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FPAR: Frequency and Power Attentive Routing Protocol for Impediment Lenient Mobile Sensor Networks

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Abstract- Impediment lenient Mobile Sensor Networks (ILMSN) is a class of promising networks that experience frequent and long-duration partitions. Evaluate with the conventional networks, the distinct characteristic is that there is no end-to-end connectivity between source and destination. The network topology may modify dynamically and arbitrarily. This characteristic and non-existence of an end-to-end path poses a number of challenges in routing in ILMSNs. So, Utilizing multi-replica schemes to develop the routing performance is reasonable. Most of the presented multi-replica approach distributes many copies of the messages into the network for increasing the packet delivery rate. This operation consumes a great amount of constrained resource of ILMSNs. To solve this problem we suggest a Radio Frequency and Power-Attentive Routing protocol (FPAR), which cut down the replicas based on the Radio Frequency between the sensor nodes and sink node and the residual Power of the sensor node. The packet delivery probability is based on sink meeting frequency and nodes movement direction. Then we develop our protocol by using diverse targets called Diverse Targets Radio Frequency and Power Attentive Routing protocol (DTFPAR). Simulation results indicate that our proposed protocol achieves higher message delivery ratios with lower transmission overhead and data delivery delay than existing ILMSNs routing protocols.

***Index Terms*-** Impediment Lenient mobile sensor networks • Routing protocols • Diverse Targets

I. Introduction

In recent years, many routing protocols have proposed for wireless sensor networks (WSNs). Traditional methods of routing are suitable for many sensor applications, but they cannot be applied to the scenarios with intermittent and low connections because of sparse network density, sensor nodes mobility and Power limitation. Two practical examples of this scenario are pervasive air quality monitoring and flu virus tracking. In these examples for the most accurate and efficient measurement, wearable sensors that adapt to human activities has been bound. AS a result, the connection between the mobile sensors is poor and thus forming a well connected mesh network to transfer data through end-to-end connections between sensor nodes and sinks is difficult.

In order to deal with this problem, Impediment Lenient Mobile Sensor Networks (ILMSNs) [1-5] has been introduced. ILMSNs are the subset of the Impediment Lenient Networks (DTNs) [6-12] which have many features such as node mobility, frequent and prolonged communication interruption between nodes, delay tolerance and resources limitations. A ILMSN under our consideration consists of two types of nodes, the wearable sensor nodes and sink nodes. The former are attached to people (or other mobile objects), collecting information and forming a loosely connected mobile sensor network for information delivery. A number of high-end nodes (e.g. mobile phones or personal digital assistants with sensor interfaces) which serving as the sinks to receive data from wearable sensors, are deployed at strategic locations with high visiting probability or carried by a subset of people.

One of the methods of data gathering in ILMSNs, are multi-replica schemes that generate manifold replicas for each message. Distributing a message to a large number of nodes will increase the probability of packet delivery rate. For a ILMSN that has limited resources, duplicate messages will increase traffic overhead, collision, delay and Power consumption of mobile nodes.

In recent years, several multi-replica routing protocols [13-17] have been presented to increase the data delivery rate. These protocols can be divided into two categories: a) flooding-based approaches b) quota-based approaches. In flooding-based approaches, the nodes send copies of a message to all neighbor nodes, while, in quota-based approaches, the nodes send fixed and limited number of copies of a message and have better efficiency than flooding-based approaches. In this paper we have tried to present a replica adaptive routing protocol for ILMSNs.

The rest of the paper is organized as follow: Section 2 discusses related work. Section 3 presents the proposed protocol. Section 4 discusses proposed protocol with multi sink. Section 5 presents imitation results. Finally, Section 6 concludes the paper.

II. Related Work

There has been wide research on routing in ILMSNs. The work dates back to before the term "delay-tolerant" was extensively used. The adjectives "intermittently-connected", "sparse" and "disconnected" are also used to explain networks without constant end-to-end connections. One of the categories of routing schemes is multi-replica methods. A majority of existing multi replica routing protocols, such as epidemic [13], are flooding-based. Epidemic protocol is attempts to give all nodes a copy of every message, through random interactions between nodes. If it is provided infinite bandwidth and buffer resources, it could achieve a high data delivery rate and low data delivery delay. It has more overhead and Power consumption that increases packet dropping and retransmission. Different from flooding-based routings, quota-based protocols such as Spray-and-Wait [17] and Spray-and-Focus [18] use fixed number of replicas. Spray-and-Wait "sprays" a number of copies into the network and then "waits" until one of these nodes meets the destination. Spray-and- Focus is very similar to Spray-and-Wait. This scheme distributes a small number of copies to a few nodes. Though, each relay node can forward its copy further using a single-copy utility-based scheme, instead of waiting to deliver it to the destination itself.

Other endeavors aiming to improve the performance of ILMSN routing include [19, 20]. In [19], a replication-based efficient data delivery (RED) protocol based on erasure coding technology is presented. RED consists of two key components for data transmission and message management. The first makes decision on when and where to transmit data messages according to the delivery probability. The second decides the optimal erasure coding parameters based on its current delivery probability, in order to achieve the preferred data delivery rate while minimizing overhead at the same time. This history-based method is not effective and cannot denote the actual ability that a node delivers data to sink nodes. In [20], the authors propose a Message Fault Tolerance-Based Adaptive Data Delivery Scheme (FAD) to increase the data delivery rate in ILMSN. The FAD approach employs the message fault tolerance, which indicates the significance of the messages. The decisions on message transmission and dropping are made based on fault tolerance for minimizing transmission overhead. The system parameters are cautiously tuned on the basis of thorough analyses to optimize network performance. That protocol still has a high overhead. Yong Feng *et al.* in [21] proposed a Distance-Attentive Replica Adaptive Data Gathering protocol (DRADG), which uses a self-adapting algorithm to cut down the number of redundant replicas of messages according to the sensor nodes' distance and sink node and leverages the delivery probabilities of the mobile sensors as main routing metrics. Creating message copies without considering the sensor nodes' residual Power maybe cause the faster sensor nodes' Power consumption and it cause hole problem in the network and reduce the network life time.

III. RADIO FREQUENCY AND POWER ATTENTIVE ROUTING PROTOCOL (FPAR)

As is described above, FPAR dynamically calculates the number of copies of each message based on two parameters: a) the Radio Frequency between the sensor node, that generates message and the sink nodes. b) Residual Power of the sensor node. Residual Power of sensor node consideration in determining number of replicas, reduce Power consumption and prevent the creation of holes in the network. Also, FPAR computes the delivery probability of every mobile node according to its frequency of meeting with the sink node and its movement direction. In this section, we will explain the proposed protocol in detail.

A. Network Model:

We assume initially all the N sensor nodes randomly deployed in a square area of A. All the sensor nodes are homogeneous. The maximum transmission range of all the sensor nodes is fixed to R.

The mobility of all sensor node is assumed to follow the community-based Mobility model depicted in [22, 23] where the whole area is divided into several non-overlapped cells, one gathering place (G) and communities (C). Each sensor node has one home community which it is more likely to visit than other communities. Nodes randomly choose a destination and a speed and move there. Upon arrival at the destination, \the nodes pauses for a while and then select a new destination. The destinations are selected such that if a node is at home, there is a elevated probability that it will go to the gathering place (but it is also for it to go to other places) and if it is away from home, it is extremely likely that it will return home. Each sensor node can compute its location by GPS (Global Positioning System) [24-26]. The sink node is immobile and it is located at G. its location is known to all sensor nodes.

B. Message Replica Number Calculation:

According to the DRADG, replica number of each message calculated based on the distance between the sensor nodes which generates the message and sink node. In this paper to increase the efficiency of this protocol, FPAR decides the replica number of each message according to residual Power of the sensor which generates the message in addition its Radio Frequency with sink node. In the header of each message there is a field of integer type that holds the number of its replica ticket. For example, when n generates a new message M, value of d that is the current Radio Frequency between node n and the sink node equals:

$$d_i = \sqrt{(x_{\sin k} - x_i)^2 + (y_{\sin k} - y_i)^2} \tag{1}$$

Where the location of node n_i is (x_i, y_i) and the location of sink node is $(x_{\sin k}, y_{\sin k})$

The value of the ticket that denotes the upper bound of replica number defined as follow:

$$ticket_M = \left[a * \left(\left[k * T_{\max} * \sqrt{\frac{d_i}{D_{\max}}} + (1-a) * \frac{EN_i}{EN_{\max}} \right] \right] \tag{2}$$

Where k and • are constant parameters between 0 and 1; T_{max} is the maximum value of the ticket; D_{max} is the Radio Frequency between farthest sensor node and the sink node in the network; EN_i is residual Power of node n_i , EN_{max} is the initial Power of each node that it is equal for every sensor node. From Equation 2, it can be found that the number of message replica is high in the node which is closest to the sink and has the highest level of remaining Power. This approach, decrease the message redundancy when sensor nodes and sink node are close to each other and the poor performance when they are far from each other. In addition, it cause Power efficiency and avoid problem of hole in the network.

C. Node Delivery Probability Calculation:

In this protocol, we establish a probabilistic metric called delivery Probability, p_i at every node i. This parameter indicates how this node will be able to directly deliver a message to the sink node. The calculation of the delivery Probability has several parts. Every sensor node calculates its delivery probability in accordance to its frequency of meeting with the sink node and its movement direction and sends the message to nodes with high delivery probability. The first thing to do is to compute the meeting frequency of n_i in the most recent interval of •, denoted as $freq_i$ by Equation 3 as follows [21]:

$$freq_i = \begin{cases} \frac{Num_i}{Num_{th}} & Num_i < Num_{th}, Num_i \geq Num_{th} \\ 1 & \end{cases} \quad (3)$$

Where Num, is the meeting time of node n_i with the sink node in the latest interval of •, Num_{th} is the threshold value that should be varied based on the application. Then, we calculate F_i as follow:

$$F_i = freq_i * \frac{dist_{i,\sin k} - dist_{j,\sin k}}{dist_{i,\sin k}} \quad (4)$$

Where $dist_{i,\sin k}$ and $dist_{j,\sin k}$ are the Radio Frequency between node i and sink and node j and sink, respectively.

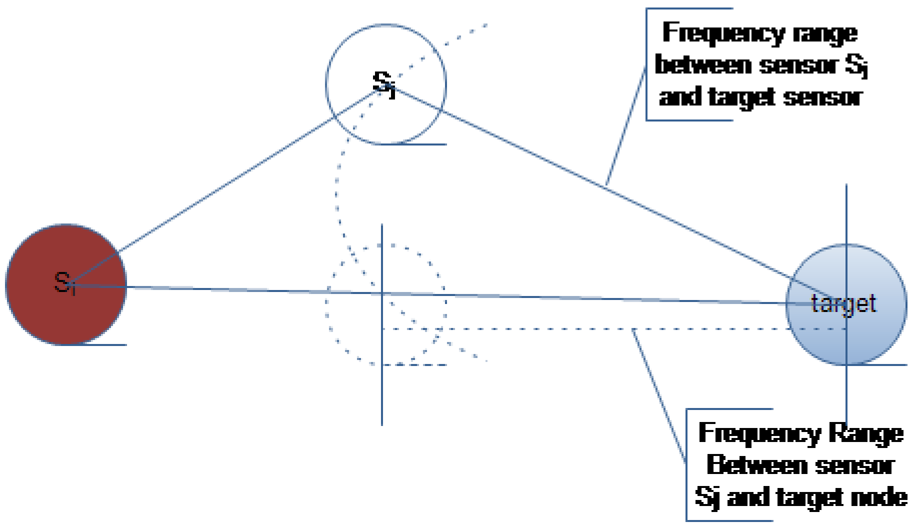

Fig. 1: Location of sensors on the way to target sensor

The movement direction of the sensor nodes is also impressive in node delivery probability. As shown in Figure 1, if the sensor node moves towards the sink node, it is likely to encounter sink node in a future period of time.

We can calculate the packet delivery probability, Pi as follow:

$$P_i = \delta * F_i + (1-\delta) * P_{i(old)} \quad (5)$$

Here in Eq 5, the 'δ' is weight parameter.

Finally, due to the node mobility, each node calculates the delivery probability periodically and broadcast the value to its neighbors by hello messages.

Forwarding Strategies:

that updates it by receiving hello messages. When node n, has a message M to forward, first of all it looks up the node with highest delivery probability in its neighbor list, denoted as n_m. If P_m is greater than P, then n_m is next hop. Secondly, if the value of $ticket_M$ is equal to 1 then n, directly forwards M to n_m; if else, n, generates a replica of M, denoted as M', set $ticket_M$ as [$ticket_M$ /2], forwards M' to n_m and finally updates $ticket_M$ as [$ticket_M$ /2] and stores message M into its routing queue.

D. Queue Management:

In challenging networks like ILMSNs, manifold message replicas may be generated and buffered by different sensors, resulting in redundancy. In order to achieve effective data delivery rate and enhance network performance, queue management scheme is essential. The main idea of the queue management scheme is employing both survival time and giving more priority to important message.

E. Message's Survival Time:

We assume each data message has a field that records its survival time. For example, the survival time of massage m in the queue of sensor j, denoted as ξ_n^m . When a message is generated, its endurance time is initialized to be zero. When node j deliveries a message m to single hop neighbor nodes, such as node n, the time required for transmission be ignored and the node inserts the message to its queue without any changes on amount of the survival time. Therefore, the initial value ξ_n^m is the same amount of ξ_j^m before transmission. If a source message has transmitted to its next hop and it is inserted into node's queue again, its survival time is also unspecified to be equal to the value before transmitting. Furthermore, for messages in the queue buffer, their endurance time should be updated with the time clock.

F. Massage's Priority:

Every sensor node maintains a list of the messages in its buffer that come from the following sources:
• After the sensor nodes sense a data, it generates a message and inserts it into its data queue. (b) When a sensor node receives a message from other sensor nodes, it may insert it to its buffer. (c) After the sensor node sends the data message from its buffer to other destination except the sink, if the message is generated by the source node itself, it may insert the message again, because there isn't any guarantee to deliver the messages to the destination. Messages in the first classification have highest priority and messages belonging to the second and third class are have middle and the lowest priority level respectively.

IV. IMPLEMENTATION OF QUEUE MANAGEMENT SCHEME

Implementation of the queue management scheme is based on two parameters, the massage priority and the data message survival time. Messages are sorted in the queue based on a descending order of the priority, if two messages have the same priority level, then they are sorted based on ascending order of survival time, indeed the massage that its survival time is less has a higher priority. The massage will be dropped from the queue in the following two occasions: a) the message survival time exceeds the network's Impediment Lenient threshold (maximum message delay value). b) When the queue is full and a new message arrives, its precedence level is compared with the priority level of the message at the end of the queue and one with less priority level is dropped among them. Otherwise if the priority levels are equal, then the one with a longer survival time is eliminated. This condition has been set to reduce Power consumption, given that the messages are delivered to the destination with the highest priority or the massage be declared invalid.

V. DIVERSE TARGETS RADIO FREQUENCY AND POWER ATTENTIVE ROUTING PROTOCOL (DTFPAR)

Due to the battery resource constraints, saving Power is a critical issue in ILMSNs, particularly in large ILMSNs. One possible solution is to deploy manifold sink nodes simultaneously. Having manifold sinks in the network gives networks compared with single sink sensor networks as follows:

1: They are more consistent because of the fact that invalidation of a sink node will drag down the whole network in single sink networks.

Generally there exists a serious node Power bottleneck (around sinks) if a single sink masses reports from too many sensors.

- They alleviate the unbalanced Power consumption.
- They suggest more adaptable functional applications and communication cooperation. In some applications, different users (sinks) may require different environmental variables (temperature, humidity, light intensity, *etc.)* or data formats (image, sound, video, *etc.).* In this time, all nodes require to cooperate with each other during the communication process.
- The work presented in this section is mainly motivated by partly stationary, multi-sink deployments of ILMSNs such as real-time surveillance and city pollution monitoring applications. Multiple sinks deployed in the network and each sensor node knows the location of all \the sensors. The sensor node that generates a data message, calculate Radio Frequency between itself and sink nodes according to Equation 6 as follows:

$$d_{si} = \sqrt{(x_{sj} - x_i)^2 + (y_{sj} - y_i)^2} Fori = 1....n \quad (6)$$

Where d_{si} is the Radio Frequency between n, and the sink nodes.

Then it determines number of hops towards every sink by Equation 7:

$$d_{si} = \sqrt{(x_{sj} - x_i)^2 + (y_{sj} - y_i)^2} Fori = 1....n \quad (7)$$

Where h_i is the hops between n_i and the sink nodes; r is the transmission range of each node that is fixed.

Every node chooses the sink that has minimum hops to it as a management sink.

Rest of the algorithm is like the FPAR algorithm that is described in section 3.

VI. EXPERIMENTAL RESULTS

We have simulated DTFPAR, EDRP[27], as well as epidemic[13] topologies using MXML and actionscript. The position per hop transmission distance is 250m. For power maintenance function, many smaller hop level nodes are taken. Power management is used in all three topologies, including normal EPIDEMIC topology, in which a transmitter adjusts the transmission power based on its actual distance to the next hop level receiver. The network area in the simulation is fixed to 1200(m) X 1200(m) and the nodes are arbitrarily dispersed in the network. The available transmission power levels are $1; 5; 10; 15; 20; 25; 30; 35$ mW. The Pm is set to 35 mW. The session arrival rate follows Poisson distribution and the session interval follows Exponential allocation. The application topology is CBR (Constant Bit Rate) and the source and target pairs are arbitrarily selected. The mobility follows customized random waypoint model [18] with pause time of thirty seconds. For each CBR session, 50 packets are sent for each second. The rate of route loss and collision are projected using method described in [12]. The detection rate, which can be described as filter memory [11], is fixed to nearly 1. A simulation result was gained by averaging over 25 executions with dissimilar seeds.

We consider that there is no power saving approach for the nodes, and therefore, a node will use power in monitoring the channel even if it doesn't receive a packet. A node also utilizes power when overhearing packet transmissions. Therefore, the receiving power cannot be dynamically controlled. In the simulations, we thus disregard the receiving power and focus only on the comparison of transmission power. We first evaluate the accuracy of the proposed cost model, we then study the performance of route detection for each topology, and finally we consider power utilization as well as RTS retransmissions in both static and mobile environment.

We compared the power utilization and the average number of RTS retransmissions of the DTFPAR, EDRP and basic EPIDEMIC topologies by varying the following parameters: node count, average size of the data transmission packets, and advent ratio of the connection. The simulation time for each topology is 5 hours. We monitored the total power utilization of all the packets delivered at target node, the count of delivered packets at target nodes, and the count of retransmissions RTS required for each execution of the simulation. The couple of evaluation metrics that used to evaluate the topologies are:

Power Utilization per Packet: It is defined by the total power utilization divided by the total number of packets delivered. This metric indicates the power efficiency for each topology.

Average RTS Retransmissions required for each Data Packet: It is defined by the total number of RTS retransmissions divided by the total number of packets delivered. The RTS packet is transmitted at the utmost power usage level and the packet size is very little. The majority of RTS retransmissions are due to collisions, together with the collisions of both RTS messages and data packets. Hence, this metric can indicate the pace of the collision for each topology. Higher collision rate will cause more power utilization, higher end-to-end delay, and lower throughput.

The simulation results are shown in Figure. 2 and 3. According to these results, DTFPAR topology performs the best in terms of Power Utilization per Packet as well as Average RTS Retransmission per Data Packet, followed by EDRP topology and EPIDEMIC.

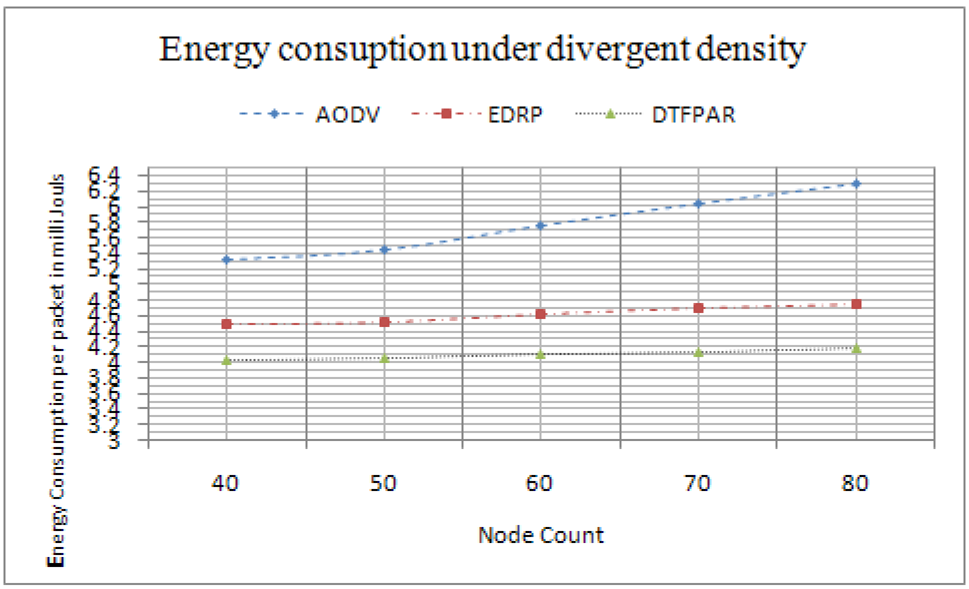

Fig 2: Power Utilization ratio between DTFPAR, EDRP and EPIDEMIC

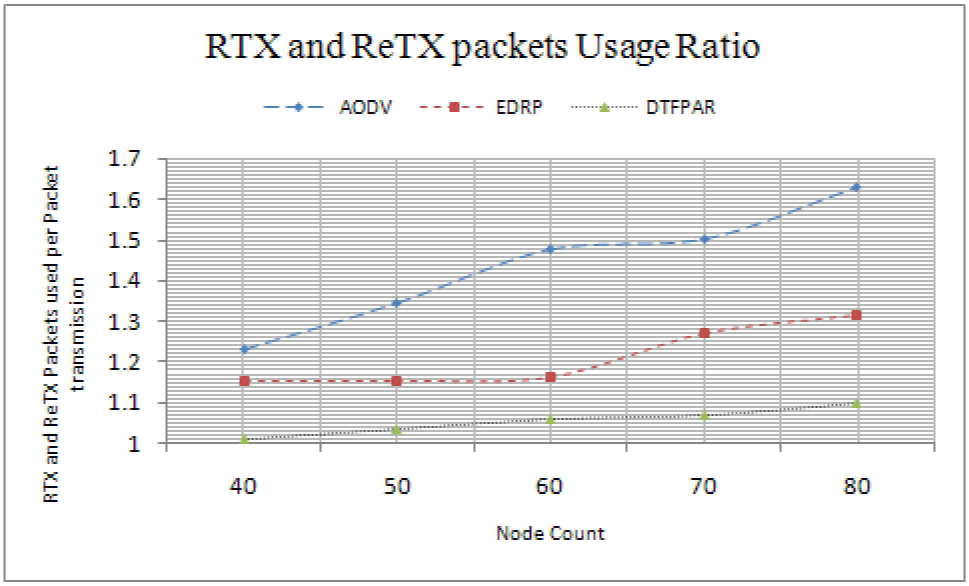

Fig 3: RTX and ReTX packets usage Ratio comparison between EPIDEMIC, EDRP and DTFPAR

VII. CONCLUSION

This paper deals with efficient data transmission in the Delay-Tolerant Mobile Sensor Network (ILMSN).By taking into consideration the unique characteristics of ILMSN, such as sensor node mobility, loose connectivity and delay tolerability, which distinguish ILMSN from conventional sensor networks, we have proposed a new routing approach called A Radio Frequency and Power Attentive Routing Protocol (FPAR) for ILMSN. In FPAR, replica number of each message calculated based on the residual Power of the sensor nodes which generates the message and its Radio Frequency and sink node. FPAR makes routing decisions according to delivery probability. The experimental results show that our proposed FPAR protocol provide better performance at the cost of lower traffic overhead and Power consumption and higher delivery rate than existing protocols. Furthermore, we improve FPAR by using Diverse Targets called DTFPAR, the simulation results show that with more sink nodes present, we have a higher delivery rate and lower delivery delay.

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