Performance Analysis of Zigbee Wireless Sensor Networks with Relaying

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Santa Margherita Ligure – April 16th, 2007
Outline

- Zigbee standard overview
- Experimental and simulation setup
- Performance analysis
  - Impact of the number of sensors
    - With the use of ACK messages
    - Without the use of ACK messages
  - Impact of traffic load
  - Impact of the ACK window duration
  - Impact of network lifetime
- Conclusions
Zigbee Standard Overview

- Low Rate and Low Power consumption standard (250 kbps)
- Based on the IEEE 802.15.4 standard
- Employs the non-persistent CSMA/CA medium access technique
- Two kind of devices:
  - Reduced Function Device (RFD)
  - Full Function Device (FFD)
    - Coordinator
    - Relay node
Experimental and Simulation Setup

Experimental Testbed

- PICDEM Z nodes (Microchip)
- Indoor environment
- 1000 packets sent for each run
- Two network configurations

a) Direct transmission

b) Transmission through one relay node
Experimental and Simulation Setup

Simulation Testbed

- Opnet simulator
- Extension of the IEEE 802.15.4/Zigbee model developed at NIST, Gaithersburg, MD, USA
- Simulation duration equal to 1 hour
- Ten different seeds for each scenario
- Packet generation rate equal to $g = 2 \text{pck/s}$
- Maximum payload equal to 118 byte/pck
Experimental and Simulation Setup
Simulation Testbed

- Three network topologies:
  
  ![Diagram]

  a) Direct transmission  
  b) Transmission through one relay node  
  c) Transmission through two relay nodes
Router Implementation

- The relay node just modifies a few fields of the received packet (i.e., source and destination addresses).
- No transmission queue is used.
- The relay nodes wait for the reception of the ACK message from the coordinator.

![Diagram of Zigbee communication](Image)

- Transmission allowed but router discards packet.
- Router can receive new packets.
- Router blocks new incoming packets.
Impact of the Number of Sensors With the Use of ACK Messages

$L = 64 \text{ byte/pck}$

THE NETWORK PERFORMANCE DROPS DOWN IN THE PRESENCE OF A RELAY
Impact of the number of sensors
Without the use of ACK messages

$L = 64 \text{ byte/pck}$

THE PRESENCE OF N RELAYS REDUCES NETWORK PERFORMANCE BY A FACTOR $1/N$
Impact of Traffic Load
Simulation Results

a) $N=20$

ACK messages are sent

b) $N=100$

THE NETWORK PERFORMANCE IS NOT INFLUENCED BY THE NUMBER OF NODES FOR A GIVEN NUMBER OF RELAYS
Impact of Traffic Load
Simulation Results

ACK messages are sent

THE PRESENCE OF A ROUTER SIGNIFICANTLY REDUCED THE THROUGHPUT
Impact of Traffic Load
Experimental Results

a) No router  

b) One router

IN EXPERIMENTAL TESTS, IN THE PRESENCE OF A ROUTER DOES NOT INFLUENCE THE NETWORK PERFORMANCE
Impact of the ACK Window Duration

$L = 64$ byte/pck

$N = 3$ RFDs

- **NO ROUTER**: THE DELAY INCREASES SLOWLY
- **ONE ROUTER**: THE DELAY HAS A MAXIMUM
Impact of Network Lifetime in Clustered Scenarios

THE NETWORK CONFIGURATION WHICH MAXIMIZES THE NETWORK TRANSMISSION RATE DEPENDS ON THE NUMBER OF NODES AND THE NETWORK LIFETIME (QoS)
Concluding remarks

- High performance degradation in the presence of a router if ACK messages are used
- Possible improvement by eliminating the ACK messages
- Dependence of network performance on the number of RFDs and required network lifetime in clustered scenarios