Forwarding Measured Data Using Zigbee

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Abstract
Zigbee is advanced and growing wireless technology that is very useful for Wireless sensor Networks (WSNs). This paper describes the way to make use of this technology in industry especially when transmitting measured data from automated instruments in a plant to the central
Control unit. The impact of increasing number of nodes with different packet sizes and its effect in terms of delays during the transmission is also discussed.

Index Terms—Zigbee, self-configuring networks, Wireless sensor networks (WSNs).

Introduction

Zigbee is a simple, reliable wireless network technology that is suitable for control applications. It provides reliable, robust, self-configuring and self-healing networks [1]. Zigbee is preferred in sensor networks for its capacity to accommodate more devices compared to other technologies. Two specifications of the Zigbee protocol stack exist. The IEEE defines only the PHY and MAC layers while the Zigbee Alliance Specification adds Network layer (NWK) and Application layer (APL) to the stack profile defined by the IEEE [4 Fig-2]. Zigbee devices can be defined as reduced function devices (RFDs) or full function devices (FFDs). FFDs can communicate with any other device assuming the role of coordinator or Router. RFDs can only communicate with FFDs. FFDs are, therefore, more complex in their design and consume more power.

State of the art

The transmission range of most Zigbee devices is the range of ~100m (outdoors) which is inadequate for deployment in vast industries. Multi-hop technology can increase network Coverage to large geographical areas [2]. Multi-hop propagation of data, however, increases latency. Zigbee has been touted as having greatest potential for use in class 4 and class 5 applications [3]. But routing mechanisms for Zigbee network formation, addressing of nodes and performance in delay sensitive applications are yet to be adequately addressed.

Research question and problem statement

In this paper, we investigate the performance of a meshed Zigbee network modeled in OPNET to forward measurement data from instruments in the plant to a central control unit. Specifically, effects of the number of nodes and packet size on network performance are examined. The main contribution of this paper is the determination of suitable Zigbee network sizes to meet design requirements through the use of OPNET simulation software.

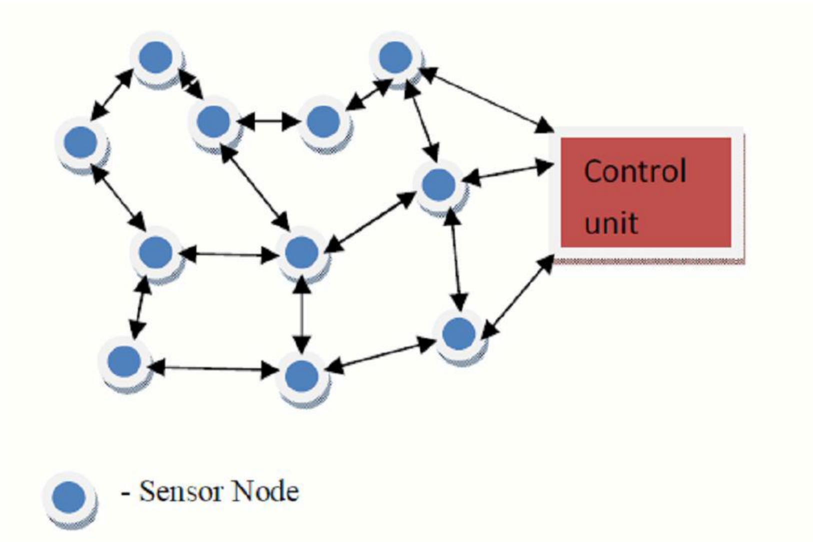

Fig. 1. Meshed Network Model.

Problem solution

Zigbee network was developed and simulated in OPNET. This network included Zigbee nodes and one Zigbee Coordinator. The Zigbee Coordinator was tied to the Control unit and collected data from all nodes in the network. Four scenarios were modeled in OPNET to simulate different network environments as shown in Table-1. Packet interval time, transmit power, number of retransmissions, acknowledgement timeouts etc were set to default values.

TABLE 1
SIMULATION PARAMETERS

Scenario	No. of Nodes	Packet Size(bytes)
1	20	256
2	20	512
3	40	256
4	40	512

The simulation was run over a period of 30 minutes. As a result, the following statistics were collected:

1. *Packet delivery rate*
2. *End-to-end delay*

Packet Delivery Rate (Packets sent vs. Packets Received)

As time progressed, more nodes joined the network, each placing its own data into the network. This explains the rapid rate of increase of packets sent. The number of packets sent per second flattens out after all nodes have joined the network. Simulation results indicate 100% packet delivery in the initial stages of the simulation. Thereafter, a fairly constant rate of packet loss (difference between packets sent and packets received) is observed for all scenarios.

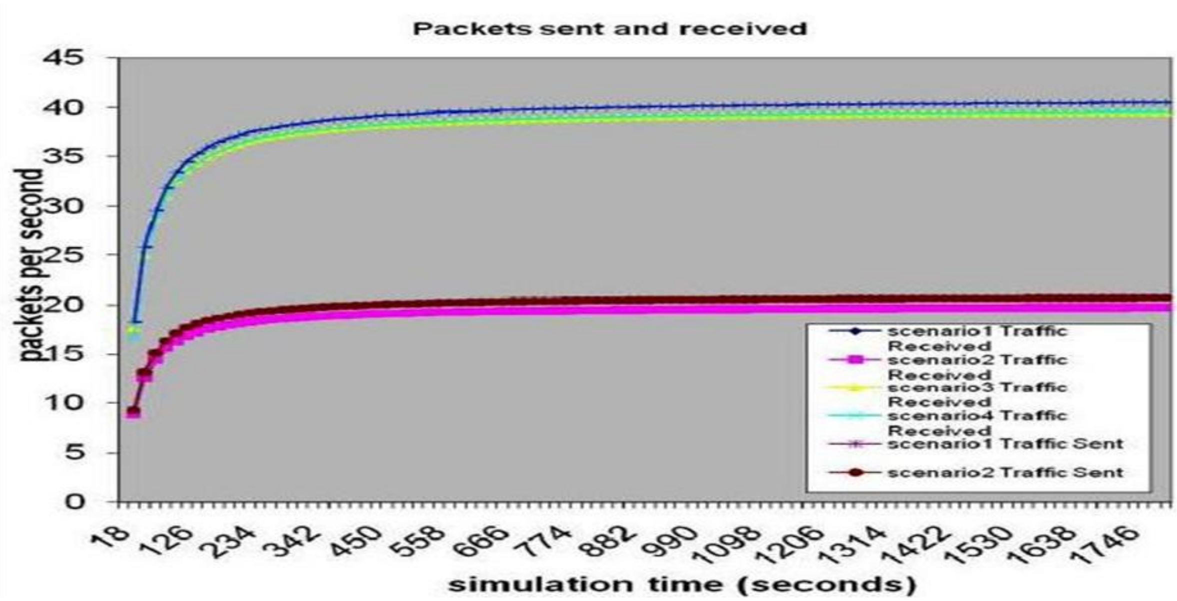

Fig. 2. Comparison between packets sent and packets received for all four Scenarios

It is worth noting that figures reported for packets received include retransmitted packets. Undelivered packets were only recorded after 5 failed retransmissions.
We observed that other factors remaining constant. The Zigbee network is able to provide a predictable packet delivery rate regardless of packet size or number of nodes.
End-to-end delay of application data. We observed that end-to-end delay for all Scenarios was greatest at the start of the simulation and thereafter fell to the range of milliseconds as simulation time progressed. This may be attributed to lack of optimum routing paths for

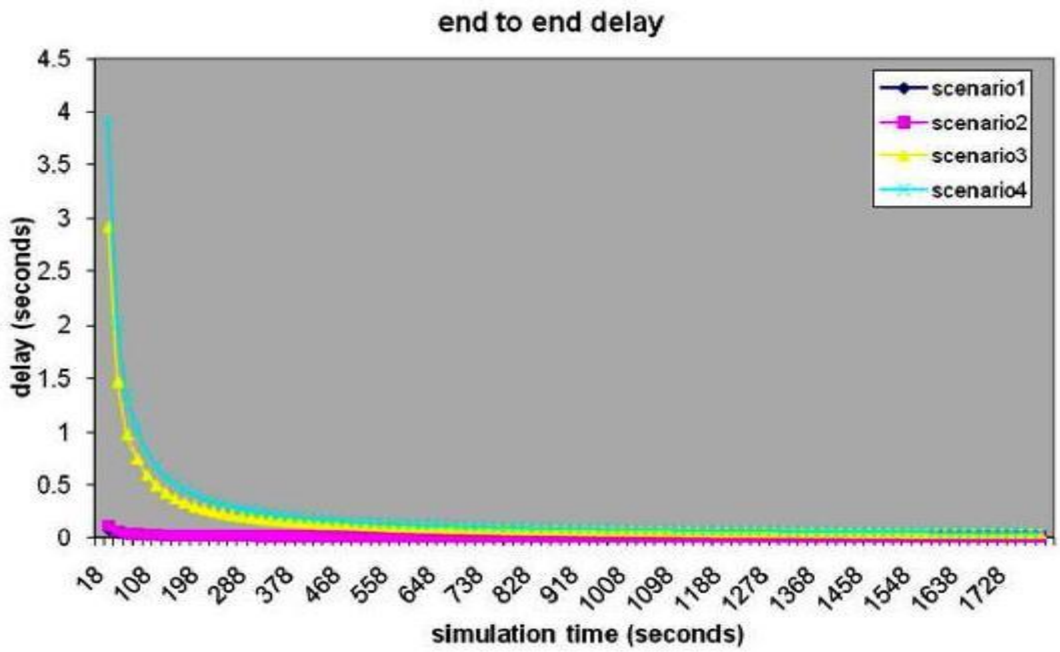

Fig. 3. End-to-end delay

Packets in the initial phases of network establishment. During this period, network control and management data as opposed to measurement data accounts for a larger portion of the traffic. Delay is greatly affected by number of nodes with scenarios 3 and 4 exhibiting the highest end-to-end delay in the initial stages. By comparison, packet size has a less significant effect on end-to-end delay.

Conclusion

Delays of 3 to 4 seconds are unacceptable in many control applications especially when the control cycle is less than 1 second. For large networks, a hierarchical system could be employed so that smaller Zigbee networks aggregate their data on an intermediate device with higher bandwidth e.g. Wi-Fi for onward transmission to the control unit. Through the use of simulation tools such as OPNET, an appropriate size for Zigbee networks can be determined depending on the delay requirements of each particular network.

References

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