Fuzzy Energy based Routing Protocol for MANET

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ABSTRACT
The main problem concerning laptops and handheld devices is the limited battery power, their batteries lifetime have a significant impact on the performance of ad hoc networks since nodes in ad hoc networks need to relay their packets through other nodes. In this paper, fuzzy controllers take number of hops, packet queue occupancy, and remaining energy along the paths into account while picking routes. The proposed fuzzy routing method is evaluated and compared with conventional AODV routing in terms of packet delivery ratio, average of end to end delay, and average of energy consumption per node using OMNeT++ 4.0 simulator.

General Terms
Computer Networks, adhoc Networks

Keywords
MANETs; AODV routing protocol;energy; fuzzy controllers.

1. INTRODUCTION
There are two major architectures for wireless communications: infrastructure based and infrastructure-less (ad hoc) networks. Infrastructure networks include cellular networks and wireless local area networks, where mobile users can be communicated via base stations or access points. Mobile ad hoc networks [1][2] are dynamically multi-hop wireless networks, they can organize themselves and support rapid and unpredictable topology changes without any central administration point; they can be used in emergency situations such as natural disasters and military communication or even where are temporary expected communication usages during conferences and business meetings; their challenges include dynamically changing network with low bandwidth, low power and resource constrained computing nodes.
Many traditional routing protocols for MANETs including ad hoc on demand distance vector (AODV) [3] use only single metric for choosing the route and do not take any smart routing decision, they may choose the route with minimum hops or the first route that has been found. However, considering only single metric might lead to inefficient routing decision since overloading nodes in some routes, while the others are rarely used causing high packet drops in queues, long waiting delay, wastage of bandwidth, very soon depletion battery, etc. Hence, decreasing the network lifetime.
In the following section, some of the recently related works are presented:
An approach which is derived from AODV routing protocol based on current energy status of each node and cached node is considered in [4].An algorithm that reduces energy consumption through overhead reduction is proposed in [5]. Arom-oon and Keeratiwintakorn [6],proposes a fuzzy path selection based on number of hops and remaining battery power along the path. In Thaw [7], the source node decide which is the best route according to a value carried in route reply packets and produced from a fuzzy controller at the destination which considers number of hops, bandwidth, and mobile speed,while Banerrjee and Dutta [8] takes remaining energy, rate of energy depletion, communication load, and distance between consecutive routes as inputs to the fuzzy controller at the destination during the route discovery process to select the routes.
In our previous papers, the routing decision is shared among the nodes along the path from the source to the destination during the route discovery process using fuzzy controllers which consider number of hops and delay factor [9]; number of hops, packet queue occupancy, and internodes distances in addition to route lifetime prediction based on fuzzy controllers [10].
In this paper, we extended the AODV routing protocol to take the remaining battery power and packet queue occupancy in addition to number of intermediate hops as inputs to the fuzzy controller to produce the routes costs to be used in the route selection process.

2. PROPOSED APPROACH
Fuzzy logic technique has proven efficiency in various applications such as decision support and intelligent control; it is often typified by an inference engine that executes the fuzzy reasoning rules in the system, input membership functions that are used for fuzzification of the input variables, and defuzzification to get the crisp outputs [11].
The proposed fuzzy controller inputs to produce the route cost are:
Number of intermediate nodes (Hopcnt) along the path:
Less number of intermediate nodes will reduce the probability of breaking the path.

Packet queue occupancy (BQO) along the path:
Less congested routes will reduce waiting time and dropping packets at the queues.

$$\mathrm{PQO} = \sum_{\mathrm{hcnt}=1}^{n} \frac{\mathrm{current\ \ PQ\ length}}{\mathrm{max\,.PQ\ length}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{..(1)}$$

Where n denotes the number of nodes in that path, PQ denotes packet queue in each node.

Remaining Energy (RE) along the path:
Considering remaining energy will increase the nodes lifetime in the network.

$$\mathrm{RE} = \sum_{\mathrm{hcnt}=1}^{n} \frac{\mathrm{RBC}}{\mathrm{FBC}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{...(2)}$$

Where linear model of battery consumption is used [12].

$$\mathrm{RBC} = \mathrm{FBC} - \sum \mathrm{E_{RS}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(3)}$$

Where

RBC: Residual Battery Capacity in each node.
FBC: Full Battery Capacity of each node.
ERS : Energy consumption in mW-sec during the four working radio states (RS): sleep, idle, transmitting or receiving.
Our proposed fuzzy controller is designed basing on experience-system knowledge obtained from experiment, then tested on a mobile ad hoc network using simulation to fine-tune or redesign the membership functions and fuzzy rules in a repeated

processes of trial and error until getting the most satisfactory network performance. Where triangle membership functions are used to represent the fuzzy controller inputs and output, with three linguistic variables for the inputs : Low, Medium, and High, and five for the output: Very Low, Low, Medium, High, and Very High; Mamdani minimum inference method is used as the fuzzy inference method with 27 rules, some of them are:
If Hopcnt is Low and BQO is Low and RE is High Then Route Cost is Very Low.
If Hopcnt is Medium and BQO is Medium and RE is High Then Route Cost is Low.
If Hopcnt is Medium and BQO is Medium and RE is Medium Then Route Cost is Medium.
If Hopcnt is Medium and BQO is High and RE is Medium Then Route Cost is High.
If Hopcnt is High and BQO is High and RE is Low Then Route Cost is Very High.
The Route Request Message (RREQ Msg.) is extended to carry the required fuzzy input parameters along the individual paths to the destination. During the route discovery process of the AODV routing protocol each node calculates the fuzzy cost each time it receives the RREQ Msg. using its embedded fuzzy system after updating these parameters. Then, updates the reverse route entry to the source of the RREQ Msg. if the new fuzzy cost less than the stored one, while the dissemination of the RREQ Msg. is continued until getting the destination which unicast a Route Reply Message (RREP Msg.) along the obtained reverse route to the source.

3. SIMULATION MODEL

The inetmanet model [13] is considered for the simulation experiments on OMNeT++ 4.0 platform [14]. Networks of 20, 40, and 60 nodes with random waypoint mobility model using a speed ranging from 0 to 10 m/s on a square area of 800 m × 800 m size are studied. The IEEE 802.11g was used as a medium access control protocol and each node had a channel capacity of 54 Mbps. 20 mobile nodes acted as traffic sources generating data packets at a rate from 2 to 4 packets/sec with packet size of 512 bytes. Two ray propagation model was used with 20 mW transmission power for each node. The started battery capacities of the nodes were randomly distributed and 3.3 V battery was used with 0.053 mA, 33.33 mA, 42.42 mA, and 102 mA draw current in a sleep, idle, receive, and transmit radio mode respectively. Each simulation was executed for 600 seconds of simulation time.

4. SIMULATION RESULTS

The performance of the conventional AODV routing protocol, fuzzy less congestion based – AODV extension using hop count and packet queue occupancy as fuzzy inputs (FLCRS-AODV), and fuzzy energy based – AODV extension using hop count, packet queue occupancy, and remaining energy as fuzzy inputs (FERS-AODV) are evaluated and compared considering packet delivery ratio in (Figure 1), average end-to-end delay in (Figure 2), and average of energy consumption per node in (Figure 3).
From the figures, the packet delivery ratio is increased by 1.81%, 2.877%, 6.855% in 20, 40, 60 nodes respectively when using FLCRS-AODV; and increased by 3.43%, 4.544%, 8.99% in 20, 30, 40 nodes when using FERS-AODV.
On the other hand, average end-to-end delay is decreased by 27.52%, 18.64%, 40.18% for 20, 40, 60 nodes when using FLCRS-AODV; and decreased by 48.73%, 26.21%, 76.10% when using FERS-AODV.
Finally, average of energy consumption per node is decreased by 3.23%, 1.21%, 5.88% in 20, 40, 60 nodes when considering FLCRS-AODV ; and decreased by 4.59%, 2.52%, 9.74% in 20, 40, 60 nodes when considering FERS-AODV.
From results; it is clearly shown that FERS-AODV performs better than FLCRS-AODV, which outperforms the AODV routing protocol under different number of mobile nodes.

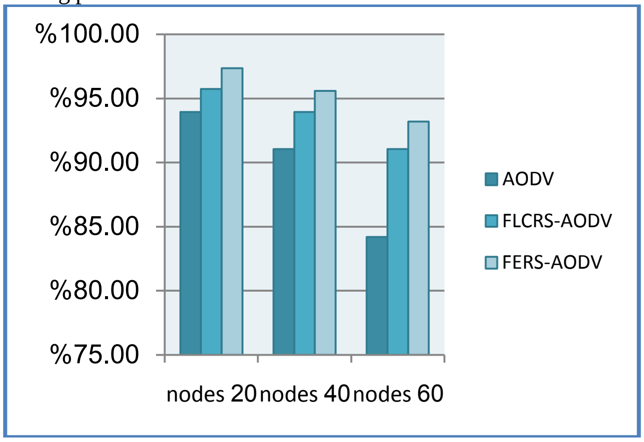

Figure 1: Packet Delivery Ratio (%)

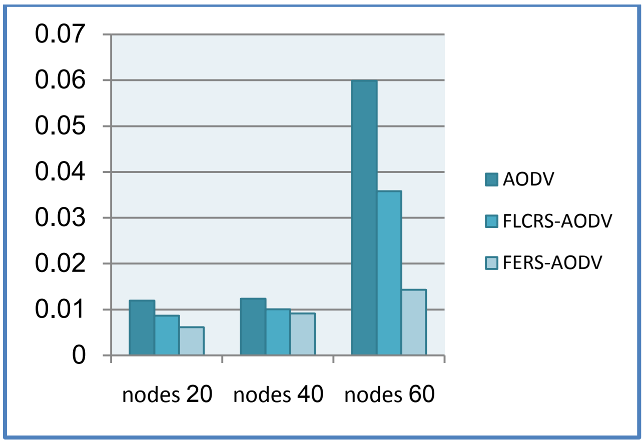

Figure 2:Average End-to-End Delay (sec)

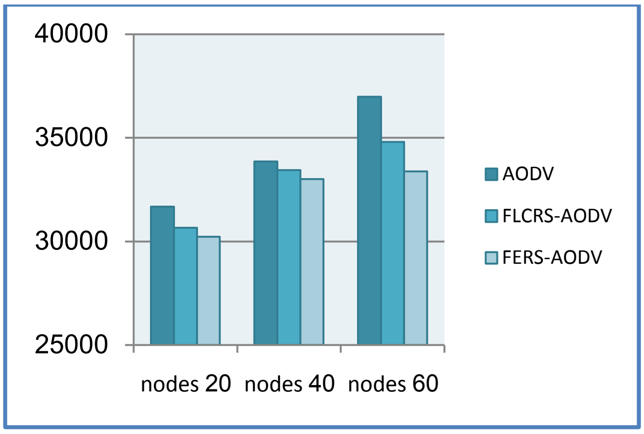

Figure (3): Average of Energy Consumption per Node (mW-sec)

5. CONCLUSION

This paper proposes an extension to the AODV routing protocol to increase the ad hoc network lifetime by mixing number of hops, packet queue occupancy, and remaining energy along the routes using fuzzy controllers embedded in each mobile node to obtain the routes costs to be used in routing decisions. The performance of the proposed method has been compared with the performance of the conventional AODV through simulation experiments. The results show that the proposed fuzzy energy based routing protocol has improved the functionality and performance of the conventional AODV routing protocol.

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