Realistic Performance Analysis of WSN Protocols Through Trace Based Simulation

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Existing Approaches to Analyze WSN Performance

- Build a prototype system
  - Very good measure of performance, but costly, time consuming, and difficult to optimize
- NS-2, OMNeT++
  - Good "average" measure of performance under significant assumptions; steep learning curve
- TOSSIM, Avrora, and Cooja
  - Focus on validating functionality; not a good measure of performance
Our Vision: a Hybrid Approach

- Network connectivity information can be easily collected from a deployed WSN
  - This captures all real-world artifacts
  - Can be shared as well: [http://wsn.eecs.berkeley.edu/connectivity/index.php](http://wsn.eecs.berkeley.edu/connectivity/index.php)

- Use these network profiles instead of synthetic models from an easy to use network simulator
Our Solution

- Split the performance evaluation
  - Hardware
  - Software
Our Tools

- **WSN Profiler**
  - Automates the collection of network connectivity data
  - TinyOS application with a Java-based central server for coordination

- **WSN SimPy**
  - A network simulator that uses collected trace data as the basis for communication
  - Built on the discrete event simulator SimPy
    - http://simpy.sourceforge.net/
TinyOS Application

- **Sender**
  - Broadcasts a preset number of packets at a some frequency

- **Receiver**
  - Reports packet receptions to the profile server
Profile Server

- Selects one node to be a sender at any time
- Records packet receptions to a log file
- Many configurable options:
  - Power level
  - Radio Channel
  - Number of transmissions
  - Packet transmission rate
  - Transmitted packet size
Network Visualization

ETX Graph
Network Visualization

- Per-node PDR
WSN SimPy

- **SimPy**
  - Discrete event simulator
  - Object oriented, process based
  - Standard Python source

- **WSN extensions for SimPy**
  - Single `network` object
  - Nodes are represented by individual objects
Selecting Recipients

- Each packet transmission from WSN Profiler is assigned a unique sequence number (included in the packet)
- Receptions can then be positively matched to transmissions
- To simulate a transmission an initially random sequence number is used to select recipients directly from the trace data
- Subsequent transmissions use sequential sequence numbers (wrapping to the beginning of the trace)
Packet Timing

- Assuming the IEEE 802.15.4 radio
  - 250 Kbit/sec (32 microseconds per byte) therefore transmission delay is computed from packet length
  - Ignore propagation delay: it is not significant over short distances
  - Processing delays are application specific; they can be simulated by the user
Radio Layer

- Half-duplex radio is simulated by the base node class i.e.:
  - A node cannot receive a packet while it is transmitting a packet
  - Packet transmission cannot start if the node is receiving a packet
Collisions

- Are also simulated by the base radio class of each node
- Currently assumes an idealized MAC layer
  - The network layer signals each node after the computed transmission delay
  - The radio layer inserts a 32 microsecond collision window on each packet reception
Sample Performance Evaluation

- Simple application using the collection tree protocol (CTP)
- Evaluated with
  - WSN SimPy
  - WSN SimPy(synthetic)
  - TOSSIM
  - Testbed
- Using two different topologies: grid and clustered
Clustered Topology
Grid: Performance

- PDR vs Duration (minute)
- Number of beacons/node vs Duration (minute)
- Churn vs Duration (minute)
Clustered: Performance
Conclusion

- We present two tools
  - WSN Profiler – automates collecting connectivity information and visualizing the performance of deployed networks
  - WSN SimPy – an extension of SimPy to simulate WSNs using network profiles collected by WSN Profiler
- Simulated results of a sample application closely match real-world performance results from a testbed
- Both tools are available at http://thor.mines.edu/