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Data Collection with Power and Buffer Consideration in Monitoring Sensor Networks

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Abstract With the rapid advance in micro-processor and wireless communication technology, it is possible to produce the cheap and tiny sensor nodes. In a wireless sensor network, huge amount of sensor are distributed over a large area. Sensor data are relayed from sensor node to node until they reached to the sink node. In this paper, we study the effect of data collection on the power and buffer of a sensor node and on the overall sensor network. We first determine the relationship among packet trasmission, source rate, buffer size, etc. We then propose buffer management policy that is truly efficient in utilizing limited power and buffer of sensor node.

Keyword power consumption, wireless sensor network (WSN), buffer utilization.

1. Introduction

Wireless sensor network (WSN), shown in Figure 1, is a network composed with a large number of micro-sensors and a sink for data collection [1]. WSNs have a wide range of applications in monitoring of a specific target area such as data acquisition, target tracking and environmental monitoring [2]. In the monitoring applications, huge number of sensors are scattered in the application area and different sets of sensor nodes are assigned to collect the different readings from its sensing environment. Those sensor readings are needed to be collected for further processing at the sink node.

Accordingly intermediate nodes in sensor network need to forward the data originating from multiple sources. Due to the limited memory, the buffer of intermediate nodes may start overflowing and it will result in loss of valuable packets. As a consequence, retransmission of the same packet will be required and resulted in unnecessary power loss. Since battery power and memory are available in very limited amount, efficient use of available buffer and power is highly desirable in WSN [3][4].

The packet format used in WSN is similar with the packet used in wireless ATM network [5] since both of them have fixed length packets. Despite the similarity between WSN and ATM networks, buffer utilization approaches for ATM networks proved not to be suitable to sensor networks. This is due to different requirements for ATM and sensor networks in several aspects. For instance,

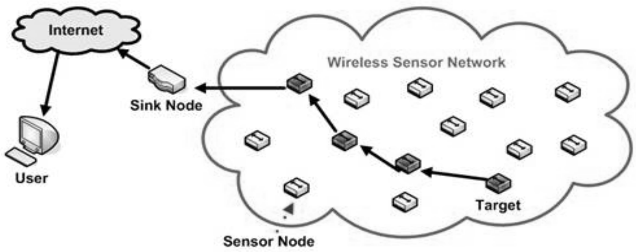

Figure 1. Wireless sensor network.

communication in sensor networks is from multiple sources to a single sink which is not the case in ATM networks [6]. Moreover, there is a major power resource constraint for the sensor nodes. Thus, the important problem of buffer management for resource-constrained WSN remains largely open.

In this work, we propose power-efficient buffer management policy for data collection in monitoring sensor networks. The major difference between our scheme and conventional one is in that we consider sensor network as multi-layer network [7] while conventional one considers the whole network as a single layer network.

The remaining of this paper is organized as follows. We first discuss the existing problems in Section 2. Section 3 describes the key idea of our proposed method for efficient use of limited power and buffer of the sensors. Simulation results and discussions are presented in Section 4. Finally, we conclude our paper in Section 5.

2. Problem Statement

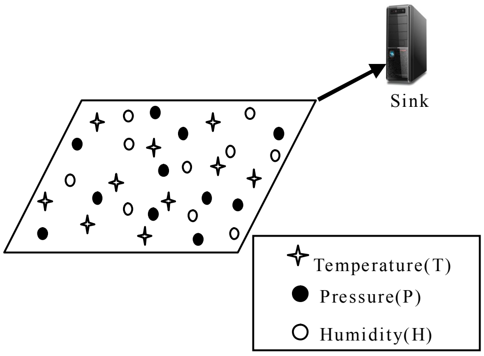

Figure 2. Monitoring sensor network application.

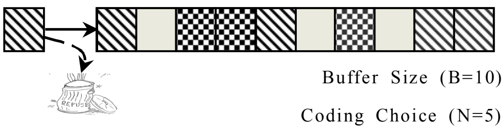

Figure 3. Buffer overflow problem at intermediate node.

One of the challenging subjects and design constraints in WSNs is efficient power consumption. Since a sensor node is a microelectronic device, it can only be equipped with a limited power source. In most application scenarios, replenishment of power resources might be impossible or infeasible. Furthermore, most of the application based on long time monitoring directly affects the network efficacy and usefulness. Knowing that power efficiency is a vital part of performance in sensor networks, people studied the power consumption of different operations in sensor nodes and tried to find suitable sensor node protocols to reduce power consumption [8][9].

In the conventional monitoring sensor network as shown in Figure 2, the whole WSN is considered as a single layer, and thus, each sensor node is responsible for relaying all the sensor data to the sink node. In fact, an intermediate node may receive multiple packets from its neighboring nodes in the process of shipment of data to the sink and it will be heavily loaded. As a consequence, due to limited memory, the buffer of intermediate node may start overflowing as shown in Fig.2. This will result in lost of important packets and retransmission of the same packets will cause unnecessary power loss. Moreover, the power consumed during transmission is the greatest portion of power consumption of any node. Since the performance of the WSN highly depends on life-time

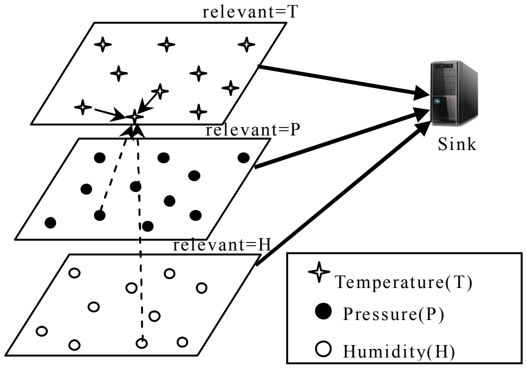

Figure 4. Proposed 3-layer WSN.

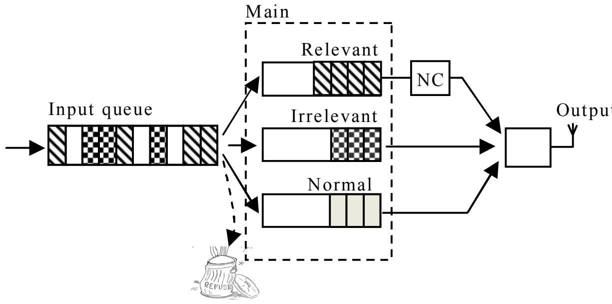

Figure 5. Buffer management policy for proposed 3-layer WSN.

of the sensor nodes, the power consideration has a great influence on buffer design of resource-constrained WSNs.

In [10], a buffer management scheme called most redundant drop (MRD) was proposed that makes use of spatial information in sensor data to improve the network coverage. MRD assumed that if the nodes are close to each other, there will be a large degree of redundancy in the sensing data reported by the two nodes. Push-out policy in MRD is mainly based on the correlation between two sensor nodes and thus whenever the buffer is full, it drops a packet from nodes closed together. However, we are concerned with the environmental monitoring applications where different sets of sensors are assigned to collect the different information. MRD will not perform well in this type of application since redundancy of sensors' data cannot be differentiated by their spatial information.

3. Propose Model for Monitoring Sensor Network

In this section, we will illustrate the network model of our study. We consider a simple environmental monitoring WSN where hundred of sensor nodes generate the readings on every unit time and send them to the sink. On the way from source to sink node, packets pass through intermediate nodes. In our network model, sensor nodes are designed to collect three different information (*temperature*, *pressure* and *humidity*) from the application area. Thus, the sensors which are assigned to collect the same information (eg. *temperature*) will virtually form as a (*temperature*) layer. Sensors in each layer will accept the packets originating from the same layer as first priority. We define the *relevant* and *irrelevant* packets used in our scheme. Sensors in each layer will consider the packets originated from the same layer as *relevant* packets, and on the other hand, the packets originated from the different layers are treated as *irrelevant* packets.

In our scheme, we use network coding as in-network processing in order to save the power in packet transmission. We will perform network coding only on the relevant packets in order to make more efficient use of limited buffer. Sensor nodes perform the encoding process on the finite *Galois Field* GF(2) and then send the encoded packet to the network layer. For irrelevant packets, sensor will not perform any in-network processing and it will simply act as a relay node.

Our proposed scheme can be classified into 2 main steps; 1) packet classification, and 2) buffer partitioning. Each sensor will classify the receiving packets into three different types. First type of packets is termed as *relevant* packets which contain same type of sensor reading and those packets are originated from the same layer sensor nodes. Sensors will treat the packets originated from differ layer sensors as *irrelevant* packets as they are carrying the different type of sensor readings. Last type of packets is called as *normal* packets which may include hello packets and other regular packets which are generated at regular interval of time.

In our approach, the entire buffer space is partitioned into three queues as in Figure 5, and each queue accepts packets with the corresponding type only. We use the complete sharing buffering scheme by which the total memory of each sensor is virtually shared between the different queues. Thus the capacities of the queues can be adjusted dynamically and a packet does not have to be dropped if there is any available space in the buffer.

4. Performance Evaluation

We perform computer simulation using NS-2, a standard tool in sensor network simulation. We have implemented a simple environmental application in which three sets of sensor nodes sense their immediate surroundings and forward those readings to the sink node by using store and forward method. The default parameter setting for the simulation is shown in Table I.

TABLE I. SIMULATION PARAMETERS

Number of nodes	100
Area (m^2)	100 x 100
Packet Size	30 *bytes*
Data Rate	4 *pkts/ UnitTime*
Transmission Range	25*m*
No. of sensor classification	3
Coding choice for NC	5

In our simulation, 100 nodes are randomly deployed in 100m x 100m area. For the sake of simplicity, we assume that MAC protocol assigns a unique channel for every node to prevent possible collisions. We also assumed that it is the responsibility of routing protocol to forward the packet towards the sink node. In our scheme, we perform network coding only on relevant packets and select the coding choice (number of packets to combine into one packet) as 5. For all the results presented below, we use the average result of 10 simulation runs for each scenario.

In order to be taken into account in determining optimal design parameters for WSN, we study the impact of design parameters on buffer management, such as buffer size, packet rate and time. First, we discuss the impact of the buffer size on the loss of relevant packets in order to select an optimal buffer size for subsequent simulations. The results in Figure 6 indicate the buffer size 10 is optimal for the packet rates of less than 5 packets per unit time to maintain the minimum loss of relevant packets. In addition, according to the nature of low data rate WSN, the sustainable rate of sensor node is supposed not to exceed 5 packets per unit time. Using the values obtained from above figure, we will use buffer size of 10 in our simulation.

Another factor to be considered is the time and thus we also evaluate the loss of relevant packets as a function of time. We use 100 sensor nodes and the memory of each sensor node can hold up to 10 packets. The result in Figure 7 shows that the loss of relevant packets is linearly proportional with the time. This is due to the fact that sensors' buffer suffer overflow from time to time.

Figure 8 shows the comparison of the power saving in terms of the lifespan of the networks. Our proposed buffer management scheme has a lifespan 2.6 times longer than the conventional scheme and 1.5 times longer than MRD scheme. Thus our proposed buffer management scheme saves 74% and 43% of the energy that the conventional scheme and MRD scheme use respectively.

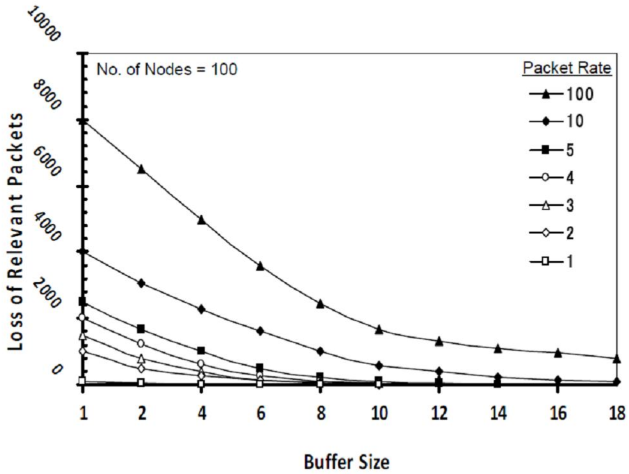

Figure 6. Loss of relevant packets vs. buffer size.

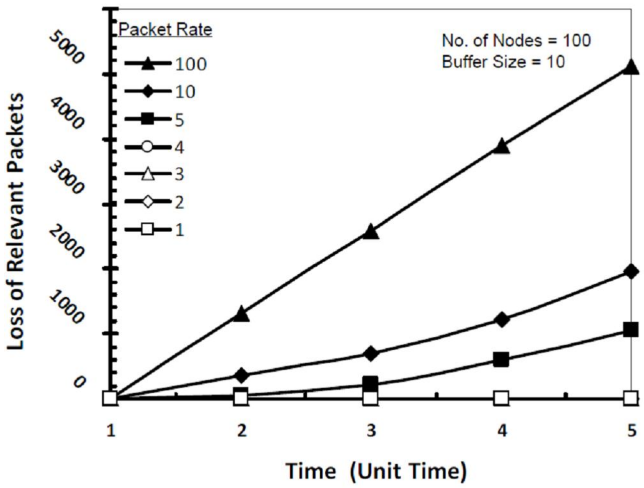

Figure 7. Loss of relevant packets vs. time.

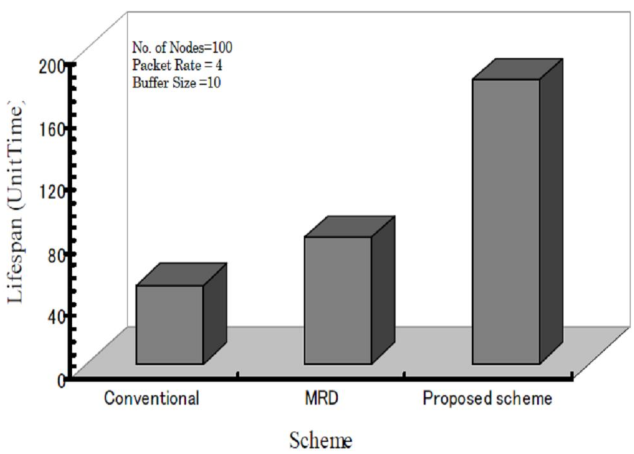

Figure 8. Comparison of the network lifespan.

5. Conclusions

Considering the limited capabilities and vulnerable nature of an individual sensor, in this paper, we proposed a multi-layer WSN with a power efficient buffer utilization policy to efficiently utilize the storage space in each sensor node. Simulation results show that our proposed buffer management scheme can significantly enhance power efficiency and lifespan of the monitoring sensor network. It saves 74% power used in a monitoring system without buffer management (conventional scheme) and over 43% power used in a most redundant drop (MRD) scheme.

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