Comparative evaluation of information dissemination methods for effective and efficient information sharing in wireless sensor networks

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Research background

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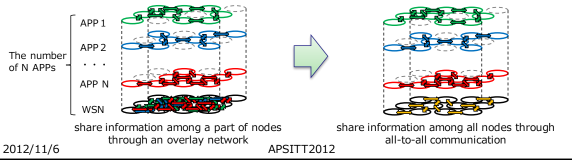
- Wireless sensor networks (WSNs)
  - Consist of a large number of small nodes with sensing, computation, and wireless communication capabilities
- When multiple applications are running on single WSN sharing nodes and devices, nodes exchange messages with each other in each overlay network
  - It is waste to send same message in different overlay networks
  - As the number of applications increases, concurrent multiple overlays dissipate energy and bandwidth

⇨ It is more energy and bandwidth efficient to share all information among all nodes through all-to-all dissemination



Purpose of our research

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- There have been many proposals for efficient information dissemination in WSNs
  - Characteristics of information dissemination methods differ from each other
  - Their performance depends on conditions such as the size of region and the node density
- The performance of methods is evaluated under a specific condition in preceding literatures and we cannot directly compare them
- We need to carefully select a method fulfilling requirements of desired functions under the expected operational condition
  - Ex. the number of nodes, the node density

We conduct comprehensive evaluation of information dissemination methods to clarify their comparative characteristics and the range of application

Procedure of our research

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- Classify existing information dissemination methods
  - Topology independent methods
    - flooding, gossiping and publish/subscribe
  - Topology dependent methods
    - ring, tree and cluster
- Evaluate these methods from viewpoint of the scalability by changing the size of observation region and the node density
  - the ratio of receiving nodes and the ratio of active time

Flooding method

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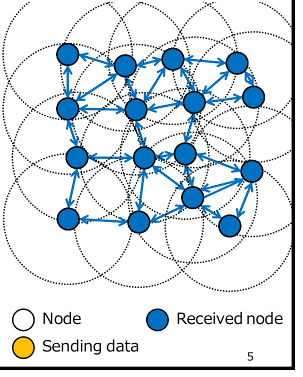
- Overview
  - When a node receives data, it broadcasts the receiving data to all neighbors

○ Simple and easy to implement
× Waste of bandwidth
× Low delivery ratio in a high density network

A neighbor receiving the data message for the first time forwards the message to all of its neighbors



Gossiping method

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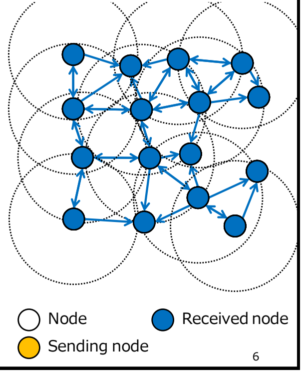
- Overview
  - When a node receives data, it forwards the receiving data to all neighbors with probability p $(0 < p < 1)$

○ Smaller number of transmission than the flooding method
× Difficult to set the optimal probability p

A neighbor receiving the data message for the first time forwards the message with p to all of its neighbors

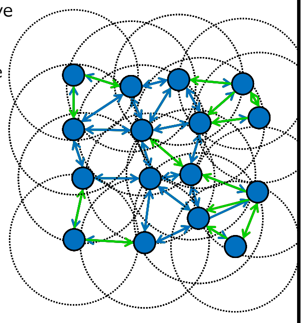


Publish/Subscribe method

- Overview
  - When a node receives data, it checks whether any neighbors have not received the data
    - Metadata: a small message which contains the information about the data to send
    - Request: forwarding request
    - Data: data message

○ Low energy consumption
× Long time for dissemination

The sender sends the data message to the requesting node



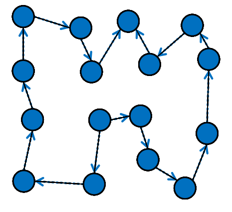
○ Node ● Received node
● Sending node ● Waiting node

Ring method

- Overview
  - When a node receives data , it sends the receiving data along the virtual ring topology

○ Low congestion
○ Low energy consumption
× Long delay for dissemination

A node receiving the data message forwards it to the neighbor on the other side



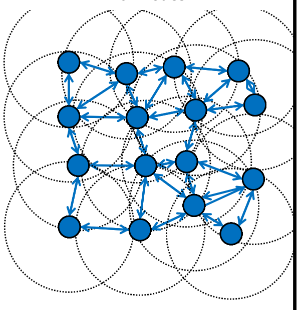
○ Node ● Received node
● Sending node

Tree method

- Overview
  - When a node receives data, it sends the receiving data to the root node of the tree
  - When the root node receives data messages, it broadcasts them to all nodes

○ Low energy consumption
○ Efficient in the high density network
× The performance depends on the topology
× High load around a root node

The root node aggregates all data messages and broadcasts them to all nodes



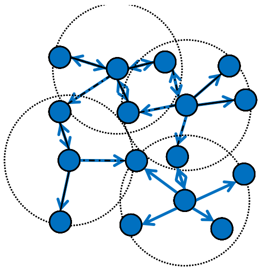
○ Node ● Received node
● Sending node ● Root node

Cluster method

- Overview
  - Cluster head aggregates the data messages which its cluster members receive
  - Cluster head broadcasts the aggregated data to neighbors

○ Low energy consumption
○ Efficient in the high density network
× The performance depends on the structure of clusters

The border node sends the data message to another cluster head members



○ Node ● Received node
● Sending node ● Cluster head

Evaluation setting

- Simulator
  - Ns-2.34
- MAC protocol
  - IEEE 802.11
- Data generation model
  - Each node generates one data at random time from 0 to 1 [s]

Parameter	value
Communication range	100 [m]
Transmission speed	1 [Mbps]
Size of data message	1 [Kbyte]
Size of meta data	16 [byte]
Size of request message	1 [byte]

Evaluation measures

- The ratio of receiving nodes
  - The average fraction of nodes which can receive data

$$D = \frac{1}{n(n-1)} \sum_{i=1}^{n} \sum_{j=1}^{n} R(T(i), i, j)$$

- The ratio of active time
  - Total time when each node wakes up for sending or receiving data

$$W = \frac{1}{n^2} \sum_{i=1}^{n} \frac{\sum_{j=1}^{n} A(i,j)}{T(i)}$$

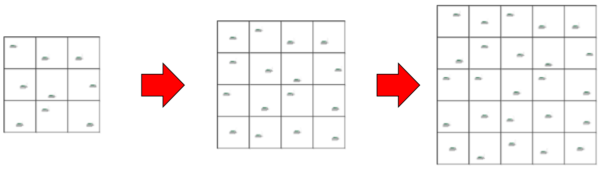
$R(t,i,j)$: Whether node j has received data generated by node i by t [s]

$$R(T(i),i,j) = \begin{cases} 1, & if\ i \neq j\ and\ received \\ 0, & if\ i = j\ or\ unreceived \end{cases}$$

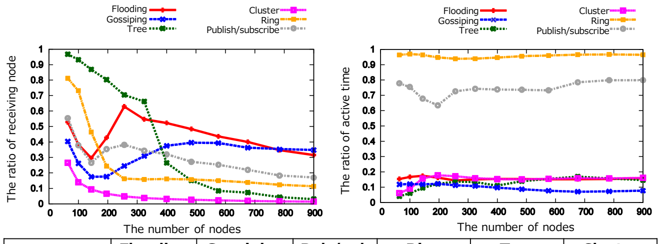
$T(i)$: Time for dissemination data generated by node i to be completed
$A(i,j)$: The sum of time spent by node j from beginning of carrier sense to completion in dissemination of data of node i
n : The number of nodes

Changing the size of observation region

- Change the size of observation region
- an area of a block is 40 × 40 [㎡]
  - One node is placed at a random location of each block
- The size of observation region is changed by changing blocks from 8 × 8 blocks to 30 × 30 blocks (64 ～ 900 [nodes])



Simulation result:size

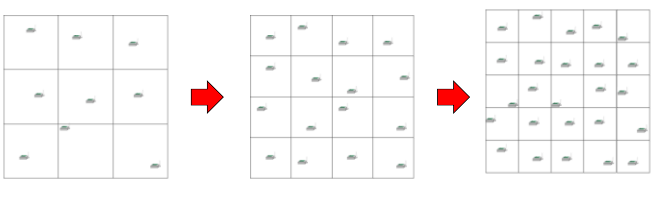


	Flooding	Gossiping	Pub/sub	Ring	Tree	Cluster
Small region	△	△	△	○	◎	×
Large region	○	○	△	×	×	×

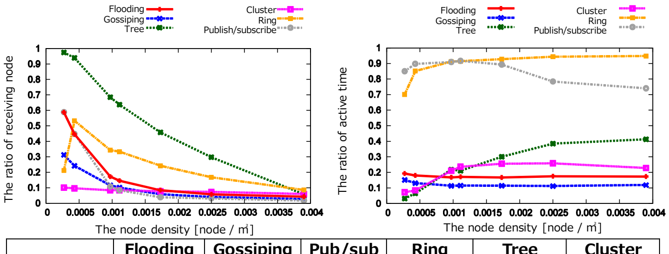
- When the size of observation region is smaller than 800 × 800 [㎡] (256 nodes), a tree method is more efficient
- For larger regions, a flooding method or a gossiping method is more efficient

Changing the node density

- Change the node density
- The size of the observation region is kept constant at 480 × 480 [㎡]
- The observation area is divided into blocks
  - Only one node is placed at a random location of each block
- The number of blocks is changed from 8 × 8 blocks (0.00028[node/㎡]) to 30× 30 blocks (0.0039 [node/㎡])



Simulation result:density



	Flooding	Gossiping	Pub/sub	Ring	Tree	Cluster
Low density	○	○	△	×	◎	×
High density	△	△	×	△	△	×

- A tree method is the most efficient in the low density network

Conclusion

- Conclusion
  - Conduct comparative evaluations of well known information dissemination methods
    - A tree method well fits to the small observation region independently from the node density
    - A flooding method can achieve the higher ratio of receiving nodes in the large observation region
- Future work
  - Consider a method which guarantees the reliable information dissemination for all-to-all communication
    - Retransmission and scheduling