AODV and DSR energy-aware routing algorithms: a comparative study

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Abstract

Mobile ad hoc networks (MANETs) are composed of mobile nodes that form complex distributed systems without any fixed infrastructure and are featured by limited battery recourses. It is known that energy failure of a node affects the node itself, affects its ability to forward data packets on behalf of other nodes and hence affects the overall MANETs lifetime. Consequently, Development of an efficient energy-aware protocol is the need of today's MANETs. Much research have been devoted to develop energy-aware routing protocols. This paper proposes two energy-aware routing algorithms: an energy-aware ad hoc on-demand distance vector (e-AODV) and an energy-aware dynamic source routing (e-DSR), and compares their performance with the well-known AODV and DSR routing algorithms. Glomosim is used to simulate and to compare the performance of the four routing algorithms (AODV, DSR, e-AODV and e-DSR) in terms of average energy consumption, average end-to-end delay and average drop packets. Results reveal that e-DSR is able to work best in terms of averaged energy consumption and averaged end-to-end delay over different mobility speeds.

Keywords: *MANETs routing, Energy-aware routing, power-aware routing.*

1. Introduction

MANETs are composed of mobile nodes that form complex distributed systems without any fixed infrastructure or centralized administration. In these systems, nodes can be freely and dynamically self-organized into arbitrary and temporary, "ad-hoc" network topologies, nodes communicate with each other directly or via intermediate nodes. Relaying packets to neighboring nodes along with the path from the source node to the destination node is done by intermediate nodes. MANETs have many applications such as emergency operations and military battlefield applications, data acquisition operations in hostile terrain, etc. MANETs are featured by limited bandwidth, CPU and battery recourses. These features put special challenges routing protocol design for MANETs. Maximize energy efficiency is one of the most important objectives of MANET routing protocol (Singh et al., 1998), since mobile nodes in MANET depend on limited energy resources. A major challenge of MANET routing protocol is to faces these resource constraints.

There are many routing protocols for MANETS that are classified into three different groups: global or proactive, on demand or reactive, and hybrid. In proactive routing protocols, the routes to all the destinations (or parts of the network) are determined at the start-up and maintained by using a periodic route update process, in reactive protocols, routes are determined when they are required by the source using a route discovery process, and finally, hybrid routing protocols combine the basic properties of two classes of protocols into one, i.e. they are both reactive and proactive in nature. Each routing group has a number of different routing strategies, which employ a flat or a hierarchical routing structure (Sarkar et al., 2013).

Devices used in MANETs require portability and hence they have size, weight and energy constraints. Increasing the battery power may make the nodes bulky and less portable. The energy efficiency remains an important design consideration for these networks. Therefore ad hoc routing protocol must optimally balance these conflicting aspects of MANETs. The majority of energy-aware routing protocols for MANET try to reduce energy consumption by means of an energy efficient routing metric instead of the well-known minimum-hop metric. This way, a routing protocol can easily introduce energy efficiency in its packet forwarding. These protocols try either to route data through the path with maximum energy bottleneck, or to minimize the end-to-end transmission energy for packets, or a weighted combination of both. To address energy problem in MANETs, many research efforts have been devoted to develop energy-aware routing protocols for MANETs such as power saving medium access control layer protocols, energy efficient routing algorithms, and power sensitive network architectures.

In MANETs, it is known that transmitting packets needs a specific transmission energy, on the other hand, receiving a packet needs another specific amount of energy which is consumed even if the packet is discarded by the node (because it was intended for another destination, or it was not correctly decoded). Mobile nodes also need some limited energy while listening where no messages are being transmitted and they need a smaller energy while sleeping (when the communication is not possible and the node is not capable of detecting signals. Minimum transmission power routing (MTPR) (Toh, 2001) is among the oldest energy efficient routing protocols that tried to reduce energy consumption by means of an energy efficient routing metric, used in routing table computation instead of the minimum-hop metric, It reduces the overall transmission power consumed per packet along the selected route.

As a matter of fact, energy efficiency in routing can be addressed at different layers in MANETs, some routing work have focused on the optimization of energy consumption of mobile nodes, from different points of view. Some routing protocols have adjusted the transmission power of wireless nodes such as the protocols named as TR-LBOP and TRDS (Ingelrest et al., 2006). While pure MAC-layer routing solutions (such as the power management of 802.11) and the combining of MAC and routing functionality (Xu et al., 2001) have efficiently managed sleep states for the mobile nodes.

Some routing protocols organize nodes into clusters and optimally determined the radius of a cluster that established an energy efficient protocol. In (Safa & Mirza, 2010), a dynamic energy-efficient clustering algorithm is proposed, their algorithm prolongs the MANETs lifetime by electing cluster heads by taking into consideration, in addition to other parameters such as mobility, their residual energies and making them dynamically monitor their energy consumption to either diminish the number of their cluster-members or relinquish their roles.

Optimized link state routing protocol (OLSR) is an example of proactive energy-aware routing protocols that selects a set of multipoint relays (MPRs) in an energy-aware way, in (De Rango et al., 2008), MPRs selection criteria modification and path determination algorithm modification is applied to increase the energy efficiency of OLSR protocol.

An energy efficient AODV based node caching routing protocol with adaptive workload balancing (AODV-NC-WLB) (Jung et al., 2005) is an example of a reactive energy-aware routing protocol, it uses an adaptive load balance mechanism and a caching enhancement strategy and applies them as an energy efficiency metrics for MANET routing protocols.

Geographical adaptive fidelity for ad-hoc wireless networks (Xu et al., 2001) is an example of hybrid energy-aware routing protocols; it conserves nodes energy by identifying the equivalent nodes from a routing perspective and then turning off unnecessary ones, keeping a constant level of routing fidelity.

While many routing proposals have tried to define new energy-aware protocols that are capable of saving the battery power of mobile nodes, others aim to add energy-aware functionalities to existing protocols, like AODV (Jung et al., 2005), DSR (Garcia et al., 2003) and OLSR (Guo & Malakooti, 2007). This paper proposes energy-aware routing protocols based on AODV and DSR protocols (e-AODV and e-DSR) and compares their performance in term of average delay, average dropped packets, average throughput and average energy consumption.

The rest of this paper is organized as follows: section 2 presents some of the related work, section 3 presents the proposed e-AODV and e-DSR routing algorithms, section 4 presents simulation results, and finally, section 5 concludes the paper.

2. Related energy-aware routing for MANETs

Routing in MANETs is unique because of the following three characteristics: (i) nodes energy is battery dependable. (ii) frequent route failures due to the mobile characteristics of nodes. (iii) the variable bandwidth of channels. Energy-aware routing is a mong the best solutions to these problems. As a result, intensive research has been done in energy-aware routing for MANETs.

In (Rajaram & Sugesh, 2011) a power aware ad hoc on-demand multipath distance vector (PAAOMDV) routing protocol is proposed, PAAOMDV overcomes the issue of energy and shortest path in a single routing protocol and updates the routing table with both the node route list and their corresponding energies.

In (Srinatha et al., 2012), a measurement-based routing algorithm to load balance intra domain traffic along multiple paths for multiple multicast sources is proposed, the application-layer overlaying is used to establish a multiple paths, the proposed power-aware routing algorithm maximizes the network lifetime and minimizes the power consumption during the source to destination route establishment.

In (Shah et al., 2012), a comparative study of DSR, minimum maximum battery cost routing (MMBCR) (Toh, 2001) and AODV routing protocols is conducted in terms of network lifetime and concluded that MMBCR gives more network lifetime by selecting route with maximum battery capacity.

In (Surya & Santhi, 2012), a priority energy aware routing protocol is proposed, it selects the highest priority path based on energy, reliability pair factor and distance, their proposed routing protocol increases the speed of reliable data transferring and decreases the end to end delay by making an optimum balance in the energy consumed by the mobile nodes.

In (Thilagavathe & Duraiswamy, 2012), an ad hoc on demand multipath reliable and energy aware quality of service (QoS) routing (AOMP-REQR) protocol is designed by including the QoS constraints (link reliability and energy consumption) in the existing protocol ad hoc on demand multipath distance vector (Marina & Das, 2001), which finds the multiple link disjoint stable paths. AOMP-REQR used an analytical expression that estimates the link reliability of MANET when the nodes have identical weibull distribution.

In (De Rango et al., 2012), a link stability and energy aware routing (LEAR) is proposed, LAER is based on the joint metric of link stability and energy drain rate and on the local topology knowledge, it makes use of a greedy technique based on a joint metric and a modified perimeter forwarding strategy for the recovery from local maximum.

In (Kanagasabapathy et al., 2012), a hybrid approach for saving power in MANETs is proposed, it is based on controlling topology, reducing power distribution and adapting variable transmission range. Similarly, in (Taneja & Kush, 2012), an effort has been done to combine security, power and stable routing by proposing an energy, efficient, secure and stable routing protocol.

In (Nayak et al., 2012), an energy-aware AODV (EA-AODV) is proposed, at the time of route selection, to improve the energy consumption at each node, EA-AODV takes care of the distance between the nodes and transmits to the nodes with least distance.

Many other energy aware routing protocols and various metrics responsible for energy optimization are discussed in (Nayak et al., 2012; Vasumathi et al., 2012).

3. The proposed energy-aware routing algorithms

3.1 e-AODV

It is known that AODV (Perkins & Royer, 1999) is an improvement to the destination sequenced distance vector (DSDV) routing algorithm. In order to reduce the number of broadcast messages forwarded throughout MANETs, AODV discovers routes on demand. In this paper, AODV is modified to handle energy issue; the proposed e-AODV is designed to use the maximum energy route to transmit data packets. When a source node that seeks sending data packets to a destination node checks its route table for a valid route to the destination node, if exists, it forwards the data packets to the next hop along the way to the destination. On the other hand, if a valid route is not existing in the route table of the source node, it starts a route discovery process by broadcasting a route request packet (The route request packet contains the IP addresses of the source and destination nodes, current sequence number, the last known sequence number and total energy) to its immediate neighbors and if any intermediate neighbour with efficient enough energy (only energy-efficient intermediate nodes can participate in the route discovery process, this maximize the lifetime of intermediate nodes), it adds the local energy of the intermediate node to the accumulated total energy field in the route request packet and it then broadcasts the route request packet further to its neighbors until the route request either reaches an intermediate node with a valid route to the destination or the destination node itself. It should be noted that an energy efficient intermediate node replies to the route request packet only if it has a destination sequence number that is greater than or equal to the number contained in the route request packet. When an intermediate node forwards a route request packet to its neighbors, it records in its route table the address of the neighbor from which the first copy of the packet has arrived and the total energy of the route. This recorded information is later used to construct the reverse path for the route reply packet. If the same route reply packet arrives later on, it is discarded. When the route reply packet arrives from the destination or the intermediate node, the nodes forward it along the established reverse path and store the forward route entry in their route table by the use of symmetric links. When receiving a route with a better total energy, the routing table of a node is updated to ensure using the maximum energy route for transmitting data packets. If the destination or the intermediate node moves away (or the local energy of any of them is not enough), a route maintenance process is initialized and performed by sending a link failure notification message to each of its upstream neighbors to ensure the deletion of that particular part of the route. Once the link failure notification message reaches source node, it restarts a new route discovery process.

3.2 e-DSR

DSR (Johnson et al., 2001) is an on-demand routing algorithm, similar to the proposed e-AODV; e-DSR is designed to use the maximum energy route to transmit data packets. When a node wishes to send data packets to some destination node, it first broadcasts a route request packet to its neighbors. Every energy efficient neighboring node within a broadcast range adds their node id to the route request packet, updates the total energy field in the route request packet using their local energy and then rebroadcasts. To maximize the lifetime of nodes, only energy-efficient ones participate in this route discovery process. Eventually, one of the broadcast messages will reach a destination or a node with a recent route to the destination. In original DSR, each node maintains a route cache, it first checks its own cache for a route that matches the requested destination. Maintaining a route cache in every node reduces the overhead generated by a route discovery phase. If a route is found in the route cache, the node will return a route reply message to the source node rather than forwarding the route request message further. The first packet that reaches the destination node will have a complete route. A route reply packet is sent to the source which contains the complete route from the source to the destination. Thus, the source node knows its route to the destination node and it then initiates transmitting data packets. The source node caches this route in its local route cache. In the route maintenance phase, route error and acknowledgements packets are used. The proposed e-DSR ensures the validity of the existing routes based on the acknowledgements received from the neighboring nodes that data packets have been transmitted to the next hop. Acknowledgement packets also include passive acknowledgements as the node overhears the next hop neighbor is forwarding the packet along the route to the destination. A route error packet is generated when a node encounters a transmission problem (or energy problem) which means that a node has failed to receive an acknowledgement. This route error packet is sent to the source in order to initiate a new route discovery phase. Upon receiving the route error message, nodes remove from their route caches the route entry using the broken link. It should be noted that the proposed energy-aware DSR help the mobile nodes in MANETs against the drop of battery energy and it avoids using nodes with less energy resources route discovery process.

In both e-AODV/DSR, when transmitting a data packet, a route request packet, a route reply packet or a link failure notification message, the energy of the nodes are slightly dropped. Accordingly, the energy associated with each node is decreased and is used to update the local energy of the node and used to update the total energy in the route request packets in the route discovery process. It noted that e-DSR has multiple routes available in its route cache while e-AODV has a single route in its route table. e-AODV uses beacons for monitoring the routes but e-DSR does not use beacons. However, the route discovery process in both is global and both use maximum energy route for transmitting data packets.

4. Experimental results

The proposed e-AODV and the e-DSR routing protocols are simulated using Glomosim network simulator (Takai et al., 1999) and compared to AODV and DSR routing algorithms. Table 1 shows the Glomosim simulation parameters.

To measure the performance of the proposed energy-aware routing algorithms (e-AODV and e-DSR), the average energy consumption, the average end-to-end delay and the average drop packets are considered: the average power consumption is power consumption calculated from radio layer for all the mobile nodes in the network. The average delay is the time it takes between the sending of a packet by the source node and its receipt at the destination node, it includes all possible delays in the source and each intermediate host, caused by routing discovery, queuing at the interface queue, transmission at the MAC layer, etc. The average drop packet is the ratio of the number of packets dropped to the total number of packets.

Table 1: Margin specifications

Simulation time	900 seconds	Radio-rx-type	snr-bounded
Terrain area	1200 m X 300 m	Radio-rx-snr-threshold	10.0
Number of nodes	75	Radio-antenna-gain	1.0 dB
Placement strategy	Uniform distribution	Radio-sensitivity	−91.0 dBm
Propagation limit	−111.0 dBm	Mac-protocol	802.11
Path loss model	Two-ray parameter	Network protocol	IP
Radio-type	Radio-accnoise	Data-size	512 bytes
Radio-frequency	2.4x109 Hz	Mobility	Varied from 0 to 25 m/s
Radio-bandwidth	2,000,000 bits per second	Radio-rx-snr-threshold	10.0

Figure 1 compares the average energy consumption of the e-AODV, e-DSR, AODV and DSR routing algorithms over different mobility speeds. Then for comparison purposes, the energy consumption is averaged over the five different mobility speeds (5, 10, 15, 20 and 25 ms), it is noted that e-DSR consumed less energy than DSR, e-AODV consumed less energy than AODV, and moreover, e-DSR consumed less energy than e-AODV.

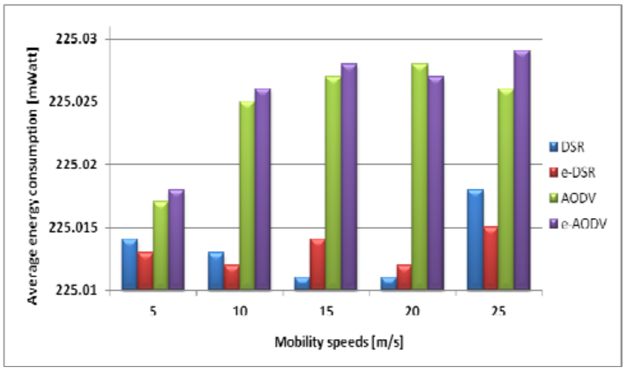

Figure 1: Average energy consumption over different mobility speeds.

As mentioned in explaining the idea behind e-AODV and e-DSR, the route with maximum energy is used to transmit data packets, such route is not the shortest path indeed, as a result, additional experiments were conducted to evaluate the performance of the proposed e-AODV and e-DSR routing algorithms in terms of average end-to-end delay and average drop packets. The average end-to-end delay and the average drop packets of the four protocols are compared over different mobility speeds, their delays and their drop packets are also averaged over the five different mobility speeds. Averaged delay results reveal that e-DSR outperformed DSR, e-AODV outperformed AODV and AODV outperformed DSR, however, e-DSR is also outperformed e-AODV (averaged end-to-end delay of e-DSR is 7% less than that of e-AODV and is 9% less than that of DSR). Averaged drop packets results reveal that e-AODV outperformed AODV, DSR outperformed e-DSR, e-AODV and AODV.

To conclude, the characteristics of the proposed e-DSR and e-AODV are as follows:

In term of averaged energy, e-DSR and e-AODV consume less energy than DSR and AODV respectively, however, e-DSR consumes less energy than e-AODV.

In term of averaged delay, e-DSR is better than DSR, AODV and e-AODV. However, e-AODV is slightly better than AODV.

In term of averaged drop packets, DSR outperformed e-DSR, e-AODV and AODV, however, e-AODV is better than AODV.

Using e-DSR, the reduction in energy is maximum when the mobility speed is 10 and 20 m/s and the reduction in delay is maximum when the mobility speed is 5 m/s, the reduction in drop packets is maximum when the mobility speed is 5 %. It is also noted that the reduction in energy consumption is maximum when the number of sent packets is large.

5. Conclusion and future work

This paper proposed two energy-aware routing algorithms: e-AODV and e-DSR routing algorithms) and it compares their performance with the well-known AODV and DSR routing algorithms. Glomosim is used to simulate and to compare the performance of the four routing algorithms (AODV, DSR, e-AODV and e-DSR) in terms of average energy consumption, average end-to-end delay and average drop packets.

This paper concludes that e-DSR is able to work best in terms of averaged energy consumption and averaged end-to-end delay over different mobility speeds, on one hand, it consumes less energy and it enhances the averaged end-to-end delay (7% better than e-AODV and 9% better than DSR).

Using a multi-objective evolutionary technique to optimize the usage of the energy with hop count to choose a better route is left for future work.

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