Low-Power Distributed Event Detection in Wireless Sensor Networks

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Outline

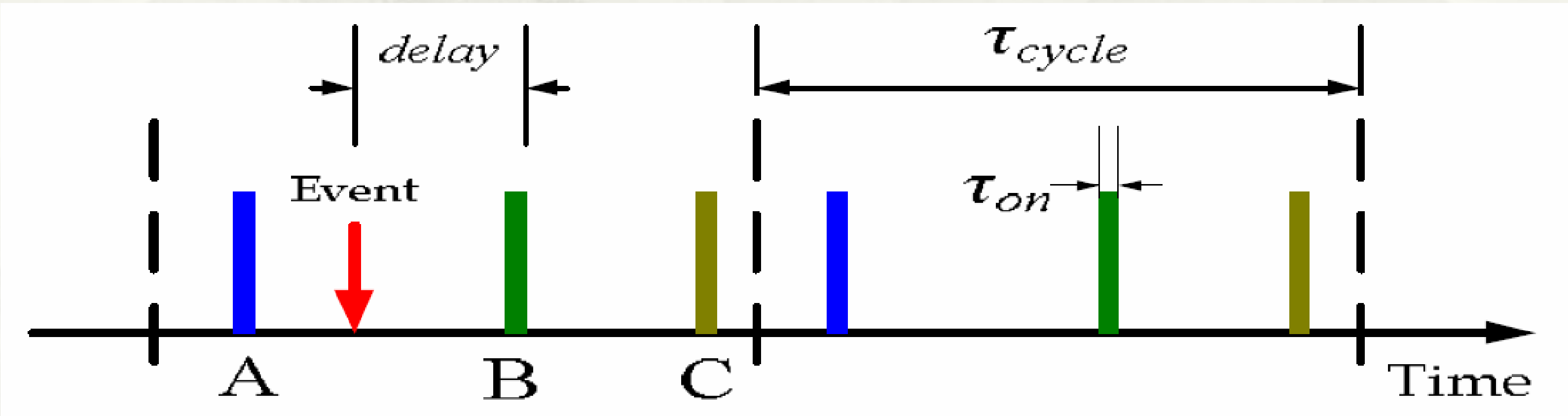
- Introduction
- Event detection
- CAS : Coordinated Wakeup Scheduling
- Performance Evaluation
- Conclusion

Introduction

- **two essential properties of event detection applications to design energy-efficient detection protocols**
  - physical events are usually persistent which can last for seconds or even longer, rather than ephemeral
  - a broad class of applications accepts a certain detection delay

Introduction

- Duty cycling is a fundamental approach to conserving energy in WSNs .



- Duty cycle $\delta = \tau_{on} / \tau_{cycle}$

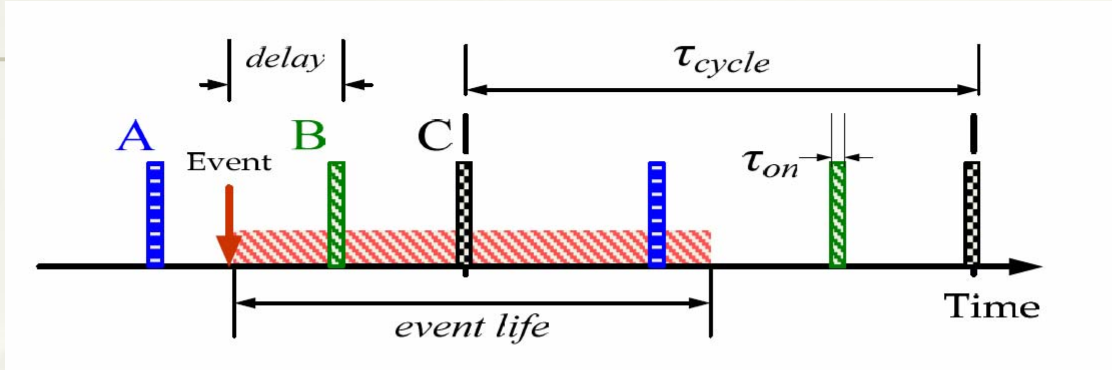
Introduction

- CAS -- a completely localized algorithm
- CAS is easy to implement and scalable to network density.
- it significantly reduces detection delay and improves detectability

Some assumptions

- **Binary detection model** --*An event is reliably detected by an active sensor if its* distance to the sensor is less than the sensing range.
- **Time synchronization**
- **Stationary events** --After an event has occurred, it remains at the location where it happens.

Event detection



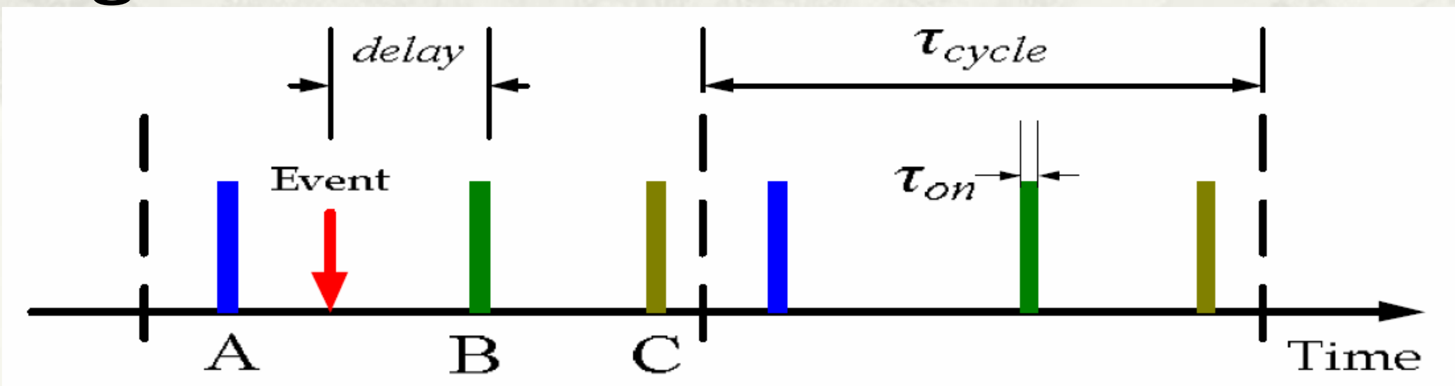
- Duty Cycle: $\delta = \tau_{on} / \tau_{cycle}$
- To conserve energy,
  - Shorten τ_{on}
    - $\tau_{on} = \tau_{wakeup} + \tau_{sensing} + \tau_{processing} + \tau_{communication}$
    - Usually τ_{on} is fixed, tens of milliseconds [1]
  - Lengthen τ_{cycle}
- Problem
  - A longer τ_{on} leads to a longer delay and lower detectability.

Event detection

* Longer τ_{cycle}
  * Longer delay
  * Lower detectability
  * Longer network lifetime
* τ_{cycle} <= τ_{event}
  * Detectability is 100%
* τ_{cycle} > τ_{event}
  * Some events possibly won't be detected.

RIW

- Random independent wakeup
- Simple but low efficient
- The sensors which are close to each other may wakeup at about the same time due to the lack of awareness about their neighborhood.



RIW

- RIW provides us a baseline of event detection with low duty-cycled sensors.
- the key issue is the scheduling of sensor wakeups that can produce minimal delay and maximal detectability when the sensing cycle is fixed. ← challenge
- we have the instructive observation that the sensors that reside closely should separate their wakeups as much as possible

CAS

- Coordinated Wakeup Scheduling
- Fully localized algorithm
- Two component:
  - Distributed scheduling coordination
  - Aggressive wakeup adjustment
- CAS assumes that every sensor is aware of the distance to each of its neighbors.

distributed scheduling coordination

- Each sensor need to cooperate with neighbors to determine their wakeup time.
- Tasks:
  - Identify neighbors, which are sensors within **CR** (cooperative range), $0 < CR <= 2R_s$
  - Determine wakeup time

CAS state diagram

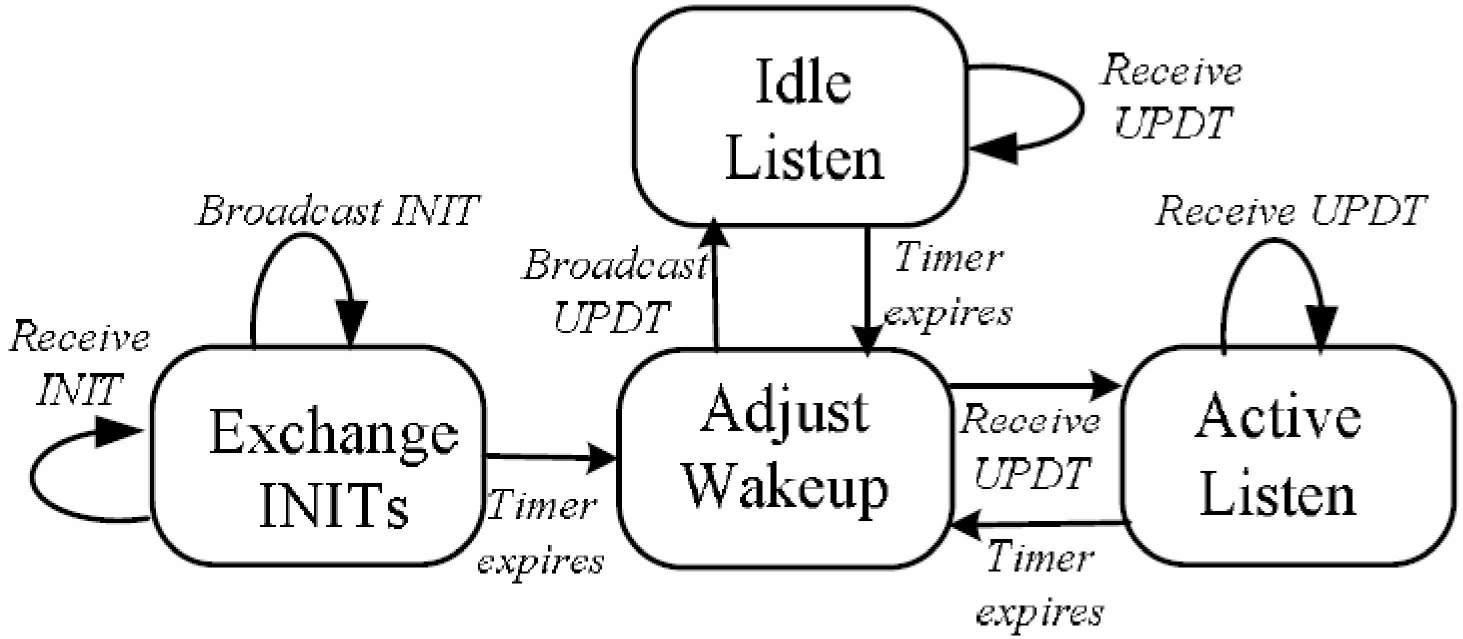
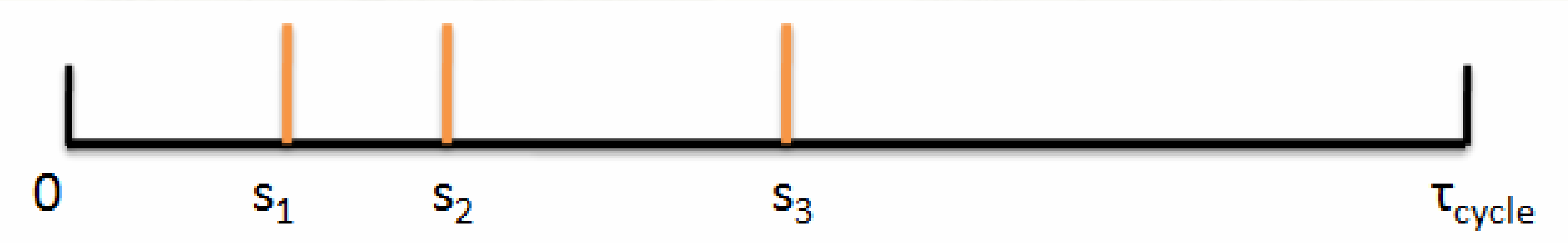


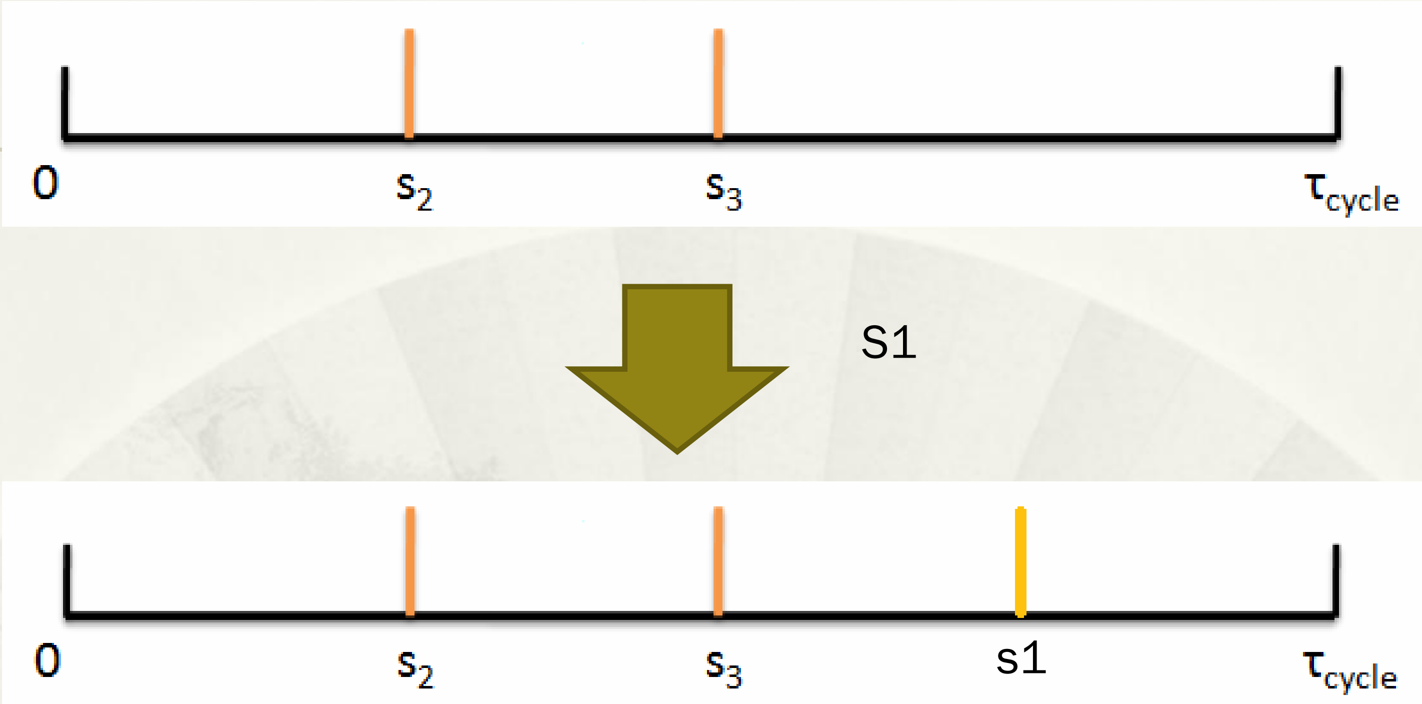
Fig. 2. CAS state transition diagram

- After using AWA to calculate the adjustment and waiting for a random time, one sensor broadcast this adjustment in a UPDT message.
- Upon receiving this UPDT message, if the sender is in the receivers *neighbor* list, the receiver cancel sending its own adjustment request and update its own wakeup time table.
- Multiple rounds of AWA is necessary to reach a reasonable schedule plan.
- Usually each sensor need to send 2 UPDT messages successfully at least.

Aggressive Wakeup Adjustment

- A sensor need to determine
  - whether it should adjust its wakeup time
  - and what the new wakeup is
- Sensor identifies the maximum separation and then selects the new wakeup by placing its wakeup in the middle of the maximum wakeup separation

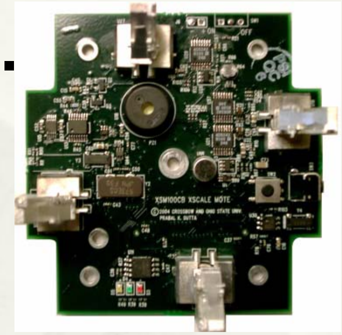




- calculate **Variance:** difference between wakeup separations
- If the new variance is decreased, sensor will generate a request to update its wakeup.

Performance Evaluation

- Based on eXtreme Scale Mote [1].



  - Communication range : 20m
  - Sensing range : 8m
  - Transceiver power consumption :19.4mW
  - Processor power consumption : 24mW
  - Sensor power consumption : 24mW
  - $\tau_{cycle} = 10s$, $\tau_{on} = 0.1s$
  - Side length : 300 m

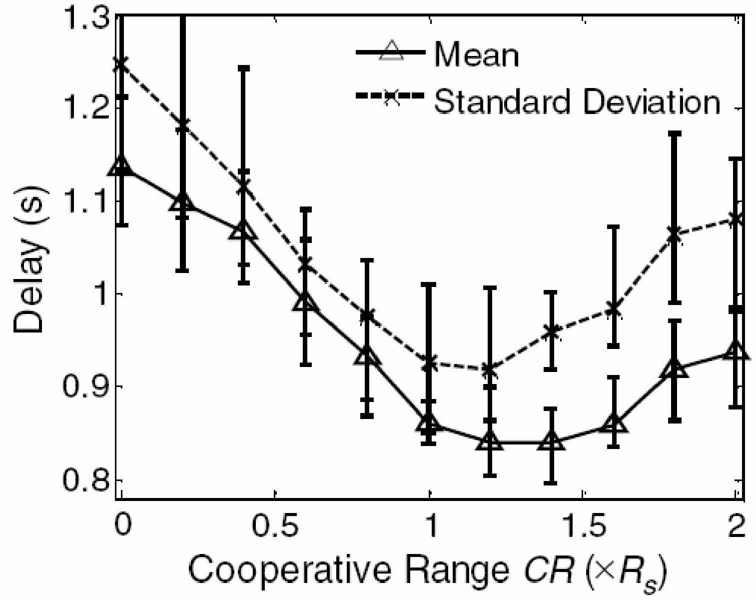


Fig. 3. Detection delay vs. cooperative

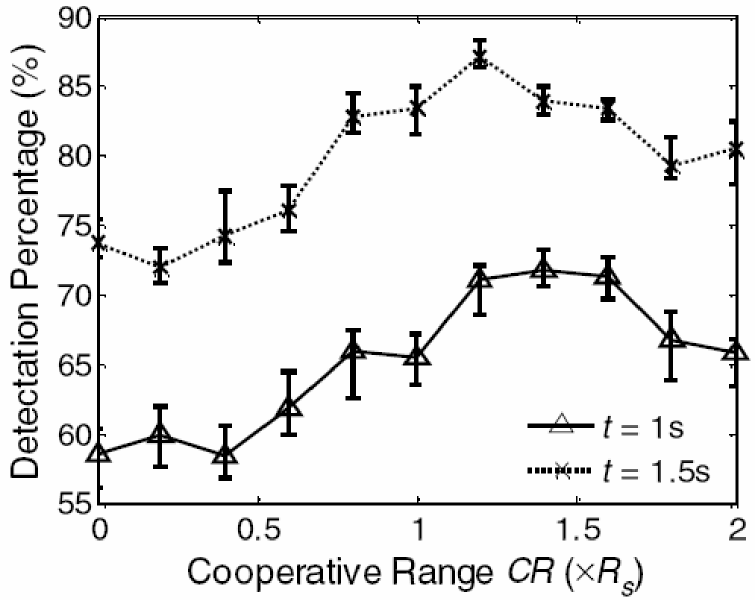


Fig. 4. Detectability vs. cooperative

- The best CR is around $1.3R_s$

Lower bound of CAS

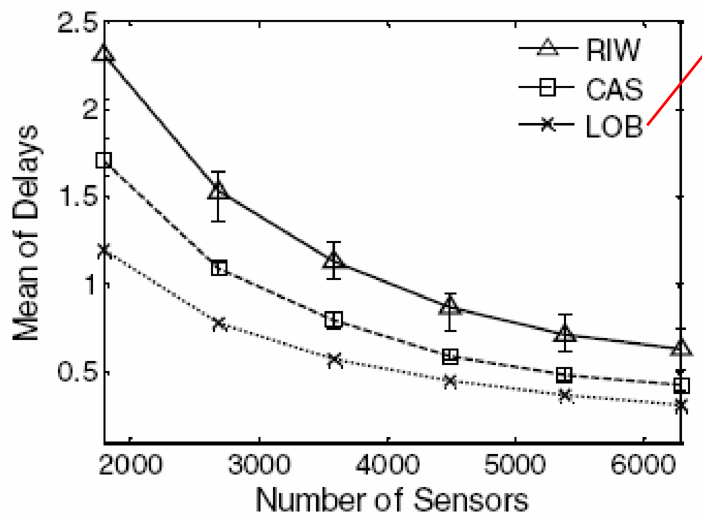


Fig. 5. Delay comparison with different densities

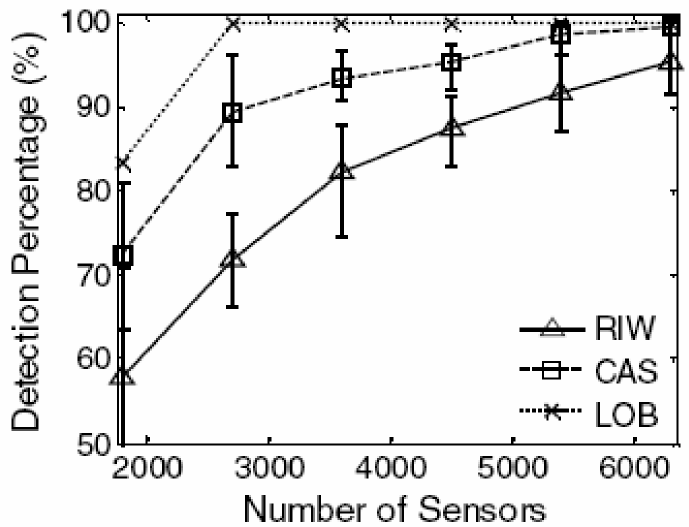


Fig. 6. Detectability comparison with different densities, t=2s

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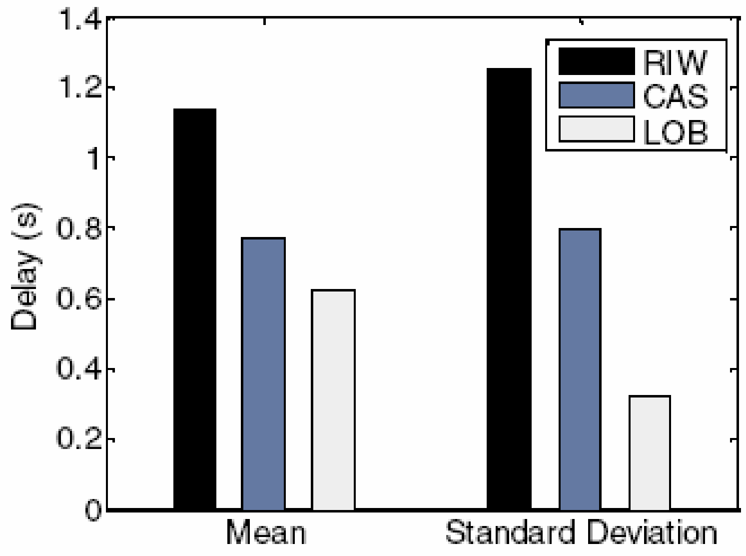

Fig. 7. Delay comparison

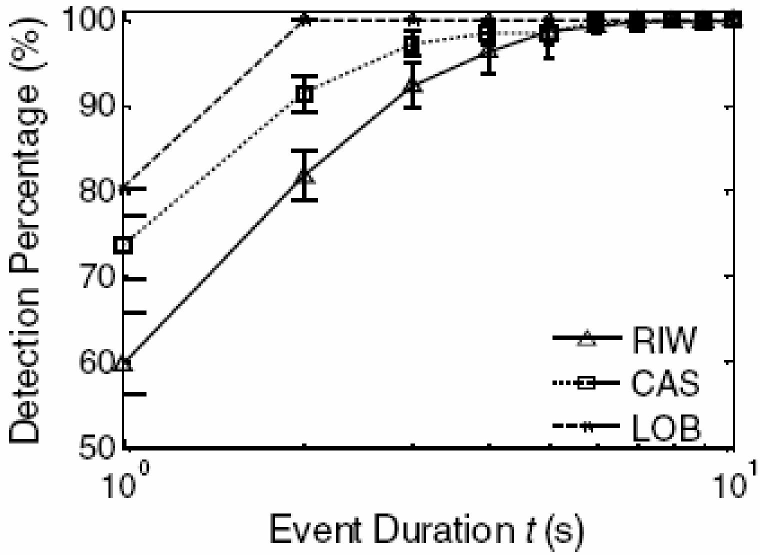

Fig. 8. Detectability comparison

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Conclusion

- We study low-power event detection in WSNs
- CAS is a fully localized algorithm for detection optimization.
- CAS only requires minimal knowledge of distances to its neighbors and is scalable to network