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ORIGINAL ARTICLE

Energy-Aware Fisheye Routing (EA-FSR) algorithm for wireless mobile sensor networks

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Abstract Energy consumption is prominent and critical issue faced by wireless sensor networks. The maximum amount of energy is consumed when the sensors communicate with each other. Therefore energy efficient routing mechanisms are required. In this paper, a routing scheme based on the fisheye state routing with a difference in route selection mechanism has been proposed to ensure the reduction in the overall energy consumption of the network. This scheme is named as Energy-Aware Fisheye State Routing (EA-FSR). It is simulated considering various parameters using QualNet5.0. Performance of EA-FSR has been compared with the original fisheye state routing algorithm which is also simulated in the same environment. For comparison various parameters like end-to-end delay average, energy consumption and throughput have been considered.

1. Introduction

Wireless sensor networks (WSN) consists of large number of energy constrained devices that autonomously form networks through which sensed information is transported from the place covered under sensor to the central control station (known as sink) [1]. The major purpose of sensor networks is to gather regional/local information to participate in global decision about the physical environment [2]. Different type of sensors like magnetic, visual, infrared, thermal, acoustic, seismic, and radar are available that encourage the use of these networks in wide range of applications like traffic control, environment monitoring, precision agriculture, weather forecasting, military surveillance, industrial sensing, etc. [3]. Despite of wide range of applications, wireless sensor networks face several design and architectural issues [4]. Energy consumption by the sensor nodes while communicating is one of the prominent issues. Energy constrained sensors hamper the communication. Improvements in the routing protocols can reduce the requirement of overhead communication, hence reducing the energy requirements of the sensors in a network.

This paper is divided into five different sections. Routing in wireless ad-hoc sensor networks and Fisheye State Routing

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(FSR) algorithm has been explained in Section 2. Section 3 discusses proposed Energy-Aware Fisheye State Routing (EA-FSR) algorithm. The simulation set-up and various environmental parameters used are discussed in Section 4. Results have been presented and discussed in Section 5. Finally, Section 6 sets the conclusion of the work done and its future scope.

2. Wireless sensor networks and routing

Routing of the information packets is one of the most difficult task due to innate characteristics of sensor networks like node mobility, dense deployment and energy consumption. The major concerns related to routing are: *lower latency,maximising network lifetime, resource awareness, topological changes, location awareness and scalability*. Out of all these issues, network lifetime is the most critical. The lifetime of a network depends upon the energy consumption of the nodes which in turn depends upon the different tasks performed by the sensor nodes. The maximum amount of energy is consumed during the communication task followed by computation and sensing respectively. Communication mechanisms that perform route selection on the basis of the residual energy of the network can improve the overall network energy thereby increasing network life time. This imposes rigorous constraints on the routing protocols [5].

2.1. Fisheye State Routing (FSR)

It is a table driven implicit hierarchical routing protocol. It uses the "fisheye" technique [6], i.e. eye of a fish captures more details of pixels near focal point. Number of details is inversely proportional to the distance from focal point. In routing, this approach corresponds to maintaining accurate distance and path quality information about the immediate neighbours of a node, with progressively less detail as the distance increases. This protocol is similar to link-state based routing protocol as it maintains topology information at each node. The difference lies in the way routing information is disseminated in the network. In link state routing, the link state messages are generated and disseminated into the network whenever a node detects a topology change. But in FSR, link state messages are not flooded. Each node maintains a link state table based on the up-to-date information received from neighbouring nodes, and periodically exchanges this information with its local neighbours only. The neighbour does not perform flooding of the messages. Through this exchange process, the entries in the topology table with small sequence numbers are replaced by the ones with larger sequence numbers. This allows nodes to have the most recent information at every point of time. Dijkstra's shortest path algorithm is then applied on the topology table to select a node from the set of neighbour nodes to forward the data packets [7]. This mechanism ensures the shortest path length between a source node and the sink node but this may lead to the selection of the same neighbour node every time a source node transmits data. This leads to the increased energy consumption of the selected node while decreasing the energy consumption of the other neighbouring nodes. It causes energy imbalances in the network and also forms energy holes.

3. Energy-Aware Fisheye State Routing (EA-FSR)

To avoid the problem of energy imbalance and the formation of energy holes, a new mechanism for path selection is suggested in EA-FSR. It uses the energy as the basis for selecting a neighbour node rather than the shortest path length. The energy of all the neighbouring nodes is compared to find the node having maximum residual energy. Then this node is selected to forward the packets. This process is performed for every node which has some packets to transmit.

This mechanism ensures the energy balancing in the network as only one node is not constrained with the task of forwarding the data packets. Also, this ensures uniform energy consumption of all nodes in the network which decreases chances of the energy-hole formation.

3.1. Modified route-selection mechanism

Route in the Energy-Aware Fisheye algorithm is selected based on residual energy of the neighbouring nodes. Node having the maximum residual energy is selected to forward the information towards sink node. This mechanism is explained below using Fig. 1 as illustration.

A network of six nodes with their respective energy levels at an instant of time is shown. Node '1' acts as source node and '3' acts as sink node. Steps to select a route in this network are:

Step 1: Node '1' searches its one hop neighbours. Residual energy of these nodes is compared to find the node with the maximum energy. From the one hop neighbours $\{2, 4, 6\}$; '4' has maximum energy, hence it has been selected as next hop.
Step 2: Node '4' selects from its neighbours $\{3, 5\}$, node '3' as it has maximum residual energy and forwards the data to it.

Hence, the path formed is 1–4–3

3.2. Energy-aware path selection algorithm

// N is the set of all nodes in a network.
// 's' denotes node that transmits data towards sink node at any instant of time.
// 'v' is any neighbour node of 's' and $D(v)$ is the energy of the node 'v' at a particular instant.
// 'w' is neighbour of node 's' that is selected for further transmission of the information
1. Initialization:
   $N = \{s\}$
2. for all neighbours 'v' of 's'
   if 'v' is one hop neighbour
   then
      $D(v)$ = energy(v)
3. loop
4. Find 'w' not in 'N' such that $D(w)$ is maximum.
   Add 'w' to 'N'
5. Repeat 2–4 for each 'w' until sink node in 'N'

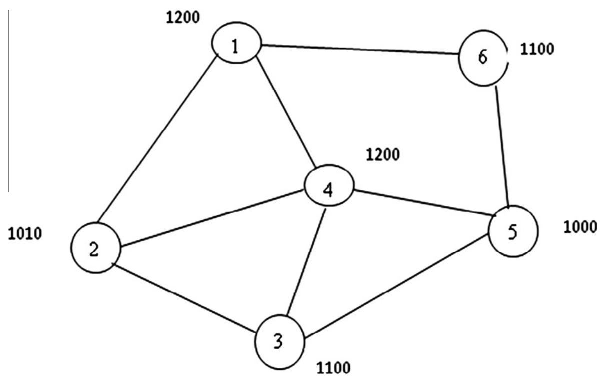

Figure 1 Sensor network used for route selection in EA-FSR.

Table 1 Simulation parameters.

Parameter	Value
Area of simulation	$1500 * 1500\ m^2$
Network density	300 nodes
Simulation time	1800 s
Physical/MAC layer protocol	802.15.4
Node mobility model	Random waypoint mobility model
Schedulers/Queues	DiffServ/FIFO
Routing protocol	FSR/EA-FSR
Battery model	Linear Model
Energy model	MicaZ
Transmission power	3 dBm
Battery charge monitoring interval	30 s
Full battery capacity	1200 mA h (sensor nodes) 12,000 mA h (Sink node)
Traffic type	CBR
Number of connections	150
Source ID	Variable
Destination ID	1 (Sink node)
Start/End time	Variable

4. Simulation setup

Simulation experiment is set up using QualNet 5.0 network simulator [8]. Over an area of about $1500 * 1500\ m^2$, a total of 300 nodes are deployed. 299 nodes are configured as sensor nodes and 1 node is configured as the sink node. Each sensor node is made mobile by varying its speed while the sink node is kept static throughout the simulation. The sensor nodes generate CBR traffic towards the sink node at varying intervals of time. Random waypoint mobility model [9] is taken as the mobility model of the nodes with a pause time of 5 s. Speed of nodes is considered corresponding to the real scenario. Various values are: walking 1.3–1.78 meter per second (mps) [10], cycling 6.70–7.15 mps [11], speed of a bike 12.5–16.66 mps, speed of a car 16.66–18.05 mps [12] and speed of a plane 178.81–268.24 mps. Effect of the changing mobility of the data gathering nodes on the network throughput, end-to-end delay and average jitter has been analysed. All the other simulations parameters are listed in Table 1 along with their values.

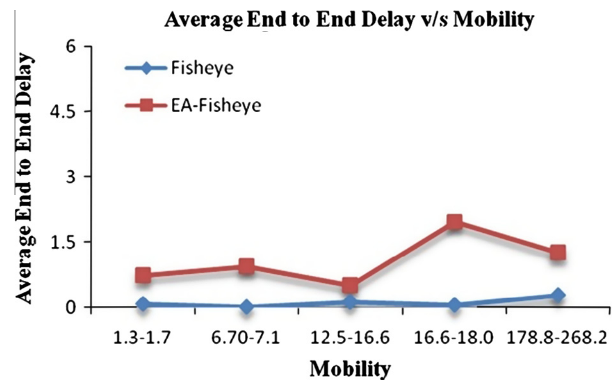

Figure 2 Variation of average end to end delay with increasing mobility of sensor nodes.

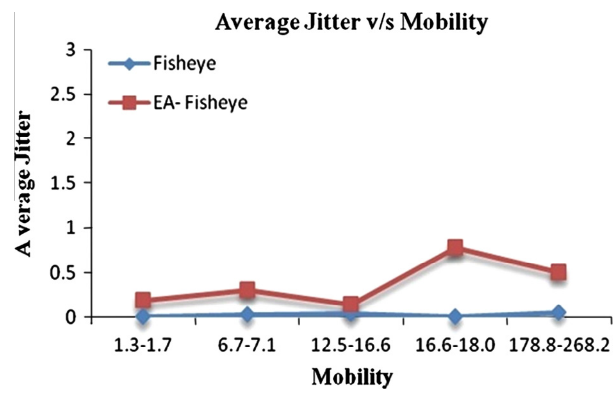

Figure 3 Variation of average jitter with increasing mobility of sensor nodes.

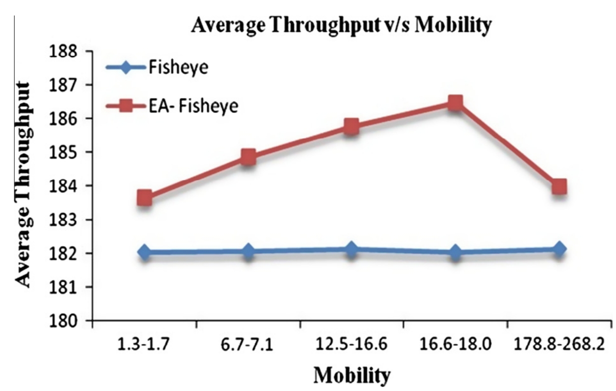

Figure 4 Variation of average throughput with increasing mobility of sensor nodes.

5. Simulation results

5.1. Average end to end delay

End-to-end delay measures the delay in the delivery of a packet i.e. the time gap between the transmission and reception of the

Table 2 Variation of energy consumption.

Routing Protocol	Energy Consumption (Joule (mA h))
Energy Aware-Fisheye State Routing (EA-FSR)	3.13
Fisheye state routing (FSR)	3.55

packet from a source node to the sink. Average end-to-end delay gives the average delay suffered by all the packets in the network.

Fig. 2 shows that the average end-to-end delay in EA-FSR initially increases with the increase in mobility and then decreases whereas for FSR, the delay values remain almost constant. Also, there is trivial difference between the values of these protocols for the given mobility values.

5.2. Average Jitter

of a network measures the variability over time of the packet latency across the network. Fig. 3 shows that the value of average jitter is higher in case of EA-FSR than FSR. It is also found that for EA-FSR, the value varies randomly with the increase in the speed of the nodes whereas for FSR, the jitter values remain almost constant.

5.3. Average throughput

is defined as the average rate of successful message delivery across a network. Fig. 4 shows that for FSR, the value of average throughput remains almost constant with the increasing mobility while in the case of EA-FSR the throughput initially increases with the increase in mobility but decreases suddenly when the mobility becomes very high. Also, the throughput of EA-FSR is higher than the FSR.

5.4. Energy consumption

is the amount of energy consumed by a sensor node while performing the tasks of sensing, computing and communicating in the network.

Table 2 shows the energy consumption on per node basis by EA-FSR and FSR. It is found that the energy consumption of the EA-FSR is lower than the original fisheye routing. The percentage decrease is around 11.8% after implementing energy aware route selection.

6. Conclusions and future scope

The results obtained from simulations shows that the Energy-Aware Fisheye Routing (EA-FSR) performs better for varying mobility values of the sensor nodes. As there is significant increase in the throughput of the network. Also the overall energy consumption of the network has decreased to almost 12%, ensuring longer network lifetime. But there is slight increase in the average end-to-end delay and jitter values. Thus this protocol can be used as a replacement for the Fisheye routing protocol for the applications in which the network lifetime and successful message delivery is more critical than the on time delivery.

In future, the energy-aware fisheye can be modified further to consume less energy and generate low control overhead by incorporating some optimisation techniques like swarm intelligence. Also, this protocol can further be analysed for other parameters like topological changes, change in duty cycles, etc. Also, real time environment can be used to study the actual behaviour of this protocol.

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