QoS Performance Analysis for CSMA/CA in IEEE802.15.5

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Journal of Networks July 2014

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Internet of Things
Fall 2015
Introduction

- Authors argue that slotted CSMA/CA is particularly suited for WSNs where traffic is discrete or non-cyclical.
- Focus is on beacon-enabled mode for IEEE802.15.4.
- QoS is used constantly in this paper but the authors’ simulated application is mathematically-based with no real intuitive notion of QoS discussed.
IEEE 802.15.4 Frame Format

- Low Bandwidth (250 kbps), low power (1 mW) radio
- Moderately spread spectrum (QPSK) provides robustness
- Simple MAC allows for general use
  - Many TinyOS-based protocols (MintRoute, LQI, BVR, ...), TinyAODV, Zigbee, SP100.11, Wireless HART, ...
  - 6LoWPAN => IP
- Choice among many semiconductor suppliers
- Small packets used to keep packet error rate low and permit media sharing.
Outline

- Introduction
- Beacon-Enabled IEEE802.15.4 and Superframe Structure
- Simulation Methodology
- Analysis of Simulation Results
- Conclusion
- Critique
Beacon-Enabled IEEE802.15.4

- In beacon-enabled mode, communication behavior is constrained by superframe structure which is synchronized when coordinator periodically sends beacon frames.
- Each sensor node’s communication process happens in the allocated slot time.
Figure 1: 802.15.4 Superframe

Figure 1. The IEEE 802.15.4 superframe structure.
Beacon Interval (BI) and Superframe Duration (SD)

- BI is defined by BO (Beacon Order).
- SD is defined by SO (Superframe Order).

\[
BI = a \cdot \text{BaseSuperframDuration} \times 2^{BO}
\]
\[
SD = a \cdot \text{BaseSuperframDuration} \times 2^{SO}
\]
\[
(0 \leq SO \leq BO \leq 14)
\]
Duty Cycle (DC)

- Duty cycle of beacon-enabled 802.15.4 is defined as:

\[
DC = \frac{SD}{BI} = \frac{a\text{BaseSuperframeDuration} 	imes 2^{SO}}{a\text{BaseSuperframeDuration} 	imes 2^{BO}} = 2^{SO-BO}
\]

Example: \(BO-\text{SO} = 2\)

\[
DC = 2^{-2} = \frac{1}{4} = 25\%
\]
For each BI, the inactive period is the node sleeping time (ST) which can be calculated as:

\[
\text{ST} = \text{BI-SD} = \text{BI-BI} \times \text{DC} = \text{BI-BI} \times 2^{\text{SO-BO}} = \text{aBaseSuperframDuration} \times 2^{\text{BO}} \times \left(1 - \frac{1}{2^{\text{BO-SO}}}ight)
\]  

(3)

Hence ST is affected by the value of BO and duty cycle (i.e., BO-SO)
Three “What if” observations

1. **BO** fixed; **BO-SO** grows:
   - **ST** grows and **DC** decreases
   - E down, D up, O down

2. **BO-SO** fixed; **BO** grows:
   - **ST** grows
   - E down, D up, O down

3. **BO** fixed; as **BO-SO** increases from 0 to 14, change in **ST** decreases.

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Slotted CSMA/CA in IEEE802.15.4
Simulation Settings

- 10 m x 10 m simulated area, 2.4 GHz, 250 kbps, 600 sec. duration using OPNET
- Sensors deployed randomly to create star-topology. {This is very unclear!}
- Power set at 1 mW, QPSK used.
- No explanation of application traffic model:

<table>
<thead>
<tr>
<th>Traffic Source</th>
<th>MSDU Interarrival Time (s)</th>
<th>MSDU Size (bits)</th>
<th>Star Time (s)</th>
<th>Stop Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACK</td>
<td>Poission (1.0)</td>
<td>Poission (100)</td>
<td>0.0</td>
<td>Infinity</td>
</tr>
<tr>
<td>UnACK</td>
<td>Uniform (0.5,1.5)</td>
<td>Poission (50)</td>
<td>0.0</td>
<td>Infinity</td>
</tr>
</tbody>
</table>
Figure 2. The simulation model of Slotted CSMA/CA based on OPNET modeler.
Figure 3. Relationship between QoS and different duty cycle (BO=14, 10 Nodes)

- Large delay
- Small duty cycle

Graph shows:
- Network Output Load (bits/sec)
- Consumed Energy (Joule)
- End-to-End Delay (seconds)
Figure 4: 30 Node Simulation

Figure 4. Relationship between QoS and different duty cycle (BO=14, 30 Nodes)

Larger delay
Figure 5: 50 Node Simulation

Figure 5. Relationship between QoS and different duty cycle (BO=14, 50 Nodes)
Simulations Varying BO

- Authors want to study first “what if”:
  - BO fixed; BO-SO varies
- Fix the number of devices at 14.  
  \{Appears to minimize slot collisions!\}
- 400 seconds simulated time.
- Use Table II for traffic sources.
<table>
<thead>
<tr>
<th>Traffic Source</th>
<th>MSDU Interarrival Time(s)</th>
<th>MSDU Size</th>
<th>Start Time(s)</th>
<th>Stop Time(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Node1,2</td>
<td>exponential(2)</td>
<td>poisson(100)</td>
<td>0.0</td>
<td>infinity</td>
</tr>
<tr>
<td></td>
<td>poisson (0.2)</td>
<td>constant(200)</td>
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<td>infinity</td>
</tr>
<tr>
<td>Node3,4,5,6</td>
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<td>none</td>
<td>infinity</td>
<td>infinity</td>
</tr>
<tr>
<td></td>
<td>poisson (1)</td>
<td>constant(200)</td>
<td>0.0</td>
<td>infinity</td>
</tr>
<tr>
<td>Node7,8</td>
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<td>poisson(100)</td>
<td>3.0</td>
<td>9.0</td>
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<tr>
<td></td>
<td>none</td>
<td>none</td>
<td>infinity</td>
<td>infinity</td>
</tr>
<tr>
<td>Node9,10</td>
<td>constant(3)</td>
<td>poisson(50)</td>
<td>0.0</td>
<td>infinity</td>
</tr>
<tr>
<td></td>
<td>poisson(0.2)</td>
<td>uniform(50,200)</td>
<td>0.0</td>
<td>infinity</td>
</tr>
<tr>
<td>Node11,12,13,14</td>
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<td>none</td>
<td>infinity</td>
<td>infinity</td>
</tr>
<tr>
<td></td>
<td>exponential(0.5)</td>
<td>constant (160)</td>
<td>0.0</td>
<td>infinity</td>
</tr>
</tbody>
</table>

**Table II. Parameters of Variable Traffic Source**

**Why this traffic?**
Figure 6: Energy vs BO

Figure 6. Relationship between energy consumption and BO

Best performance
Figure 7: Output Load vs BO

Network Output Load (bits/sec)

Figure 7. Relationship between network output load and BO
Figure 8. Relationship between end-to-end delay and BO

End-to-End Delay (seconds)

Best performance
Conclusions

Basically authors argue this presentation lets one see the tradeoffs in setting for beacon-enabled, slotted CSMA/CA for IEEE802.15.4
Critique

- No justification or explanation of traffic sources.
- They use QoS inappropriately - end-to-end delay never defined.
- No discussion of traffic routes.
- No sense of slotted collisions and no formal assignment to slots.
- Why only star-topology?