# An Energy-Efficient MAC Protocol for Wireless Sensor Networks

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# Outline

- Introduction
- Sensor-MAC design (SMAC)
  - Periodic Listen and Sleep
  - Collision and Overhearing Avoidance
  - Message passing
- Experimentation and Discussion
- Conclusion

# Introduction

- Important attributes of sensor networks we have considered
  - Primary concerns
    - The energy efficient
    - The scalability to the change in networks size, node density and topology
  - Secondary concerns
    - Fairness
    - Latency
    - Throughput
    - Bandwidth utilization

# Introduction

- The major sources of energy waste
  - Collision
  - Overhearing
  - Control packet overhead
  - Idle listening
    - Idle: receive: send ratios are 1:1.05:1.4 [2]
    - Idle: receive: send ratios are 1:2:2.5 [3]

  =>periodic sleep and listen

# Sensor-MAC design (SMAC)

- Consumptions
  - The sensor networks to be composed of many small nodes deployed in an ad hoc networks.
  - The sensor networks to be dedicated to a single application or a few collaborative applications.
  - The applications will have long idle periods and can tolerate some latency.

# Sensor-MAC design (SMAC)

- Three major component of the S-MAC
  - Periodic Listen and Sleep
  - Collision and Overhearing Avoidance
  - Message passing

# Periodic Listen and Sleep

- Basic scheme

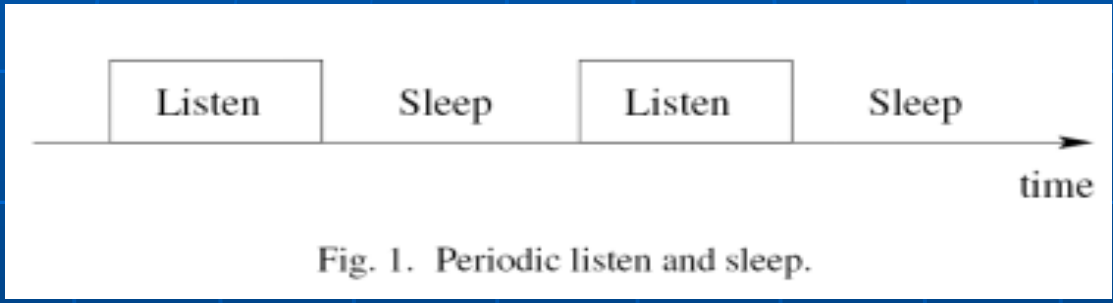



Fig. 1. Periodic listen and sleep.

- Two techniques to remedy synchronization errors
  - All timestamps that are exchanged are relative rather than absolute.
  - The listen period is significantly longer than clock error or drift.

# Periodic Listen and Sleep

- Each node maintains a *schedule table* to store the schedules of all its known neighbors
- Two steps to choose its schedule and establish its schedule table
  - Synchronizer
  - Follower
- Maintain synchronization

# Periodic Listen and Sleep

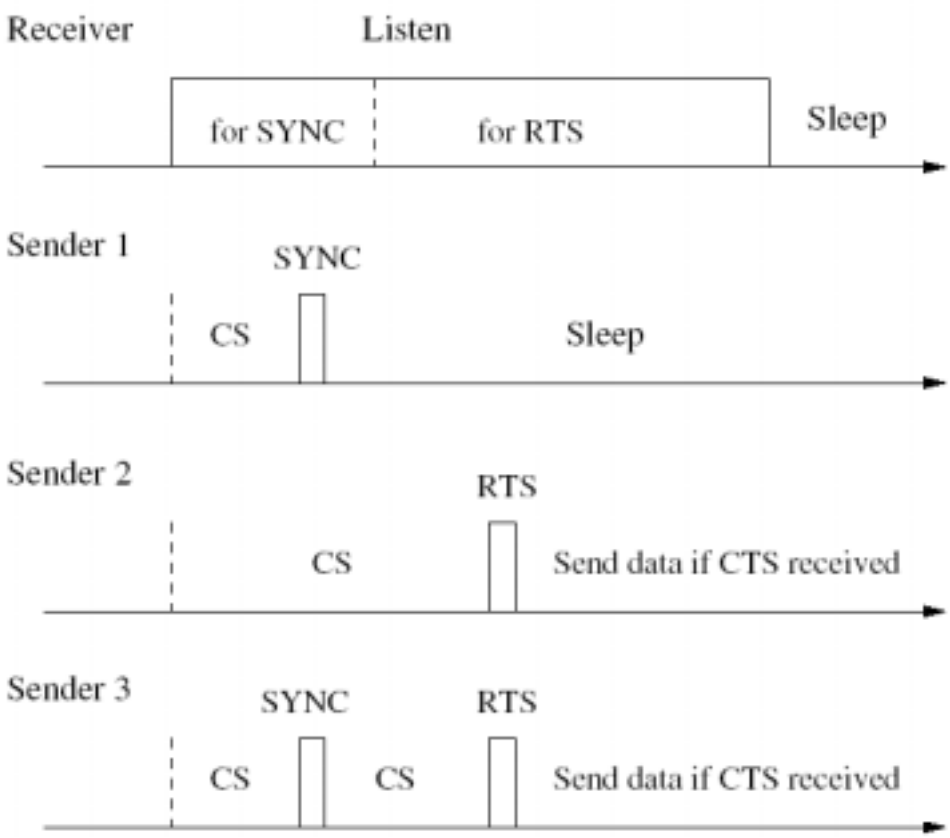



Fig. 3. Timing relationship between a receiver and different senders. CS stands for carrier sense.

# Collision and Overhearing Avoidance

- Collision Avoidance
  - RTS/CTS
  - Virtual carrier sense
    - Set network allocation vector (NAV)
  - Physical carrier sense
- Overhearing Avoidance
  - Let interfering nodes sleep after they hear an RTS or CTS packet that is not directed to itself.

# Message Passing

- To fragment the long message into many small fragments, and transmit them in burst
- Tradeoff
  - Fragment-level fairness
  - Message-level latency

# Experimentation and Discussion

- Rene mote, developed at UCB[7]
  - which has 8K bytes of programmable flash and 512bytes of data memory
  - The radio transceiver on the mote is the model TR1000 from RF Monolithics (receiving: transmitting: sleep ratios are 900:1625: 1 )
- Three MAC modules
  - Simplified IEEE 802.11 DCF
  - Message passing with overhearing avoidance
  - The complete S-MAC

# Experimentation and Discussion

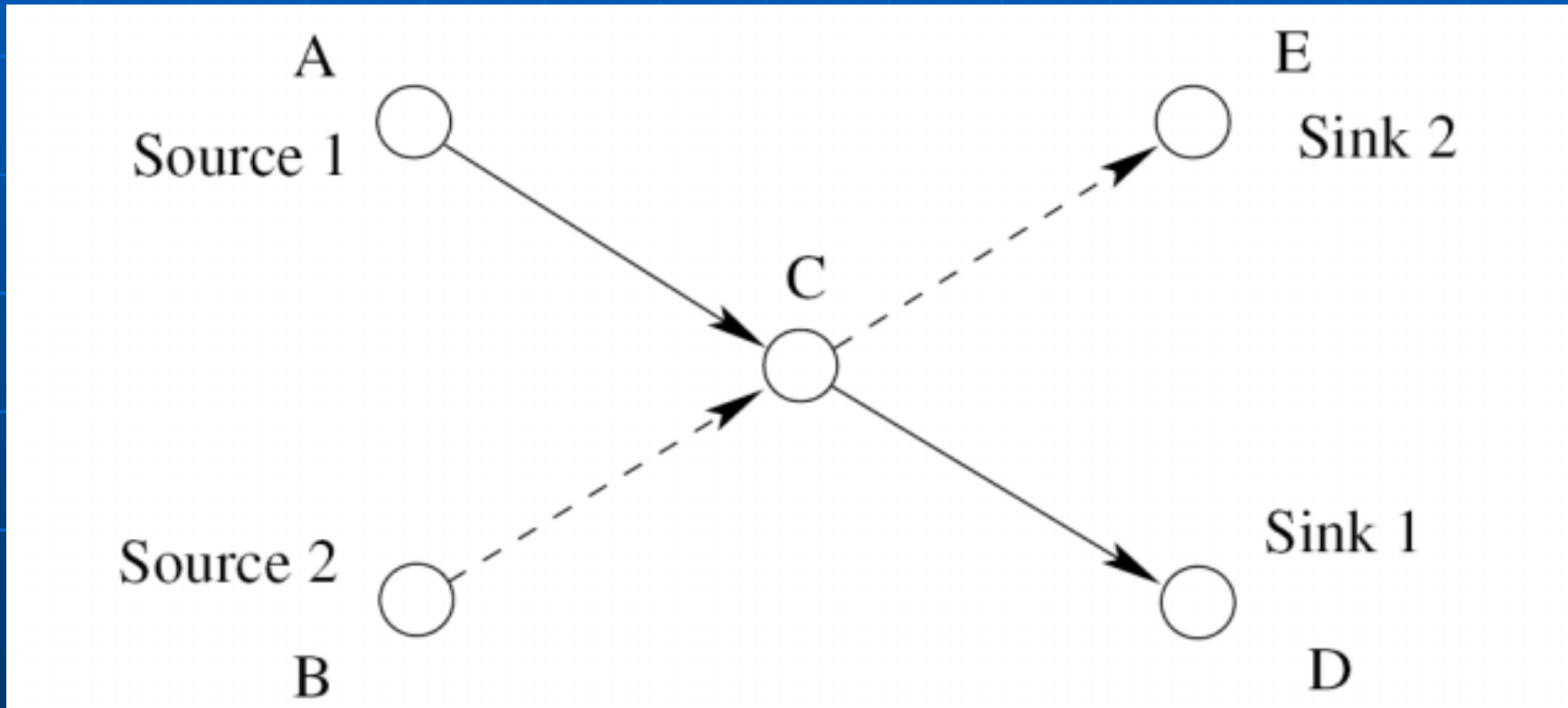



Fig. 7. Topology used in experiments: two-hop network with two sources and two sinks.

# Experimentation and Discussion

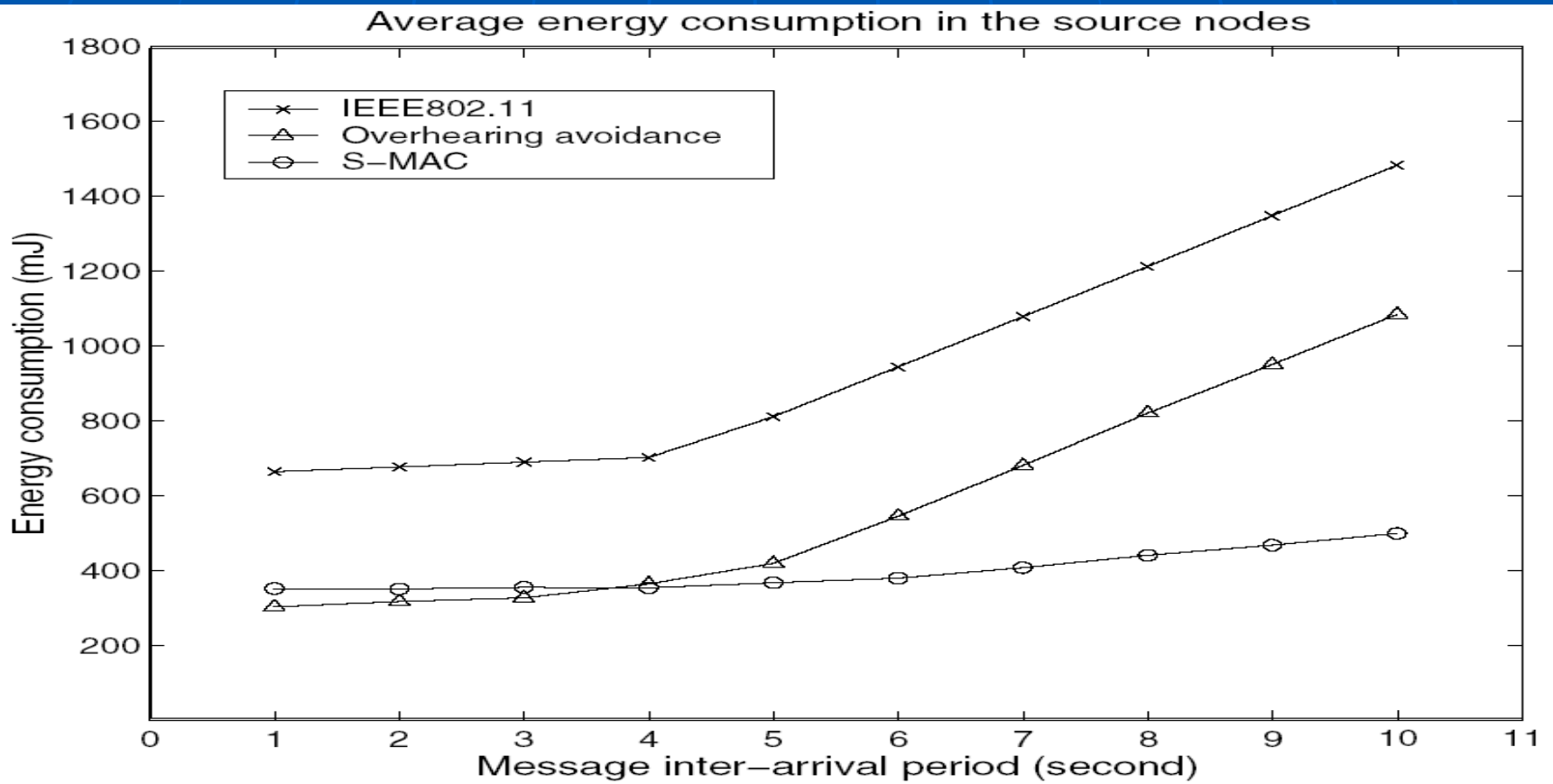



Fig. 8. Measured energy consumption in the source nodes.

# Experimentation and Discussion

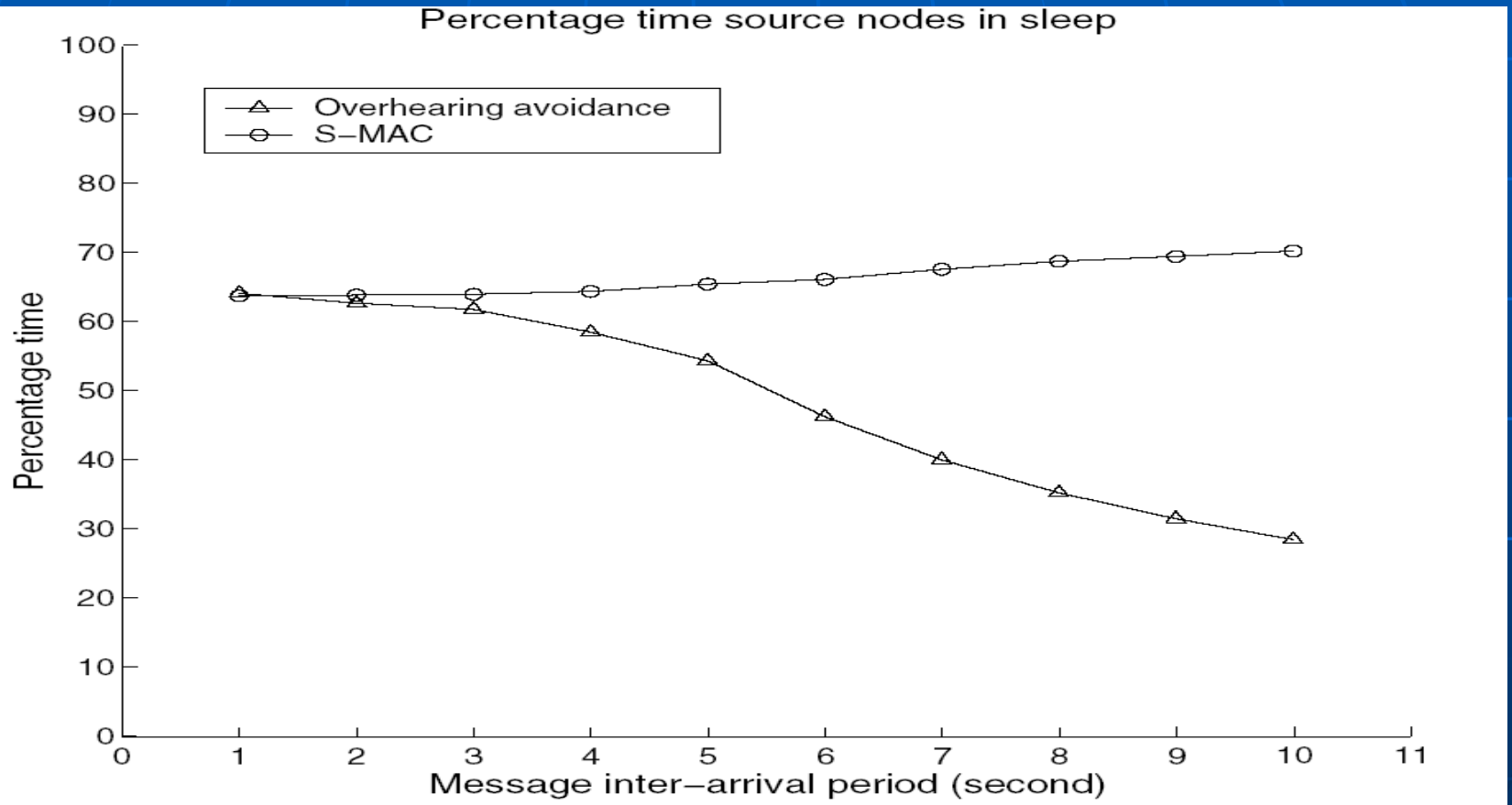
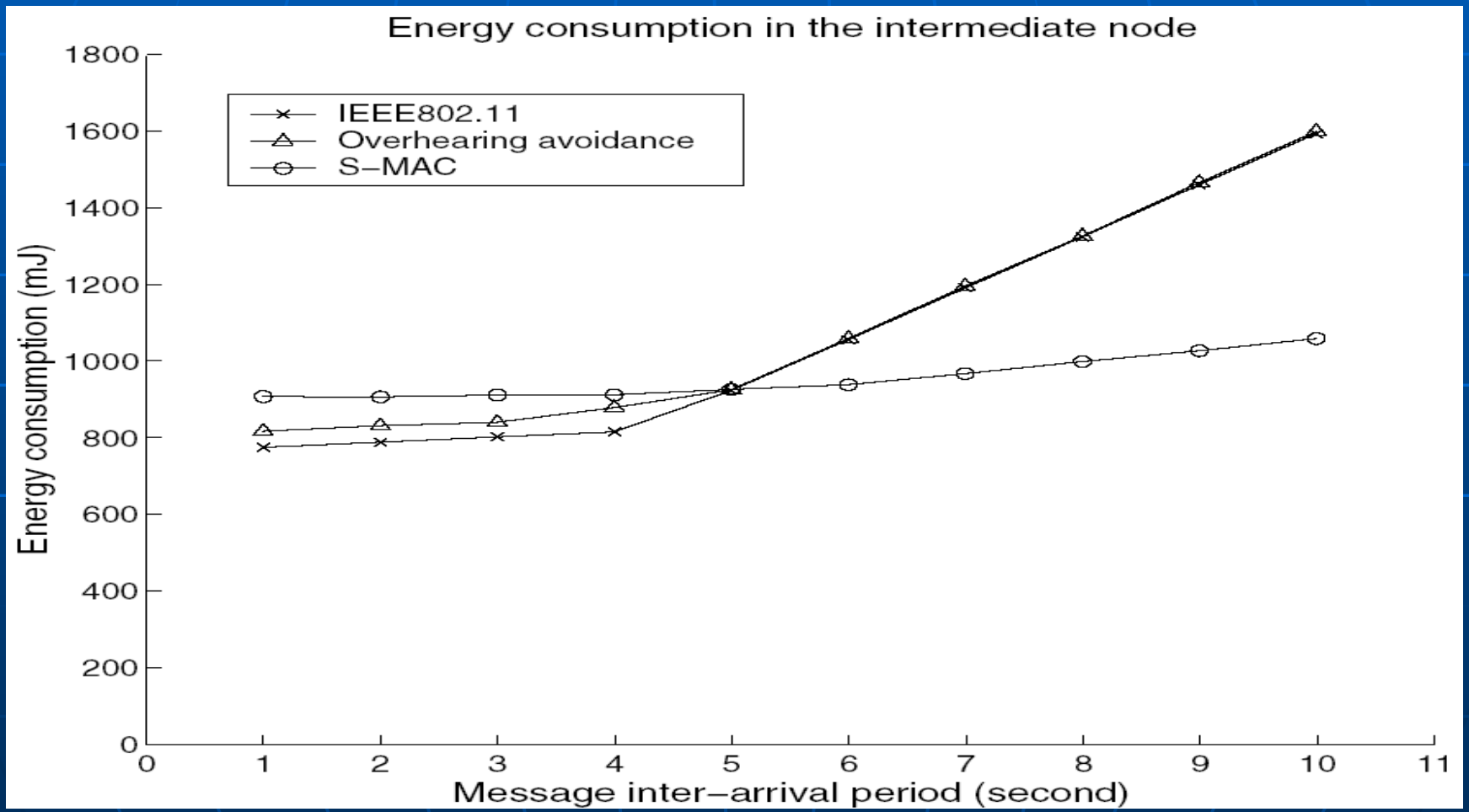



Fig. 9. Measured percentage of time that the source nodes in the sleep mode.

# Experimentation and Discussion



# Conclusion

- The new protocol has very good energy conserving properties comparing with IEEE802.11
  - The scheme of periodic listen and sleep reduces energy consumption by avoiding idle listening
  - The use of in-channel signaling to put each node to sleep when its neighbor is transmitting to another node
  - Applying message passing to reduce application-perceived latency and control overhead
- Evaluating an implementation of the new MAC over sensor-net specific hardware

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