Energy Evaluations in Wireless Sensor Networks – A Reality Check

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Energy Evaluations

- Most future WSN applications need small and cheap sensor nodes
  - Implicates heavily constrained energy, memory and processing resources
  - Requires special care for resource efficiency, e.g. energy-efficiency

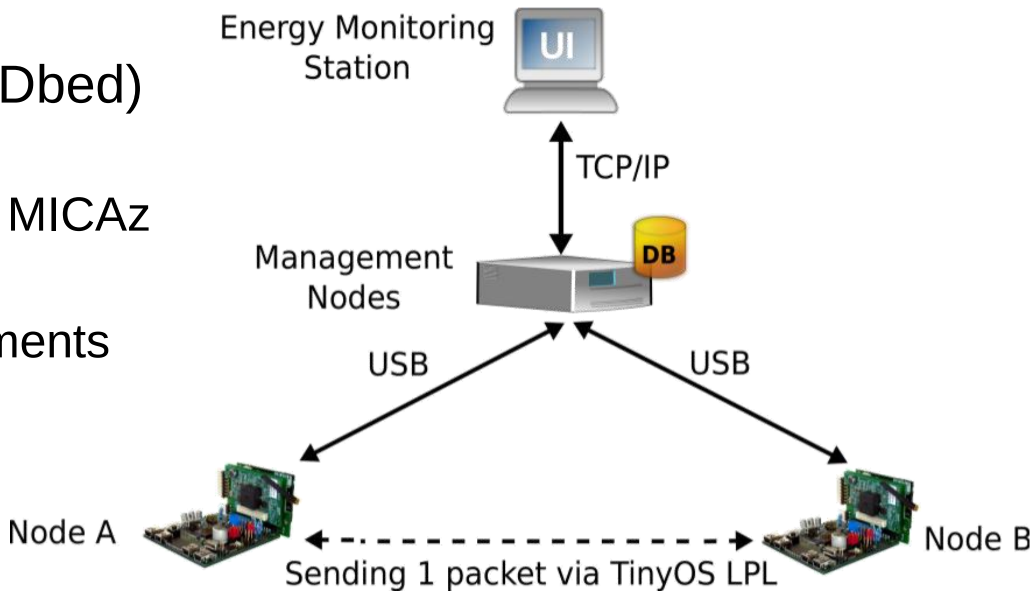
- Common practices to proof energy-efficiency
  - Protocols are evaluated in isolation
    - Possible influence of cross-layer effects neglected
  - Use “simple” simulator tools, e.g., TOSSIM, OMNeT++
    - Need application code modification or separate implementation
    - Not designed for getting energy data
  - Estimate energy consumption by
    - Counting packages
    - Sum up data volume

- What is appropriate or “sufficient”? → We check with reality!

Experiment setup

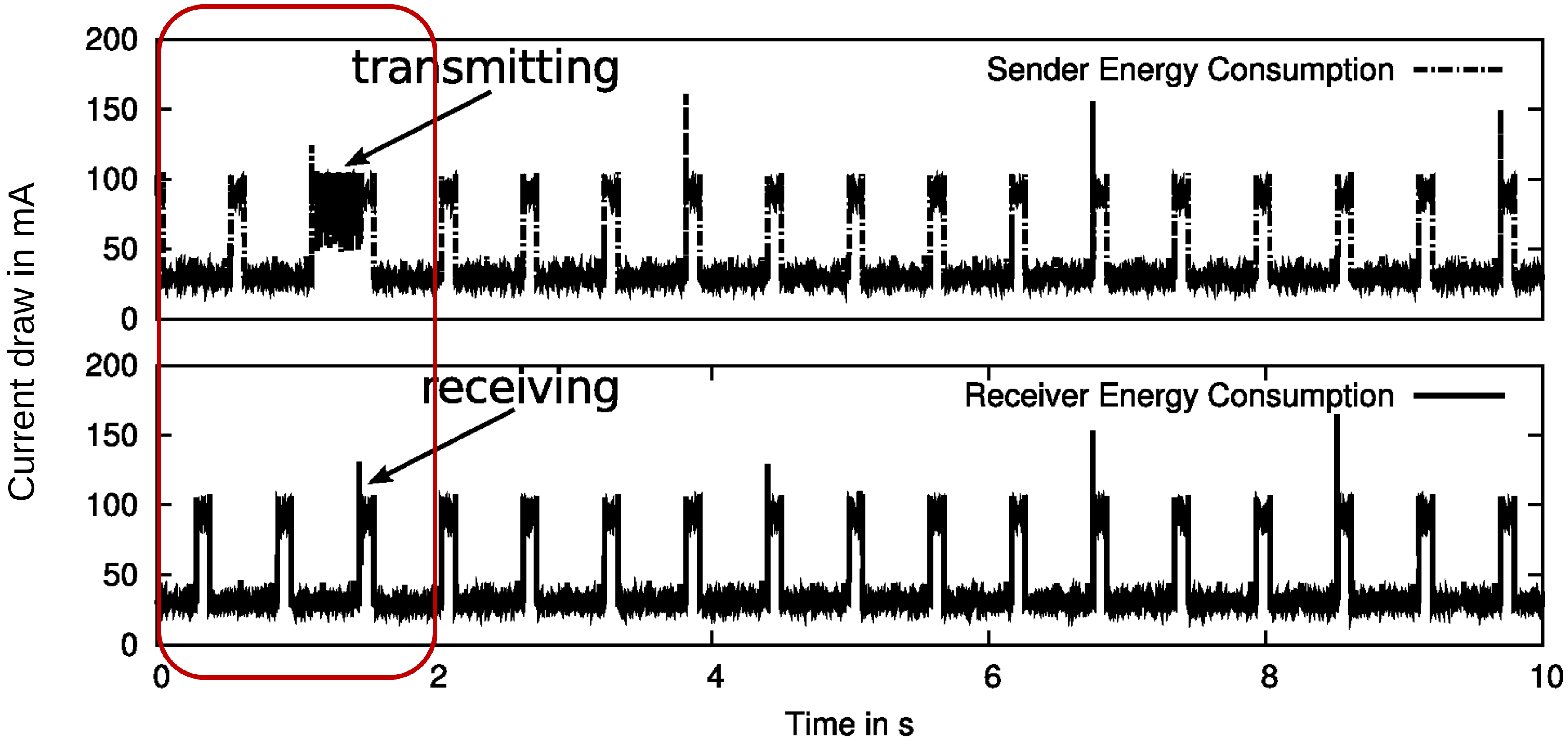
- Send a single data packet from node A to node B
  - Use TinyOS, Low Power Listening enabled
  - Measure an interval of 10 seconds, that includes exactly one transmission
  - Trigger transmission at random time, repeat 100 times

- Use local WSN testbed (SANDbed)
  - Provides distributed energy measurement of approx. 20 MICAz nodes
  - High resolution of measurements (up to 250 kHz)
  - Proven measurement error below 1% [1]

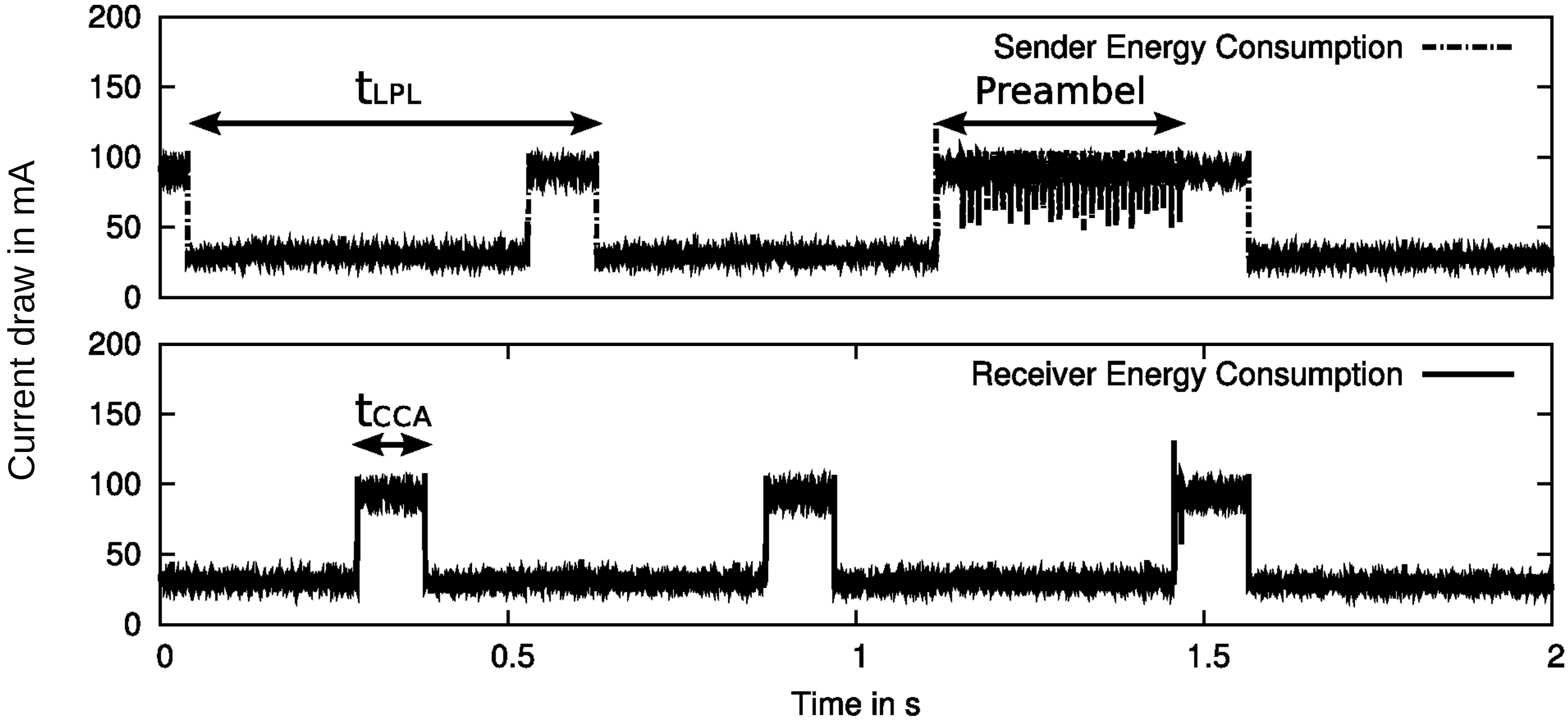


[1] A. Hergenröder, J. Horneber. Facing Challenges in Evaluation of WSN Energy Efficiency with Distributed Energy Measurements. Proc. of 7th International Wireless Communications and Mobile Computing Conference, pp. 1004-1009, Istanbul, Turkey, July 2011

Experiment Example



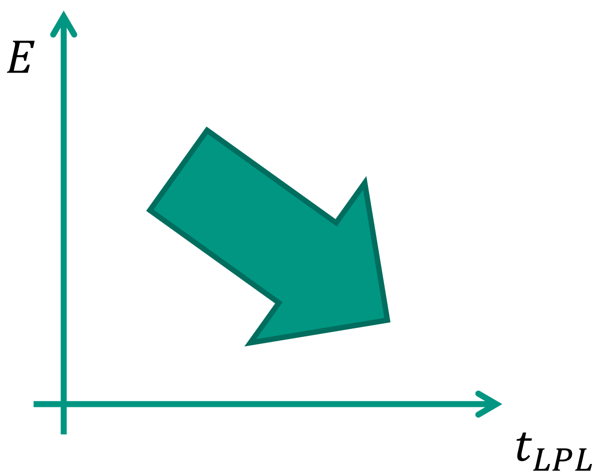
Experiment Example – Detailed View

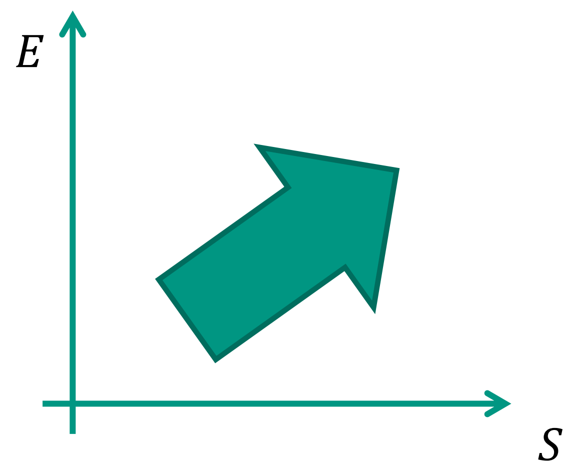


Experiment Parameters

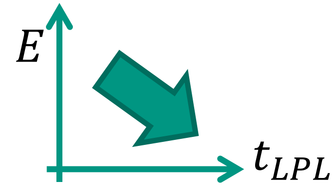
- Important parameter
  - t_{LPL} – LPL sleep interval
  - t_{CCA} – Duration to check the medium for activity
  - S – payload size

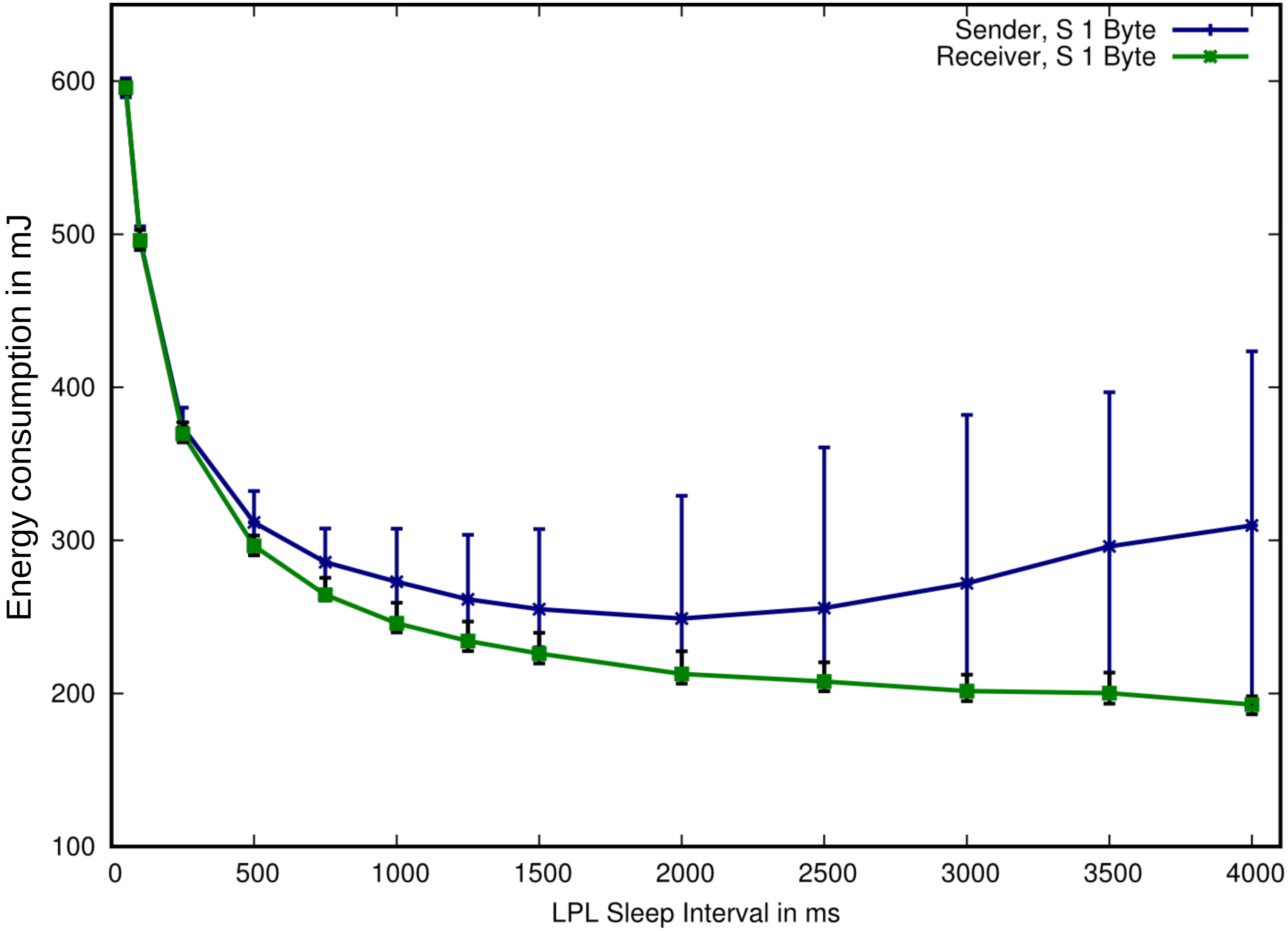
- Expectations
  - The lower t_{LPL} the more energy is consumed (i.e., higher duty cycle)
  - The bigger the payload S is, the more energy is consumed





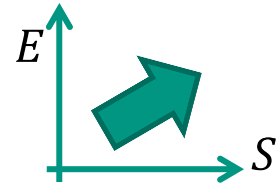
Influence of t_{LPL}

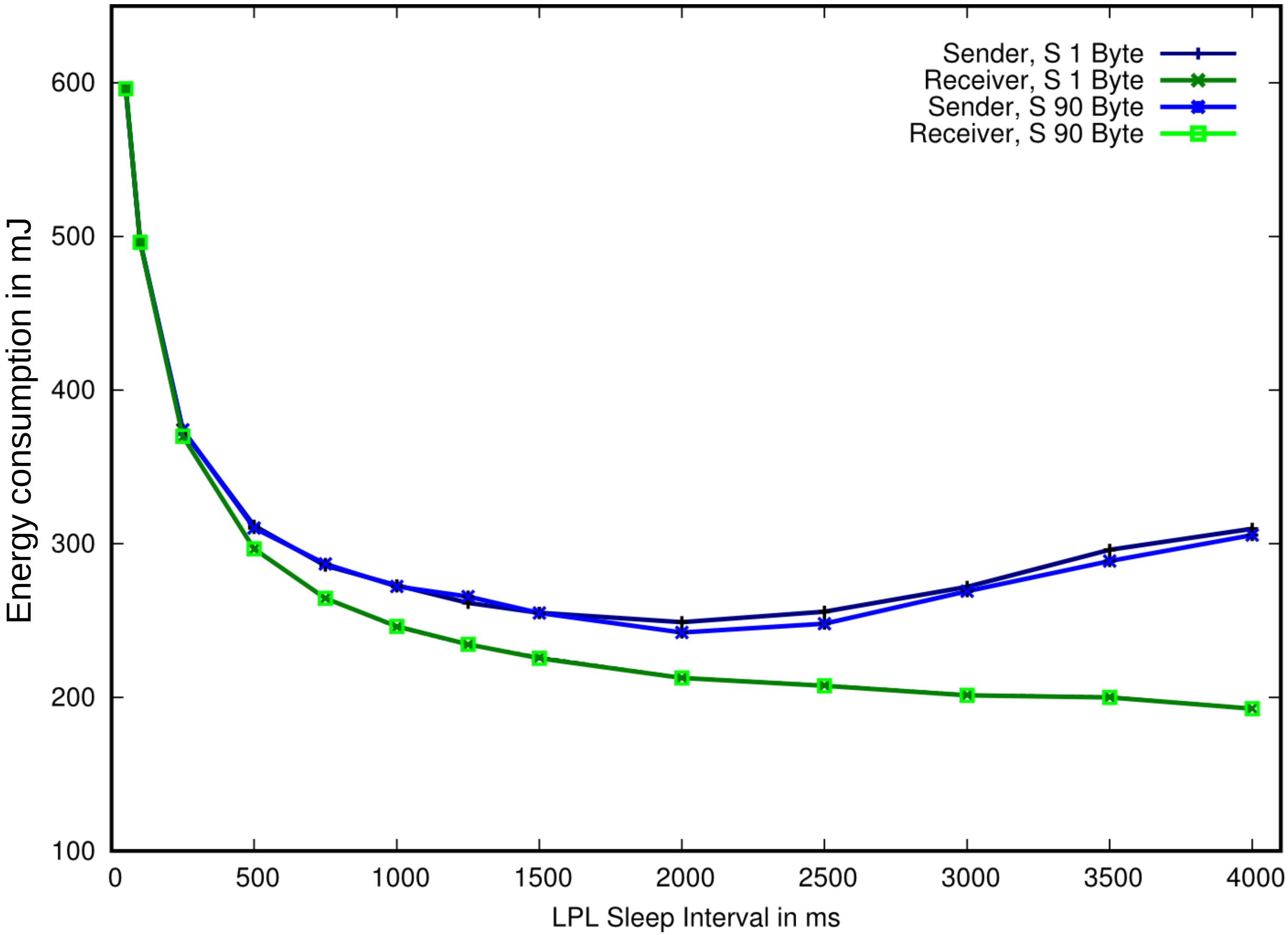




- Sending (mostly) more expensive than receiving
- Larger t_{LPL} not always decreases energy consumption
- Optimal value for t_{LPL} exists
- High fluctuation, depending on transmission and timing of transmissions

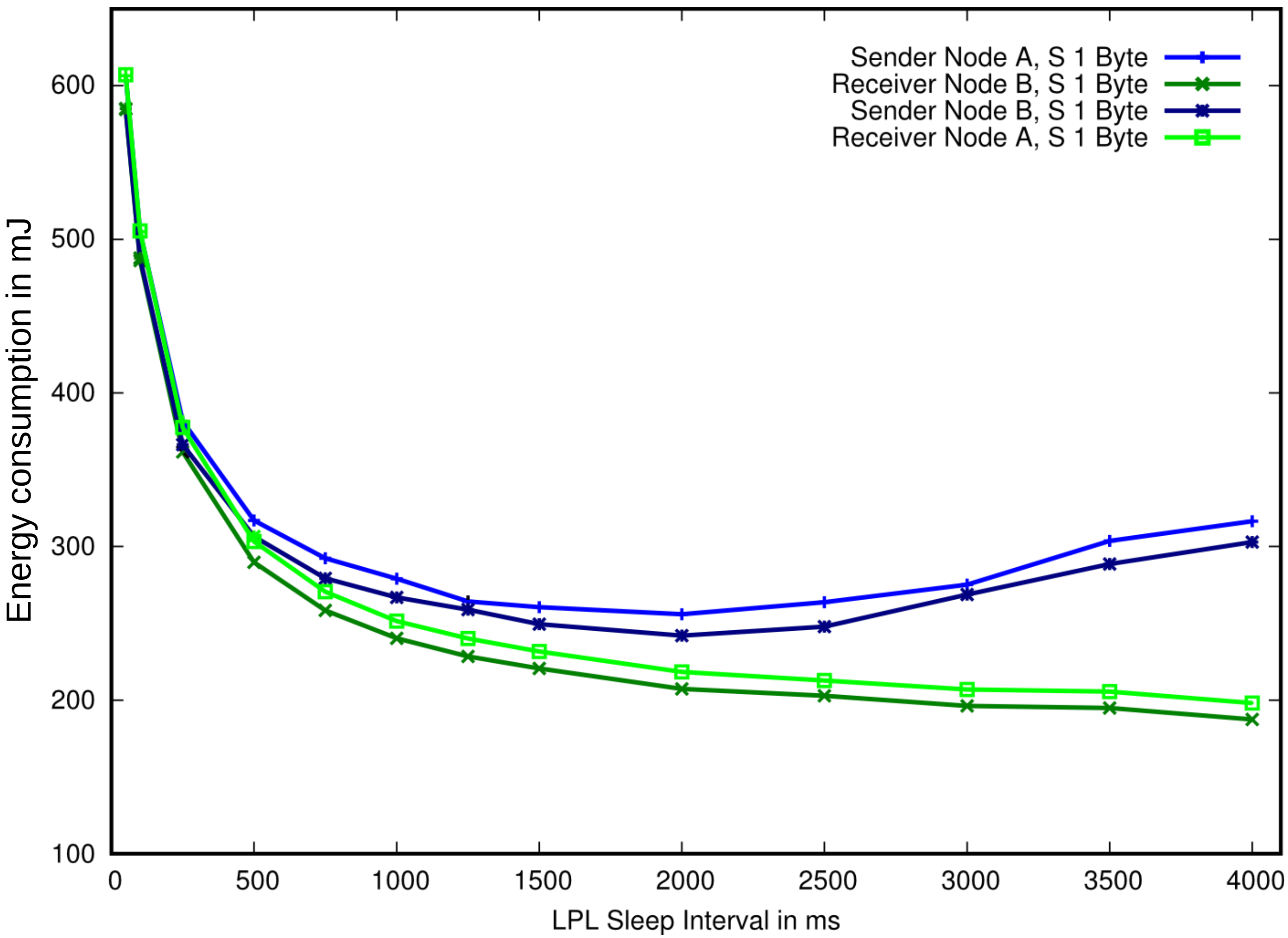
Influence of payload size S





- Receiver: Payload size makes no difference
  - t_{CCA} dictates energy consumption
- Sender: 90 Bytes payload is sligthly less expensive
  - Tx state is less expensive than Rx state
- Influence of MAC parameter more important!
  - Results only valid for CC2420 radio and TinyOS LPL!

Influence of hardware tolerances



- Node A consumes more energy than node B
- Independant of node role
- Experiments with all 20 testbed nodes give up to 10% deviation

Lessons learned

- Power on nodes asynchroneously
  - Avoids timing based effects
  - Requires many runs of the same experiment setup
- Wait after startup
  - Nodes have to be powered on and off many times for evaluation
  - After startup current consumption of a node fluctuates for the first few seconds
- Be aware of hardware tolerances
  - Important with lifetime estimations and comparison of experiments run on different nodes
- Take your time and have space available
  - This way of evaluation is much more time consuming than simulation
  - We collected several gigabytes of raw measurement data (using only 9 kHz sampling frequency)

Conclusion

- Results of real measurements are worth time and effort
- Disproved some common beliefs
  - Energy consumption and data volume not necessarily correlate
  - Protocols cannot be evaluated in isolation
- Made aware of cross layer effects (e.g., MAC)
  - Is often more important than other parameters (communication)
- Summarized best practices
- Only trust (energy) evaluation results if cross-checked with reality

- Future work
  - Compare results with simulator tools
  - Improve AVRORA where possible
    - Hardware tolerances
    - Energy model
  - Goal: Make most evaluations by simulation, but be aware of reality

Thank you for your attention!

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