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Energy Efficient Opportunistic Routing Protocol for Large Scale WSN

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Abstract: *OPPORTUNISTIC routing is a new design trend of wireless routing protocols. In traditional routing, the source takes one "best" path to the destination while in the opportunistic routing, the source takes multiple opportunistic paths to forward packets to the destination. It is proved that, opportunistic routing can better cope with the unreliable, and varying link qualities that are typical of wireless networks. In the literature many routing protocols are presented for efficient routing but all existing opportunistic routing protocols have to periodically build the network graph with all link qualities among the whole topology. In large-scale networks, this would be a tedious task. Recently the new approach is introduced in which it solves all limitations of existing routing protocols. In this method LOR and MTS-B algorithms are introduced which practically outperform the existing algorithms. But this protocol does not consider energy efficiency which is an important issue in WSN. This work is done to consider energy efficiency in opportunistic routing. To achieve this Energy Efficient Local Opportunistic Routing protocol (ELOR) is proposed. Results show that it can provide better energy efficient sensor nodes than the previous opportunistic routing protocols in the literature. In this, the shortest path for routing and threshold value of power for energy efficiency is used. This protocol can realize opportunistic routing using local routing information and can be used for large scale WSN without needing global information for every routing.*

***Keywords*—** *Energy Efficiency, Routing Protocol, Wireless Sensor Network*

I. Introduction

A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations. They have different area of application such as industrial process monitoring and control, machine health monitoring, environment and habitat monitoring, healthcare applica- tions, home automation and smart space and traffic control. However, there are many challenges to bring the WSNs into real-life application. In many applications, a sensor node is powered by a finite energy source such as a battery or a super capacitor that restricts the WSNs lifetime. Therefore, energy consumption of the WSNs needs to be taken into account when planning the network operation. For some critical applications end to end delay and throughput is also an important factor.

Routing protocol design for wireless networks is often guided by two essential requirements: minimize energy cost and maximize network throughput. The traditional routing protocols select the best sequence of nodes for the source-destination pair and forward every packet through that sequence. However this does not take into consideration the broadcast nature of WSN that is transmission can be heard by all the nodes within transmission range of sender. In contrast opportunistic routing allows any node that overhear the transmission to participate in forwarding the packet. Also in traditional routing various factors like fading, interference and multipath routing can lead to packet losses in a preselected routing path. While in opportunistic routing path is selected on the fly and completely opportunistic based on network condition and link qualities at that time. Many variations of opportunistic algorithms have been proposed. However opportunistic routing also has many challenges.

One challenge is that multiple nodes may hear a packet and unnecessarily forward the same packet. Extremely Opportunistic Routing (ExOR) [1] deals with this challenge by considering the MAC while routing, imposing a strict scheduler on routers access to the medium. The scheduler goes in rounds. Forwarders transmit in order such that only one forwarder is allowed to transmit at any time. The other forwarders listen to the transmissions to learn which packets were overheard by each node. These forwarders cannot transmit at the same time, although they are not within the same radio range. This would result in high end-to-end (E2E) latency, particularly when the source and the destination are multiple radio ranges away. This issue is tackled in MAC independent Opportunistic Routing (MORE) [2] by exploiting a linear network coding technique.

In contrast to ExOR's highly structured scheduler, MORE addresses this challenge with randomness. MORE randomly mixes packets before forwarding them. This ensures that routers which hear the same transmission do not forward the same packet. As a result, MORE does not need a special scheduler; it runs directly on top of 802.11. In MTS, the Minimum Transmission Selection (MTS) [3] scheme is proposed, which can choose the optimal forwarder list for the source–destination pair in a centralized (Dijkstra-like algorithm) manner. ExOR, MORE and MTS showed that this kind of opportunistic routing strategy can improve the wireless network's performance.

However many of the opportunistic routing protocols for efficient routing have to rely on global information on the whole wireless topology to compute the forwarder list for each node pair. That is, each node has to periodically build the network graph with all link qualities among the whole topology. In large-scale networks, this would be a tedious task. Existing opportunistic routing schemes, including ExOR, MORE, and MTS, cannot be applied in a large-scale wireless network very well because all of those schemes are designed as centralized algorithms and have to rely on the whole topology information, which is costly to realize in practice, particularly when the topology is highly dynamic and time varying. These give rise to the problem of whether we could realize opportunistic routing in a distributed manner with only sufficient, yet limited, local information. With this taken into consideration, Local Opportunistic Routing (LOR) [4] algorithm was proposed. It partitions the topology into sub topologies using Close Node Set (CNS) theory. It works on distributed algorithms like Bellman-Ford instead of centralized algorithms in previous protocols. LOR can realize local optimal performance for opportunistic routing in large scale WSN. But any of the above protocols do not consider energy efficiency into consideration. To address this challenge Energy Efficient Local Opportunistic Routing protocol (ELOR) is proposed.

II. Related Work

A literature review is a body of text that aims to review the critical points of current knowledge including substantive findings as well as theoretical and methodological contributions to a particular topic. In this section work done on opportunistic routing and energy efficiency is mentioned.

Dubois-Ferriere et al. proposed the least-cost opportunistic routing (LCOR) [5] algorithm. In opportunistic routing, each node maintains a group of candidate relays to reach a particular destination, and transmits packets to any node in this group. In this paper a specific cost function is introduced defined with respect to a set of candidate forwarders to identify the best candidate set that minimizes the said cost function.

Zeng et al. studied the E2E throughput of opportunistic routing in multirate networks using a linear programming framework [6]. One of the current trends in wireless communication is to enable devices to operate using multiple transmission rates. The inherent rate-distance trade-off of multirate transmissions has shown its impact on the throughput performance of traditional routing. This rate-distance-diversity trade-offs will no doubt affect the throughput of OR, which deserves a careful study. In this paper, these two gaps are bridged by studying the throughput bound of OR and the performance of OR in a multi-rate scenario. The solution of the optimization problem provides the performance bound of OR.

Acer et al. proposed a weak state routing mechanism, with which wireless nodes transmit packets in a "biased random walks" manner [7]. In a large-scale, highly dynamic network, the ID-to-locator mappings are both large in number, and change often. Traditional routing protocols require high overhead to keep these indirections up-to-date. In this paper, they propose Weak State Routing (WSR), a routing mechanism for large-scale highly dynamic networks. WSR's novelty is that it uses random directional walks biased occasionally by weak indirection state information in intermediate nodes. Energy consumption based Routing (ECBR) protocol is proposed in [8]. In this paper it is suggested that it is more important to use node cost (which are functions of remaining battery power) as metrics. Validity of these metrics is verified on Matlab which demonstrated that significant reductions in cost can be obtained by using shortest-path routing. It is also observed that energy consumed is directly proportional to the Packet size. But this work still needs to be implemented in real network scenario. In this paper [9] the proposal is to determine an optimal routing path from the source to the destination by favoring the highest remaining battery power, minimum number of hops, and minimum traffic loads. It is suggested with the intent to efficiently route data through transmission path from node to node and to prolong the overall lifetime of the network. In this paper a new algorithm is proposed by using a combination of both Fuzzy approach and A-star algorithm. The new method is capable of selecting optimal routing path from the source node to the sink by favoring the highest remaining energy, minimum number of hops and lowest traffic load. Simulation results demonstrate the effectiveness of the new approach with regards to enhancement of the lifetime of wireless sensor networks with randomly scattered nodes. This paper [10] is represented by building a two-level hierarchy to realize a protocol that saves better the energy consumption. This TL-LEACH protocol uses random rotation of local cluster base stations (primary cluster-heads and secondary cluster-heads). In this way it is possible to build a two-level hierarchy. This permits to better distribute the energy load among the sensors in the network especially when the density of network is higher. TL-LEACH uses localized coordination to enable scalability and robustness.

III. Proposed Approach Framework And Design

A. Problem Definition

ELOR is proposed for large scale WSN to be delay and energy efficient. First part of the algorithm gives the steps to find out the shortest path. To transmit data this path is identified for source-destination pair. Initially all the nodes are considered at equal energy level and in sleep mode. Data transmission is started on this route. Further steps talk about energy efficiency. A routing table for neighboring nodes and their energy level is maintained at every node. While transmitting data, every node checks this table for energy level. Depending upon this energy level value decision is taken whether to forward data using that neighboring node or to identify another node as forwarder node to minimize energy consumption.

A topology $G = (V, E)$ with $|V| = N$ nodes and E set of edges.

Let $FoL(s)$ denotes forwarder list of node s.

$N(s, d)$ Be the number of transmissions required to transmit packet from s to d i.e. from source node s to destination node d.

B. Assumption

Link hop qualities are already calculated and denoted as $\Pr(s, vi)$ where vi is any neighbouring node of node s.

C. Algorithm

1) All the nodes are in the sleep mode initially. Initiate forwarder list and number of transmissions for every node in a WSN as:

If link quality between corresponding two nodes is greater than 0 then number of transmissions required are taken as reciprocal of that link quality otherwise it is taken as infinity as in equation 1.

Same is done for forwarder list creation. A node is included in forwarder list if that node is in the neighbor set of source node and forwarder list is set empty if a node is not present in neighbor set of that node as in equation 2.

$$Ns(v) := \begin{cases} \frac{1}{\Pr(s,v)}, & if\ v \in Bs \\ \infty, & if\ v \notin Bs \end{cases} \qquad (1)$$

$$FoL(s) := \begin{cases} \{s, v\}, & v\epsilon Bs \\ \emptyset, & v \notin Bs \end{cases} \qquad (2)$$

2) Each node s exchanges the local information FoL(s) and N(s) with neighbors by piggybacking them in the Probe/Hello messages.

3) Upon receiving forwarder list information from its neighbor, node s updates its own information to reflect any changes.

4) Node s broadcasts its updated information so that other nodes can be updated further.

5) For each source to destination pair s orders its own neighbors by number of transmissions required in ascending order.

6) Node s now decides whether to update its forwarder list or not as -

If number of transmissions from any intermediate node is less than previously given number of transmissions then forwarder list is updated to include this neighboring node. Otherwise forwarder list is not updated.

7) In this way each node in a wireless topology $G = (V, E)$ can compute the optimal forwarder lists and the corresponding number of transmissions to any other node.

8) A node constructs a local forwarder list once it collects sufficient local information.

9) Each path is given through this local information. This process ends when hop counts included in the local exchanged information exceed the average number of neighbors in the wireless network.

10) Each node in the network maintains a local optimal forwarder list information to any other member in its vicinity, which lists the corresponding best forwarder node. If there are multiple forwarder nodes to the same neighbor we will select the node with the least number of transmissions to the neighbor node as the best forwarder node.

11) When any of the source nodes wants to send the data, that node should activate the path through which data is going to be sent.

12) When energy level of any node goes below threshold, as given by its parent, or congestion is detected at that node then,

   a) That node informs its parent.
   b) Parent will find another path towards destination.

When any node detects all its lower depth nodes below current threshold value

   a) It calculates new threshold and,
   b) Start sending data on those paths again.

IV. Experiment And Results

The performance evaluation of routing protocols is evaluated with the NS-3 simulator. Then our proposed protocol is compared with the LOR and MTS algorithm in terms of energy efficiency, throughput and end to end delay. Simulation parameters are considered as given in Table I.

Table I: Simulation Parameters

Number of Nodes	200
Traffic Patterns	CBR (Constant Bit Rate)
Network Size	1000 x 1000 (X x Y)
Max Speed	10, 20, 30, 40, 50 and 60 MPH
Simulation Time	51s
Transmission Packet Rate Time	10 m/s
Packet Size	1000 Bytes
Routing Protocol	MTS[AODV]-existing LOR[MTS-B]-base paper ELOR[LOR+ Energy _Efficient]-Proposed
MAC Protocol	802.11

Simulations are carried out for MTS, LOR and ELOR in terms of average throughput, average energy consumption and average end-to-end delay for 200 nodes. Node mobility is varied as 10, 20, 30, 40 and 50 m/s for every protocols considered for comparison.

1) Throughput- Throughput is the number of bits divided by the time needed to transport the bits. The throughput for each protocol and for each network configuration can be seen in Figure 1. Simulation results show that ELOR performs better than MTS and LOR for average throughput parameter.
2) Energy Consumption- The energy consumption is evaluated by simplifying the power consumption of the battery operated nodes. From Figure 2 it is clear that average energy consumption is lesser in ELOR as compared to MTS and LOR.
3) Average End-to-End Delay-E2E Delay is time by which packets are reaching late at the destination node than expected time. Fig.3 shows that MTS performs better in this aspect rather than LOR and ELOR.

After simulation, values of throughput, energy used and delay are recorded for every protocol.

Fig.1 shows comparison of throughput values for three protocols. It shows that throughput is better in ELOR than MTS and LOR. Fig.2 is about energy consumption which shows that ELOR has the least energy consumption when compared to MTS and LOR. Figure three shows comparison of delay parameter for three protocols. It is clear from the graph shown that E2E delay is reduced in ELOR as compared to MTS and LOR.

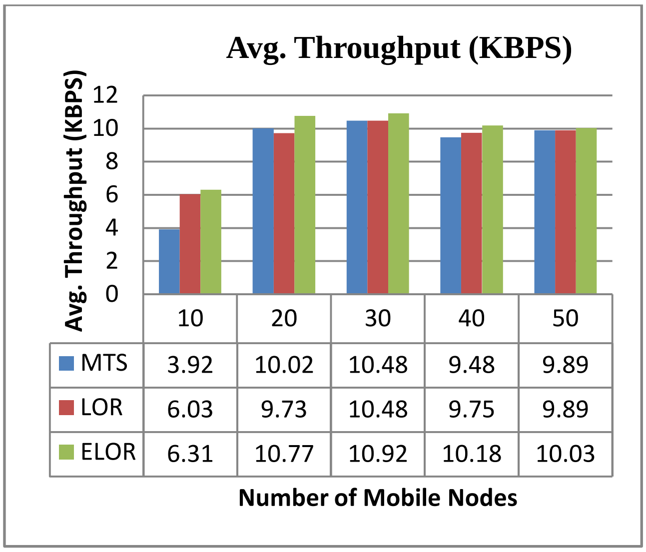

Figure 1: Average Throughput (Average Throughput vs. Number of Mobile Nodes)

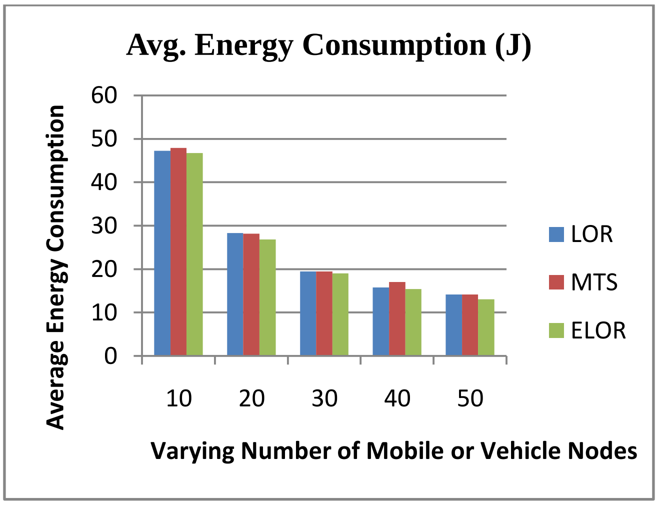

Figure 2: Average Energy Consumption (Average Energy Consumption vs. Number of Mobile Nodes)

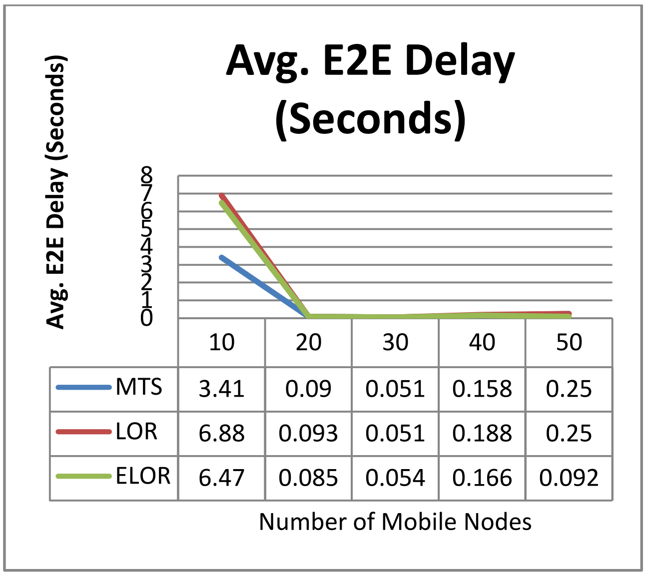

Figure 3: Average E2E Delay (Average E2E Delay vs. Number of Mobile Nodes)

V. Conclusion

Opportunistic routing protocols are designed using centralized and distributed algorithms. Distributed algorithms tend to use more features of opportunistic routing giving better results for large scale WSN. ELOR protocol uses distributed algorithm for routing along with energy efficiency consideration. Extensive simulation results demonstrate that ELOR outperforms the existing MTS, LOR in terms of average throughput, average energy efficiency and average E2E delay.

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