A Routing Protocol to Evade Congestion in Time Critical Events in Wireless Sensor Networks (ECTCE)

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Abstract— **Many applications of Wireless Sensor Network (WSN) are designed for vital event monitoring and to ensure timeliness and reliability for the measured environmental values. The communication protocol needs to prioritize the real time data and ensure the timely delivery of the data to the sink node. In this paper, a routing protocol for WSN has been proposed in congestion and delay aware manner to realize highly reliable and timeliness information delivery to the sink. In case of congestion occurrence, it is mitigated by data rate adjustment. The effectiveness of the proposed protocol depends upon how successfully the management packets are delivered, which carries the vital congestion and delay information. A simulation is conducted to investigate the result of the proposed protocol. The results of the proposed protocol have been compared with the similar known techniques and better results are observed.**

Keywords- Wireless Sensor Network (WSN) ,Relaibility ,Timeliness, Congestion Mitigation.

I INTRODUCTION

A typical WSN may consist of tens to thousands of the sensor nodes and these sensing nodes are deployed in a particular field where they work together to accomplish a particular task [1]. In general the sensors are deployed in the remote and inaccessible areas. In order to achieve proper functionality, the sensors require continuous power supply and hence these sensors have their own inbuilt power supply, but it becomes very mammoth work to replace the battery after depletion of the energy. The existing research works have emphasized only on the energy consideration for a WSN [2]. The most expected and desired factors are reliability and timeliness. There are many situations like fire detection, where the reliable and timely data communication becomes very important where we get temperature data of the nodes that are high compared to the threshold temperature. Here, information delivery success rate of those crucial nodes is equally important because of the energy effectiveness. But reliable information delivery is inherently correlated to congestion. Congestion within the network causes packet drop that reduces the reliability of information transmission [3]. It is required to get a proper congestion management technique to realize the specified level of reliability. In case of event sensing WSNs, time crucial reliability of transmitted information is important. Some real time event will be controlled with minimal effort if the event is detected early. Beside the congestion management, a delay aware routing of information is required in these phenomena to meet the time criticality in order to make early detection of events feasible. In this paper, applications where sensor nodes are deployed in ad-hoc manner to detect crucial events in the deployed space are considered. All sensor nodes forward their information towards one static sink node.

A routing protocol is designed that proactively avoids congestion and meets delay needs of transmitted information by selecting gently loaded and low delay incurring nodes during information forwarding towards the BS. All nodes broadcast periodic management information packets describing the congestion status and delay measurements in order that the neighboring nodes will utilize this information throughout route discovery process. The performance of the proposed theme is very avid about the successful delivery of those management packets. Special effort has been created to enhance the success rate of those control packets. The proposed protocol additionally contains a congestion mitigation technique. A feedback from the MAC layer is sent to the network layer regarding the achievable information forwarding rate. If the application layer contains a higher traffic generation rate, the protocol suggests the application layer to lower its rate. The network layer merely drops an applicable fraction of packets received from different nodes if the incoming rate is more than the data forwarding rate of MAC layer. In this paper, our primary objective is to improve the reliability and the timeliness of data transmitted by the vital nodes (i.e., nodes close to the current event) through congestion avoidance and mitigation. The rest of the paper is organized as follows: section II provides a discussion on relevant existing works; section III thoroughly explains the design issues of the proposed protocol whereas its performance has been examined in section IV and finally section V presents conclusions on this research work.

II RELATED WORK

Every WSN communication system is considered with the priority to mitigate the congestion as soon as it emerges. Many of the protocols which are mentioned in CODA [4], Siphon [5] and TARA [6] mitigate congestion rather than avoiding it. Congestion in the communication pathway causes the drop of packets and thus the reliability of the WSN communication system is reduced. The technique like congestion avoidance plays a vital role in mitigating the drop of packets. RTMC [7] provides a reliable transport with memory considerations of the nodes. A node defers transmission till it gets a node with free buffer area. Although, the authors claim to realize congestion management, actually they avoid congestion without considering delay in data transfer. CAM [8] provides a routing protocol that tries to avoid congestion to confirm successful event detection similar to that of RTMC. The theme assumes that a high variety of vital packets (packets sent by the nodes close to an event) have successfully reached the sink node because of the successful detection of critical events. But generally it will not consider the delay of those packets. In most cases, an event packet reaching the destination or the sink has some significance only if it reaches within the required deadline. Moreover, the performance of the protocol depends on periodic neighbor node management table broadcasted by nodes; however the theme has no special technique to confirm successful delivery of the broadcasted messages.

The technique presented in Residual Time Aware Forwarding for Randomly Duty-Cycled Wireless Sensor Networks [9], deploys the residual-time-aware routing where every sensor node is static and randomly duty cycled of alternative nodes. The scheme is applicable when only one node within the network acts as a knowledge source. Moreover, end-to-end knowledge delivery is not guaranteed. It cannot be employed in event detection system where end-to-end data delivery from multiple vital nodes is crucial. In EARQ: Energy Aware Routing for Real-Time and Reliable Communication in Wireless Industrial Sensor Networks [10], Heo et al. gift a routing protocol where every node considers energy, delay and reliability of its neighbors to choose an acceptable route. Nodes periodically broadcast beacon messages to exchange management knowledge with neighbors. Here, the successful transmission of the beacon message is the key factor which influences the performance of the protocol. The protocol considers IEEE 802.11 DCF as its MAC protocol, however does not take any special effort to ensure successful transmission of beacon messages which may get collided and also the performance of the protocol can be considerably degraded. On the other hand Munir et al. proposes a mathematical model which may play a vital role to reduce the delay within the network through the selection of appropriate transmission scheduling and is described in Distributed Algorithm for Minimizing Delay in Multi-Hop Wireless Sensor Networks [11]. This model is suitable where the sampling process is incorporated by individual transmission schemes. There are certain scenarios or the occasions where the sampling process of some nodes changes abruptly in response of certain events and thus the mentioned model does not work well, additionally the model is computationally expensive. So the model will be applied to networks with few nodes and hence cannot be used for large WSNs for event sensing. SPERT [12] provides an energy aware real-time routing protocol. In order to decide the optimum acceptable route, every node uses the energy level and hop-count of its neighbor node. Hop-count of a node suggests the number of intermediate nodes required to transmit the packet to sink node or destination. This protocol uses hop-count of the node to measure the delay of the node, which may not be suitable for large WSNs. Because of congestion around a selected event, every link can have a unique delay associated with it. Hop-counts of neighbors are obtained exclusively once during the network setup, however energy levels of neighbors are obtained periodically through management messages sent by neighbors. CAM [8] and EARQ [10] protocols will not take any special effort to enhance success of management messages.

All schemes in [9 - 12] treat all the data packets with equal importance. However the consideration is that the nodes that are near to the critical events and provided with high generation rate. The remaining nodes will generate the data with a normal generation rate. Our protocol aims at routing the critical data in congestion and delay aware manner in order that the vital data will reach the destination or the sink node timely which is crucial for successful event detection.

III CONGESTION AND DELAY AWARE ROUTING

Here a Routing Protocol to Evade Congestion in Time Critical Events in Wireless Sensor Networks that tries to enhance congestion control in the nodes that are close to the critical events and additionally tries to scale back the latency of those time critical data is designed. A static WSN with one sink node where nodes generate monitoring or regular data with a low generation rate is considered. Once a node senses a critical event, same nodes generate critical data packets with a higher generation rate. To detect the event successfully, the sink node should receive a high range of critical data packets. Moreover, each vital data packet should reach the destination within a certain time after its generation. Delay of normal data arriving at the sink node or the destination is not harmful. The critical data generating nodes are known as vital nodes and alternative nodes are known as normal nodes. When the event is no longer critical, the vital nodes would become normal nodes.

A. Evasion of Congestion

The assumption is that all nodes have the same fixed transmission power. Contention based MAC protocols are considered as they are faster in event notification. The efficacy function is described in algorithm 1:

Algorithm 1:

Step 1: find the ratio of distance of the next node (say e) towards the BS from the node B to the maximum distance that can be covered by the transmission power of each node.

Step 2: multiply the ratio derived in step 1 by a constant β and $0 < \beta < 1$.

Step 3: find, HR_e which is the hit rate of node *e* defined as the ratio of the number of packets transmitted from MAC layer to the number of packets forwarded from network layer to MAC layer over a small period.

Step 4: multiply HR_e by $(1-\beta)$.
Step 5: add the results in step 2 and 4 to get the efficacy function f (e).

To calculate *f* for each neighbor *e*, node *B* needs the values of D_e and HR_e. The protocol assumes that each node knows its location. Each node *e* can broadcast its location and *HR* value using control packets after receiving a fixed number of packets from other nodes or after a fixed interval whichever is earlier. With its own and *e*'s locations, *B* can calculate D_e.

IV RESULTS AND DISCUSSIONS

In order to investigate the performance of the protocol, it is compared with similar protocols like CAM [8]. But on the other hand CAM considers the critical data as delay insensitive which is not true in many cases of critical events. But the proposed protocol ensures high success rate of delay sensitive critical data. In distance vector based schemes the focus is on routing the data based on the distance to the neighboring nodes. In the proposed scheme the routing is based on distance as well as node status. This would improve the success probability of the vital packets and increase the reliability of the protocol.

A Proposed Simulation Environment

In this simulation 100 sensor nodes in an area of 100 meter×100 meter with uniform node distribution are placed. An ideal environment is considered and also energy expenditure is considered only during transmission (as energy loss during reception is low). The protocol employs 1 Mbps IEEE 802.11 DCF MAC protocol. Both critical data generation and regular data generation are considered. In this protocol, $\beta = 0.50$. The simulation was done using wsnbase which is a WSN toolbox for MATLAB.

B Proposed Simulation Results

The protocol is made to explored three different scenarios. In the first scenario, transmission ranges of every node and the critical data generation rate are kept fixed whereas the regular data generation rate is varied. Transmission ranges of nodes and the regular data generation rate stay constant whereas the critical data generation rate is varied in the second scenario. In the third one, data generation rate is constant and transmission range of nodes is varied. Packet success rates and average packet delays of each regular and vital nodes are measured in each experiment. Lifetime of the network is limited by the utmost energy employed by any node within the network.

V CONCLUSION

In this protocol a simple and sophisticated architecture or method to ensure the optimum node density distribution in the inaccessible area has been designed. The protocol presented in this paper has the potential to scale back congestion by avoiding congested nodes throughout route discovery process and conjointly by dropping of futile data packets. It provides high success rate by accurately adjusting the data rate of a node throughout congestion mitigation. In achieving its success, this protocol utilizes congestion parameters into routing and at the same time, it works in a distributed manner because it wants management data solely from neighboring nodes. It conjointly endeavors to provide higher success rate of management packets that will increase its reliability. Simulation results show that this protocol provides significantly high success rate and low average packet delay of critical data that eventually leads to reliable and timely event detection. Future study can focus in enhancing the success rate of the control packets reaching the BS by improving the value of efficacy function. As individual nodes are located at completely different locations of the network, completely different values of β for various nodes may accurately sense the node's congestion level and that in turn might facilitate higher congestion management.

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