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Relative Distance Based Routing for Delay Tolerant Mobile Sensor Network

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Abstract

Delay Tolerant Mobile Sensor Network (DTMSN) is the network for pervasive information gathering. Traditional static routing approaches may not fit for DTMSN due to its intermittent connectivity. This paper proposes an relative distance based routing (RDBR) strategy for DTMSN, in which nodes delivery probabilities are calculated and updated according to the latest relative distance from themselves to the sink node, and data are delivered according to nodes' delivery probabilities. RDBR also introduces a redundant copies controlling technique based on the message priority. Simulation results show that RDBR achieves a well tradeoff between the data delivery ratio/delay and the delivery overhead.

Index Terms: Delay Tolerant Mobile Sensor Network; Probability; Routing; Queue Management

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1. Introduction

Delay Tolerant Mobile Sensor Network (DTMSN) [1] is the network for pervasive information gathering, it belongs to the general category of Delay Tolerant Networks (DTN) [2]. DTMSN consists of two types of nodes, the wearable sensor nodes and the sink nodes. Sensor nodes are attached to mobile entities, such as animals, people or vehicles, gathering target information and forming a loosely and intermittent connected network. Sink nodes may fixed or mobile, which receive data from sensors and forward them to access points of the backbone network. The typical applications of DTMSN are flu virus tracking, air quality monitoring, or wildlife tracking for biological research.

Traditional data delivery approaches in wireless sensor network usually rely on well connected end-to-end routes, sensors in the network collaborate together to collect and transmit the request information to the sink nodes. However, these approaches can't work effectively in DTMSN due to the intermittent connectivity, and how to deliver data to the sink node effectively and achieve a well tradeoff between the data delivery ratio/delay and the delivery overhead is the central problem in DTMSN routing. To address this tradeoff, we propose a Relative Distance Based Routing scheme(RDBR) , RDBR utilizes nodes position information to

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decide the probability of delivering data to the sink successfully, and data delivery is proceeded on the basis of that, we also introduce a message queue management strategy based on the message priority.

The rest of this paper is as follows. Section II describes some related work. Section III presents our relative distance based routing strategy, RDBR. Section IV describes our simulation methodology and presents results. Finally, Section V presents conclusions and future research directions.

2. Related Work

Researches for DTMSN are motivated mainly by the Delay-Tolerant Network (DTN) and its applications in sensor networks and mobile ad hoc networks. Various approaches have been proposed to address the data delivery problem in DTN, directed transmission[3-4] is one of the most basic strategies, in which data would be only allowed delivering when sensors are in direct proximity of the sinks, although it is with very low transmission cost, this method will bring long delay . In order to increase the transmission opportunities, many routing approaches are designed based on message replication. Epidemic[5] routing protocol replicates messages at all transfer opportunities hoping to find a path to the destination, however, unlimited flooding wastes resources and can severely degrade performance. Therefore, proposed protocols attempt to limit replication in various ways, SWIM[6] utilizes sensors to gather the biological information of whales, it distributes message based on the locally-optimal tree which enhances the distributing speed. Similarly, ZebraNet[7] employs the mobile sensors to support wildlife tracking for biology research, ZebraNet proposes a history-based approach for data gathering in which routing decision is made according to sensors' past success records of delivering message to the sink nodes directly, however it is not accurate by using the rough history level to estimate the sensor's delivery ability. On the basis of that, Wang et al present the data delivery protocol RED[8] and FAD[9], both approaches work based on the delivery probability, which is calculated according to the history contact information, and indicates the likelihood that a sensor can deliver data messages to the sink. FAD further using fault tolerance value associated to each message to manage the limited buffer. SRAD[10] predicts the node delivery probability based on the location of the next destination, however, the prediction is difficult in reality environment, and its survival time based message queue management strategy may not be reasonable since messages with shorter survival time may reach the sink earlier than those with longer survival time.

3. The Proposed Relative Distance Based Routing Strategy

The proposed routing schemes [7-9] are all based on the nodes contact records in the history to decide nodes delivery probabilities, however, these approaches will be not effective in the scene that sensors may experience long time before meeting others since sensors are distributed sparsely and intermittent connected.

Since messages will be delivered to the sink ultimately, sensors delivery abilities in short term are more rely on nodes locations. In addition, messages may be stored in the buffer for a long time before they are delivered to others due to the network intermittent connectivity, while sensors' storage spaces are limited, so how to manage the message buffer effectively is of vital importance.

3.1. Delivery Probabilities of Sensors

We assume initially M sensors are randomly deployed in a plane area, each sensor can locate itself at any time by GPS, and the location is denoted by (x,y), there is a fixed sink node S and its location (x_s,y_s) is known to all sensors.

Let R denotes the sensor's transmission range, when nodes are within the transmission range of each other, they can communicate directly. Suppose the position of sensor v_i is (x_{ij},y_{ij}) at time t_j, and the distance between v_i and the sink node is d_{ij}, which can be achieved by the plane distance formula since the coordinates of v_i and S are known. Further let P_{ij} denotes the probability of v_i delivering message to the sink node successfully at t_j.

$$P_{ij}=\begin{cases} e^{-\beta(\sqrt{(x_{ij}-x_s)^2+(y_{ij}-y_s)^2}-R)} & d_{ij}>R \\ 1 & d_{ij}\le R \end{cases} \tag{1}$$

Where β is a constant, we can see from (1) that when the distance between v_i and S is greater than R, the father v_i is from S, the smaller the P_{ij} becomes, otherwise, P_{ij} is increasing as the distance is decreasing, when the distance approaches to R, P_{ij} gets close to 1, and v_i can deliver messages to the sink node directly if S is within v_i's transmission range (means $d_{ij} \le R$).

However, since sensors are mobile, it may not be accurate to decide a node delivery probability only rely on its instant position. So we then consider the sensor's recent location status, which can reflect the node latest status and also give a short-term prediction for the future. For a given sensor node v_i, it gets its location through GPS every period of T, and calculates its delivery probability according to the locations of the latest N periods, which is calculated as (2).

$$P_i=\sum_{h=1}^{N}P_{ih}t_h \Big/ \sum_{h=1}^{N}t_h \tag{2}$$

Where t_h is the time when the latest hth period expires, v_i gets its location through GPS at t_h, and P_{ih} is the delivery probability at t_h according to (1) .In (2), the timestamp t_h is used as the weight value for relevant P_{ih}, that means the newer the P_{ih} is, the larger the proportion of the P_{ih} in P_i is. By calculating P_i in this way, sensors' real time status are considered sufficiently, and it can also predict nodes future status in certain degree. Sensors update their P_i every period of T.

3.2. Data Delivery

The data delivery process is shown in Table I.When the distance between the sensor and the sink node is smaller than R, the sensor delivers data to the sink directly and deletes the delivered messages. While when there is a contact between sensor v_i an v_j ,they exchange their messages index lists and delivery probabilities first, if $P_i<P_j$, then v_i manipulates the messages which not hold by v_j to v_j, v_i also keeps the copies at the same time. If $P_i>P_j$,v_j does the similar ways as v_i.

Table 1. Data delivery process for RDBR

```
when $v_i$ meets $v_j$
If $v_j$ is sink node then
    deliver_message_to_sink($v_i$)
    delete_delivered_message($v_i$);
else if $v_j$ is sensor node then
    if ($P_i$<$P_j$) then
        Exchange_message_index_ list($v_i$,$v_j$) ;
        for each message not in $v_j$ but in $v_i$
            forward_message($v_i$,$v_j$)
      end for
    end if
end else
end if
```

3.3. Queue Management

Replication-based routing can increase the message delivery chances, but it results in more copies in the network, in order to make full use of the sensor's limited buffer and minimize the transmission overhead, message queue management is essential, this is of great importance to the network performance.

In RDBR, the dropped value(*DV*) is set for each message to indicate the message priority, the smaller the *DV* is, the higher the message priority is. *DV* is changing with the replication process going on. Suppose sensor v_i deliver a copy of message *m* to sensor v_j, v_i and v_j update *m*'s *DV respectively* as follows.

$$DV_{(m,j)} = DV_{(m,i)}' \tag{3}$$

$$DV_{(m,i)} = DV_{(m,i)}' + P_j \tag{4}$$

Where $DV_{(m,i)}$ and $DV_{(m,j)}$are *m's* current *DV* in v_i and v_j respectively, and $DV_{(m,i)}'$ is *m*'s *DV* before v_i duplicates it to v_j, P_j is v_j's delivery probability. Messages will be delivered in turn according to their priorities, the one with high priority will be send prior to that with low priority. The DV of newly generated message is 0, and that message is with the highest priority and will be delivered first. But the message with large *DV* is that has been transferred by many sensors or by those with high delivery probabilities, so the message is more possible received by the sink node, and its priority is low and will be delivered later.

In order to manage the data buffer effectively, messages are queued in the buffer according to their *DVs* , messages with small *DVs* are placed in the front of the queue and send first, and messages with large *DVs* are set in the back of the queue and send later. When the message queue is full, those in the tail of the queue will be dropped first to vacate spaces for the newly coming messages with smaller *DVs*.

Table 2. Simulation parameters

Parameter	**Default value**
Network size(m^2)	200×200
Grid size(m^2)	40×40
Number of sensor node	100
Position of sink node	(100,100)
Transmission radii R(m)	3
Speed of sensor V (m/s)	0~5
Size of each message(bits)	200
Message generation rate	0.02/s
T of RDBR (s)	40
N of RDBR	5
β of RDBR	0.02
Δ of FAD (s)	30
Fault tolerance threshold of FAD	0.9
α of FAD	0.1

4. Simulations

4.1. Simulation Environment

The simulation environment is as follows, 100 sensors are randomly scattered in an area of 200×200 m^2, and a sink node is placed in the center of the area, the whole area is divided into 25 non-overlapped zones, each with an area of 40×40 m^2. A sensor is initially resided in its home zone. It moves with a speed randomly chosen between 0 and 5 m/s. Whenever a node reaches the boundary of its zone, it moves out with a probability of 20%, and bounces back with a probability of 80%. After entering a new zone, the sensor repeats the above process. However, if it reaches the boundary to its home zone, it returns to its home zone with a probability of 100%. We assume the data generation of each sensor follows a poisson process with an average arrival interval of 50s, the channel bandwidth is 10 kbps. Other simulation parameters and their default values are summarized in Table II.

For Epidemic, when the message queue is full, the tail message in the queue will be dropped in order to adopt the new generate message. All the simulation results are averaged over 100 independent runs.

4.2. Performance Comparison

Simulation results(Fig.1-Fig.3) show RDBR achieves higher delivery ratio with lower average delivery delay and cost than FAD and Epidemic, that confirms the effectiveness of the data delivery strategy and the buffer management scheme of RDBR. As the simulation time goes on, there are more messages received by the sink node, which results in the delivery ratios and the average copies for all protocols are increasing. At the same time, the average delivery delay for all protocols is also increasing, that because some messages, which can't reach the sink when the simulation time is short, are received as the simulation time goes by. RDBR and FAD's average copies and delay are increasing smoothly owing to their selective replication and effective queue management. However, Epidemic performs poor, for flooding results in great copies and frequent collisions, furthermore, the lack of management for the message buffer affects its network performance.

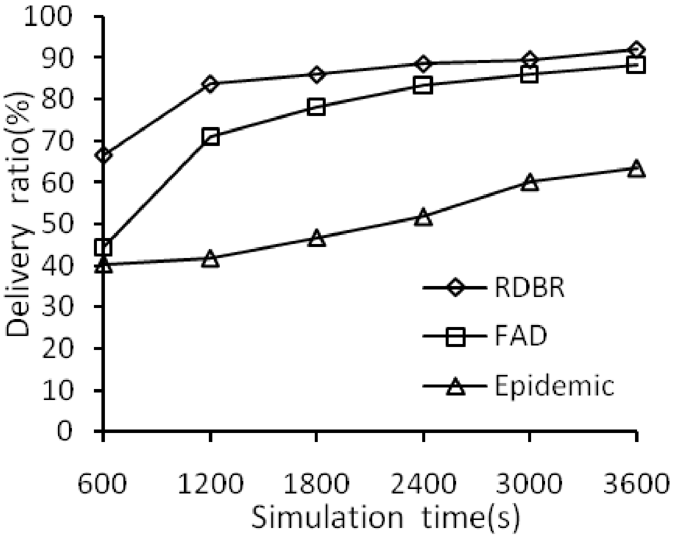

Fig. 1. Delivery ratio

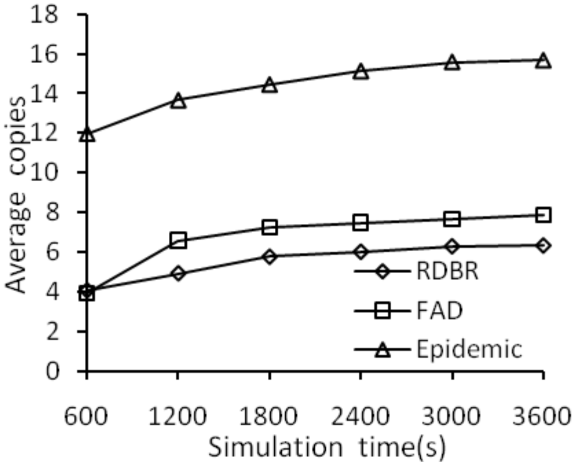

Fig. 2. Average copies

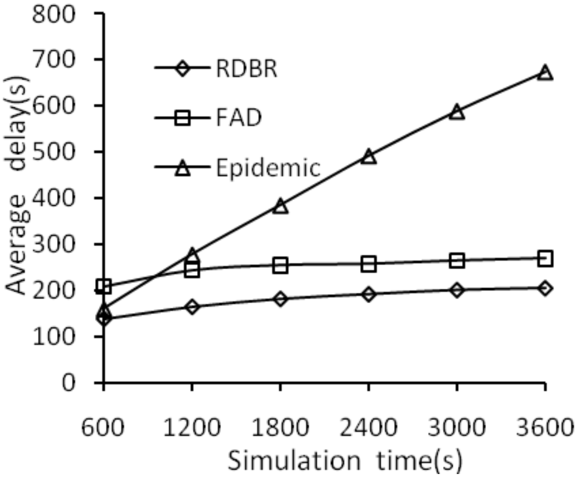

Fig. 3. Average delay

5. Conclusions

In DTMSN, sensors are distributed sparsely and intermittent connected due to the sensors mobility, sensors' data delivery abilities in short term depend more on their locations. This paper proposed a relative distance based routing strategy RDBR, in which nodes delivery probabilities are calculated according to the latest relative distance from themselves to the sink, RDBR also employ the message priority to manage the message queue. Simulation results confirm the effectiveness of the proposed RDBR. However, the reality environment may be more complex, such it may exit several sink nodes or the sink node may be mobile, so the future work is focused on the research of more effective routing scheme in the complicated environment.

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