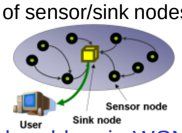
Lifetime Extension Based on Residual Energy for Receiver-driven Multi-hop Wireless Network

Chuluunsuren Damdinsuren, Daichi Kominami, Masayuki Murata *(Osaka University)*
Masashi Sugano *(Osaka Prefecture University)*
Takaaki Hatauchi *(Fuji Electric Co., Ltd.)*

Agenda

Background

- Wireless Sensor Networks (WSN)
  - composed of a large number of sensor/sink nodes
    - Sink nodes collect data from sensor nodes
    - Sensor nodes operate with limited battery



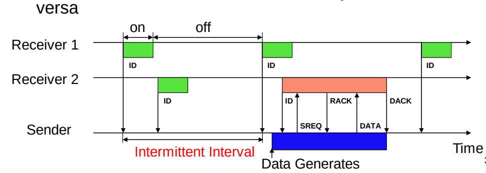
- Energy efficiency is a critical problem in WSN
  - How to reduce energy consumption to extend the network lifetime?

⇨ Intermittent operation: get into sleep state when there is no data communication

2

Intermittent Receiver-driven Data Transmission (IRDT) Protocol

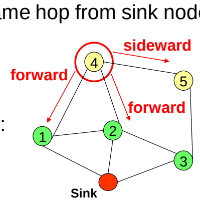
- MAC protocol with intermittent operation
  - Receiver-Driven: Receiver node starts communication
    - Receiver nodes periodically sends an ID included packet
    - Sender nodes transmits data for an appropriate sender of an ID
  - Applied into gas-metering systems
- Possible to change node's relay load by controlling Intermittent interval
  - Short intermittent interval increases relay load, and vice versa



3

Routing Protocol of IRDT

- Definition
  - Forward node: a node in fewer hops from sink node
  - Sideward node: a node in same hop from sink node
- DV-based routing
  - When sender receives an ID:
    - From a forward node -> transmits data packet
    - From a sideward node -> transmits data packet with a probability of 50%

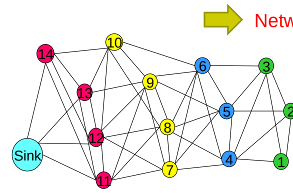


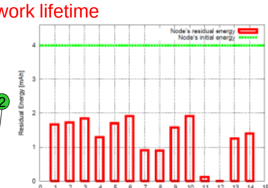
4

Problem & Purpose

- Problem of IRDT: unbalanced relay load of nodes decreases the time until the first node runs out of battery

⇨ Network lifetime



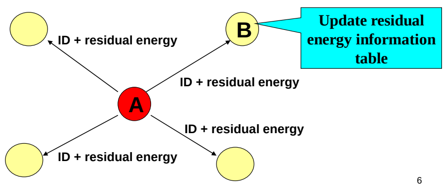


- Purpose: Balancing the load of nodes by using "residual energy information", and then extending network lifetime

5

Proposed Load Balancing Method (1/3)

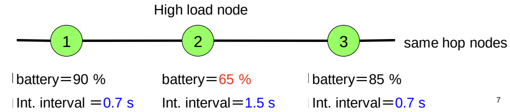
- Sharing residual energy information
  - Node A attaches the residual energy information into its ID packet, and broadcasts it
  - When node B receives this ID, it updates node A's residual energy information in its table



6

Proposed Load Balancing Method (2/3)

- Controlling intermittent interval with residual energy information
  - Nodes compare own residual energy with the average residual energy of their sideward nodes
    - If own residual energy is smaller (heavy relay load), the node makes its intermittent interval longer
    - If own residual energy is larger (light relay load), the node makes its intermittent interval shorter



7

Proposed Load Balancing Method (3/3)

- The algorithm for controlling the intermittent interval
  - Each node compares its residual energy with the average residual energy of its sideward nodes every 100 s

if $(E[i] < Es[i])$ // Compare residual energy level	$E[i]$: residual energy
$\{T[i] = T[i] + \alpha + \delta;\}$ // If own residual	$Es[i]$: average residual energy
//energy is smaller, down the load	of sideward nodes,
else	$T[i]$: intermittent interval,
$\{T[i] = T[i] - \alpha + \delta;\}$ // If own residual	α, δ : constant values,
//energy is bigger, up the load	$T\min, T\max$: lower and upper
if$(T\min < T[i] < T\max)$ //checking restrictions	bound of intermittent interval

8

Evaluation

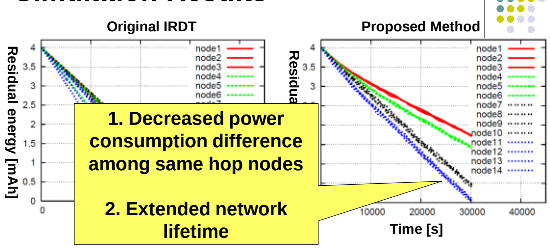
- Method:
  Computer simulation
- Metrics:
  - **Network lifetime**:
    the time until the first node runs out of its battery
  - **Packet collection ratio**:
    the ratio of all collected packets to all generated packets
  - **Average Delay time**:
    the average end-to-end delay time of all collected packets

Main Parameters

# of nodes	14
# of sinks	1
Intermittent Interval (initial)	0.3 s
Packet generation ratio	0.01 packet/node/s
Speed	100 kbps
Data size	128 byte

9

Simulation Results

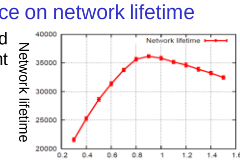


	Network lifetime	Packet collection ratio	Average delay
Original IRDT	20724 s	99.8 %	0.50 s
Proposed Method	35275 s	99.7 %	0.57 s

10

Analysis of Parameter: T_{max} (1/3)

- T_{max} has a big influence on network lifetime
  - T_{max} is the upper bound value of the intermittent interval



- How to derive the optimum value of T_{max} ?
  - Expressing the energy consumption as a function of T_{max}
  - Finding the optimum T_{max} that minimizes the energy consumption of the heaviest loaded node

$$T_{max} = \arg\min \left(\max_{i \in nodes} \{E_{total}[i]\} \right)$$

11

Analysis of Parameter: T_{max} (2/3)

- Power consumption per unit time of node i
  - Total power consumption per unit time:

$$E_{total}[i] = E_{rec}[i] + E_{send}[i] + E_{ID}[i]$$

- Power consumption per unit time for data reception:

$$E_{rec}[i] = P_{rec} * N_a$$

- Power consumption per unit time for data transmission:

$$E_{send}[i] = (T_{wait} * P_{wait} + P_{send}) * (N_a + N_g)$$

- Power consumption for ID transmission :

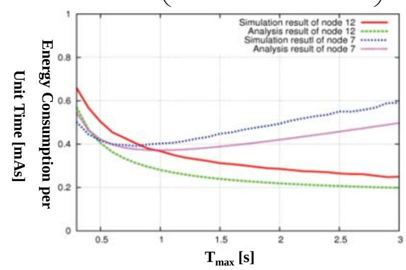
$$E_{ID}[i] = \left(\frac{1}{T_{avg}} - N_a \right) * (P_{ID} + P_{wait} * T_{id})$$

12

Analysis of Parameter: T_{max} (3/3)

- The highest energy consuming node is 7 and 12

$$T_{\max} = \arg\min\left(\max\{E_{total}[7], E_{total}[12]\} \right)$$



13

Conclusion & Future work

- We proposed a load balancing method by controlling the intermittent interval based on residual energy.
- It clarified that proposed method can extend network lifetime without degrading network performance by simulation.
- Future work
  - More accurate analysis
  - Further evaluation of various networks and load environment.

15

Q & A

Thank you for your kind attention