# Analysis of QOS and Energy Consumption in IEEE 802.15.4/ZigBee Wireless Sensor Network

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## ABSTRACT
In the last few years, Wireless sensor networks have gained worldwide attention from both the research communities and the actual users. It comprises of a large number of extremely small autonomous computing, communication, and sensing devices, with limited energy and computing capabilities which co-operates to accomplish a large sensing task. Wireless sensor network raise some problems like limited energy resources replacement task. Therefore good functions of such networks depend on energies of nodes. In this paper two analytical models which predict the QOS in terms of throughput, jitter, average end-to-end delay and energy consumption have been introduced. These two different formats of nodes are organized as cluster and grid based network and for simulation analysis QualNet 6.1 simulator is used.

## Keywords
WSN, IEEE 802.15.4, Cluster based, Grid based, ZigBee, QualNet 6.1 simulator

## 1. INTRODUCTION
Nowadays, Wireless sensor networks (WSNs) are the most important technologies. It has gained world-wide attention in recent few years. These sensors are small, with limited transmission range, and computing resources. These sensor nodes are battery operated and need to operate without battery replacement for several years. There are two things which are to be reviewed i.e. how to achieve balancing energy drainage across all the nodes and how to achieve high routing efficiency under multihop transmission circumstance. Therefore, for designing such type of networks researchers must focus on both the energy consumption and routing efficiency.

IEEE 802.15.4 [1] is a low rate, low power consumption wireless communication technology, which can be widely used in the wireless sensor network. Thus the lifetime of the WSNs is a major concern. Hence, for the reliable prediction of lifetime the analysis of energy consumption is compulsory. The most important sources of energy consumption is transmitting and receiving data packets, overhearing, idle listening, collisions and overheads. An analytical model based on IEEE 802.15.4/ ZigBee wireless sensor network using QualNet 6.1 simulator. The rest of the paper is organized as follows: Overview of IEEE 802.15.4 networks are discussed in section 2. The main related works is analyzed in section 3. The simulation setup is presented in section 4. Simulation results are analyzed in section 5 and final conclusion is in section 6.

## 2. OVERVIEW OF IEEE 802.15.4 NETWORKS
IEEE 802.15.4 [1] is a standard which was originally designed for low rate wireless personal area networks (LR-WPAN). The IEEE 802.15.4 protocol defines the characteristics of the physical and data link layers for low rate wireless personal are networks (LR-WPAN).The physical layer supports three frequency bands i.e. 2.4 GHz, 915 MHz and 868 MHz in which 2.4 GHz is an Industrial, Scientific and Medical (ISM) band. Its aim is to allow the interconnection of wireless devices with battery powered and it does not require high bit rate.

### 2.1 Devices and modes
Two types of devices are defined in IEEE 802.15.4: FFD (full functional devices) and RFD (reduced functional devices). FFDs are operating on the three modes i.e. PAN coordinator, coordinator and device. PAN coordinator is the central controlling device of the network. It might be in beacon-enabled mode or beaconless mode. Coordinator act as a router and relay messages to end devices. FFDs can work as a PAN coordinator, coordinator or end devices. RFDs are end terminal devices.

IEEE 802.15.4 MAC has two modes of operation:

- Asynchronous beaconless mode
- Synchronous beacon-enabled mode

In asynchronous beaconless mode, the node needs to listens other nodes transmission all the time which drains the power of battery faster. In synchronous beacon-enabled mode, the transmission of periodic beacons packets between transmitter and receiver provides synchronization between the nodes.

### 2.2 Network topology
The IEEE 802.15.4 adopts two network topologies: star topology and peer-to-peer topology. In star topology, there is communication established between a single central controller, called the PAN coordinator and the RFD devices. Peer-to-peer topology allows more complex topologies such as mesh and cluster tree. RFDs can communicate only with FFDs while FFDs can communicate with other FFDs using multihop communication. Therefore, this topology allows the more complex networks.

## 2.3 Superframe Structure

IEEE 802.15.4 defines a Superframe structure shown in figure 1. This Superframe structure is divided into active and inactive periods. The active period divided into 16 equally spaced slots in which first slot is used for transmission of beacon and is further divided into contention access period and contention free period. Guaranteed time slot mechanism is used for contention free period. In the inactive period, the device goes to sleep mode to conserve energy.

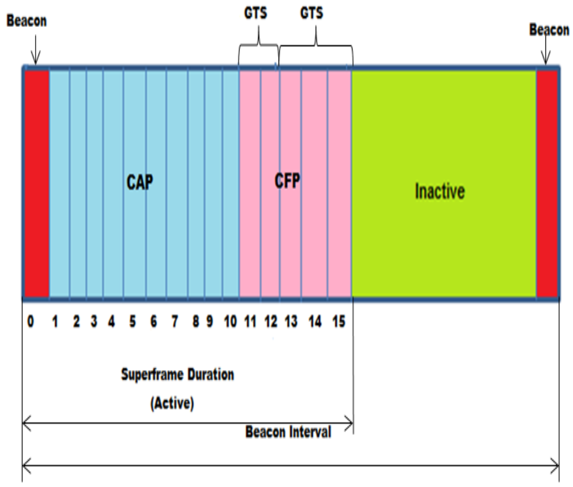


**Fig 1: Superframe structure of IEEE 802.15.4**

In beacon enabled mode of IEEE 802.15.4, communication and synchronization is established by PAN coordinator. PAN coordinator transmits a beacons packet periodically which contains information such as PAN identification, synchronization and Superframe structure. The Superframe structure is determined by coordinators using Superframe order (SO) and beacon order (BO). SO determines the active portion length and BO determines the beacon interval. The relationship between BO and SO can be expressed as $0 \leq SO \leq BO \leq 14$.

## 3. RELATED WORKS

In this section, the related work based on the energy consumption and QOS of grid and cluster network for wireless sensor networks have been reviewed. The researchers in [2] proposed the time based scheduling mechanism for ZigBee cluster tree WSN. In [3, 4] the researchers investigated on the energy conservation by balancing the load in WSN. The researchers in [5, 6] analyzed the network lifetime for WSN. The researchers in [7] investigated on the beacon enabled mode in IEEE 802.15.4 WSN.

## 4. SIMULATION SETUP

The performance of cluster and grid based network is evaluated by QualNet 6.1 Network Simulator [8]. In these scenarios similar parameters are used to evaluate the performance and energy consumption of nodes in both network scenarios.
In figure 2, the proposed cluster based network scenario in which the sensor nodes are distributed in the area of dimension 100m*100m.This network consists of 16 sensor nodes in which four sensor nodes are FFD (full functional devices) coordinator i.e. nodes 6,8,14 and 16, one sensor node is PAN coordinator i.e. node 1 and the remaining 11 nodes are (reduced functional devices) RFD.PAN coordinator is placed at the centre of the simulation network area and act as the main powered device. The beacon order used is 3 and Superframe order is 2. AODV [9] routing protocol is used in this network. Here, LINEAR battery model and GENERIC energy model is used.

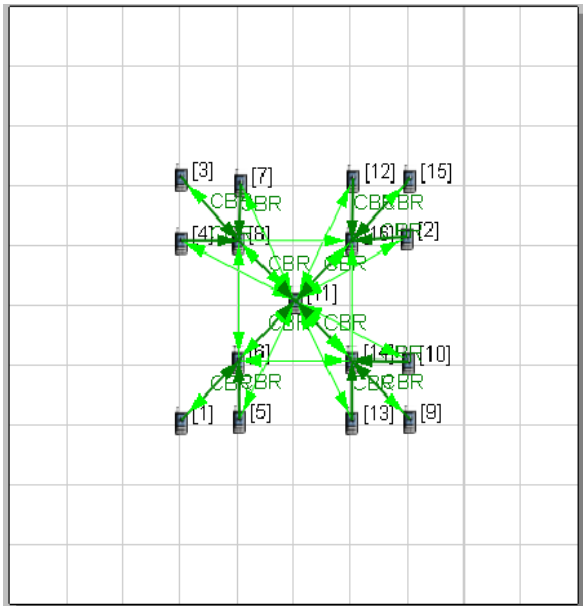


**Fig 2: Proposed cluster based network model**

In figure 3, the proposed grid based network scenario in which the sensor nodes are distributed in the area of dimension 100m*100m. This network consists of sixteen sensor nodes in which two sensor nodes are FFD (full functional devices) coordinator i.e. node number 12 and 15, one sensor node is PAN coordinator i.e. node number 16 and the remaining nodes are RFD (reduced functional devices). All sensor nodes are connected by using CBR. The beacon order used is 3 and Superframe order is 2. AODV [9] routing protocol is used in this network. Here, LINEAR battery model and GENERIC energy model is used.

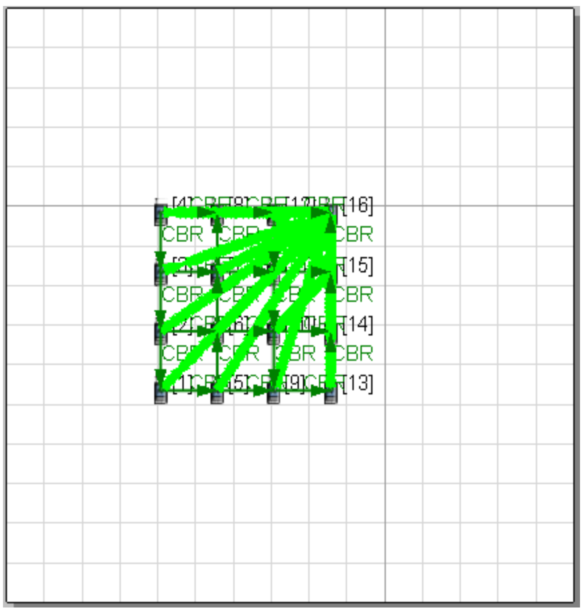

**Fig 3: Proposed grid based network model**

**Table 1. Simulation Parameter**

| Parameter Name | Parameter Value |
|---|---|
| Number of nodes | 16 |
| Area | 100m*100m |
| Simulation time | 510 |
| Number of items and payload size | 500 and 64 bytes |
| Packet rate (packet per sec) | 1,2,3,4,5 |
| Channel frequency | 2.4 GHz |
| Physical and MAC layer | IEEE 802.15.4 |
| Energy model | Generic |
| Battery model | Linear |
| Modulation | O_QPSK |
| Traffic type | CBR |
| Routing protocol | AODV |

## 5. SIMULATION RESULTS

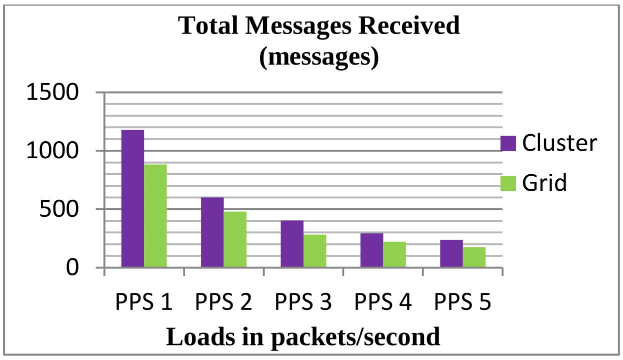


**Fig 4: Total messages received (messages) comparison**

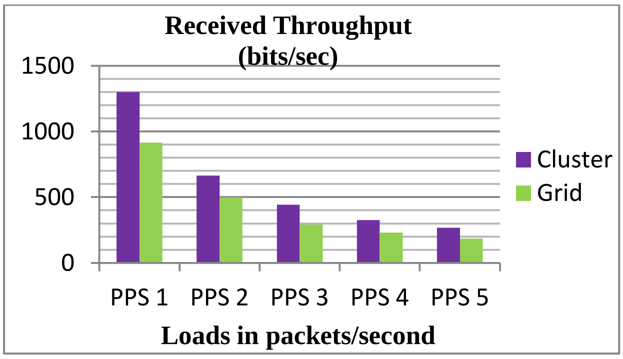


**Fig 5: Received Throughput (bits/sec) comparison**

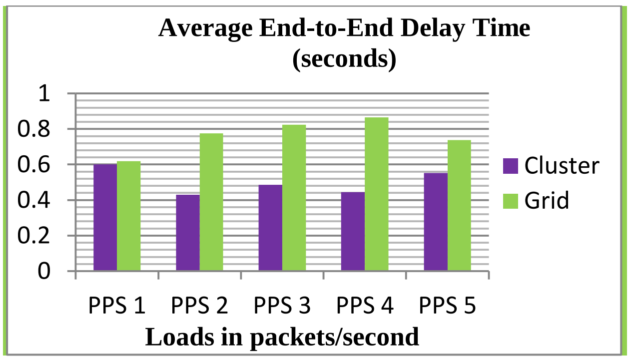


**Fig 6: Average end-to-end delay time (seconds) comparison**

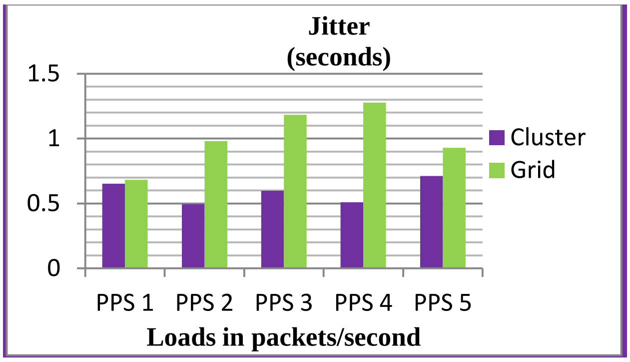


**Fig 7: Jitter (seconds) comparison**

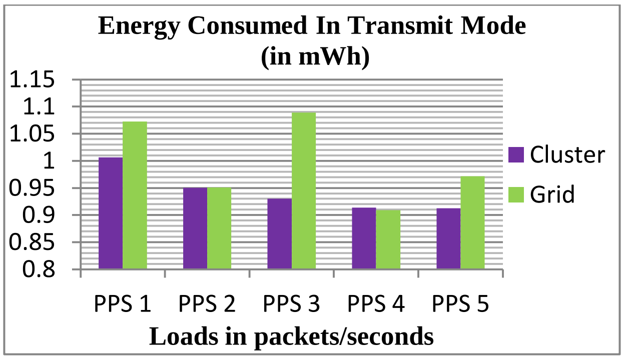


**Fig 8: Energy consumed in transmit mode (mWh) comparison**

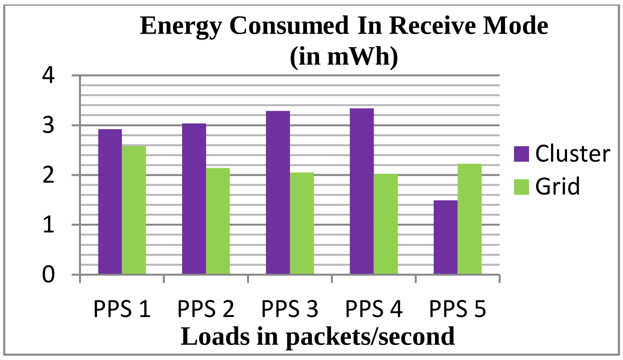


**Fig 9: Energy consumed in receive mode (mWh) comparison**

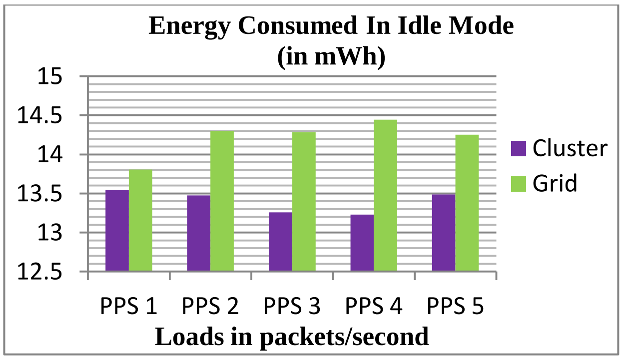


**Fig 10: Energy consumed in idle mode (mWh) comparison**

It can be analysed from the simulation results that when the packet transmission interval or packet per second (pps) increases network throughput decreases and average end-to-end delay increases in both cluster and grid based network scenarios and while calculating the total energy consumption the maximum energy is consumed during idle mode and minimum energy is consumed in transmission of packets in both scenarios.

## 6. CONCLUSION

In this paper two analytical models in which the nodes are organized as cluster and grid based networks are analysed in beacon-enabled mode to calculate the energy consumption and QOS using QualNet 6.1 Simulator. It is found that when the packet transmission interval or packet per second increases the network throughput decreases or we can say that while increasing the packet generation rate more number of packets is received and therefore packet loss ratio decreases. The network throughput increases with the increasing rate of packet generation because more number of packets is transmitted per second and the average end-to-end delay decreases because small delays are experienced by the nodes. It is also concluded that during idle mode the maximum energy consumed by the nodes and minimum energy consumed in the transmission of the packets in both networks.

## 7. REFERENCES

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