Optimum Packet Length Over Data Transmission for Wireless Sensor Networks

Murat DENER
Graduate School Of Natural And Applied Sciences
Gazi University
Ankara, 06500, Turkey
muratdener@gazi.edu.tr

Abstract- Wireless Sensor Networks (WSNs) consist of large number of tiny sensor nodes, all of which have sensing capabilities. As sensor nodes are typically powered by nonrenewable batteries, energy efficiency is a critical factor in wireless sensor networks. Sensor nodes want to continue their lives with limited energy. Each of them using its own energy in minimum level and they aims to provide maximum efficiency to network. In this paper; We show that optimum packet length over data transmission at the data link layer. An example scenario is developed in OMNet simulation platform using IEEE standard 802.15.4. The optimal packet length is obtained in terms of energy efficiency.

Keywords: Wireless Sensor Networks, Optimum packet length, Data transmission

I. INTRODUCTION

A sensor network is an infrastructure comprised of sensing (measuring), computing, and communication devices that gives an administrator the ability to instrument, observe, and react to events and phenomena in a specified environment [1].

These devices, each equipped with central processing unit (CPU), battery, sensor and radio transceiver networked through wireless links provide unparalleled possibilities for collection and transmission of data and can be used for monitoring and controlling environment, cities, homes, etc. In most cases WSNs are stationary or quasi-stationary, while node mobility can be ignored. There is no prearrangement assumption about specific role each node should perform. Each node makes its decision independently, based on the situation in the deployment region, and its knowledge about the network. In the case of networks comprising several hundreds or thousands of nodes, it is necessary to choose an architecture and technology which will enable relatively cheap production of individual devices. For this reason, WSNs need some special treatment as they have unavoidable limitations, for example, limited amount of power at their disposal. Each battery powered device, participating in WSN needs to manage its power in order to perform its duties as long, and as effective as possible. Wireless sensors are thus characterized by low processing speed, limited memory and communication range[2].

The wireless sensor network is quite different from the traditional wireless networks. It has a large number of sensor nodes and they are densely deployed. The distance between neighbor nodes is shorter compared to other wireless networks. The data rate and mobility in the wireless sensor network are low. Because of the remote nature and the size of the individual nodes, they rely on limited battery energy that cannot be replenished in many applications [3]. Thus, low power consumption technology is a major issue in wireless sensor networks in order to prolong system lifetime.

Unlike other wireless networks, it is generally hard (or impractical) to charge/replace the exhausted battery, which gives way to the primary objective of maximizing node/network lifetime, leaving the other performance metrics as secondary objectives [1]. Since the communication of sensor nodes will be more energy-consuming than their computation, it is a primary concern that the communication is minimized while achieving the desired network operation.

The structure of this paper is as follow. In Section 2 we explain optimum packet length problem as detailed. In Section 3 we show example network and give parameters for the channel control. In Section 4, simulation results are presented. Finally, we conclude this paper in Section 5.

II. PROBLEM DESCRIPTION

It is well known that longer packets experience higher loss rates, while short packets suffer from greater overhead. This has been the main theme behind packet size optimization in other wired and wireless networks. However; the energy consumption of start-up transients can be significant in the context of energy constrained sensor nodes. This must be taken into account while calculating the optimal packet size for data transmission in WSNs[4].

The energy dissipated for data transmission and receiving in the air has direct effect on the lifetime in WSNs. To utilize energy consumption, there has
been a significant amount of research in the area of low-energy radios [5].

IEEE 802.15.4 [6,7] standard is used, which specifies the physical layer and media access control for low-rate wireless personal area networks, in example scenario.

The 802.15.4 standard was specifically designed for the requirements of wireless sensing applications. The standard is very flexible, as it specifies multiple data rates and multiple transmission frequencies. The power requirements are moderately low; however, the hardware is designed to allow for the radio to be put to sleep, which reduces the power to a minimal amount. Additionally, when the node wakes up from sleep mode, rapid synchronization to the network can be achieved. This capability allows for very low average power supply current when the radio can be periodically turned off. The Standard supports the following characteristics:

- Transmission frequencies, 868 MHz/902–928 MHz/2.48–2.5 GHz.
- Data rates of 20 Kbps (868 MHz Band) 40 Kbps (902 MHz band) and 250 Kbps (2.4 GHz band).
- Supports star and peer-to-peer (mesh) network connections.
- Standard specifies optional use of AES-128 security for encryption of transmitted data.
- Link quality indication, which is useful for multi-hop mesh networking algorithms.
- Uses direct sequence spread spectrum (DSSS) for robust data communications.

It is expected that of the three aforementioned standards, the IEEE 802.15.4 will become most widely accepted for wireless sensing applications. The 2.4-GHz band will be widely used, as it is essentially a worldwide license-free band. The high data rates accommodated by the 2.4-GHz specification will allow for lower system power due to the lower amount of radio transmission time to transfer data as compared to the lower frequency bands.

The link layer data packet is the smallest communication entity between neighboring sensor nodes in a WSN. It consists of a header field, payload of size and a bit trailer, as shown figure 1.

<table>
<thead>
<tr>
<th>Header</th>
<th>Payload</th>
<th>Trailer</th>
</tr>
</thead>
</table>

Fig 1. The link layer packet format

The header field generally includes the current segment number, total number of segments in the corresponding higher layer packet, higher layer packet identifier and the source and destination identifiers. The payload contains information bits and the trailer is composed of parity bits for error control [4].

We measure the packet reception rate (PRR) and the transmission efficiency (E, which is defined as the received useful bytes divided by the overall transmitted bytes) for each packet payload length. A high E value indicates a high goodput and a high energy efficiency provided that the transmission time and the transmission energy consumption are approximately linear to the packet length. The packet payload length increases, PRR decreases while E reaches its maximum value at packet payload length. Using the optimal packet length improves approximately 40% performance in terms of E compared to using the smallest packet length in this case. Also other experiments at different distances and transmission powers. Results show that the optimal packet length varies in different conditions. Therefore, packet length optimization is beneficial in WSNs [8].

III. EXAMPLE NETWORK

OMNeT++[9] is used for create a example network. OMNeT++ is an extensible, modular, component-based C++ simulation library and framework, with an Eclipse-based IDE and a graphical runtime environment. Domain-specific functionality (support for simulation of communication networks, queuing networks, performance evaluation, etc.) is provided by model frameworks, developed as independent projects. There are extensions for real-time simulation, network emulation, alternative programming languages (Java, C#), database integration, SystemC integration, and several other functions. OMNeT++ is free for academic and non-profit use, and it is rapidly becoming a preferred simulation platform in the scientific community worldwide.

We randomly 10 nodes in an area 1000x1000 m2. The base station is located at location (X=0, Y=0). Parameters for the channel control is given below which is the same IEEE.802.15.4.

```c
channelcontrol.carrierFrequency=868E+6
# max transmission power [mW]
channelcontrol.pMax = 110.11
# signal attenuation threshold [dBm]
channelcontrol.sat = -120
# path loss coefficient alpha
channelcontrol.alpha = 2
channelcontrol.sendDirect = false
channelcontrol.useTorus = false
```

The example network is given as shown figure 2.
Coordinate of nodes is given in Table 1.

<table>
<thead>
<tr>
<th>Node</th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>1</td>
<td>40</td>
<td>150</td>
</tr>
<tr>
<td>2</td>
<td>90</td>
<td>180</td>
</tr>
<tr>
<td>3</td>
<td>190</td>
<td>200</td>
</tr>
<tr>
<td>4</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>5</td>
<td>500</td>
<td>340</td>
</tr>
<tr>
<td>6</td>
<td>650</td>
<td>400</td>
</tr>
<tr>
<td>7</td>
<td>40</td>
<td>800</td>
</tr>
<tr>
<td>8</td>
<td>130</td>
<td>700</td>
</tr>
<tr>
<td>9</td>
<td>460</td>
<td>800</td>
</tr>
</tbody>
</table>

Table 1. Coordinate of sensor nodes

Sensor nodes is distributed which are quite far away from each other. We aims show that location of sensor nodes are important for energy efficiency.

IV. SIMULATION RESULTS

It is apparent that if the packet length is too short, it suffers from an efficiency problem due to the larger overhead. On the other hand, if the packet length is too long, it experiences higher packet error rates especially for the wireless channel with high error rates. Since an error packet means a total loss of energy consumed for the packet transmission, it also suffers from an efficiency problem in this case. Therefore, there exists an optimal packet length in the sense of maximizing the energy efficiency[3]. 90 packets sent to base station. Different values is given as packet length which seen in Fig. 3. If packet length is 10,32,64 or 128 byte, received packets is not changed. 70 packets received by base station. Dropping of packets (90-70=20 packets) is because of network’s topology. Distance between nodes in the network is too far. So, when the node is sent the packets, then there is an interference and packet is dropped. Optimum Packet length is should be between 128 byte and 256 byte to see in Fig 3. While Packet length increases until 128 byte, received packets is same and 70. But; each of packet length after 128 byte, received packets are decreasing. Therefore, the packet length values which between 128 byte and 256 byte are tried to find optimum packet length. The results are presented in Fig 4.
Fig 3. Simulation results (10-1024 byte)

Yellow line is shown received packets. Pink line is shown sent packets and navy line is shown packet length at data link layer in each figure. While packet length values between 10-1024 byte in figure 3, this values 128-256 byte in figure 4. Figure 3 shows that first tries to find optimum packet length. Moreover, figure 4 shows that detailed tries to find optimum packet length.

Fig 4. Simulation results (128-256 byte)

After 160 byte, received packets is decreasing. This action is risk for network. Because the datas which sent by nodes, are dropped. Consequently; optimum packet length is 160 byte for this application.

However, in case involving packet length variables, when a small packet is received, the sensor node may be still in wakeup state after data transmission. Until the sleep phase begins, the sensors adapt accordingly. Therefore, small packets lead to high energy wastage. Similarly, as data packet length increases, data transmission may span one cycle to reach the next cycle, thus resulting in synchronization damage and error in communication. As such, if the data phase is set to large values to accommodate the largest packet length, energy wastage becomes high [10]. So, packet length should be optimal over data transmission in wireless sensor networks.

V. CONCLUSIONS

In this paper, we have show optimum packet length over data transmission for wireless sensor networks. Optimal packet length is variable in each of application. So; network topology is important point. If distance between nodes in network too far, there will be packet lose. When optimum packet length is found, dropped packets and packet errors reduces. However; Energy efficiency provides which is critical for sensor networks.

REFERENCES


Murat DENER received her M.Sc. and Ph.D. degrees in Electronic and Computer Education Department from Gazi University, Turkey, in 2008 and 2012, respectively. His doctorate thesis entitled by Design and Implementation of a Secure Data Link Layer Protocol for Wireless Sensor Networks. He worked in Georgia Tech E-Stadium Team in 2011. From 2005 to 2012, he was a Research Assistant in the Graduate School of Natural and Applied Sciences. Since 2012, he is Doctor in Gazi University. His research interest includes the Next-Generation Wireless Networks, Wireless Ad Hoc and Sensor Networks, Cognitive Radio Networks.