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Reliable Fault-Tolerant Multipath Routing Scheme for Wireless Sensor Networks

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Abstract— Several routing schemes have been designed in the recent years for wireless sensor networks (WSN). This protocol improves the reliability of data routing in WSN networks. In future WSN networks are expected to carry different traffic such as voice and video as well as data to serve both real and non-real time applications. Therefore, the reliability and quality of the data transmitted to support diverse applications is very important. In this paper, we proposed a new on demand routing protocol i.e. Reliable Fault-Tolerant Multipath (RFTM) routing protocol. RFTM is a multi-objective routing protocol that meets diverse application requirements. Proposed protocol improves both reliability and link quality to determine the number of desired multiple disjoint paths between the sink and source nodes. RFTM routing protocol provides the fault- tolerance and achieves the desired.

Keywords— WSN, Multipath routing, RFTM routing scheme

I. INTRODUCTION

Wireless Sensor Network (WSN) consists of thousands of sensor nodes and these sensor nodes are massive, small and of low cost deployed in a monitoring area. These sensor nodes collect data from monitoring environment and transmit to base station (BS) by multi-hope or single hope communication. In this way whole sensed data are sent to the observer for its analysis. Typically a WSN consists of various sensor nodes, base station and gateway and the main objective is to sense, collect and process the information about objects in the coverage region, and then send it to the observer for processing and analyzing the information. In WSN, fault occurrence probability is very high compare to other traditional Wireless networking [1]. The main function of WSNs is to gather information about the environment and transmit the information to destination. Therefore, WSNs is mainly used for diverse applications such as environment monitoring, military surveillance, fire detection and health monitoring. In different applications, different kinds of sensor nodes are used. These sensor nodes may have different level of Quality of service (QoS) requirement that may differ according to various applications.

Multipath routing technique consists of multiple paths instead of a single path for routing. It is successfully used for maximum utilization of network resources. Multipath routing can effectively utilize network bandwidth and balances network traffic as compare to single-path routing. In this routing a node have a choice of next hop for the same destination. Multipath routing provides reduced end to end delay, load balancing, large throughput, bandwidth aggregation and can ensure high reliable data transmission, which is one of the main transmission requirements of wireless sensor networks [3].

Mostly routing protocols might differ depending on the specific applications and network architecture. WSNs routing protocol design is influenced by the network restrictions as well as some other specific metrics, such as; energy consumption. In this paper, Reliable Fault Tolerant Multipath (RFTM) routing protocol is proposed which involves fault recovery process. In this proposed protocol sensed data is transmitted through a shortest path. In case, any faulty data occurs in the network, recovery is very fast. In this paper our main purpose is to design a multi objective routing protocol (MRFTM)[2]. In this protocol, sensor nodes just need to have information of its neighboring nodes not

the whole path information. The data is transmitted to base station with minimum delay and energy loss. This technique also controls the data traffic during transmission of data to the base station. A multi-objective routing protocol MRFTM considers the link quality during data transmission to avoid poor link connectivity when choosing next nodes to route data. This protocol uses multipath routing to deliver data to sink node for desired reliability. The number of paths varies based on the level of reliability required. With the increasing level of reliability the number of paths also increases. When the required reliability is small then only one or few paths are required. The data packets are coded by source node using erasure code [5] and transmit each coded packet through one of the selected paths in order to provide degree of fault tolerance to different levels of information based on the level of reliability required. The selection criteria of these multiple path depend on different application requirements.

II. PROPOSED RFTM ROUTING PROTOCOL OVERVIEW and RELATED WORK

Reliable Fault-Tolerant Multipath (RFTM) is an on-demand routing protocol. On-demand routing enhances the security and reliability of the routing protocol and builds multiple disjoint paths using route request/reply (RREQ) phases to provide the fault tolerance mechanism due to availability of alternate path and the use of erasure coding at the source node. Erasure coding is used to increase the protocol security and reliability [4].

Route Request (RREQ) phase is started when source node wants to send a message to sink node. When this message is received by each intermediate node then each node generates and maintains its neighbors routing table and updates the RREQ message and also rebroadcasts the message till it reaches the sink node. At the end of this process multiple disjoint paths are obtained from the source to the sink as well as all paths information and the minimum available energy of a node on that path. After receiving RREQ messages the sink node collects all the information in the messages and measures the best paths depending on the required reliability. After this, the sink node starts the route reply phase. In this phase the sink node broadcasts the route reply (RREP) message through selected paths towards the source node [2].

A. Control Packets format

Source node generates its route table for a route to sink. If there is no route, Source node generates a RREQ message with the following components

- Source and sink ID
- Request ID
- Sender ID
- Desired reliability DR
- Minimum Energy Level, minimum energy available at a node
- Hop count, source node hop count=0, then increases at each node.
- Successful probability on a link [3]

Suppose a node P receives the RREQ from sink node. P node first checks whether it has received this RREQ before or not. The pairs of all the recent received RREQ are stored by each node. If P node has seen this RREQ from sink node already, P node discards the RREQ. Otherwise it processes the RREQ [6].

As shown in Figure 1, the shaded fields will be kept unchanged for the RREQ message while the other fields will be modified at each intermediate node [3].

Request ID	Source ID	Min. Energy Level EL	Sender ID	Hop Count HC	Successful Probability q_i	Desired Reliability DR	Sink ID

Figure 1: RREQ message format [3]

In this protocol second control message is Route Reply message (RREP). When sink node receives the RREQ message then the sink node broadcasts the RREP message and finding the best path to the source. RREP message consists of the following fields: Request ID, Source ID, Sender ID, Sink ID and Coding ratio, which is a measure of the desired reliability (Figure 2) [3].

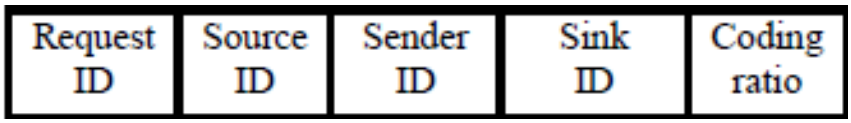


Figure 2: Route Reply Message [3]

B. Phases in RFTM Routing Protocol:

Following three phases exist in this protocol:

i) Route discovery
ii) Route Reply
iii) Multipath construction

i) ROUTE DISCOVERY

The RFTM routing protocol uses route discovery phase to discover the nodes routing for multiple routes to a given destination. This phase started when the source node has data packet to transmit to the destination [10]. At the end of this process multiple paths are obtained from the source to the destination as well as all paths information. After receiving RREQ messages the destination node collects all the information and measures the best paths depending on the required reliability. After this, the destination node starts the route reply phase.

ii) ROUTE REPLY

In this phase the sink node broadcasts the route reply (RREP) message through selected paths towards the source node [11]. Data transmission takes places when the source node receives the destination decision carried by the RREP message on the number of paths to transmit data.

RREQ message reaches the destination with a valid route, that destination node responds with a Route Reply (RREP) message. This RREP message travels to the source along the reverse path [7]. All nodes that route the RREP message to the source also make corresponding forward information in their routing table such that the next hop to the destination is the node from which the RREP message was just received by the source. After receiving the RREP message, the source node starts sending the data to the destination. Each RREP message contains the destination sequence number, which is used to prevent routing loops.

iii) MULTIPATH CONSTRUCTION

After the Route Discovery phase, each node possesses their neighbor information and then the Multipath Construction phase starts[8]. Because the source node location is known to the destination and based on the location of the source the destination starts the route request process. There are two types of nodes primary and alternate. The primary nodes find two paths towards the source; the primary path and the alternate path[9]. The primary path is built with the best possible neighbor and the alternate path is constructed with the next best neighbor. The alternate nodes find one single path towards the source node.

III. SIMULATION AND EVALUATION

In this section, we simulate the performance of our routing protocol using MATLAB. In our simulation we use various metrics to evaluate the performance of proposed routing protocol.

1) Data Delivery Ratio (DDR): DDR metric indicates the end to end successful transmission. The greater value of packet delivery ratio means the better performance of the protocol. Data Delivery Ratio can be represented as:

$$DDR = \frac{\text{packet received at the sink}}{\text{packet generated by the source}}$$

The result for this metric for different network size is 50 to 200 with different initial energy. Figure 2 shows the effects of initial energy on the reliability of the network. This figure shows that how the data delivery ratio increases with the increase of initial energy (IE) and number of nodes in the network.

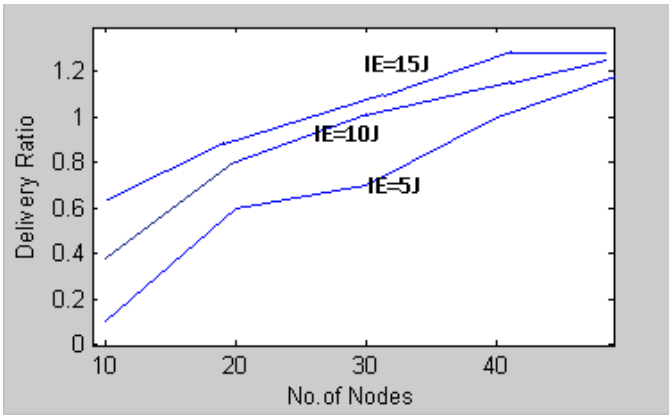
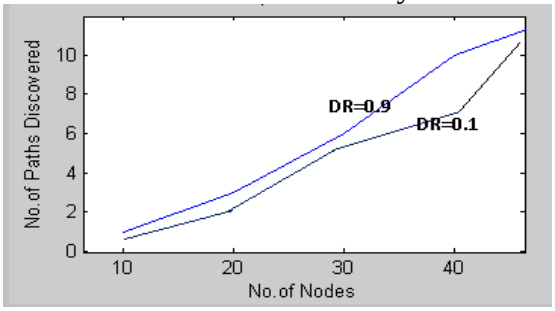


Figure 3. Average Delivery Ratio

2) Number of Paths Discovered: When Mobility of nodes is increases then the average number of path also increases. When node reaches the maximum value then the path between the sources to destination is found for all nodes. After the source has received a path to the destination, it sends the data packet on it. Figure 4 represents the average number of paths discovered between the source and destination. Number of paths discovered is related to the number of nodes and desired reliability. For different number of nodes the path number does not affect the reliability since the erasure coding is used.



Fgure.4 Number of Paths Discovered

3) Energy Consumption: This metric measures the average energy dissipated by the node in order to data packet transmission from source to destination. It measures the network lifetime. Energy consumption is defined as the difference between the initial level of energy (E_{int}) and the final level of energy (E_{fin}) that is left in the node.

$$(E_{consp}) = E_{int} - E_{fin}$$

Thus the average energy consumption (E_{avg}) is given by:

$$(E_{avg}) = \sum_{i=1}^{N}(E_{consp}) / N ; \qquad N = \text{number of nodes}$$

Figure 5 show that more reliability demanded consumes more energy in the network. Thus, in proposed routing protocol data transmission reliability obviously increases while node energy consumption increases.

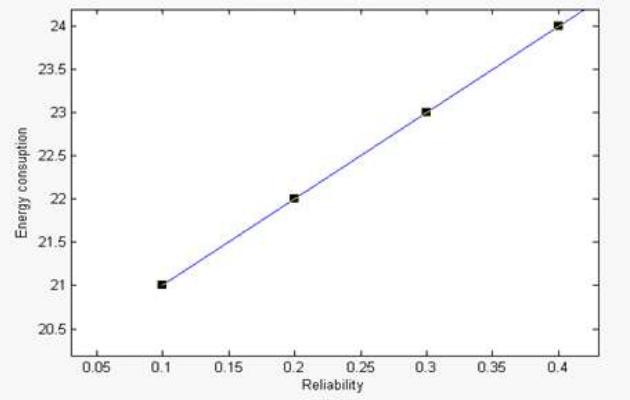


Figure 5. Energy Consumption

IV. CONCLUSION

New reliable fault-tolerant routing protocol for wireless sensor network is presented. The main objective of this protocol is to provide a reliable path for data transmission with a minimum network overhead. We introduce different metrics such as delivery ratio and energy consumption which are used for path selections by the destination node to meet the applications reliability requirements. This protocol uses multipath routing to deliver data to destination for desired reliability and the number of these paths is different for the level of reliability required.

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