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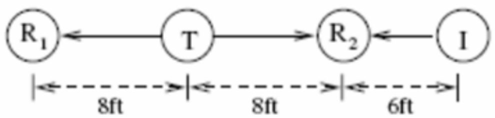
E-CSMA: SUPPORTING ENHANCED CSMA PERFORMANCE IN EXPERIMENTAL SENSOR NETWORKS USING PER-NEIGHBOR TRANSMISSION PROBABILITY THRESHOLDS

OUTLINE

- Introduction
- E-CSMA Design
- Experiment
- Conclusion

INTRODUCTION

- CSMA
  - Fully distributed
  - Low implementation complexity
- Some problem…



(a.)

	Free Receiver (R_1)	Interfered Receiver (R_2)
Pkt. Txn. Attempts	96.4 (+/− 0.8) pkts	95.4 (+/− 0.8) pkts
Rxn. Succ. Ratio	100 (+/− 0.0)%	25.8 (+/− 14.1)%

(b.)

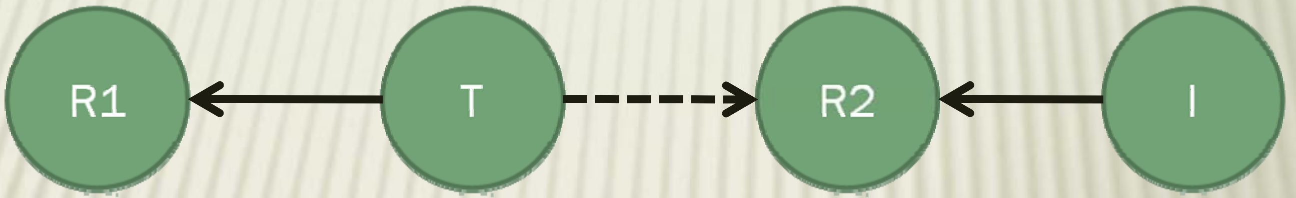
Fig. 1. (a.) A simple topology to show the hidden terminal problem; (b.) the 75% packet loss from T to R_2 is a huge energy penalty to the network.

INTRODUCTION

- To improve CSMA
  - There may be a correlation between the transmitter and receiver channel state.
  - For each transmitter, the state of the wireless channel at each potential receiver in its radio range is unique.

INTRODUCTION

- Example

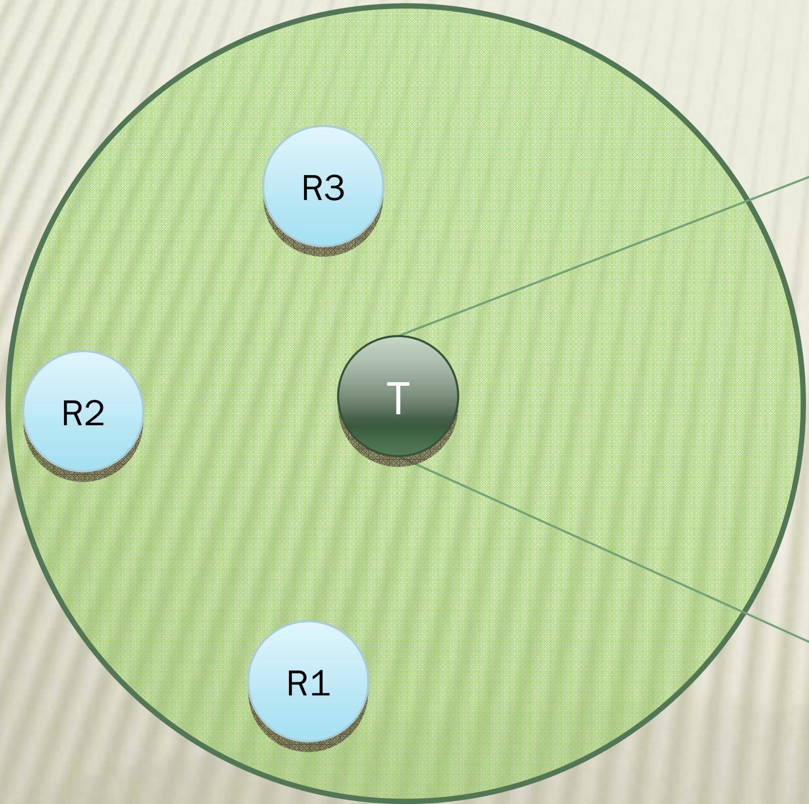


E-CSMA DESIGN

- Channel State Management
  - Transmitter observe channel condition, receiver check packet.
  - Record channel condition and corresponding success probability
  - bin: RSS interval

E-CSMA DESIGN

- Channel State Management



	bin 1	bin 2	…	bin n
R1	0.54	0.66	…	0.1
R2	0.2	0.1	…	0.48
R3	0.71	0.8	…	0.26

E-CSMA DESIGN

- Channel Feedback Mechanism
  - Positive Feedback
    - Receiver send an ack for each packet received
  - Periodic Feedback
    - Receiver send an aggregated ack after successfully received a specified number of packets

E-CSMA DESIGN

- Periodic Feedback

E-CSMA DESIGN

- Transmit/Defer Decision(Condition 1)
  - Transmit only if historically the transmit to the receiver succeeded at least a fraction α when the RSSI fell in the same bin as the current RSSI.
  - As α increases the probability of channel loss decreases, but delay and the probability of packet drops at the transmitter queue increase.

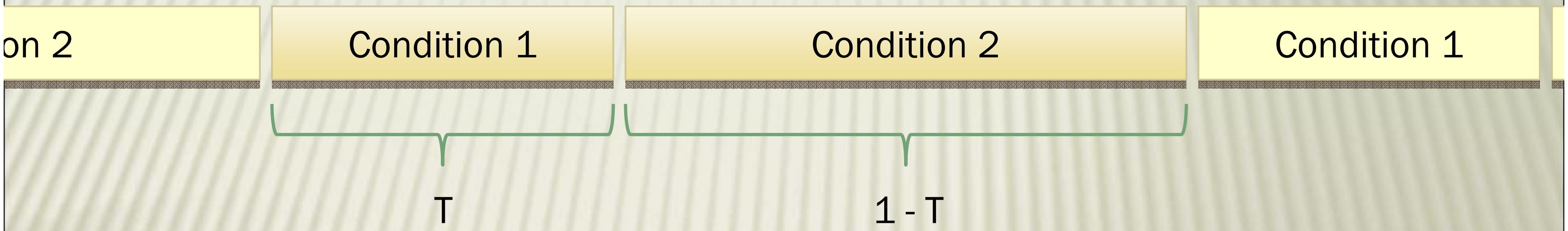
E-CSMA DESIGN

- B-MAC(Condition 2)

$$C^t < \text{Threshold}_{\text{B-MAC}} = f_{\text{EWMA}}(\text{Noise Floor}) - Bias$$

E-CSMA DESIGN

- Medium Access Strategy



$$T_{i+1} = T_i + \begin{cases} \tau, & \frac{f_{\mathrm{EWMA}}(\mathrm{E\!-\!CSMA\ \ Succ.\ \ Ratio})}{f_{\mathrm{EWMA}}(\mathrm{CSMA\ \ Succ.\ \ Ratio})} \geq 1+\delta; \\ -\tau, & \frac{f_{\mathrm{EWMA}}(\mathrm{E\!-\!CSMA\ \ Succ.\ \ Ratio})}{f_{\mathrm{EWMA}}(\mathrm{CSMA\ \ Succ.\ \ Ratio})} \leq 1-\delta; \\ 0, & \text{otherwise.} \end{cases}$$

EXPERIMENT

- Testbed configuration
  - Comprises 31 Mica2 motes arranged in a roughly rectangular grid.
  - Multi-neighborhood
  - Node x is a neighbor of node y, if the packet delivery ratio of transmission from x to y is at least 80%
  - Transmit power: -10dBm

EXPERIMENT

- E-CSMA Performance Metrics
  - Link Tax = (Packets dropped across a link)/(Packets received across a link)
  - Link Fidelity = Packets received across a link
  - Link Power = (Link Fidelity)/(Link Tax)

EXPERIMENT

- Decision Input Value Selection
  - Raw RSS vs. Outlier Magnitude
  - The Raw RSS tends to be noisy and can lead to a false indication of channel state
  - The Outlier Magnitude is based on an EWMA of recent RSS samples that provides a more stable value stream
  - Use Outlier Magnitude as the input value set for the remainder of the experiments

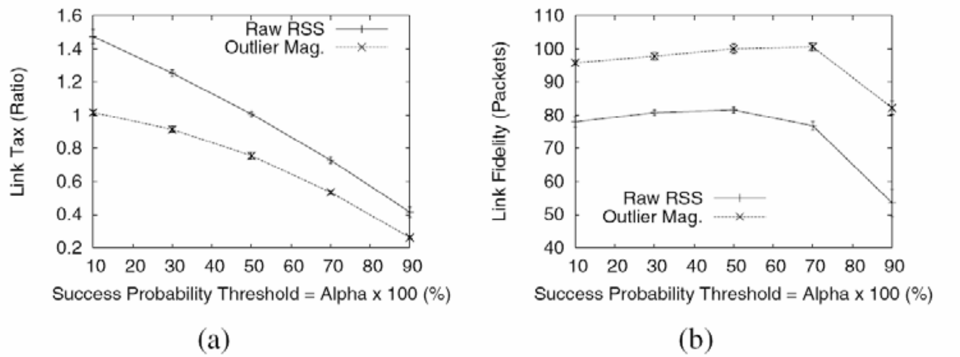


Fig. 3. Comparison of 'Raw RSS' and 'Outlier Magnitude' in terms of average (a) Link Tax and (b) Link Fidelity, as candidates for the E-CSMA decision input value. Outlier Magnitude outperforms Raw RSS by leading to fewer dropped packets per delivered packet network wide.

EXPERIMENT

- Impact of success Probability Threshold
  - Use T=1
  - As α increase, Link Tax decrease and Link Fidelity also decrease
  - Use α =0.9 for remaining experiment

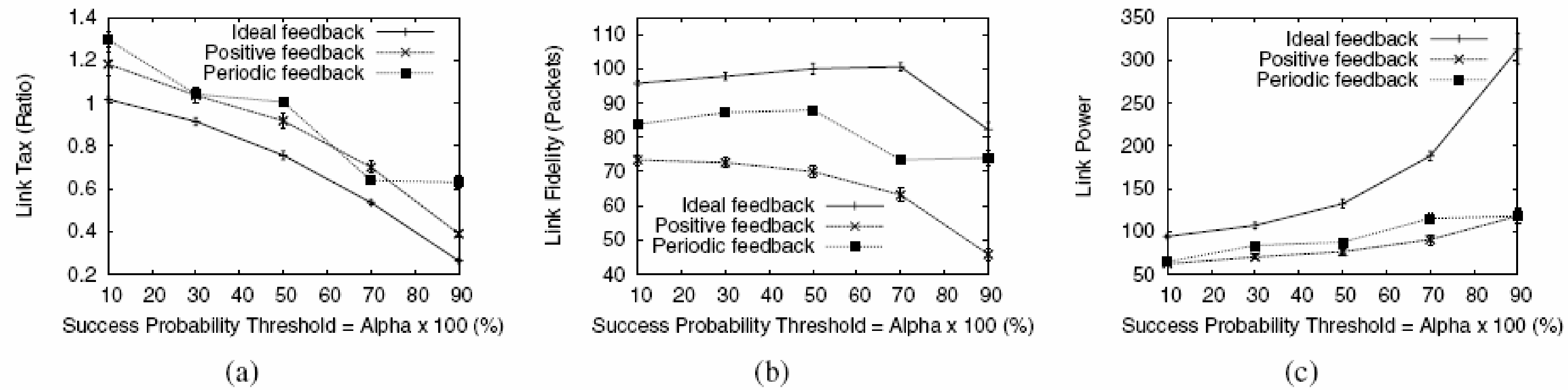
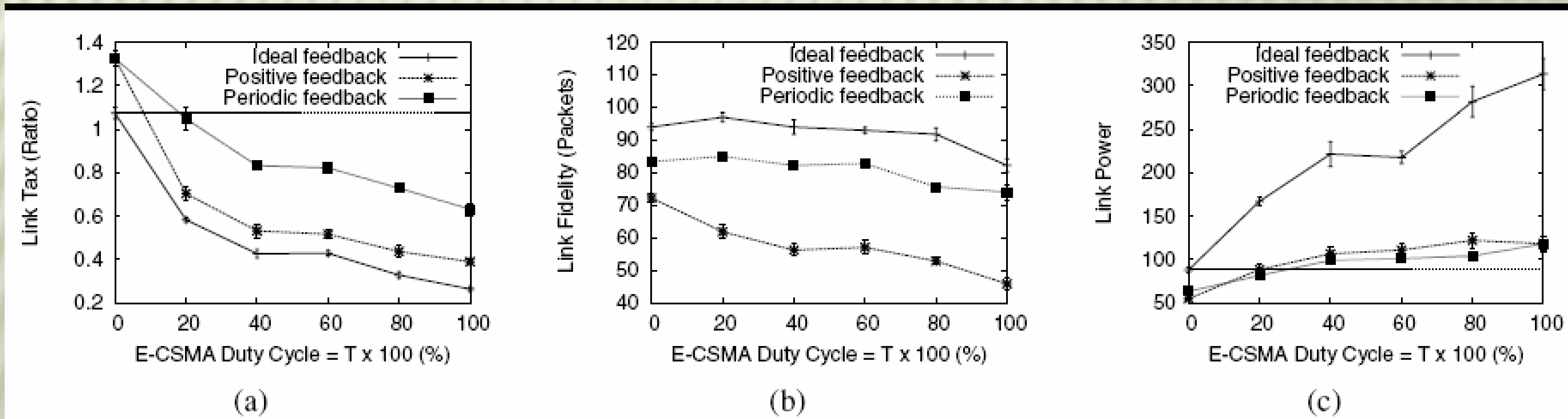


Fig. 4. Impact of α on (a) Link Tax, (b) Link Fidelity, and (c) Link Power for the ideal, positive and periodic feedback schemes.

EXPERIMENT

- The Impact of E-CSMA Duty Cycle
  - T=0, plain B-MAC
  - T=1, all traffic is sent using E-CSMA



EXPERIMENT

- Impact of Traffic Load
  - Every curve decreases sharply with increasing rate as channel contention.
  - Positive E-CSMA maintains a small Link Power advantage over Periodic E-CSMA

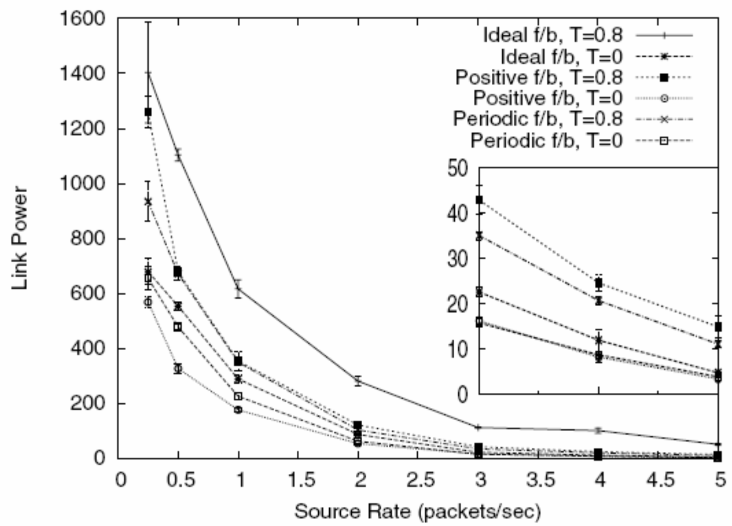


Fig. 6. Link Power versus offered load (per node) for the ideal, positive and periodic feedback schemes. Source rate on the x-axis is for each of the 31 concurrent sources. A zoom of the tail of the bottom five curves is shown as an inset at the same x-axis scale (from 3 to 5 packets/sec).

EXPERIMENT

- Importance of Receiver Differentiation
  - It is important to maintain per-receiver state data.

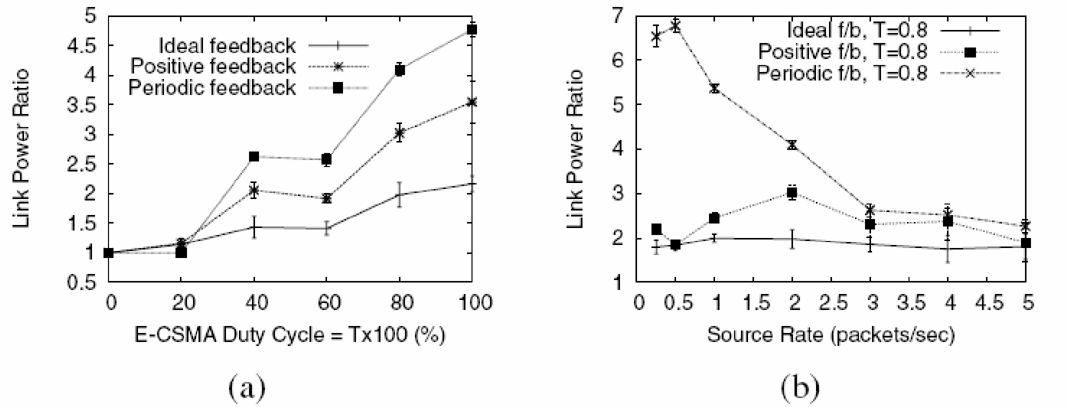


Fig. 7. The Link Power Ratio, i.e., the Link Power of baseline E-CSMA over the Link Power of E-CSMA$_{neighborhood}$, shows the advantage of using per-neighbor probability distributions over per-neighborhood. (a) shows the advantage across values of T, where at $T = 0$ (B-MAC) the ratio is 1 since the transmit/defer decision does not involve the distributions. (b) shows the advantage across source rate, where at all tested rates baseline E-CSMA performs better (Ratio > 1) for all feedback schemes.

CONCLUSION

- Fully distributed MAC framework targeted at increasing the chance of successful packet reception in wireless sensor networks using carrier sensing.
- The efficacy of E-CSMA in reducing average link tax with a relatively small decrease in average link fidelity has been demonstrated.