Topic 04: Networking Issues in Sensor Networks

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ICTP-ITU School on Wireless Networking for Scientific Applications in Developing Countries

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Outline

- MAC protocols: S-MAC, B-MAC
- Routing protocol approaches
- Transport protocol: PSFQ
- Time synchronization: FTSP
- Overview of other issues: localization, data aggregation, topology/power control

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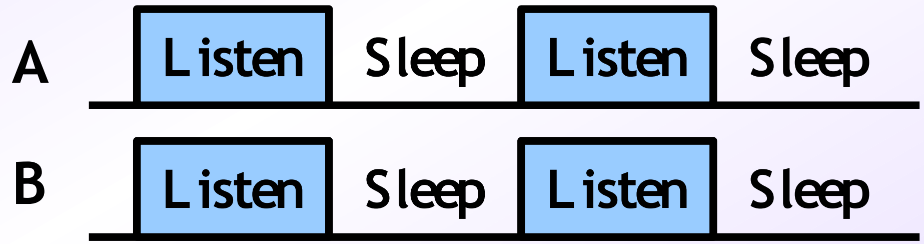
MAC Protocol

- Classical wireless protocol: CSMA/CA w/ RTS/CTS
  - Carrier-Sense: listen before transmit
  - Collision Avoidance: backoff before transmit, and on collision
  - Request-to-Send, Clear-to-Send to address hidden node
- Challenge in embedded sensor platforms:
  - Power consumption during listen is significant

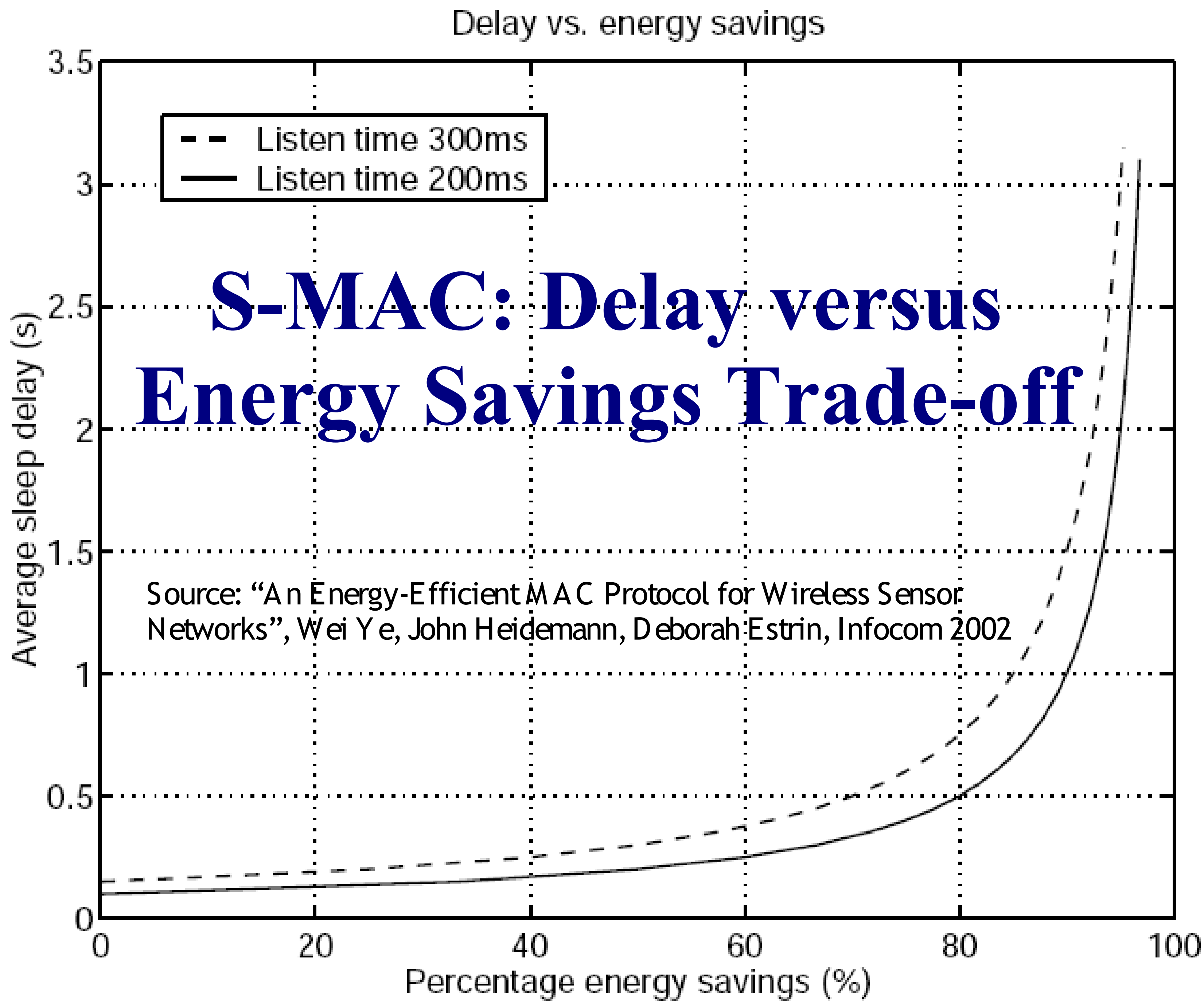
S-MAC (Sensor MAC)

- Reference: "An Energy-Efficient MAC Protocol for Wireless Sensor Networks", Wei Ye, John Heidemann, Deborah Estrin, Infocom 2002
- S-MAC ideas:



  - Periodic listen/sleep cycle
  - In listen phase, sleep on overhearing RTS/CTS
  - Virtual clusters
    - Neighbours (only) have to synchronize
    - Listen time has to account for clock drift also
    - Initial setup: synchronizer and follower
    - At border of two overlapping clusters: nodes have to wake-up on two different cycles

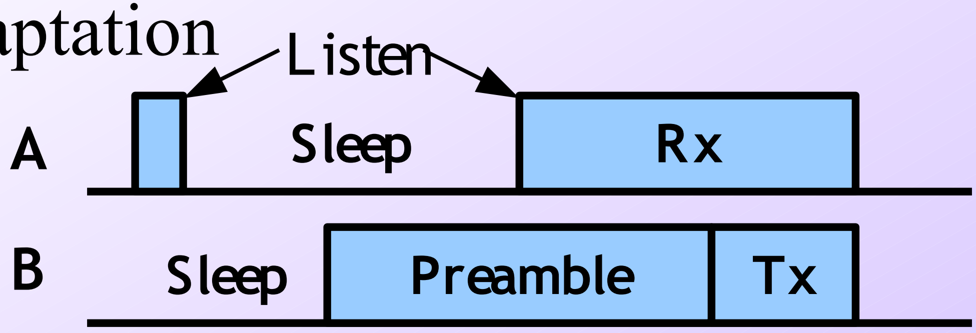
S-MAC: Delay versus Energy Savings Trade-off



Source: "An Energy-Efficient MAC Protocol for Wireless Sensor Networks", Wei Ye, John Heidemann, Deborah Estrin, Infocom 2002

B-MAC (Berkeley MAC)

- Reference: "Versatile Low Power Media Access for Wireless Sensor Networks", Joseph Polastre, Jason Hill, David Culler, SenSys 2004
- B-MAC ideas:
  - Long preambles (> sleep time) while transmitting
  - Listen time further reduced, no synchronization needed
- B-MAC exports interface:
  - For application specific adaptation
  - Enable/disable CCA
  - Enable/disable ACK
  - Low-power listening: preamble length & check interval



Check Interval & Energy Consumed

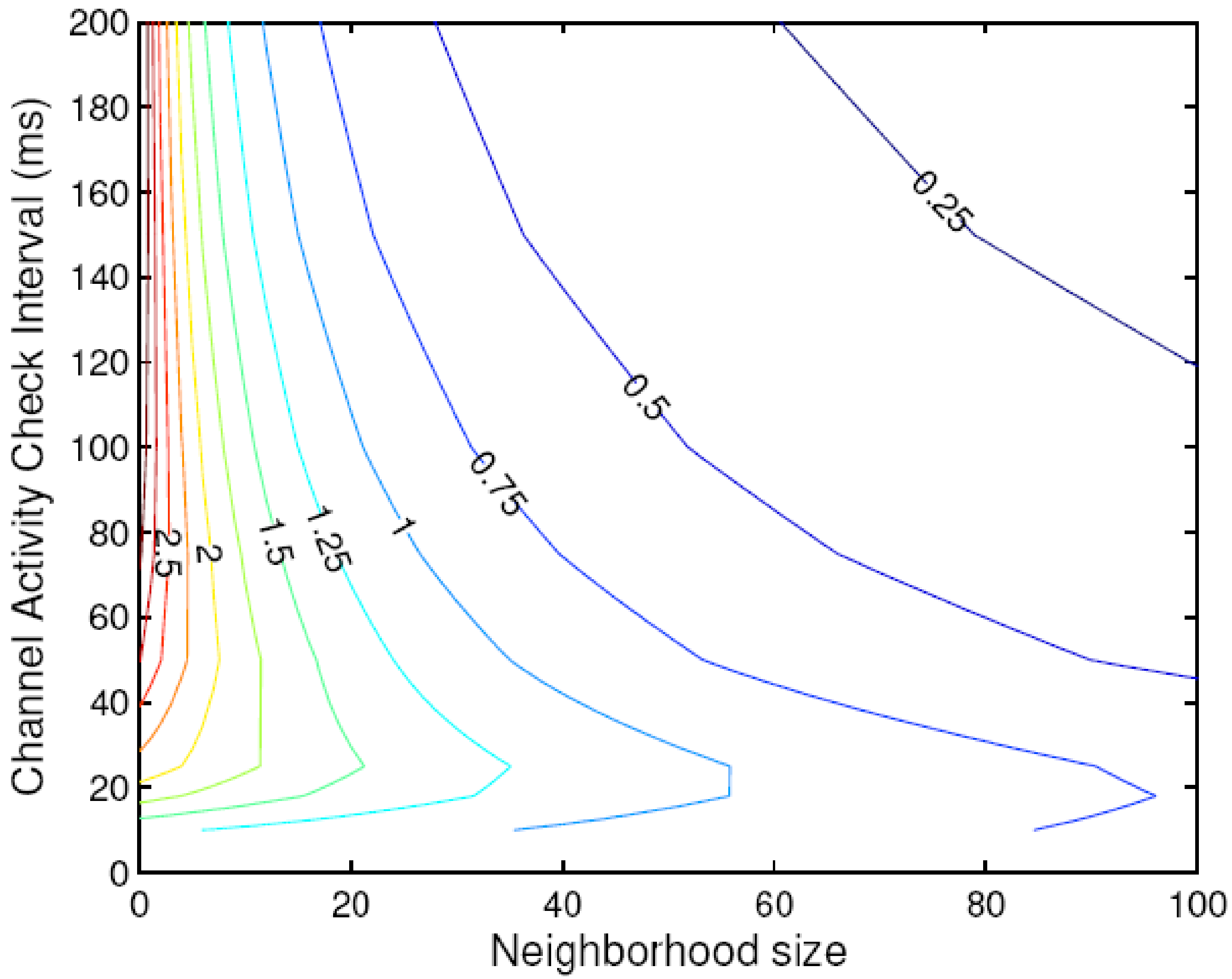


Figure 4: Contour of node lifetime (in years) based on LPL check time and network density. If both parameters are known, their intersection is the expected lifetime using the optimal B-MAC parameters.

Source: "Versatile Low Power Media Access for Wireless Sensor Networks", Joseph Polastre, Jason Hill, David Culler, SenSys 2004

S-MAC/B-MAC Applicability

- For which applications is S-MAC/B-MAC applicable?
  - ✔ Habitat monitoring
  - ✗ Industrial motor monitoring (large sleep period, large data)
  - ✗ Bridge monitoring (large sleep period, large data)
  - ✗ Volcano monitoring (no sleep period, large data)

Routing Protocol

- Why is wireless different from wired?
  - Lack of link abstraction
    - Packet errors
    - Interference from neighbouring “links”
    - Self-interference (within a path)
    - Broadcast medium
- Challenge in embedded sensor platforms: low power
  - But blown out of proportion, in my opinion
  - Quick proof: no evaluation of any (non-trivial) routing protocol using any real application parameters

Some Routing Approaches

- Data centric:
  - SPIN (Sensor Protocols for Information via Negotiation)
    - ADV, REQ, DATA
    - Better than flooding/gossiping
  - Directed diffusion:
    - Flood query (specify value range, area of interest, etc.)
    - Response "diffuses" toward sink
- Hierarchical:
  - LEACH (Low-Energy Adaptive Clustering Hierarchy)
    - Cluster head chosen randomly
    - Nodes choose which cluster to belong to
    - Cluster head rotates

Routing Approaches: Applicability

- For which applications are the above routing approaches applicable?
  - ✗ Habitat monitoring
  - ✗ Industrial motor monitoring
  - ✗ Bridge monitoring
  - ✗ Volcano monitoring
  - ✔ No application has even considered using any of these
    - ✔ Too complex and abstract
  - ✔ No concrete application given
    - ✔ And I cannot think of any either

Routing Metrics

- Minimum-hop can cause problems
- Multi-hop LQI
  - 1/LQI is the metric
  - Assumes LQI to be stable over time
    - Assumption may not hold
    - Stability of routing?
- Used in the Redwood deployment

Transport Protocol

- Some applications require reliable data transfer
  - Examples: bridge monitoring, volcano monitoring, industrial motor monitoring
- TCP is not really applicable
  - Wireless errors
  - Broadcast medium
  - Congestion control is not an issue
  - Do not always have to deal with competing flows

PSFQ

- Reference: "Pump-Slowly, Fetch-Quickly (PSFQ): A Reliable Transport Protocol for Sensor Networks", Chieh-Yih Wan, Andrew T. Campbell, Lakshman Krishnamurthy, IEEE Journal on Selected Areas in Communications (JSAC), Vol. 23, No. 4, April 2005
  - An example protocol designed for sensor networks
  - For reliable transfer of data
  - Specifically designed for one-to-many data transfer, works for one-to-one transfer too
  - Example usage: code update from base to all other nodes

PSFQ: How it Works

- Main idea:
  - Pump-Slowly: refers to data going in forward dirn.
  - Fetch-Quickly: refers to error recovery in reverse dirn.
  - Cycle repeats until data transfer is done successfully
- Protocol details:
  - Timers: Pump timer & fetch timer are used
  - Fetch can be signal strength based (who is parent in tree)
  - Proactive fetch: when nothing received for some time
  - Report bit: used by sender to request for ACK

PSFQ Performance

- When can you expect PSFQ to perform well?
  - When effect of pipelining is seen
  - That is, multiple simultaneous hops being used simultaneously
- Crucial parameters: timers
  - May not be that easy to determine optimally
  - Industrial monitoring paper reports poor performance

PSFQ Applicability

- For which applications is PSFQ applicable?
  - ✗ Habitat monitoring (reliability not needed)
  - ✗ Industrial motor monitoring (they have used it, but reported poor performance, small networks anyway)
  - ✗ Bridge monitoring (PSFQ is an overkill)
  - ✗ Volcano monitoring (PSFQ is an overkill)

Time Synchronization

- Required for some applications
- Useful for other protocols (e.g. MAC)
- Challenges:
  - Different clocks
  - Clocks drift
  - Clock drift rate may change (with temperature, for e.g.)
  - Multi-hop

FTSP

- FTSP: Flooding Time Synchronization Protocol
  - Reference: "The Flooding Time Synchronization Protocol", Miklós Maróti, Branislav Kusy, Gyula Simon, Ákos Lédeczi, SenSys 2004.
- Goal: achieve micro-second granularity synchronization for networks of 100s of nodes

FTSP: How it Works

- Message time-stamping to synchronize clocks
- Multiple such messages to estimate clock drift
  - Using linear regression
- Such synchronization messages can be sent by root, or any synchronized node

FTSP Applicability

- Which applications find use for FTSP?
  - ✔ Volcano monitoring (really needed? or was it used because the software was available?)
  - ✗ Bridge monitoring (FTSP is an overkill)
  - ✗ Industrial motor monitoring (no need for micro-s synch.)
  - ✗ Habitat monitoring (no need for micro-s synch.)

Other Issues Considered in Literature

- Data aggregation
  - Scenario description lacks depth thus far
- Localization
  - Requirement description lacks depth thus far
- Topology, power control
  - Feasibility in question: RSSI variability
  - Usefulness in question: power consumption does not increase that much with tx-power in practice
- Security
  - Depth justified only for military applications (if at all), which is taboo for these lectures

Summary

- Several protocols designed in literature, books have been written
  - MAC, Routing, Transport, Synchronization
  - Data aggregation, Localization, Topology/power control, Security
- Field is rich for paper generation (lots of abstract constraints)
- But real applications thus far have used only simple protocols