Performance Evaluation of a Low-Energy-Consumption Ad Hoc Mesh Network Based on Intermittent Operation

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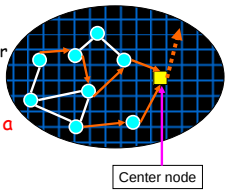
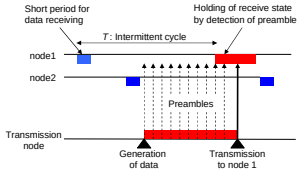
Ad hoc Mesh Network

- The network which consists of nodes with the relay function by wireless communications
  - Redundancy of a communication link is high
- Applications in various fields
  - Environmental monitoring
  - Urgent network at the time of a disaster
  - Security management of a building
- Each node is operating with battery
  ⇒ Reduction of power consumption is a large subject



Suppress of the power consumption by intermittent operation

- Intermittent operation
  - Each node repeats active state and sleep state in a fixed cycle
  - Each node communicates in an active state
- Low Power Listening (LPL) [6]



Problem of LPL system

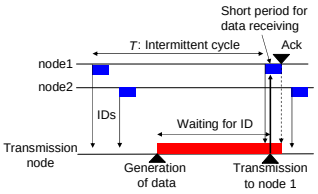
- One node occupies a channel at the time of preamble transmission.
- Since the receiving node is specified in the preamble, the transmission node can communicate only with a specific node.

[6] R.Jurdak, P.Baldi, and C. V. Lopes, "Adaptive low power listening for wireless sensor networks," IEEE Trans. Mobile Computing, vol. 6, pp. 988-1004, Aug. 2007

Proposed Method Developed by Fuji Electric Co. Ltd.

- Intermittent ID transmission of Receivers (IIDR)

Both of nodes 1 and 2 can receive the packet from the transmission node



Merit of an IIDR system

- Transmission node can transmit to either of two or more nodes specified as an destination, and can shorten the time which holds the packet.
- Channel occupancy by preamble is avoidable.

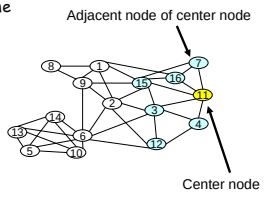
Purpose of Our Research

- To clarify the performance characteristic of IIDR method
  - Power consumption for each node
  - Packet collection rate
  - Packet transmission delay

  Clarify these characteristics by simulation experiments
- Parameter settings for improving the performance of IIDR
  - Goal:
    - Extension of life of the network by reduction of power consumption
  - Parameters:
    - Sleep time for each node
    - Maximum transmission number

Simulation Model

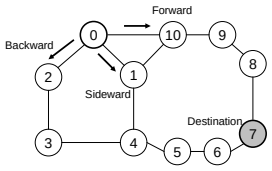
- Behavior of each node
  - Constitute mesh topology
  - Each node generates a packet according to packet generation rate
  - Each packet is transmitted along the one of multiple routes
  - Sleep time of all the nodes is 3 seconds
- Energy consumption model
  - Receiving state: 6.25 × 10^{-2}w
  - Transmitting state: 7.20 × 10^{-2}w
  - Sleep state: 0 w



Routing of Target System

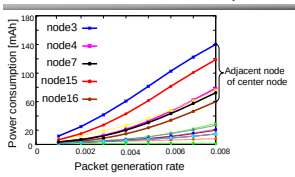
- Priority of selection of destination nodes
  - The nodes whose number of hop to the center node are the minimum
    ⇒ Forward node
  - The nodes whose number of hop to a center node are the minimum plus 1
    ⇒ Sideward node

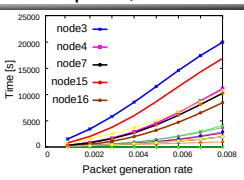
1. First, packet is transmitted to either of the nodes of a forward route
2. If forward transmission fails, sideways routes are added to the candidate of receiving nodes.

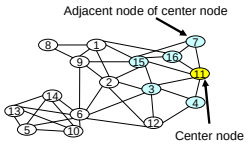


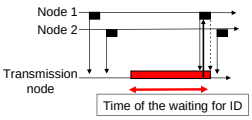
7

Simulation results (Power Consumption)





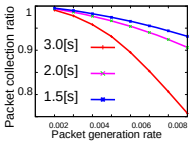


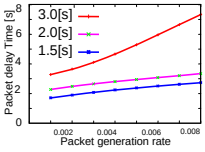


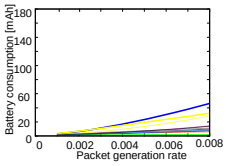
Power consumption is depend on time of the waiting for ID

8

Performance Improvement (Setting of Sleep time of Center Node)







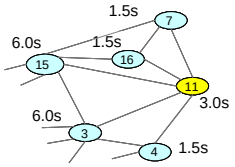
Shortening of the sleep time of center node

- The packet transfer processing to center node became smooth
  - Increase in packet collection rate
  - Decrease of packet propagation delay
- Packet transfer between the adjacent nodes of center node decreased.
  - Decrease of the power consumption in the adjacent node of center node

9

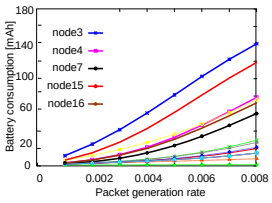
Performance Improvement (Sleep Time Setting according to Each Node)

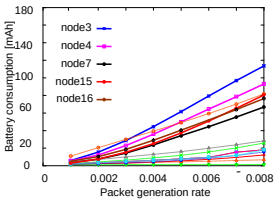
- In center adjacent nodes, sleep time is set up for each node according to its load
  - Node with high load: 3, 15 ⇒ 6.0 second
  - Node with low load: 4, 7, 16 ⇒ 1.5 second
  - Other nodes ⇒ 3.0 second



10

Result (Sleep Time Setting according to Each Node)





Load sharing was realized by setting up sleep time according to load.

⇒ Extension of Network Lifetime

11

Conclusion

- Basic performance characteristic of IIDR was clarified
  - Power consumption of a node is dependent on ID waiting time
  - Load of adjacent node of the center node is high
    - Packet discard by excess of the maximum number of transmission increases, and packet collection rate decreases
    - Packet transmission delay increases by the transmission failure to the center node
- Performance Improvement by parameter settings
  - Sleep time of the center node
  - Load balancing by setting up sleep time according to load of each node
- Future work
  - Adaptive and distributed control method for IIDR

12