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Wireless Sensor Networks

- Small battery-powered electronic devices
- Adhoc multi-hops large scale networks
- Unreliable links
Anomaly detection

Critical applications:
- Forest fire detection
- Landslide detection
- ...

Required:
- Timeliness

"Does the alarm reach the sink before the deadline?"

There is a need for formal verification
WSN verification in the literature

● Model Checking:


● Senor Network Calculus


● Probabilistic Model Checking:

WSN verification in the literature

● Model Checking:


● Senor Network Calculus


● Probabilistic Model Checking:

Analysis of the problem(1):
Radio link
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\[ P_{cr}(d) = 1 - PER \]
Analysis of the problem(1):
Radio link

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Analysis of the problem(1): Radio link

\[ P_{cr}(d) = 1 - PER \]
Analysis of the problem(2):
Topology dynamics

sink
Analysis of the problem(2): Topology dynamics

\[ P_{cr}(d) \]

\[ 1 - P_{cr}(d') \]

\[ P_{topo1} \]

sink
Analysis of the problem(2):
Topology dynamics

$P_{cr}(d)$

$1 - P_{cr}(d')$

$P_{\text{topo}2}$

sink
Analysis of the problem(2): Topology dynamics

"With which topologies the protocol can provide real-time communications?"

\[ P_{cr}(d) \]
\[ P_{topo2} \]
\[ 1 - P_{cr}(d') \]

Reliability
Verification algorithm

Output: probability that the real-time property holds

Generate logical topologies: $T$

Select topologies: $T'$

verify topology in $T'$

Does the Property hold ?

yes $P_{Pv}=P_{Pv}+P_{topo}$

no

Not verified topology in $T'$ ?

yes

no

Output: $P_{Pv}$
Verification algorithm

Output: probability that the real-time property holds

Generate logical topologies: $T$

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Does the Property hold?

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$P_{Pv} = P_{Pv} + P_{topo}$

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Output: $P_{Pv}$

There are $2^N$ topologies !!!
Verification algorithm

Output: probability that the real-time property holds

Generate logical topologies: $T$

Select topologies: $T'$

verify topology in $T'$

Does the Property hold?

no

Not verified topology in $T'$?

no

Output: $P_{pv}$

yes

$P_{pv} = P_{pv} + P_{topo}$

There are $2^N$ topologies !!!

Depends on the property to be verified
Verification algorithm

Output: probability that the real-time property holds

- Generate logical topologies: $T$
- Select topologies: $T'$
- $\text{verify topology in } T'$
- Does the Property hold?
  - yes: $P_{\text{PV}} = P_{\text{PV}} + P_{\text{topo}}$
  - no: Not verified topology in $T'$?
    - yes: Output: $P_{\text{PV}}$
    - no: Output: $P_{\text{PV}}$

There are $2^N$ topologies !!!

Depends on the property to be verified

Check that real-time deadline is met or not on a model of the network (protocol and topology)
Case study

- f-MAC protocol
- Topology
- Property
Case study

- f-MAC protocol

- Topology

- Property
Case study

- f-MAC protocol
- Topology
- Property
Case study

- f-MAC protocol
- Topology
- Property

Topology A

Topology B
Case study

- f-MAC protocol
- Topology
- Property
  "All nodes successfully send a packet to the sink (node 0) before the deadline"
Network model

A[ ] z>deadline imply rcvd==Nn
Verification results

<table>
<thead>
<tr>
<th>Number of nodes</th>
<th>Number of topologies</th>
<th>Number of verified topologies</th>
<th>Duration (s) A</th>
<th>Duration (s) B</th>
<th>$P_{pv}$ A</th>
<th>$P_{pv}$ B</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>8</td>
<td>2</td>
<td>0.30</td>
<td>0.21</td>
<td>0.931</td>
<td>0.746</td>
</tr>
<tr>
<td>4</td>
<td>64</td>
<td>8</td>
<td>0.32</td>
<td>0.33</td>
<td>0.918</td>
<td>0.368</td>
</tr>
<tr>
<td>5</td>
<td>1024</td>
<td>64</td>
<td>15.11</td>
<td>15.22</td>
<td>0.875</td>
<td>0.323</td>
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<tr>
<td>6</td>
<td>1073741824</td>
<td>1024</td>
<td>69066.86</td>
<td>69173.25</td>
<td>0.771</td>
<td>0.268</td>
</tr>
</tbody>
</table>
Comparison with simulations

![Graph 1](image1.png)

![Graph 2](image2.png)
Conclusions and future works

Conclusions on the proposed method:

- Estimation of topologies probabilities
- Timed verification on the topologies
- Verification tool independant
- Tested with a case study
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Future works:

- Application to a more realistic protocol
- Consider asymmetric links
- Scalability problem ...