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RMST: Reliable Multi-Segment Transport Protocol in Sensor Networks

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Abstract - The factor of reliability of data transport in the fields of wireless sensor networks is a one that has many sides and the layers concerned with it are the physical, network and transport layers. We are going to study the working of RMST protocol in this paper which would provide reasons for recommendation of this protocol at the transport layer in order to achieve the factor of reliability.

Keywords - *Wireless Sensor Network, MAC (Media Access Control) Layer, Gradient, Interest, Exploratory Path, Reinforcement Path.*

1. Introduction

Wireless Sensor Networks are helpful in places where conventional networks cannot be thought of as feasible options as the former provide an economical, sensing and computable solution for the environments. The problem concerned with reliability also gets with it the problem of energy conservation[1]. Nodes in the sensor networks have a fixed amount of energy and they cannot be recharged, so any kind of wastage of energy can lead to the shortening of their useful lifetime[2].

The constraints relating to energy and the low wireless bandwidths add to feasibility and desirability for processing in the network[3]. Evaluation of placing the reliability for transport of data at different levels of protocol stack is the main contribution of RMST and thus we consider implementation of reliability at the MAC, transport and application layers. The reliability at the MAC-level not only provides hop-by-hop recovery of error for transport layer but is also needed for route discovery and maintenance.

We develop RMST as a new transport layer for understanding the role of processing for reliable data transfer and the benefits it provides in terms of diffusion routing and traffic control. We prefer RMST for the reason that it guarantees delivery of data even when very high error rates are exhibited by multiple hops[4].

2. Proposed Architecture

RMST, since its inception was so designed that it could run along with directed diffusion. Directed diffusion[5,6] is used for multipoint-to-multipoint communication in sensor networks. Benefits of using directed diffusion are that it provides sensitivity to energy conservation, data-centric routing, also it provides a solution to the limitation of traffic volume.

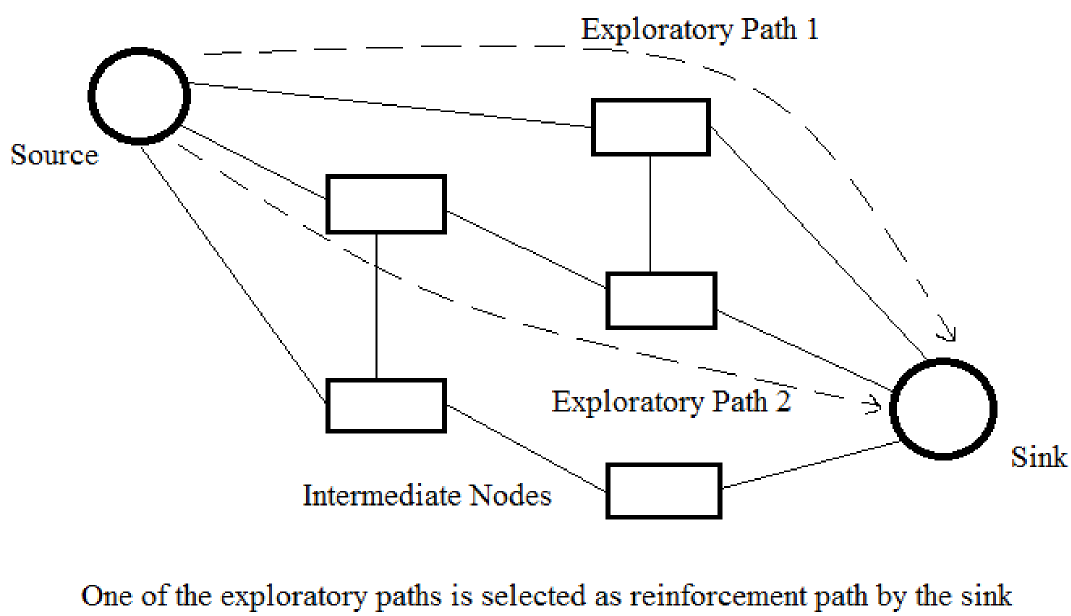

Fig 1. The representation of the network. The blocks are the intermediate nodes.

In the process of diffusion, the sink acts as a *subscriber* to an *interest.* An interest names a particular type and source of data, by means of attribute-value pairs. Sensor node possessing the data, indicates the same to the local diffusion code. All the nodes satisfying the requirements of the sink form a group which will be later on connected by a distribution tree. An interest moves towards the source from the sink. Every node through which the interest passes along the path from the sink to the source stores the same information. This information is known as *gradient.*

Corresponding to a unique interest, there exists a set of gradients. When a source node knows that it has the data that a sink is asking for, it sends the data. Such data sent in the initial stage by the source across the network, is marked as 'exploratory'. This data is sent back along the reverse paths of the gradients, which constitutes the reverse gradient propagation of data originating at source and travelling towards the sink.

Then, the sink, based on an application dependent heuristic, decides which incoming exploratory message represents the best choice for reinforcement. In this manner, single optimal reinforced path is generated. Thus, the reinforcement path is nothing but the path from the sink to the source, which will be used for traversals of the reinforcements.

Wireless sensor networks are prone to rapidly changing environments. When a sink no longer intends to maintain a particular interest, it unsubscribes from that interest. This will lead to the removal of gradients of reinforcement path elements from the network.

3. Modes

Modes of RMST

RMST works in 2 modes:

3.1 Cached mode

a. Sensor node/source node stores the sensed data in its internal buffer before transmitting the data to the next node.
b. The intermediate nodes also store the received data in their internal buffers, respectively, before transmitting it to their neighbor.
c. The above step is followed until the Sink receives all the transmitted data from respective source nodes.
d. If data packets are dropped during transmission, the receiver node sends a request to the preceding node to resend the dropped data packets.
e. The preceding node then resends the data stored in its buffer.

f. Once the node has received all data packets, the preceding node empties its buffer.
g. The above procedure is repeated for all source nodes.

3.2. Non-cached Mode

a. Sensor node/source node transmits data to next node without caching the data in a buffer.
b. The intermediate nodes transmit the data to their neighbor without caching.
c. In a similar way, the data is forwarded to the sink, via intermediate nodes
d. If data packets are dropped during transmission, the Sink sends a request to the source node to resend the dropped packets.
e. The above procedure is repeated for all sensor nodes.

4. Working

We propose a probability model which can be used to estimate the number of hops of a packet from source to destination and the reliability of the network. The parameters are defined as follows:

- n: Number of hops between source and destination. In the previous example, if the path is 1->4->5->8, number of hops is 3

- Ph: Probability of error for a single attempt across one hop.

- R: *maximum number of transmission,* which is maximum number of times that node transmit a packet. It means when the node sends a packet, it will store a copy of the packet in its buffer, and establishes a count variable with initial value 1. If the packet cannot reach destination successfully, the node will resend the packet. The variable will increase by 1 each time that the packet is resend.

- S: *number of hops of a packet,* which is the number of links that a packet has to pass to reach its destination.

- Pe: *Probability of error*, which is probability of event that a packet cannot reach its destination after using retransmission.

- ε: *maximum probability of error*, which is required threshold of Pe.

In every network, the expectation is that Pe and S are as small as possible. Our model will estimate reliability and number of hops.

First, consider the need to send a packet using one hop link. The probability of the event that a packet will reach the destination after 'i' transmissions is:

$$P_i = P_h^{\,i-1}(1-P_h) \tag{1}$$

Probability of the event that a packet cannot reach destination after R transmissions is given by:

$$P_R = P_h^{\,R} \tag{2}$$

The estimated number of hops of a packet is:

$$S_h = \sum_{i=1}^{R} iP_i = \sum_{i=1}^{R} iP_h^{\,i-1}(1-P_h) + RP_h^R \tag{3}$$

We know that:

$$\sum_{i=0}^{R} P_h^i = \frac{1-P_h^{R+1}}{1-P_h} \tag{4}$$

By getting derivative of two sides of Eq. (4), we have:

$$\sum_{i=1}^{R} iP_h^{i-1} = \frac{RP_h^{R+1}-(R+1)P_h^R+1}{(1-P_h)^2} \tag{5}$$

Using Eq. (5), we can reduce Eq. (3) such that:

$$S_h = \frac{RP_h^{R+1}-(R+1)P_h^R+1}{(1-P_h)^2}(1-P_h) + RP_h^R$$

$$S_h = \frac{1-P_h^R}{1-P_h} \tag{6}$$

To reach the destination, the packet needs to take n links. So the number of hops is:

$$S = nxS_h = n\frac{1-P_h^R}{1-P_h} \tag{7}$$

The probability of forwarding a packet successfully after R transmissions through 1 hop is:

$$P_{sh} = 1-P_R = 1-P_h^R \tag{8}$$

The probability of sending a packet **successfully** after R transmissions from source to destination is given by:

$$P_s = P_{sh}^n = (1-P_h^R)^n \tag{9}$$

The probability of sending a packet **unsuccessfully** after R transmissions from source to destination is:

$$P_e = 1 - P_s = 1 - (1 - P_h^R)^n \qquad (10)$$

So, we can see that the estimated number of hops of a packet is determined by Eq. (7) and the reliability is determined in Eq. (10). To guarantee reliability of operation, it is required that $Pe<\varepsilon$ (ε=0.01, 0.1,…). Therefore:

$$P_e = 1 - (1 - P_h^R)^n < \varepsilon \qquad (11)$$

From Eq. (11), the maximum number of transmission R is satisfied:

$$R > \frac{\log\left|1-(1-\varepsilon)^{1/n}\right|}{\log P_h} \qquad (12)$$

Thus, the value of R needs to be a positive integer which agrees with Eq. (12) and minimizes Eq. (7). The solution for this problem is transmission optimization that we need to find.

5. Future Work

We understand that it is important to apply RMST concepts in an actual sensor network. At the time of writing this paper we have begun implementation of this protocol on a system of sensor nodes which would sense temperature and transport this data to a destination node in the circuit. The actual role of RMST protocol will be implemented at the time of transportation of data over the network. This can be later used in hilly areas as nodes can be set between edged of hills sensing the movement of rocks and providing notifications wirelessly to the nearest base station in cases of heavy rock displacements or landslides. The movement of the stones can be captured beforehand and the disasters can be prevented.

6. Conclusion

In this paper we have studied the need and reasons to use RMST protocol for achieving reliability for data transport. A guaranteed delivery in sensor networks can be assured by applying a NACK based transport layer over a selective-ARQ MAC layer being the most appropriate solution. It can be concluded that RMST constitutes well for expanding the application domain of directed diffusion in areas which require guaranteed delivery and fragmentation by leveraging the strengths of diffusion and yet minimizing the amount of extra overhead required to support itself. Applications that will benefit from the capability of RMST to be dynamically configured for caching are those that have large numbers of sinks or those that require in-network processing. Thus the model made using RMST protocol will surely benefit from the others using conventional protocols.

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