Performance Evaluation of Intermittent Receiver-driven Data Transmission in Wireless Sensor Networks

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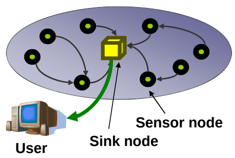
Outline

- Background of our research and our goal
- Intermittent Receiver-driven Data Transmission (IRDT) scheme
- Performance evaluation by computer simulation
- Improvement of IRDT
- Conclusion and future works

Wireless Sensor Networks

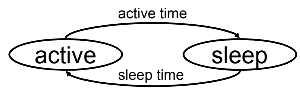
- The network consisted of a number of sensor nodes
  - Sensing "temperature", "humidity ", "light", and etc.
  - Send those data to the sink node
  - User analyze those data
- Various applications
  - Environment monitoring
  - Security management in buildings
- Limited batteries



⇨ Energy-saving is needed for long-term operation

Intermittent Operation for Energy-Saving

- Intermittent operation of sensor node
  - Alternating 'active'/'sleep' state repeatedly at the "**intermittent interval**"
    - Communicating in 'active' state
    - Saving energy consumption with 'sleep' state



Intermittent interval = active time + sleep time

- Intermittent Receiver-driven Data Transmission (IRDT) [7]
  - Receivers start communication by sending IDs at active state
  - Senders can choose an appropriate receiver by waiting for IDs
  - Basic performance characteristics have not been clarified

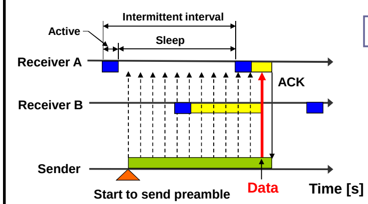
[7] M. Sugano, R. Fukushima, M. Murata, T. Hayashi, and T. Hatauchi, "Performance Evaluation of a Low-Energy-Consumption Ad Hoc Mesh Network Based on Intermittent Operation," in *The 3rd IEEE Workshop on Wireless Mesh Networks (WiMesh 2008, Poster session)*, Jun 2008.

Our Goal and the Method of the Research

- Clarifying the basic performance characteristics of IRDT
  - Performance:
    - Packet collection ratio
    - Packet delay time
    - **Energy consumption**
- Performance evaluation using computer simulation
  - Investigating the performance characteristics in various packet generation rate
  - Comparison between IRDT and Low Power Listening (LPL) [6]
    - IRDT: Receiver-driven method
    - LPL: Sender-driven method

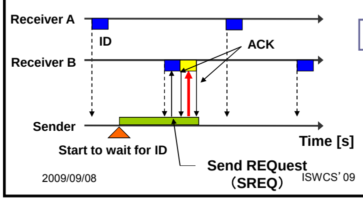
[6] R. Jurdak, P. Baldi and C. V. Lopes: Adaptive low power listening for wireless sensor networks", IEEE Trans. MobileComputing, **6**, 8, pp. 988-1004 (2007).

Differences between IRDT and LPL



Features of LPL

- Receivers check the channel condition
  - Continuing active state to receive data when the channel is in use
- Senders send preamble
  - Sending for a longer time than intermittent interval
  - Sending data after preamble



Features of IRDT

- Receivers send their own ID
- Senders wait for ID
  - Waiting for the ID from one of the appropriate receivers

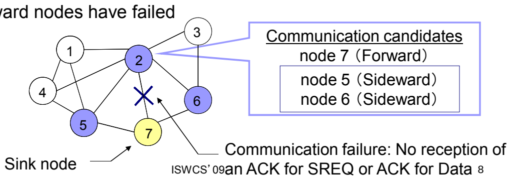
Simulation Model

- Network model
  - 49 sensor nodes and 1 sink node are deployed over 400-m-square
- Assumptions
  - Each node sends data to the sink node according to a Poisson process
  - No failure and energy depletion of nodes
  - The collided packets are discarded
- Variables
  - Packet generation rate（0.002～0.028 packets/s）
  - Intermittent interval（0.1 s or 1.0 s）
- Parameters

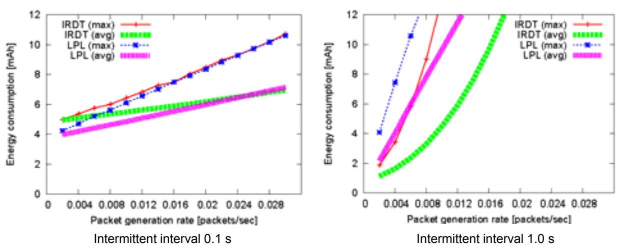
Simulation time	6 [hour]
Communication range	100 [m]
Communication rate	100 [kbps]
Waiting current	25 [mA]
Sending current	20 [mA]
Sleeping current	0 [mA]
ID packet size	40 [byte]
Data packet size	128 [byte]
Other packet size	26 [byte]

Routing Algorithm

- Each node has a topology management table
  - Each node knows the numbers of hops from the sink node to any node
    - Forward node：neighbors that are nearer from the sink node
    - Sideward node：neighbors that have the same hops from the sink node
- Next hop is selected from communication candidates
  - Returning SREQ for the first ID from a communication candidate
  - Communication candidates include all forward nodes
  - Sideward nodes are added when communications with all forward nodes have failed

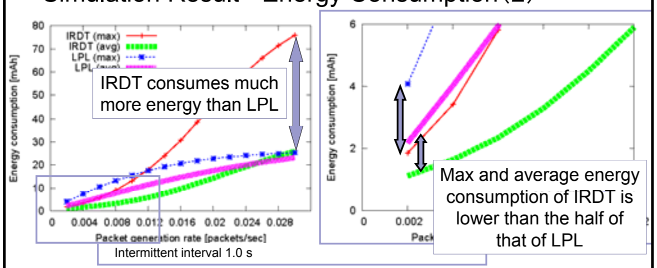


Simulation Result - Energy Consumption（1） -



- Shorten the intermittent interval
  - increases duty cycle of nodes
    - Minimum energy consumption at 0.1 s is higher than at 1.0 s
  - suppresses the sharp rise in energy consumption

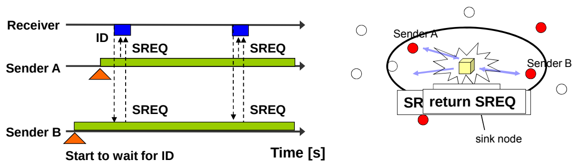
Simulation Result - Energy Consumption（2） -



- The highest loaded node of IRDT consumes much more energy at high packet generation rate
  - This problem is caused by SREQ collisions
- IRDT keeps lower energy consumption at low packet generation rate
  - Thanks to being able to select multi-receivers

SREQ Collisions

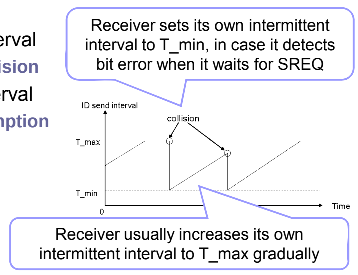
- Causing the high energy consumption in IRDT
  - SREQ collisions increase ID-wait time for retransmissions
  - SREQ collisions tend to happen at high loaded nodes like the sink node



- SREQ collisions happens repeatedly at the sink node
  - Because the sink node is always the forward node for its neighbors

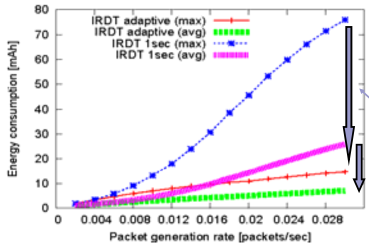
Proposal of Improved IRDT

- Setting intermittent interval dynamically and adaptively
  - Shorter intermittent interval
    - **decrease SREQ collision**
  - Longer intermittent interval
    - **save energy consumption**



- Random disregard of the forward nodes
  - For the prevention of repeated SREQ collisions
  - Only after communications with all forward node have failed

Simulation Result of Improved IRDT -Energy Consumption-



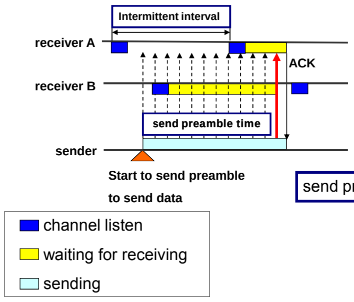
- Parameter settings
  - T_max = 1.5 s, T_min = 0.2 s
- Performances are improved at any packet generation rate
  - Energy consumption of the highest loaded node is also reduced by 13 % at low packet generation rate

Conclusion and Future Works

- Clarifying the basic performance of IRDT
  - Saving energy consumption at low packet generation rate
  - The highest loaded node in IRDT consumes much more energy than in LPL
- Proposal of improved IRDT
  - Energy consumption of highest loaded node is reduced from the original IRDT at 1.0 s intermittent interval
    - At high packet generation rate: 83% reduction
    - At low packet generation rate: 13% reduction
- Future works
  - Optimal determination procedure of T_max and T_min
  - Performance evaluation considering wireless channel condition, node failure, battery depletion
  - Comparing with other Sender-driven methods

- Thank you for your attension

Low Power Listening (LPL) [7]

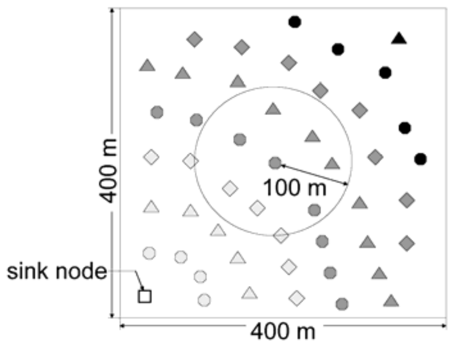


- Start with sender's preamble
  - Before sending preamble LPL needs to select the receiver
- channel is occupied by preamble

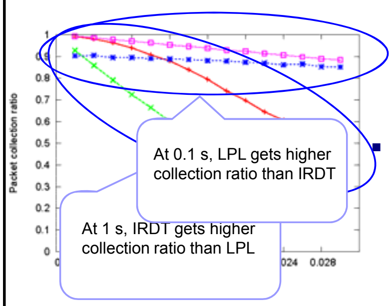
send preamble time ≧ intermittente interval

- advantageous for short II
- disadvantage for long II

Network model

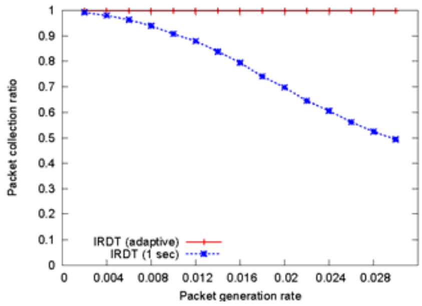


Simulation Result - Collection Ratio (1)

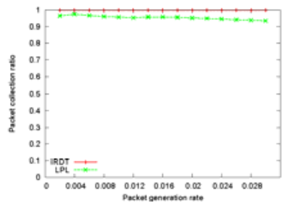


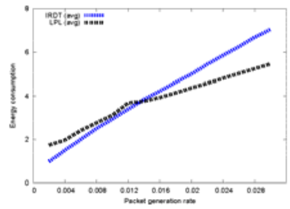
- **Long intermittent interval**
  - Smaller number of data can be received per unit time
  - In LPL, channel is occupied → low collection ratio
  - IRDT has sharp decay of collection ratio
- **Short intermittent interval**
  - Larger number of data can be received per unit time
  - LPL can get high collection ratio
  - In IRDT ID-sending collides against other packets

Simulation Result - Collection Ratio（2）



Improved IRDT and adaptive LPL





- In LPL, Priority for settings of intermittent interval is primarily given to the energy-saving