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Congestion Control in Healthcare Wireless Sensor Networks- A Data Centric Approach

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Abstract:**The emergence of wireless sensor networks was a revolutionary movement in the field of technology. Wireless sensor network- a collection of sensor nodes, each with its own sensor, connected via a wireless medium provides a unique ability to examine the physical world accurately. Wireless Sensor Networks have found their application in various areas ranging from medical to military, and from home to industry. One among such applications includes the healthcare environment. Here, the wireless sensor networks are set to continuously monitor the physically ailing patients. The healthcare environment loses its quality due to packet loss which occurs as the result of congestion in the network. Other problems like high energy utilization, longer delays etc cause serious risks in the healthcare environment where a zero level of tolerance is expected. The congestion kept under control helps to increase the life time of sensor nodes. In this paper we analyze various congestion control techniques and propose a technique to control congestion thus decreasing packet loss and delay in network.**

Keywords: WSN, Healthcare, Congestion Control

I. INTRODUCTION

Wireless sensor networks emerged as a ground breaking technology offering unprecedented ability to monitor the physical world with at most accuracy. WSNs found their applications in areas like military, health, agriculture, machinery, environment, aerospace and many other office domains. Each domain demands its own characteristics and features. Some domains can tolerate a certain amount of packet loss and delay in the network. But when it comes to healthcare we expect an operation with zero tolerance. Wireless sensor networks for healthcare emerged because of the need to collect data about patients' physical, physiological, and vital signs in the spaces ranging from personal to hospital and availability of the low cost sensors that enables this data collection. Healthcare aware Wireless Sensor Networks (HWSNs) have received a great attention due to the properties of WSNs such as reliability, interoperability, efficiency, low-power consumption and inexpensiveness. Congestion becomes a crucial factor here. Congestion leads to problems like packet loss, increased delays, decreased throughput etc.Healthcare WSNs carry critical data whose lose cannot be tolerated. Hence some efficient methods are to be adopted for congestion control.

In Wireless Sensor Networks, packet loss due to congestion cannot be eliminated, but can be mitigated. We need a study on the various congestion control algorithms and the techniques they use to control congestion, so that the packet loss can also be lowered. We conducted a survey over the various congestion control techniques being used for WSNs and based on this result we are proposing a simple algorithm for congestion control.

In WSN, all sensor nodes periodically report data to a single node called the sink node. The individual sensor nodes are called motes. The main purpose of motes is to take the data from environment in which the application is deployed and convert it into signals. These signals are then forwarded to sink node. Sink node is the parent node for many motes. It collects information from motes linked to it and forwards it to the appropriate destination.

The communication in WSNs has two components: An Upstream traffic and a Downstream traffic. While upstream traffic refers to the data flow from the individual sensor nodes or motes to the sink node, downstream on the other hand refers to the data flow from sink node to the motes. WSN are believed to follow a hierarchical structure and hence the upstream traffic tends to converge as it moves towards the sink node. Enormousincrease in data transfer from various sensor nodes leads to a high bit rate which in turn leads to congestion in the network. Congestion results in deterioration of the energy efficiency of the sensors. In healthcare applications where strict constraints exist on the energy level of sensors, congestion usually results in frequent replacement of sensor nodes by other sources.

Problems like packet loss, delayed arrival of packets etc are also to be addressed. Existing congestion control protocols do not take care of these issues.

We conducted this survey with the aim to find out a better solution to control packet loss and buffer drops.

II. LITERATURE SURVEY

Congestion control in WSNs has gained high importance in the field of research. A detailed survey on congestion control techniques reveals that the main aim of those techniques is to prevent the network from a congestive collapse - a situation where in all the paths in the network are congested and the whole network is doing very little useful work.

Any transport protocol operating in the WSN environment has 2 main components in its congestion control framework – Congestion detection and Congestion avoidance. Congestion detection is crucial because if congestion detection is accurate, appropriate congestion control algorithms and techniques can be applied.

An extensive survey on various congestion control techniques revealed that majority of them are designed based on either upstream or downstream traffic or a general design not specific to any traffic. A thorough study on various congestion control algorithms being used nowadays reveal that most of them focus in adjusting the rate at which packets are sent from a sensor node to the sink node upon the occurrence of a congestion. Most of the current protocols lack an appropriate queue management system, which if implemented increases the system throughput.

An efficient congestion avoidance scheme for mobile healthcare WSN introduced in [2] provides a innovative approach by incorporating a learning automaton wherein a automaton responds to a previously saved set of rules or dynamically adapts to the changing environment. The LACAS (Learning Automaton based Congestion Avoidance Scheme) serves as an efficient algorithm for reducing delays and being fair to all nodes by avoiding buffer drops. LACAS learns from its experience and can react to changes in the network significantly. LACAS is implemented in the nodes for mobile healthcare to address congestion avoidance. Adaptive rate control algorithm (ARC) [5] keeps track of how packets are being introduced in the traffic and also notices the transit of traffic through sensors. The scheme splits the bandwidth proportionately between transit traffic and locally generated traffic. Higher priority is given to local traffic. Hence the bandwidth allocation would become approximately fair. In rate controlled reliable transport protocol (RCRT) [6] a negative acknowledgement (NACK) based scheme is used; It uses end to end explicit loss recovery. The protocol is specifically designed for applications that are loss intolerant. The sinks in the network play an important role for this protocol to function efficiently since all the technicalities of congestion detection and control is implemented at the sink. Interference Aware Fair Rate Control Protocol (IFRC) [7] uses the length of queue in order to determine the number of packets at different intervals of time in order to find out if congestion has occurred.

Many researchers have proposed congestion control techniques based on priority some of which are summarized as follows: An upstream congestion control protocol for WSNs is proposed by Wang et al [9] in which they make use of node priority index which determines the priority of each sensor node. They introduce a cross layer optimization and make use of hop by hop approach to control congestion.

Another node priority based congestion control protocol for wireless sensor networks is proposed by Chonggang et al [11]. Along with node priority index, packet inter arrival time is calculated along with packet service time to determine the congestion degree of each node. Liqiang et al [12] proposed a different strategy for controlling congestion called Enhanced congestion detection and avoidance which consists of three important modules. The first module implements congestion detection by using buffer and weighted buffer difference. The second module takes care of the rate at which the source sends data and the third module uses queue scheduler to transfer packets. This is an energy efficient congestion control scheme.

Padmashree et. al. [16] proposes a simple congestion control method by initially sending HELLO packets and finding out the distance between source and sink. Then a threshold value is set slightly higher to the so found distance value. This is set as the time out value and the next packet is sent only after this threshold value expires, thus avoiding congestion.

Abbas Ali et. al. [17] presents a more intelligent approach for congestion control in healthcare WSNs. They propose a data centric approach for congestion control. It consist of two phases: a congestion detection phase and a congestion control phase.

III. PROPOSED ALGORITHM

As foresaid, congestion control in healthcare WSNs is a critical task. Healthcare WSNs are set to continuously monitor and collect data from physically ailing patients. Sensor nodes are worn on the body and these nodes collect the behavioral, physiological, information from the patients on a regular basis. They have internet technology interference too which allows data from various sensor nodes being collected together.

The National Institute of Health [NIH] Genes and Environmental Initiative have set their goal in developing field deployable sensing tools to collect data related to environment such as diet, physical activity, stress etc [13]. Under their Genes, Environment and Health Initiative (GEI) they have two components which are Genetic Program and Exposure Biology program. Exposure biology program is an environmental technology development program to produce and validate new methods for monitoring environmental exposures that interact with genetic variation to result in human diseases. GEI also invests in innovative new technologies to measure environmental toxins, dietary intake, and physical activity, and to determine an individual's biological response to those influences.

Healthcare WSNs have made a significant impact in the areas such as sleep anea where the blood pressure, breathing and heart rate of patients are monitored, data collected and stored when they are asleep and awake. If any substantial increase in data value occurs an alert can be provided. WSNs provide with various features like, if the patient is at home, the heart rate is regularly monitored and the recorded data is sent to the physician. Also in case of emergencies, an automatic call may be generated via the communication system.

While analyzing the existing protocols we realized that as the number of patients in casualty incidents increases, there occurs an abrupt decrease in the accuracy of data in the network.

Congestion control algorithms are classified as source based or network based[17]. Source based algorithms are deployed at the end host where the transport protocol is responsible for detecting congestion in the network. Network based algorithms, on the other hand, are implemented in the intermediate network devices, especially routers. Based on the degree of congestion detected in the network, source based algorithms adapt the rate at which the application is sending traffic. This mechanism, more popularly known as end to end congestion control is employed by transport protocols such as the Transmission Control Protocol (TCP). In network based algorithms, the intermediate network equipments are responsible for detecting oncoming as well as subsisting congestion and provide feedback to the sender forindicating the situation. Source based algorithms work well for traffic that is responsive to congestion e.g. TCP traffic. However non-sensitive traffic e.g. User Datagram Protocol (UDP) trafficmay still cause congestion due to its greedy behavior. Thus, the need arises for network based congestion avoidance and control mechanisms.

There are different factors involved in the design of transport protocols for sensor networks: congestion control and reliable data delivery. Since most data move from sensor nodes to the sink, congestion is likely to occur around the sink. In order to increase the speed of the connection process, improve efficiency and decrease transmission delay; sensor network transport protocols should facilitate the process of the initial connection or use protocols without connection. Most applications in wireless networks are passive, meaning that the network is monitored inactively and waits for an event before sending data. When an event occurs, this application may have quantitative packets to send.

We try to address the problem of congestion by proposing a new approach to avoid it. In this approach, congestion will be avoided by distributing packets through multiple routes and if congestion still occurs, we run a novel congestion control algorithm.

Basically, two factor causes congestion in sensor networks. The first is when the packet arrival rate is higher than packet service rate which occurs mostly in nodes closer to the sink. The second is the performance at the link level including competition, collision and bit error. This type of congestion occurs on the link.

There are different congestion detection methods thatare employed in wireless sensor networks. Onecommon mechanism is the use of queue length,packet service time or the ratio between service time and the time between packets in an intermediate node. For sensor networks using MAC layer protocols such as CSMA, channel load can also be used as a tool for congestion detection. When congestion is detected, transport protocols transfer congestion information from the congested nodes to other nodes on the route to the sink or the source nodes that have had a part in detecting congestion. Sensor nodes can adjust their sending rate after receiving congestion notification.

In most of congestion control methods, the rate of packet sending is reduced immediately after congestion occurs and the lost sensitive packets are tried to be retrieved. This need of an extra buffer in the previous nodes in order to keep the packets in it until receiving acknowledgment for them make these methods costly. Also, this makes sensitive traffic streams to reduce their sending rate.

In the proposed protocol, we have developed a congestion avoidance phase in which several paths are made primarily and the nearest one is allocated to sensitive traffic. Having multiple paths makes the traffic streams be distributed among them fairly based on their sensitiveness. This leads to less probability of packet loss especially for sensitive packets and hence less probability of sensitive packet rate reduction. The mentioned problem is more critical for the sensitive applications like health care in which the rate of sensitive data packets hasn't to be decreased.

Also, we try to allocate an appropriate bandwidth for sensitive traffic along with using (PQ) priority queue approach in every node's output while servicing. This means that the more sensitive a packet is the sooner it is serviced. Our proposed protocol, results in reduction of packet loss rate for sensitive data packets and consequently reduced delay for them until reaching destination. In this protocol, through a congestion control problem, some QoS parameters like delay, packet loss and network lifetime are compared with respect to the other methods. In the applications like healthcare, these parameters are very considerable because dropping of a sensitive packet may leads in a patient death. Also, in such application, delay in packet arrival will cause later decision and hence harming the patients. This is more noticeable in patients bedridden in ICU. If the battery of a sensor attached to a bedridden patient in ICU is discharged earlier than normal just when there is a fluctuation in his vital signs like blood pressure or hear beat, the patient's life can face a serious risk. The proposed protocol is composed of two main parts, routing and congestion control. Proposed routing protocol is a data centric protocol which is designed for congestion management in wireless sensor networks for healthcare applications. The main objective of the proposed protocol is to avoid, or if not possible, control congestion in wireless sensor networks.

The proposed protocol works in the following phase:1) request dissemination which is performed by thesink, 2) event occurrence report which is performedusing packets that are forwarded from sensors located on patients body to the sink, 3) route establishment,4) data forwarding and rate adjustment in case of congestion occurrence.

First, the sink (the telemedicine center)[17] sends its requirements (required information) to network nodes (sensors connected to the patient's body). In the meantime, any network node observing the event specified by the sink, will inform the sink with an event report (patient's condition) using the phase 2 procedure. In the second phase, the initial routing tables are formed. These tables are then used in the third phase where different routes are chosen in the final routing tables. The final tables are produced in the third phase depending on the priority of the transferred data. The fourth phase is the data forwarding phase in which the data recorded from the events observed by nodes are given to the sink. A large volume of data is moved in this phase; therefore a procedure for congestion control is needed. Here, the congestion control includes two components: congestion control and congestion avoidance. Congestion avoidance is realized using the distributed routing algorithm. Congestion control and network degradation avoidance can be achieved using the AQM (Active Queue Management) techniques.

In the event occurrence reporting phase, the information related to the occurringevent is sent to the sink, however basic data related to the event are sent in the data forwarding phase. Moreover, the preliminaries of packet routing are also determined in this phase. For this purpose, the patient node creates a packet containing the information related to the sensed event and sends it toall its neighbors. Since nodes (patients) are aware of their own positions the packets are sent to the neighbors that are closer to the sink than the sender.The routing tables required for the routing of node data in the route from the packet to the sink will beprovided. And the final routing will be carried out in the route forming phase.

After the arrival of phase 2 packets at the sink, a type3 confirmation packet is sent to the source node bythe sink which notifies the source node to send itsdata to the sink for processing. Then, sensors from one or more patient(s) may send messages. In this stage, the sink chooses one or several nodes for the final transfer of data based on the information sentfrom source nodes. In phase 2 packets, each node specifies the level of its importance. For example, the heart beat sensor connected to the patient's foot sends a message to the center andspecifies the level of importance. The sink chooses the source node for the patient's report based on thespecified level of importance. Following the selection of the source, phase 3 packets are sent. As the phase 3 packet moves along the route, it creates a phase 3 routing table. Phase 3 routing table is the final routing table for routing the data sent from the source. The transfer confirmation depends on the priority of the sensed event. When a node receives a phase 3 packet with high priority, it creates a highpriority record for the packet in the phase 3 routingtable. This table consists of the followingcomponents: sender (the source node of the receiving phase 3 packet with high priority), receiver (the destination node for the phase 3 packet with high priority), source node (the node sensing the eventwhich is the final destination of the phase 3 packet) and type of application (this component will be usedin networks designed for multiple applications).

The proposed AQM works as follows: -In a WSN, asensor node should first determine its distance to the sink node by initially sending a HELLO packet [16]. The sensor nodes along with its original functionality should be designed to have a timer module. The timer begins as soon as HELLO is sent. The HELLO packet determines the time required to reach from sensor to sink node. We now calculate a threshold value such that, the value lies a little greater than the value received on calculation. After the threshold value is reached the next packet is sent to the sink node. This way, the load on the networkis reduced.

IV. CONCLUSION

The main challenge for healthcare WSN application is reliability and efficient data transfer. We aim to focus on addressing congestion control by congestion avoidance. We try to use a novel approach when congestion cannot be avoided. We try to realize the aim by adopting the proposed data centric approach. Our future work would concentrate on developing an algorithm for the proposed method and then simulating the network to obtain results upon an efficient simulator.

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