Measurement of QoS in Wireless Sensor Networks with Single Multimedia Traffic-Class

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***Abstract*— Hardware and energy limitations hamper sensor nodes to work with traffic classes-video, voice, picture and stream data effectively. Unlike other networks, in WSNs Quality of Services (QoS) metrics should have direct relation to energy consumption. In other words, all QoS should be modeled so that it would diminish power usage and increase network life. In this paper we proposed QoS model based on Queueing Theory in order to control multimedia packets in the queue and decrease packet loss. In this paper we estimated optimal values for each server and proposed desirable buffer size and service intensity values for sensor node in order to minimize data loss.**

Keywords*— *wireless sensor networks; buffer; queuing theory; QoS; multimedia data

I. Introduction

In last decades rapid growth in Micro-electro-mechanical systems (MEMS) increased range of application of wireless sensor networks (WSNs). WSNs are composed of small, limited resourced, cheaper sensor nodes that are wirelessly connected to each other [1]. The nodes are embedded with the sensor boards to sense the environmental phenomenon and are scattered over the unattended areas in order to sense environment process and forces in the physical world. Tiny and low-cost sensor nodes can be placed densely throughout an experimental area for gathering and delivering information to other nodes. Dense deployment of sensor node helps to increase high connectivity between nodes.

So far there isn't any unique standard for sensor nodes in terms of utilization, connection and etc. Although there are different standards for WSNs, such as WirelessHART, ISA100, IEEE 1451, ZigBee/802.15.4, it makes that an interesting research area. WSNs have many application areas such as indoor/outdoor fire fighting, security, agricultural, military, health monitoring and etc [2].

Sensor nodes have resource strains, such as limited and low processing speed, storage, communication bandwidth and energy consumption. Individually these devices don't make essential sense in sensor network. Main purpose in sensor network implementation is to create optimal and less-cost connectivity among sensor nodes. Communication between sensor nodes is based on multi-hop connection. In general the sensor nodes are unreusable, therefore, they mainly are assembled of low-cost and off-the-shelf devices in order to keep its cost cheaper.

Since the sensor nodes are deployed in remote, unattended areas that are not easy to reach, their batteries are irreplaceable. In this context power supply becomes main challenge in sensor node and network implantation. To reduce energy consumption, most of the node's components, mainly the radio and CPU, go to TURN OFF mode [3].

As a main problem- power consumption should be taken into consideration in network and sensor node design, routing protocols, network management, error correction and etc. Furthermore sensor nodes plays role of router to deliver data as well as environmental monitoring. It sends gathered data to the sink through mediate nodes and receives the packet coming from the neighbor nodes. A battery-depleted or failed nodes change network topology and directly or indirectly shorten the life of the sensor networks [4]. If one node goes off, new node might replace it depending on the application area.

Main point in network design is to maximize the network life and to use the strained resources effectively by implementing new mechanisms, algorithms and protocols that take into account energy consumption as a main priority. Besides network design and management, software packets are also important factor in power control. High-computational software required high energy for task computation. Therefore, sensor node software is mainly designed for specific application based on the environmental phenomenon. Another factor that affects negatively energy consumption is routing protocol. Routing protocols should be modeled so that it would require less computation in order to conserve energy by reducing retransmission [5].

One of the unique characteristics of the traditional WSNs is the packet size delivered from the source node to the destination node. These packets mainly consist of text-based data as origin. In the case of multimedia data, such as video streaming, pictures, sounds and video files, where size is significantly big relative to text-based data, it is too complicated to transfer data through the sensor network. Therefore, multimedia WSNs need other standards different from traditional WSNs. In multimedia WSNs energy consumption still remains one of the main challenges. As we expand hardware specifications, more energy will be consumed for computation. One of the ways to prolong the life of nodes is to add additional power supply such as a solar cell. However, it will increase the cost of the sensor nodes and therefore will squeeze the application areas [6]. Regardless of the challenges mentioned above, there should be trade-off between energy consumption and resource utilization. Furthermore, increased packet size requires additional time to be served by the traditional sensor nodes. Regardless of how fast sensor devices are, service time for each arrival packet is not enough to serve them completely. Therefore, number of packets waiting in queue in the buffer will be swelled. The loss of some video and voice packets might not seriously affect overall data in destination, so that remaining packet can convey the necessary message to the listener. In the case of loss of image packet, it is difficult to recollect whole frame in order to get original picture back.

Unlike other networks, in WSNs Quality of Services (QoS) metrics should have direct relation to energy consumption. In other words, all QoS should be modeled so that it could diminish power usage and increase network life. In this paper we proposed QoS model based on Queueing Theory in order to control multimedia packets in the queue and decrease packet loss. Decrease in the number of retransmission of dropped packets will result in less energy consumption as well.

II. System Background

A. Conventional WSNs

Wirelessly connected sensor nodes are consist of processor unit (CPUs, microcontrollers), memories (random access memory (RAM) and low-sized flash memory), power supply, a RF transceivers (to connect with other sensor nodes) and sensor board (to sense the environmental process) [7]. Sensor nodes sense an environmental phenomenon, gather data and transfer them via the intermediate nodes to the destination host called a sink. A sink is an end point that connects WSNs to the internet or global network (Fig. 1). An administrator can send request to the sensor nodes through the sink. In general there are three way to awake sensor board to collect data: *a) event-driven:* when an environmental phenomenon acts, sensor boards are automatically activated to gather data; *b) periodically:* sensor nodes are configured manually by administrator to act on specific time. Time synchronization is the main factor in this regards; *c) query-based*: an administrator send query on particular task to all nodes in the network via a sink. As a destination node gets request, it starts sensing an environment and responses back to the sink.

State-of-the-art microcontrollers used in WSNs are designed on single integrated circuits consisting of a processor core, memory, and programmable I/O peripherals. Furthermore these microcontrollers perform functionalities of personal computer. Selection of relevant components of microcontrollers are important factor in designing of sensor nodes in order to get well balanced power, voltage, cost and support for other external devices. Another factor in selection of microcontroller family is to minimize energy consumption during installation and implantation. Peak power consumption might not always be suitable for the task specified on curtain applications. Microcontrollers in sensor nodes consume subtle energy during the sleep mode. During the sleep mode CPU stops its work and shifts to the save mode where very less energy is needed for computation. Furthermore, the processor has to be awake in order to maintain the systems memory and time synchronization [8].

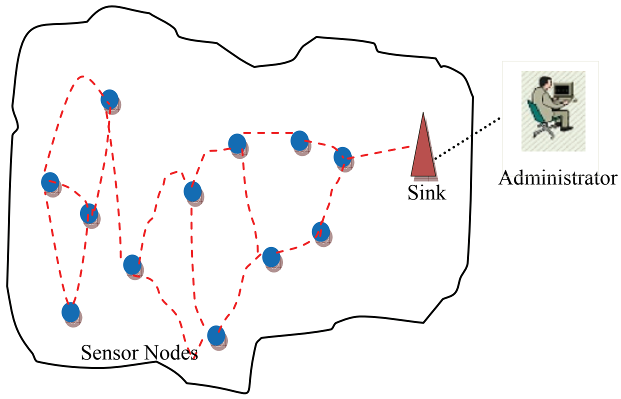

Figure 1. Typical Wireless Sensor Networks.

B. Protocol Stack

Like other networks in WSNs the network layer are necessary to make unique rule of "dialog" between sensor nodes. In WSNs there are five network layers: the application layer, transport layer, network layer, data link layer, physical layer. In the application layer different type of software are deployed related to functionality of the sensor. The transport layer control data flow from the application layer to lower layers. It controls number of segment of whole data and re-combination of arriving packets. The network layer takes care of routing the data supplied by the transport layer. The Data Link layer is intermediate layer that plays a role of transition between digital information and physical medium. This is the layer that makes link between software and medium. In this context, Data Link layer are divided into two sub-layers: 1) Upper sublayer – Logical Link Control (LLC) layer and 2) Lower layer- Medium Access Control (MAC) layer. Since the environment is noisy and sensor nodes can be mobile, the MAC protocol must be power aware and able to minimize collision with neighbors' broadcast. Creating frames, packet modulation, transmission and receiving techniques are take place in the physical lay*er* addresses [1].

C. Multimedia WSNs

In multimedia WSNs low-cost video cameras or sound recorders are attached to the sensor nodes. Once a sensor senses observed phenomenon or intruders, video cameras or sound recorders are activated, where they consume additional energy [9]. State-of-the-art sensor nodes have ability to analyze data and deliver relevant part of them; where in turn perform less processing computation. Main energy-deplete parts of sensor networks are transmission and receiving data, in other words is radio part [10].

Hardware and energy limitations hamper sensor nodes to work with traffic classes-video, voice, picture and stream data effectively. Currently available small sized and low-cost Complimentary Metal Oxide Semiconductor (CMOS) cameras are ideal equipments for multimedia data in WSNs. However, file (packet) size taken by these cameras is still big to transfer and requires high bandwidth. Routing protocols, encoding/decoding mechanism, path selection and etc modeled for conventional WSNs, where they were considered only small sized packets, won't work effectively in multimedia WSNs. Furthermore, probability of packet loss in multimedia data is higher than the conventional one, because of packet size [11, 12].

Decreasing data loss in multimedia communication is the priority factor in multimedia WSNS. Data loss mainly happens during the queue management at MAC layer. It is fact that the bigger queue in each node, the bigger the probability of data loss. In this paper we analyzed queue mechanism in the processing unit where the buffer is placed in order to increase Quality of Services.

III. Proposed Framework

As we mentioned above, in WSNs all QoS models should be taken into consideration power consumption. In our research we studied buffering and queue mechanism in the MAC layer in order to increase QoS by preventing data loss. Furthermore, decreasing probability of data loss leads to minimum retransmission which in turn results in less power consumption. In this model, we studied system in two parts, where each part was given as a server (Fig. 2). First part consists of the physical layer and the data-link layer (mainly the MAC layer). Second part consists of aggregation of reaming layers – the network layer, the transport layer and the application layer. To prevent data loss we put buffer with size R before the server 1 with service intensity μ_1 in order to move arrival packets in it when the server is busy. Second server with service intensity μ_2 receives packets coming from the first server.

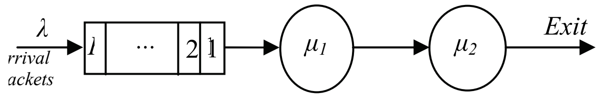

Figure 3. Datagram of data flow in the Queuing Process

A state diagram for the given model is given in Fig. 3. When packet arrives to the server 1, they go the buffer if server is busy, other vise they are being transferred to the server 2. However if the server 2 is busy, where it cannot accept packets coming from the server 1, system goes to the *block state.* In this state *served packet* in the server 1 wait for a while till the server 2 is idle. Moreover, arrival packets in the server 1 wait in queue. If buffer size reaches to R, then arrival packet will be dropped.

State probabilities for given state diagram are given in the form *balance equation* as below:

$$\pi(0,0)\,\lambda=\pi(0,1)\,\mu_2 \quad (1)$$

$$\pi(i,0)(\lambda+\mu_1)=\pi(i\text{-}1,0)\,\lambda+\pi(i,1)\,\mu_2,\ i=1,2,\ldots,R \quad (2)$$

$$\pi(R+1,0)\,\mu_1=\pi(R,0)\,\lambda+\pi(R+1,1)\,\mu_2 \quad (3)$$

$$\pi(0,1)(\lambda+\mu_2)=\pi(1,0)\,\mu_1+\pi(b_1)\,\mu_2 \quad (4)$$

$$\pi(i,1)(\lambda+\mu_1+\mu_2)=\pi(i+1,0)\,\mu_1+\pi(b_{i+1})\,\mu_2+\pi(i\text{-}1,1)\lambda,\quad i=1,2,\ldots,R \quad (5)$$

$$\pi(b_i)\,\mu_2=\pi(i,1)\,\mu_i,\ \ i=1,2,\ldots,R+1 \quad (6)$$

$$\pi(R+1,1)(\mu_1+\mu_2)=\pi(R,1)\,\lambda \quad (7)$$

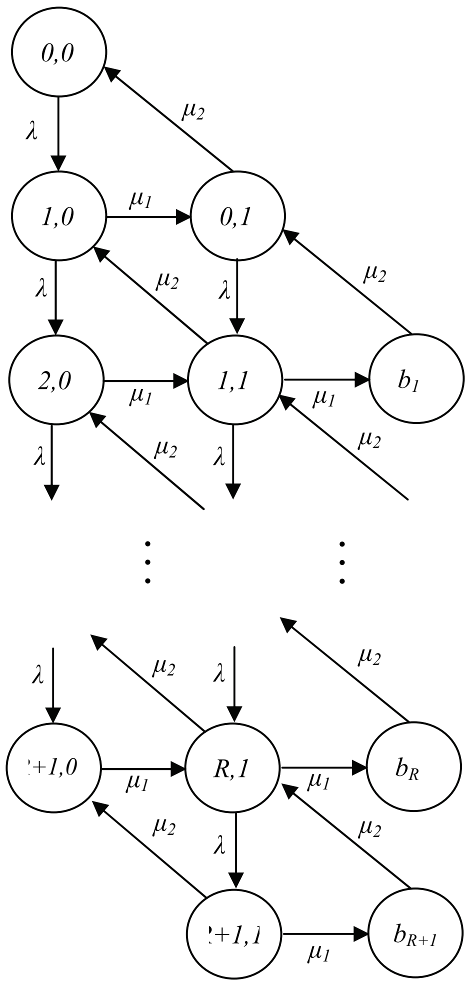

Figure 2. State diagram of data flow datagram with buffer.

Here (1), (3), (4) and (7) are the equations for *boundary states.* Normalizing condition for the given model is:

$$\sum_{i=0}^{R+1}\pi(i,0)+\sum_{i=0}^{R+1}\pi(i,1)+\sum_{i=1}^{R+1}\pi(b_i)=1 \quad (8)$$

In the given state diagram it is too complicated to figure out a price formula for each π state probabilities. Since number of variables and equations are the same $3R+5$, we used matrix calculation in MATLAB 10.0 version to calculate values of each state probabilities π.

As a consequence of all the above the following approximate formula for calculation of QoS metrics can be suggested.

$$PB_1 = \pi(R+1,0)+\pi(R+1,1)+\pi(b_{R+1}) \quad (9)$$

$$PB_2=\sum_{i=1}^{R+1}\pi(b_i) \quad (10)$$

$$L_q=\sum_{i=1}^{R}\left[\pi(i+1,0)+\pi(i+1,1)+\pi(b_{i+1})\right] \quad (11)$$

$$L_s=\sum_{i=1}^{R+2}\left[\pi(i,0)+\pi(i-1,1)+\pi(b_{i-1})\right] \quad (12)$$

$$W_q=\frac{L_q}{\lambda(1-PB_1)} \quad (13)$$

$$W_s=L_q+\mu_1^{-1}+\mu_2^{-1} \quad (14)$$

where PB_1- Probability of Blocking in the buffer*;* PB_2- Probability of Blocking in *blocking state;* L_q – Average length of queue in the buffer*;* L_s- Average length of queue in the system; W_q- Average waiting time in the buffer; W_s- Average waiting time in the system.

IV. Conclusion

Based on our result it is possible to determine desirable rate of transmission/receiving and the specification of microcontrollers. We estimated optimal values for each server and proposed desirable buffer size and service intensity values for sensor node in order to minimize data loss. Probability of blocking (*PB_2*) gives us clear picture how system specification should be choose so that blocking state would be minimized.

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