Robustness of Receiver-driven Multi-hop Wireless Network with Soft-state Connectivity Management

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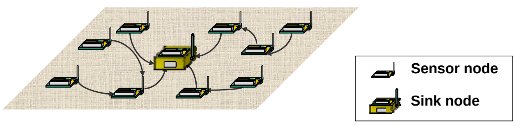
Outline

- Background of our research
  - Intermittent Receiver-driven Data Transmission (IRDT)
- Our goal
- Soft-state connectivity management
- Performance evaluation by computer simulation
- Conclusion

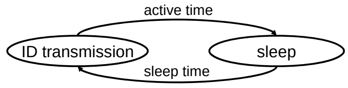
Wireless sensor networks



- Consisted of a number of sensor nodes
  - Collect data over a large area
    - "Temperature", "humidity ", "light", and etc.
- Limited batteries — Energy saving is necessary
- Low reliability — Robustness is necessary
  - Nodes are prone to failure
  - Poor quality of wireless channel

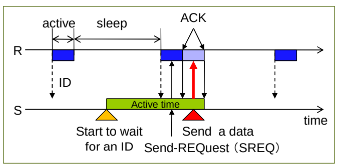
Intermittent operation for energy saving

- Intermittent operation of sensor node
  - Alternating 'active' / 'sleep' states repeatedly at the *intermittent interval*
    - Communicating in 'active' state
    - Saving energy consumption with 'sleep' state
- Intermittent <u>Receiver-driven</u> Data Transmission (IRDT)



  - Receiver nodes start communication by sending an ID
  - Sender nodes choose an appropriate receiver by waiting for an ID
  - We are proposing this technique to IEEE 802.15 Task Group 4

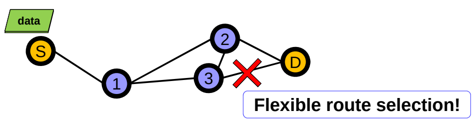
IRDT: MAC layer



- Receiver nodes
  - Transmit own ID periodically
  - Sleep to save energy
- Sender nodes
  - Wait for a receiver's ID
  - Return an SREQ according to the <u>routing layer</u>
- Sender nodes can communicate with multiple receivers
  - Decrease of sender nodes' active time
    ⇒ Save energy!
  - Construction of mesh networks
    ⇒ Improve robustness?
    ⇒ Depending on routing layer!

IRDT: Routing layer

- Based on distance vector routing
  - All nodes have hop count tables and exchange them
- SREQ transmission depends on minimum hop routing



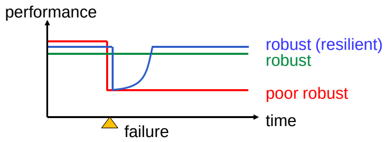
- Hard-state management of neighbor node in hop count table and neighbor nodes' hop count tables
  - Slow response to environmental changes

⇓

Poor robustness

Our goal

- Improve robustness of wireless sensor network using IRDT
  - Robustness: the property that allows network performance to maintain or recover against environmental changes



- Propose a soft-state management of routing information in IRDT
  - Performance evaluation by using computer simulation
    - Evaluate overhead of soft-state management
    - Evaluate robustness of soft-state management

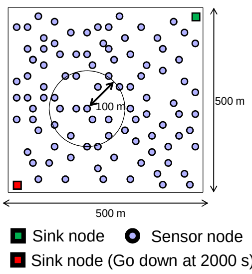
Soft-state management

- Periodical ID transmission in IRDT is used as update message
  - Each node listens channel for obtaining IDs every T_i
- Management of neighbor node (Update interval)
  - Register ID-sender in hop count table as a neighbor node
  - Delete a neighbor node from hop count table if the neighbor node's ID cannot be arrived during T_i
- Management of neighbor node's hop count table
  - Exchange hop count table after receiving ID
  - Delete the neighbor node's hop count table if the neighbor node's ID cannot be arrived during T_i

Improve robustness!

Simulation Model

- 100 sensor nodes are randomly deployed
- 2 sink nodes are arranged at two corners

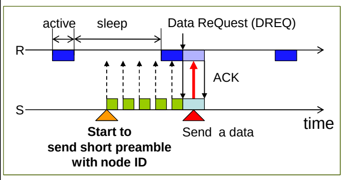


- Overhead evaluation
  - Compare with sender-driven MAC (AX-MAC)
- Robustness evaluation
  - Against sink node failure
- Examine packet collection ratio and energy consumption
- Change the value of T_i
  - Smaller T_i : soft state
  - Larger T_i : hard state

Parameters

Parameter	Value
Transmission speed	100 kbps
Transmission range	100 m
Data packet generation rate (Poisson process)	0.003 packet/s/node
Current consumption (TX)	20 mA
Current consumption (RX)	25 mA
Current consumption (Sleep)	0 mA
Packet size（ID, SREQ）	24 byte
Packet size（RACK, DACK）	22 byte
Packet size（DATA）	128 byte

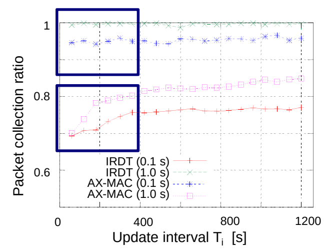
Attribute-based X-MAC (AX-MAC)



- Receiver nodes
  - Check channel condition periodically
  - Return DREQ after receiving ID according to routing layer
  - Sleep to save energy
- Sender nodes
  - Transmit own ID continuously
  - Transmit data after receiving DREQ
- AX-MAC is Sender-driven MAC protocol
  - IRDT is receiver-driven MAC protocol
- Comparing IRDT with AX-MAC for evaluating overhead of soft-state

Evaluation of overhead of soft-state management

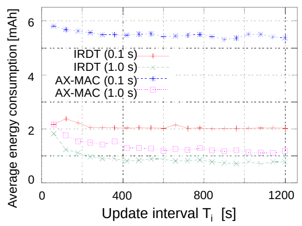
Traffic overhead



- Mainly caused by hop count table exchanges
  - Small T_i decreases packet collection ratio
  - IRDT (1.0 s) and AX-MAC (0.1 s) are unaffected

Evaluation of overhead of soft-state management

Energy overhead

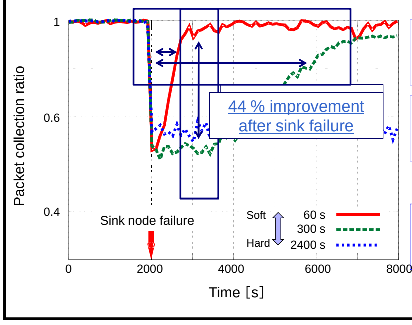


- Mainly caused by update message listening
  - Nodes must listen at least for one intermittent interval
- Energy consumption of IRDT (1.0 s) is smallest
  - Packet collection ratio of IRDT (1.0 s) is highest

Evaluation of robustness against sink node failure

Robustness of packet collection ratio

- One of two sink nodes go down at 2000 s
- Update interval [T_i] is set to 60 s, 300 s, 2400 s



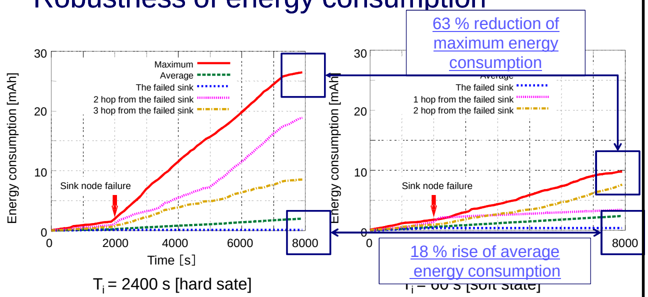
Improvement of Packet collection ratio 1000 s after sink node failure

Improvement of 90 % recovery time after sink node failure

Soft-state management improves robustness of Packet collection ratio

Evaluation of robustness against sink node failure

Robustness of energy consumption



T_i = 2400 s [hard sate]

- Soft-state management improves robustness of maximum energy consumption
  - Average energy consumption slightly increases

Conclusion

- Evaluate overhead of soft-state management in IRDT
  - On packet collection ratio, traffic overhead is very low
  - On energy consumption, lower overhead than sender-driven MAC protocol
- Evaluate robustness against sink node failure in IRDT with soft-state management
  - 44 % improvement of packet collection ratio 1000 s after sink node failure
  - 87 % reduction of 90 % recovery time of packet collection ratio
  - 63 % reduction of maximum energy consumption
- Future work
  - Improvement of scalability in IRDT
    - All nodes use N^2 size of hop count table (N is the number of nodes)

Thank you