Distributed Systems Seminar: Cyber Physical Systems

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Versatile Low Power Media Access for Wireless Sensor Networks

SenSys'04

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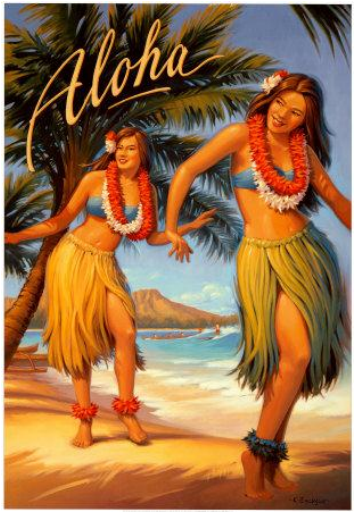
MAC Basics

Medium Access Control (MAC)

- Nodes share a physical medium
- Interference
  - Garbage, useless data, …

- **ALOHA 1971 (ALOHAnet)**
  - Collision → back off and send later
  - Slotted ALOHA: Discrete timeslots
  - 37% channel utilisation for slotted ALOHA
  - Does not scale to many nodes



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IEEE 802.11 – CSMA/CA

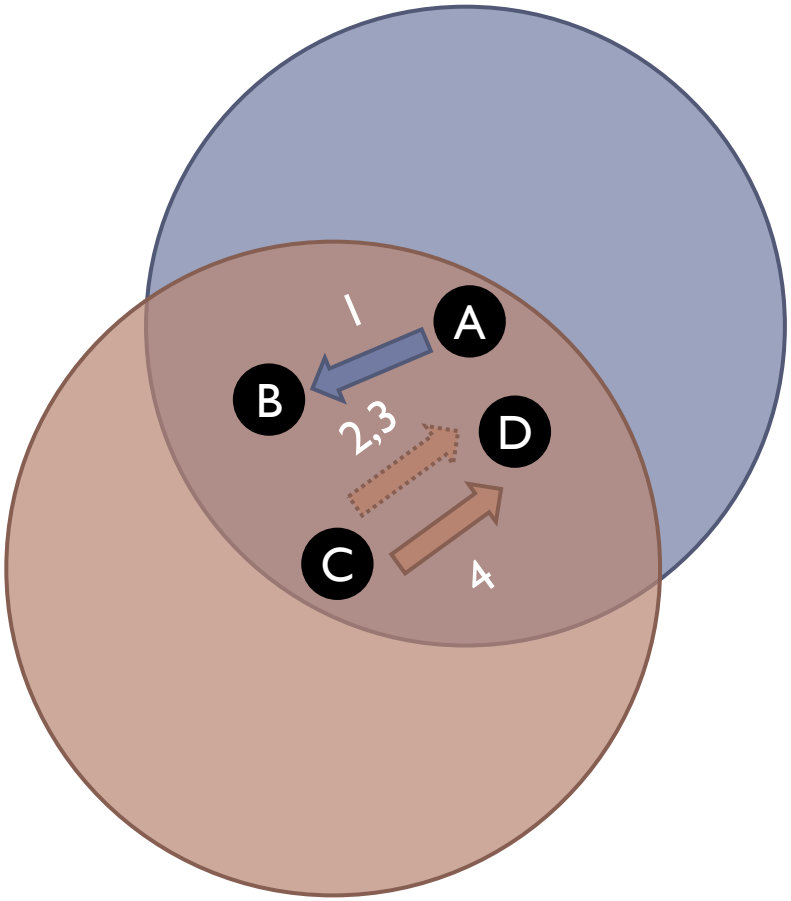
- Channel not full duplex
  - Cannot transmit and receive at the same time
  - Collision Avoidance – Listen before send!

- Request to send - Clear to send (RTS-CTS)
  - Only allowed to send after receiving a CTS
  - Solves hidden terminal problem -- *other nodes wait*

- Idle listening
  - Node continuously checking if channel is clear
  - Maximise bandwidth, minimise latency

CSMA/CA: Collision Avoidance

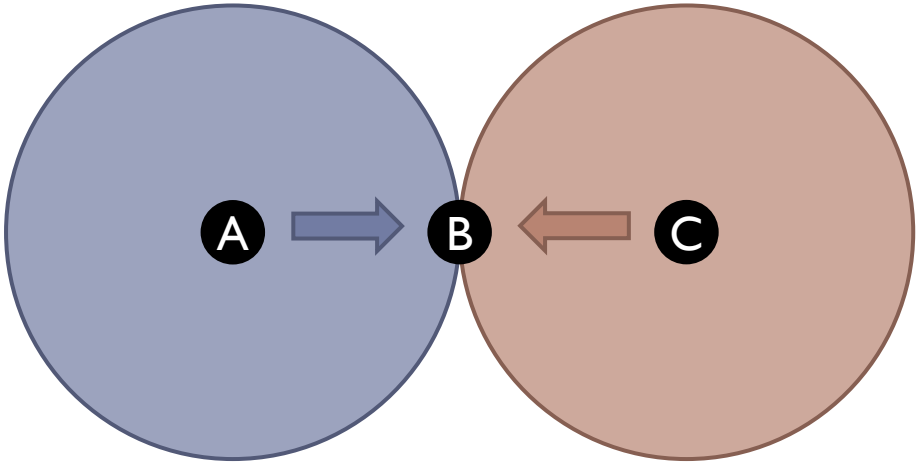
1. A sends a message to B
2. C examines the medium
3. C sees A's transmission
   backs off… (2)
4. Eventually, C transmits…



Note: In ALOHA, C sends first and then checks if there was a collision

Hidden Terminal Problem

1. A sends a message to B
2. C examines the medium (at the same time)
3. C starts transmitting…
4. B receives data from both – **interference!**



RTS/CTS helps to overcome this as C would not start transmitting without first receiving a Clear-To-Send

Interlude:
MAC in Wireless Sensor Networks I

- CSMA-CA?!

- Idle listening =

  - Nodes run on battery
  - Usually up for months/years
  - Few transmissions (every second)

- Idle listening major component of energy consumption
  - $E = E_{rx} + E_{tx} + \boldsymbol{E_{listen}} + E_{sampling} + E_{sleep}$
  - A good MAC protocol reduces $\boldsymbol{E_{listen}}$

Interlude:
MAC in Wireless Sensor Networks II

- Critical issues
  - Low energy consumption
  - Scalability
  - Small code size
  - Zero configuration
- What about?
  - Low latency
  - High bandwidth
  - Fairness??
- Common problems
  - Overhearing
  - Idle listening
- Infrastructural problems
  - Adverse network conditions
  - Changing network conditions
  - Faulty nodes

B-MAC

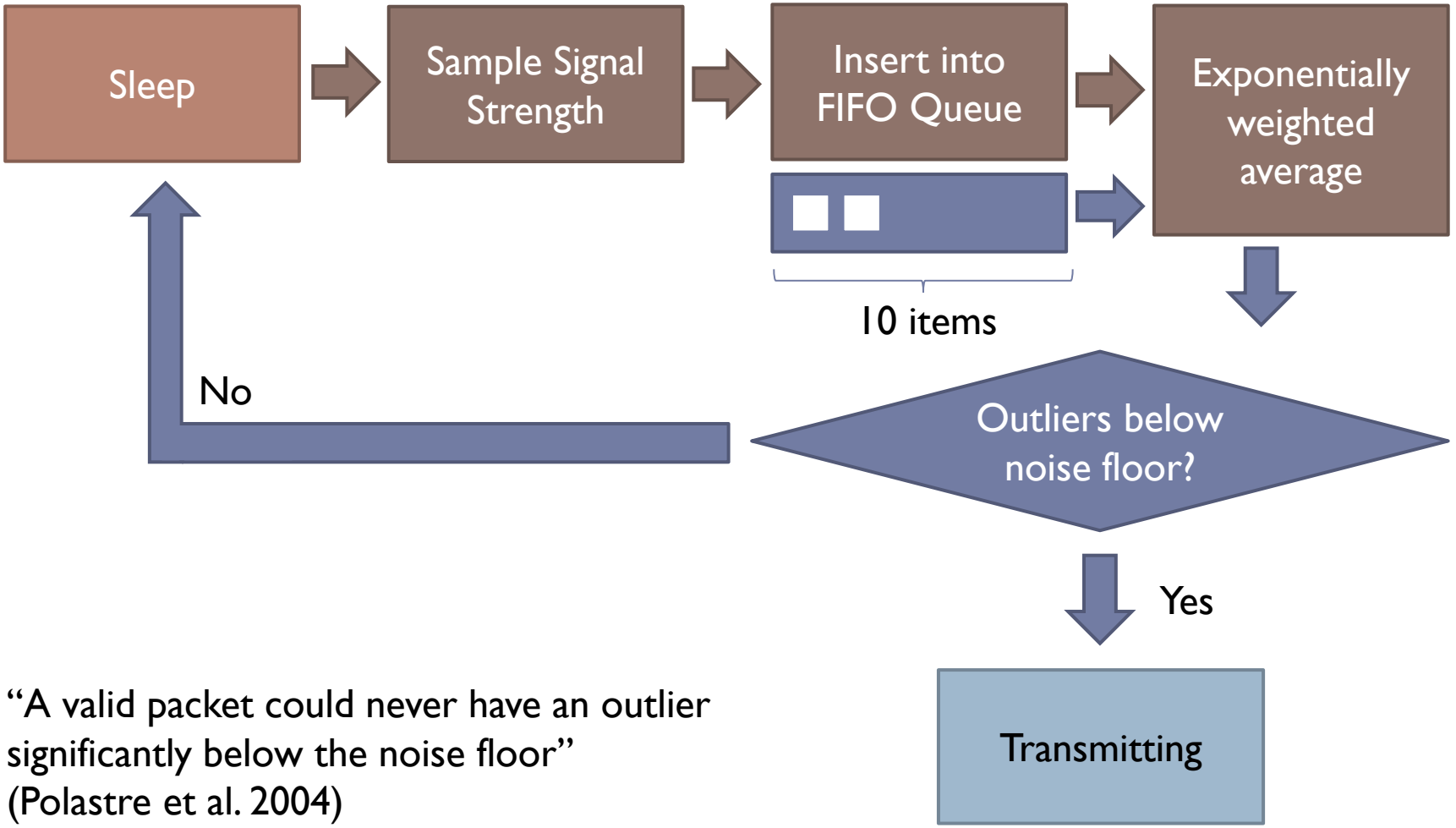
Implementation

B-MAC (Polastre et al. 2004)

- Carrier Sense based system
  - With some ALOHA sugar (Preambles)
- Only link layer protocol (OSI Layer 2)
  - Organisation, synchronisation, routing build above
  - No hidden terminal support
  - No message fragmentation
  - No enforced power policy
- But… Interfaces
  - Allow services to tune B-MACs operation

B-MAC: Clear channel assessment (CCA)

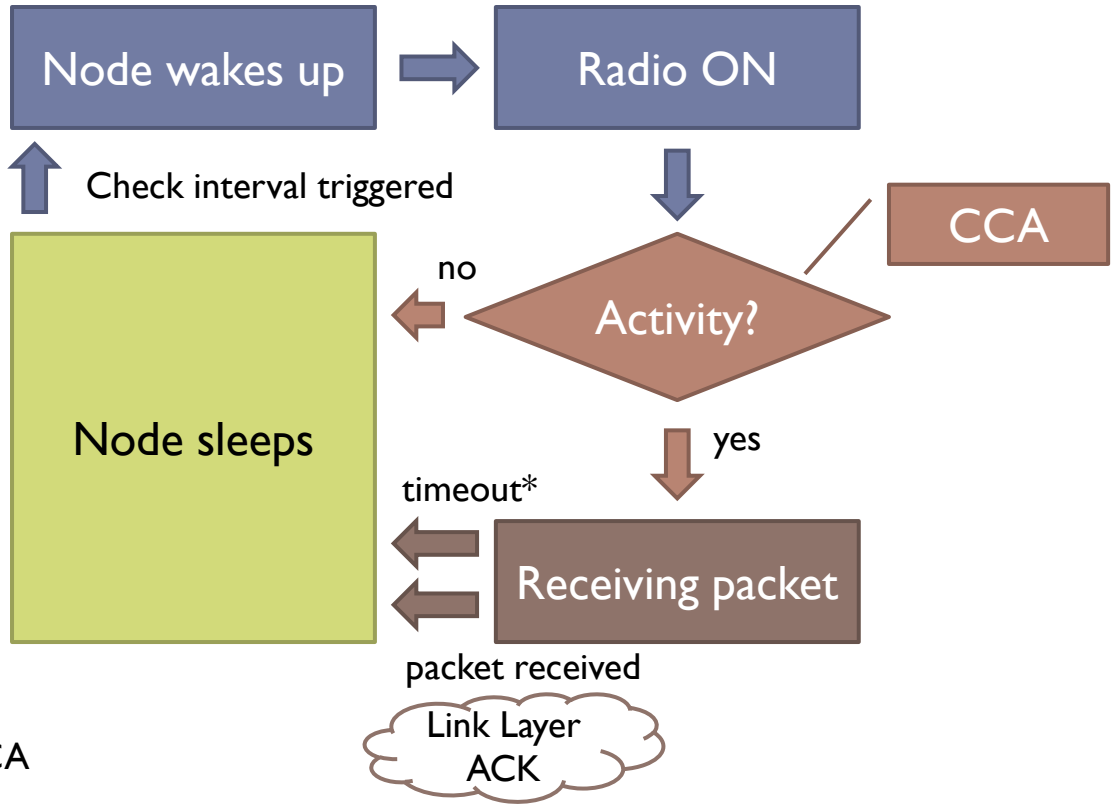
A node wants to transmit…



"A valid packet could never have an outlier significantly below the noise floor"
(Polastre et al. 2004)

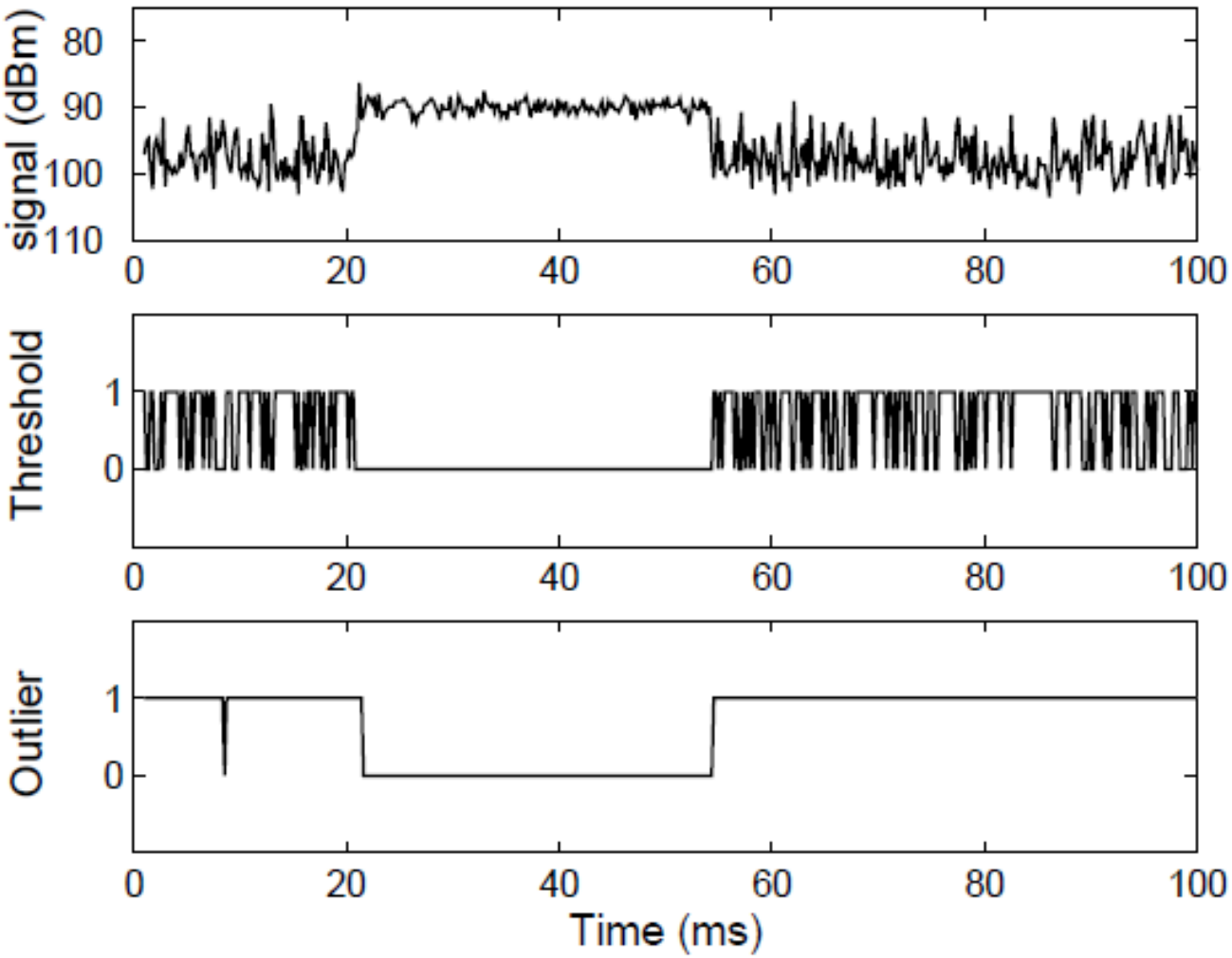
B-MAC: Low Power Listening (LPL)

- Periodic channel sampling
  - Transmission of preambles → Indicate channel is used
  - Check every 100ms → Preamble length at least 100ms long **(overhead)**



* False positive from CCA

B-MAC: Low Power Listening (LPL)



Other approaches

WiseMAC (El-Hoiydi et al. 2004)

- MAC for downlink in infrastructure networks
  - Between nodes and access point
  - Similar to ALOHA

- How it works
  1. Access point learns sampling schedule of nodes
  2. AP can predict when to send data for the nodes to receive it

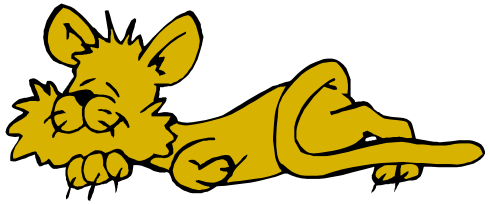
- More (energy) efficient than 802.15.4 / ZigBee
  - Star network topology (no multi hop)

S-MAC (Heidemann et al. 2002)

- MAC Protocol for multi hop sensor networks

- How it works
  - Node wakes up (periodically)
  - …listens to the channel (active period) 115ms
    - SYNC (Synchronising all nodes to a common schedule)
    - Transmission using RTS-CTS
  - …returns to sleep variable time

- Duty cycle determined by sleep period



- Network Allocation Vector
  - Knowledge about length of transmission = How long can I nap?

S-MAC: Problems

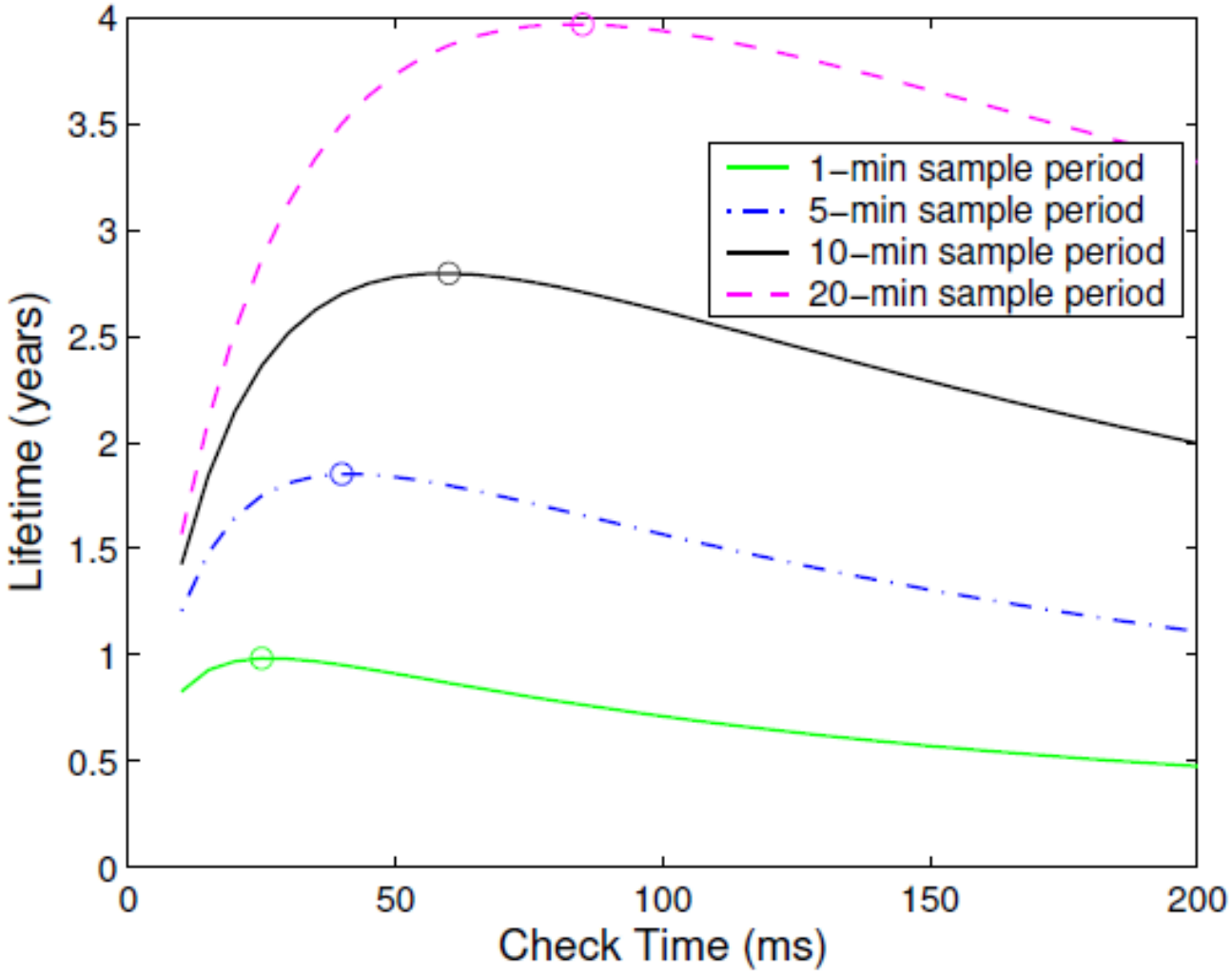
- Protocol is complex

- SYNCs can be a problem in a larger network
  - Higher maintenance cost (neighbours schedules)
  - Overhead (repeated rounds of synchronisation)

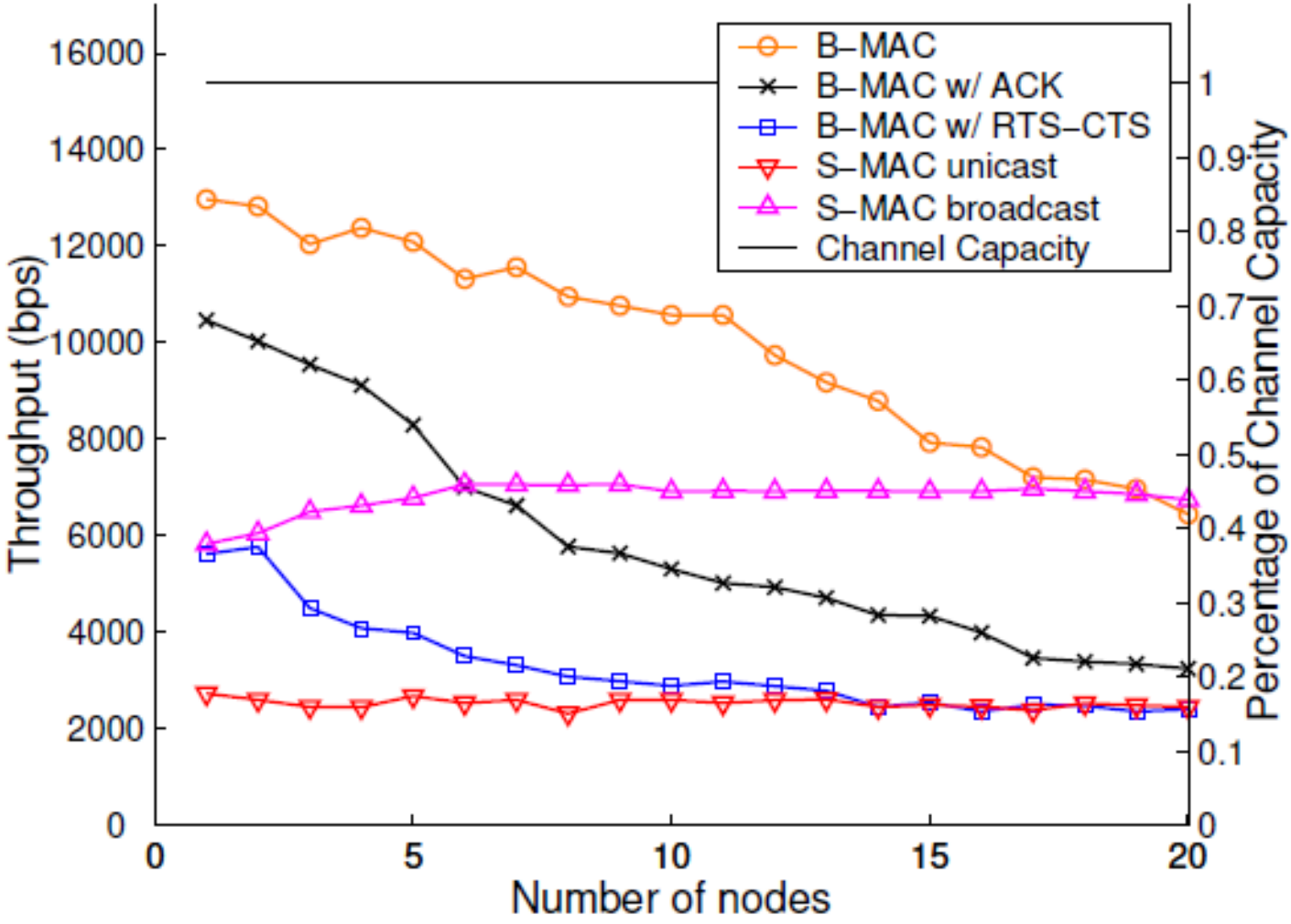
B-MAC

Results

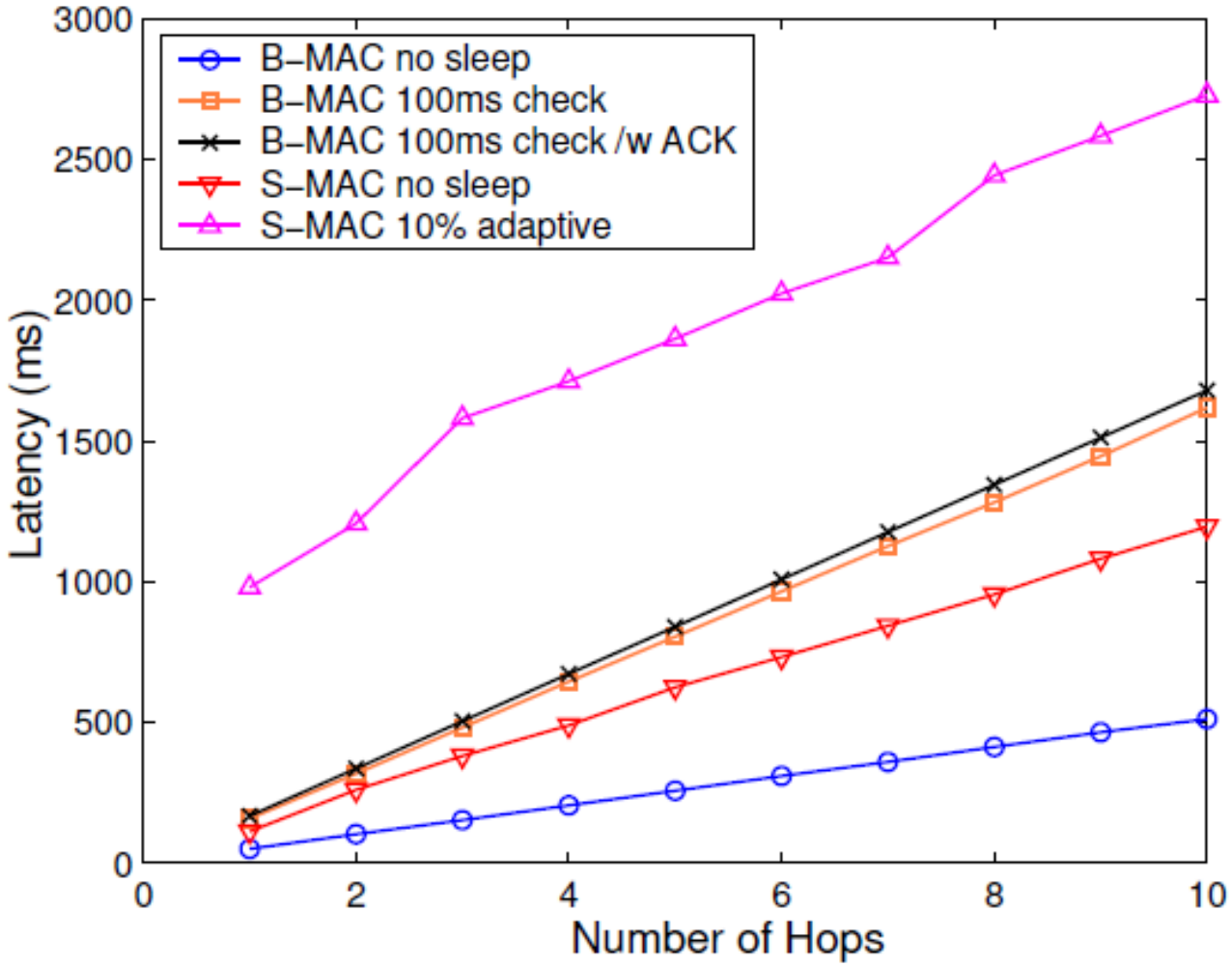
LPL check time vs lifetime



B-MAC in comparison



Number of hops vs latency



B-MAC - Recap

- Link Layer MAC Protocol (with ACKs)
  - Low Power Listening
  - Clear Channel Assessment
- Modular approach
  - Control interfaces
- Already implemented in tinyOS
  - Free to be used/modified/extended

References

- Polastre J, Hill J, Culler D. Versatile Low Power Media Access for Wireless Sensor Networks. 2004.
- El-Hoiydi A, Decotignie J-D. WiseMAC: An Ultra Low Power MAC Protocol for the Downlink of Infrastructure Wireless Sensor Networks. 2004.
- Heidemann J, Estrin D. An Energy-efficient MAC Protocol for Wireless Sensor Networks. 2002.