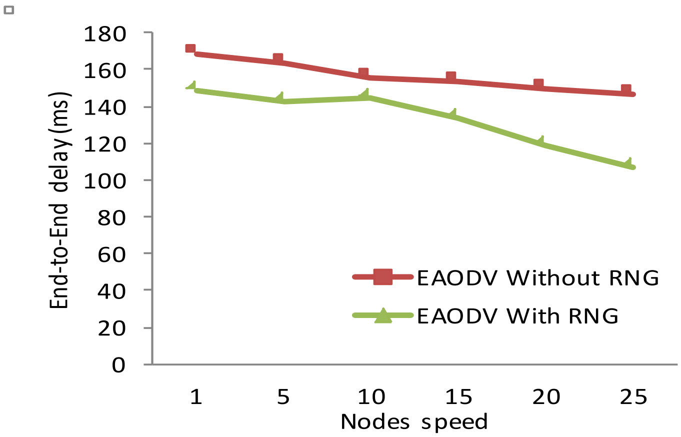

Fig. 4. Average end-to-end delay

Energy: is the average energy consumption of all nodes in sending, receiving and forwarding operations. For each broadcast, we calculate the total energy consumption $E_{total} = \sum_{u \in V} E(u)$. This total energy consumption is compared with the total energy consumption needed for blind flooding protocol with maximal range as follows: $E_{flooding} = n \times (R^{\alpha} + c)$. We computed then the average expended energy ratio (EER) that is defined by: $ERR = \frac{E_{total}}{E_{flooding}} \times 100$.

Figure 5 shows the energy consumption for both QAODV with and without establishing the e-NRG. Results show that the energy consumption for QAODV, when e-RNG is computed, is almost reduced by 60% . We can also see that as nodes speed increases, energy consumption increases due to the higher number of the packet REEQ.

Energy consumption		
Speed	QAODV Without RNG	QAODV With RNG
1	16.12	4.7
5	22.2	8
10	25.24	11
15	26.5	13.23
20	30.6	15
25	35.4	17.3

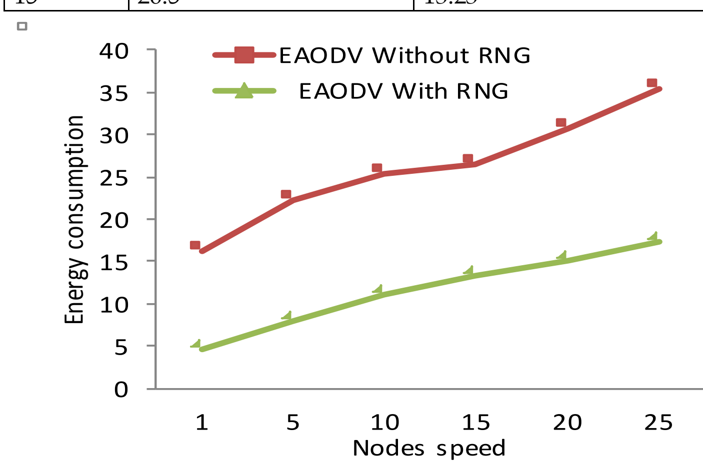

Fig. 5. Energy consumption

5 Conclusion and Perspectives

In this paper, we have studied the influence of computing e-RNG on the performance of AODV. We first compute the e-RNG in order to reduce the nodes degree before broadcasting packets RREQ. Nodes will only process packets submitted by other nodes that are withing e-RNG. This will ensure that the network is not disconnected, and then routes exist between all nodes. Simulation results showed less consumed energy, low ened-to-end delay, and high throughput.

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