RESEARCH PAPER

Analytical Framework for the Capacity and Delay Quantification Wireless Sensor Network (WSN)

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ABSTRACT

Real time applications are critical performance applications that require critical delay performance. For time sensible data numerous Wireless Sensor Networks (WSNs) applications require end-to-end delay guarantee. Nodes for event-driven sensor networks produce and transmit data only when an event of interest happen, so they produce unpredictable traffic load, in this case end-to-end delay is difficult to restrictive. Data collection performance can be measured by its fulfilled network capacity. Terms are needed for real-time capacity that characterizes the ability of a network to deliver data on time also develop network performance that fulfills this capacity. The objective of this paper is to focus primarily on the analysis of performance of the QoS based on Delay and Throughput Performance using Opnet 14.5.

KEYWORDS: Wireless Sensor Network (WSN); Opnet; QoS; End-to-End delay; Throughput.
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INTRODUCTION:

Wireless Sensor Networks (WSNs) have been increasingly diffused for a broad variety of real-time applications, for example industrial and medical Internet-of-Things (IoT), emergency response, process measurement and control critical infrastructure monitoring. The real-time wireless sensor networks are WSNs that have the ability to provide limited guarantees of delay in parcel delivery. In order to provide real-time WSNs applications many problems need to be solved. Because the WSNs network utilize shared wireless medium of communication, a distributed access control protocol (MAC) is required in order to provide guaranteed bandwidth. A first steep that we need to do is End-to-End packet delivery guarantee. Low power and small message overload is needed to support Real-time WSNs networks this can be achieved with to limit interference and preserved power. Network real-time capability can be defined as its ability to convey The information specific deadlines. The underlying network needs to support Quality of Service (QoS) so that we can satisfy our customer with services of the system. In order to measure QoS in data delivery we need to use some of the Known performance metrics, such as delay, packet loss, and throughput. There is a tradeoff between QoS requirements like throughput and packet loss. So in order to upgrade the WSNs network many efforts have been done like designing a real-time routing protocol and quality measurement of forwarding data (Tan2016).
Currently, most of WSNs researches deal with the designing of efficient energy and computational algorithms and protocols because extreme wireless sensor devices available nowadays are controlled in terms of computational power, memory, efficiency and communication capacity due to economic and technological reasons while the application domain was limited to simple monitoring and reporting applications. In this document it has been focused primarily on the analysis of the performance of the QoS parameter and based on Delay, throughput, etc.

1. WIRELESS SENSOR NETWORK

A wireless sensor network (WSN) consist of a group of independent nodes that communicate wirelessly through a restricted frequency and bandwidth environment. If we compared the modernity WSNs with traditional sensor networks we can notice that they rely on dense implementation and coordination to perform their tasks successfully (Talib 2016). WSNs are generally designed to send a small amount of data, such as temperature status or light intensity. Each sensor node is equipped with a certain type of sensor, for example seismic, temperature, humidity, acoustics and radar, low magnitude, thermal sampling frequency, etc. The ability, combined with wireless connection and computer technology, should be implemented in a wide range of applications thanks to the features of low cost, low power consumption and easy-to-fabric sensor nodes. However, the limited computing resources, the severe energy restrictions of sensor nodes and the specific features of the application present important challenges to meet this expectation (Mosleh 2017).

2. WSN ARCHITECTURE

The general architecture of WSNs are a number of nodes which may reach to thousands elements. Those nodes are interacted the surrounding environments to sense the physical parameters. The nodes are co-operated with each other to transfer the sensing data toward the base station without reducing. Such co-operative is come from the limited power and small size equipment of such nodes. In some cases the network is often divided into multi-cluster, each one have a cluster head which aggregate the data from the cluster members and deliver the collected data to the base station. general the data is transferred to the cluster or to the base station through directly (single-hop) or multi-hop, Figs. 1 and 2 illustrate single and multi-hop respectively. Multi-hop is preferred to reduce the power consumption as the distance becomes shorter with large distance (Mosleh 2017).

Figure 1. Single-hop network

Figure 2. Multi-hop network

The sensor node consists in general of sensing unit, microprocessor, communication unit and power delivered to each unit as illustrate in Fig.3. The sensing unit may be included an analogue to digital convertor as the microprocessor don't received analogue signal. A small memory is connected to processor unit to store data and some instructions. The communication unit is responsible to transfer the data wirelessly but it consume large amount of power, so that many algorithms are designed to turn-off this unit more time with no effect on its performance.
to reduce the power consumption. ZigBee protocol is preferred for WSNs communication link because of its reliable data with low error, low cost and small size (Talib 2017).

3. EXPERIMENT AND SIMULATION ANALYSIS

OPNET was chosen as a simulation program for this study. OPNET is one of the most mensuration and effective simulation tools that study all phases of a network.

It has powerful tools such as comprehensive graphical user interface (GUI), supports configuration of model design and protocols, data collection, analysis and animation. With this tool, it is easier to analyze and examine the behavior and performance of nodes on the network and then optimize the network. OPNET is suitable because it evaluates all the statistics needed for this study. Model parameters can be reconfigured to optimize the result of the network. There are three hierarchical levels of configuration in OPNET namely the node, process and network level. To evaluate the performance of OPNET in simulating ZigBee WSNs, the mesh topology of WSN is used; the network is simulated for duration of 30 minutes. There were five sensors for each patient. Different scenarios were taken to study the performance of system for single coordinator with increasing number of sensors. The experiment is simulated with a number of nodes ranging from 5 to 20. The simulation scenario parameters are shown in Table 1. A set of performance metrics has been considered for comparing different topologies, including delay and throughput.

### Table 1. WSN Simulation Parameters.

| Parameters                        | Values |
|-----------------------------------|--------|
| Packet size (bit)                 | 1024   |
| Min backoff exponent              | 3      |
| Net reception-power threshold (W) | 0.5    |
| Traffic type                      | Poisson|
| Simulation time (s)               | 1200   |

3.1 First Case Study

In this case, there was one coordinator in the different number of sensors ranging from five to 20 sensors in this case assuming all sensors transmit at the same time. Delay for Media Access: Refer to the total delay contention and queuing of the 802.15.4 MAC transferred data. Media Access Delay for scenario 1, 2 and 3 is taken on the same graph for comparison when the number of patients was increased from 1 to 2 to 4 patients with number of sensors was increased from 5 to 10 to 20 sensors as shown in Fig.(4).

![Figure 4. Media Access Delay for first case study](image)

3.2 Second Case Study

In this case, there was one coordinator in different number of sensors ranging from 5 to 20 sensors. In this case assuming all sensors transmit

![Figure 5. Data traffic received for first case study](image)
with the same data rate. The service time per transmission is given as:

\[ T = \frac{K_i}{\text{data rate}} \]  \hspace{1cm} (1)

where \( K_i \) is the number of bits, so that, the total time needed is given as:

\[ T_t = \sum_{i=1}^{n} T \]  \hspace{1cm} (2)

over all time needed

\[ T_s = T_t + T(x) \]  \hspace{1cm} (3)

where \((x) = \text{random transmission delay}\)

Comparison between the scenario 1, 2 and 3 of changing the number of sensors where all of the sensors transmit at different times with the same data rate the difference in delay and received data traffic for 5, 10 and 20 sensors are shown in Fig.(6), Fig(7).

**Figure 6**: Media Access Delay for second case study.

3.3 Third Case Study

In this case, there was one coordinator in the different number of sensors ranging from 5 to 20 sensors. In this case a Comparison between the scenario 1, 2 and 3 of changing the number of sensors assuming all sensors transmit with different time at the same data rate, the difference in delay and received data traffic for 5, 10 and 20 sensors are shown in Fig.(8), Fig(9).

**Figure 7**: Data traffic received for second case study.

**Figure 8**: Media Access Delay for third case study.
3.4 Fourth Case Study.

In this case, there was one coordinator in the different number of sensors ranging from 5 to 20 sensors. In this case a Comparison between the scenarios of changing the number of sensors assuming all sensors transmit with different data rate, the difference in delay and received data traffic for 5, 10 and 20 sensors are shown in Fig.(10), Fig(11).

4. Discussion and Conclusions

1- In First Case Study, Media access delay was increased when the number of sensors was increased from 5, 10 to 20 sensors. Media access delay differs and increased as well as the number of sensors was increased. For 5 sensors, media access delay reaches 0.018, for system with 10 sensors, media access delay reaches 0.0185, for system with 20 sensors, media access delay reaches 0.022. This difference in media access delay showed the increase in delay as the number of sensors was increased in single coordinator system.

2- In First Case Study, Data traffic received was increased when the number of sensors was increased from 5, 10 to 20 sensors. When the number of sensors was five, data traffic received reaches average of 10,000 bits/sec. As the number of sensors was increased to ten, data traffic received reaches 11,000 bits/sec. As the number of sensors was increased to 20, data traffic received had been so increased which it reached 26,000,182,561 bits/sec.

3- In Second Case Study, Media access delay was increased when the number of sensors was increased from 5, 10 to 20 sensors. Media access delay differs and increased as well as the number of sensors was increased. As the previous case but as noticed the delay is less than the first case for all scenarios.

4- In Second Case Study, Data traffic received was increased when the number of sensors was increased from 5, 10 to 20 sensors. Data traffic received differs and increased as well as the number of sensors was increased.
as the first case study but as noticed the data received is greater than the first case for all scenarios.

5- In Third Case Study, Media access delay was increased when the number of sensors was increased from 5, 10 to 20 sensors. Media access delay differs and increased as well as the number of sensors was increased as the previous two cases, but as noticed the delay is less than the first and the second case for all scenarios.

6- In Third Case Study, Data traffic received was increased when the number of sensors was increased from 5, 10 to 20 sensors. Data traffic received differs and increased as well as the number of sensors was increased as the first case study but as noticed the data received is less than the second case and greater than the first case for all scenarios.

7- In Fourth Case Study, Media access delay was increased when the number of sensors was increased from 5, 10 to 20 sensors. Media access delay differs and increased as well as the number of sensors was increased as the previous two cases, but as noticed the delay is greater than all cases.

8- In Third Case Study, Data traffic received was increased when the number of sensors was increased from 5, 10 to 20 sensors. Data traffic received differs and increased as well as the number of sensors was increased as the first case study but as noticed the data received is less than the second case and greater than the first and third cases for all scenarios.

9- As a result, the delay and received data traffic are increased as the number of sensors increased but the greater delay is for the fourth case where all sensors transmit at the same time with different data rate, the greater received data traffic is in the second case study where all sensors transmit at the same time and at the same data rate.

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