Energy-efficient Information Dissemination Based on Received Signal Strength in Wireless Sensor Networks

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Wireless Sensor Networks (WSNs)

- Have already been applied in many fields
  - Disaster detection
  - Environmental monitoring
  - Environmental management
- When the network status change
  - Difficult to determine a path in advance
  - Disseminating information to the entire network is a method for guaranteeing the message is sent to a destination node

Different network environments
-nodes movement
-nodes failure
electric power

Disseminating Information

- Necessary in many cases when operating applications in WSNs
  - Efficiently gathering information [3]
  - Mitigating the effects of node failures [4]
  - Installing program to nodes with certainty [5]
- WSNs will be used in many fields and applications on WSNs will increase in numbers

Information dissemination methods will become much more important in WSNs

Problem of Disseminating Information

- Increases electric power consumption
- In WSNs, the amount of electric power consumed by wireless communications accounts for a large percentage of the electric power consumed by nodes
- It becomes important to reduce the power consumed by wireless communications

Objectives

- Propose an Information dissemination method that takes into account the electric power consumption
  - It controls the broadcast timing of messages using the strength of the received wireless signal
- Show propose method works effectively by simulation experiments
  - The farther the transmitting distance of the wireless radio wave becomes, the more efficiently our method can disseminate information

Flooding Method

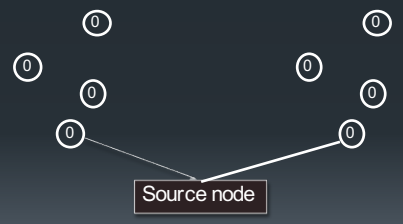
- A node having a new message
  - Broadcasts a message to all adjacent nodes
- The node received the message
  - Rebroadcasts the message, if the received message was new
  - Does not rebroadcast the message, if it was not new

Outline of Proposed Method

- Controls the broadcast timing of messages by using the strength of the received wireless signal
  - Received signal strength decreases when communicating over long distances
- The lower the signal strength is, the sooner the node will rebroadcast the message
- The node farthest from the sending node will rebroadcast the message first
- If the message is received multiple time before rebroadcast, the node cancels the rebroadcast

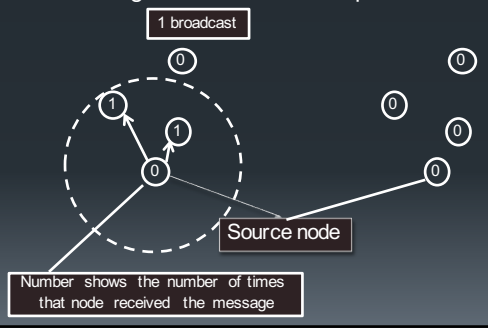
Process of Disseminating a Message

- Flooding method
- Proposed Method



Process of a Message Dissemination

- Flooding method
- Proposed Method



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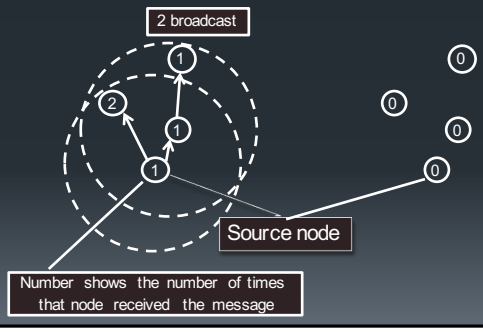

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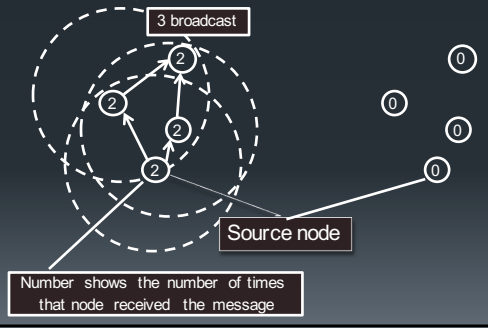
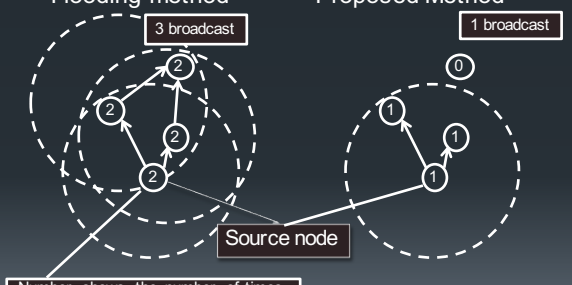


Process of a Message Dissemination

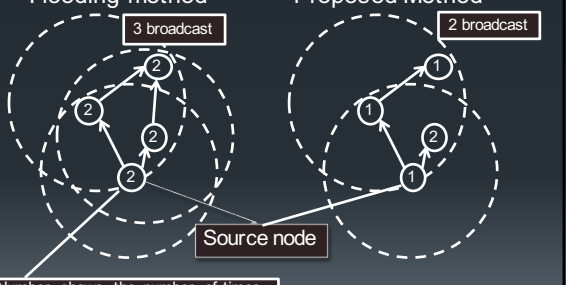
- Flooding method
- Proposed Method



Process of a Message Dissemination

Proposed method can reduce the number of transmissions and receipts of the message

- Flooding method
- Proposed Method



Broadcast Time

Transmission power, Distance, Antenna gain of send node, Propagation loss, Antenna gain of receiving node

- Receiver signal strength

$$P_r(d) = P_{tx} + G_t - L_p(d) + G_r$$

- Maximum receiver signal strength
  - Assume network consists of identical nodes

$$P_r^{max} = P_{tx} + G_t + G_r$$

- Broadcast time

$$T = DIFS + \left(CW + \left\lfloor CW \times \frac{P_r}{P_r^{max}} \right\rfloor\right) \times slot\_time$$

Parameters of CSMA/CA

Performance Evaluation: Sensor Node Model

- Assumed to be Crossbow MICAz motes
  - Frequency band: 2.45 [GHz]
  - Transmit data rate: 250 [Kbit/s]
  - Frame size: 127 [bytes]
  - Voltage: 3.0 [V]
  - Current when the node receives the message: 19.70 [mA]
  - Receive sensitivity: -90 [dBm]

Performance Evaluation: Energy Consumption Model

Distance, Radio Wavelength

- Propagation loss follows free space loss model

$$L_p(d) = (4\pi d/\lambda)^2$$

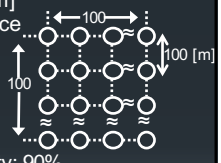
- Radio ranges: 100, 150, 200 [m]
- Determine the transmission power so that receiver signal strength is -80 [dBm] when the distance is 100, 150, 200 [m]
- Current with radio range of 100, 150, 200 [m]: 85.19, 178.81, 309.87 [mA]
- Electrical energy

$$J = I \times V \times \frac{L}{r}$$

Frame size, Transmit data rate

Performance Evaluation: Network Model: square lattice

- Comprising a 100 x 100 square lattice
  - each edge distance set at 100 [m]
- Nodes are arranged in square lattice according to the node assignment probability



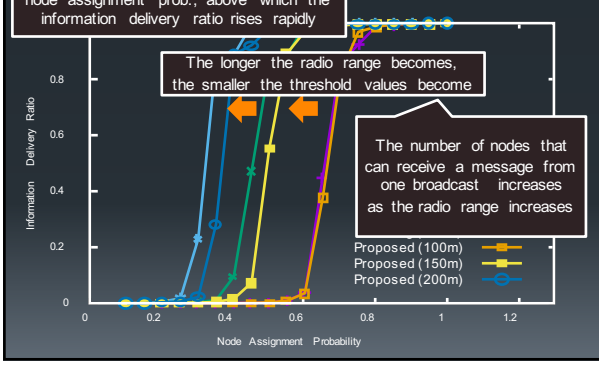
- Communication success probability: 90%
- 100 simulations and measure
  - Information delivery ratio
  - Total electric power consumption

Simulation Results: Information Delivery Ratio

Both methods have threshold values for node assignment prob., above which the information delivery ratio rises rapidly

The longer the radio range becomes, the smaller the threshold values become

The number of nodes that can receive a message from one broadcast increases as the radio range increases



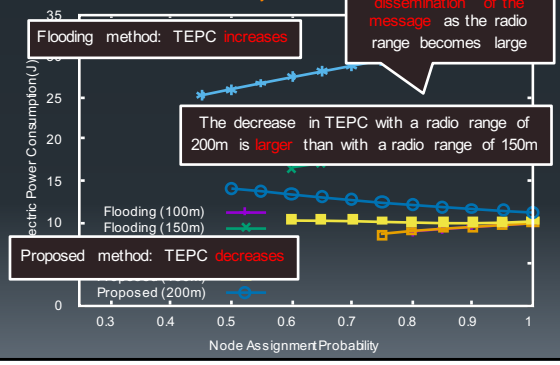
Simulation Results: Total Electric Power Consumption (TEPC) when the information delivery ratio is at least 95%

Flooding method: TEPC increases

The proposed method allows more efficient dissemination of the message as the radio range becomes large

The decrease in TEPC with a radio range of 200m is larger than with a radio range of 150m

Proposed method: TEPC decreases

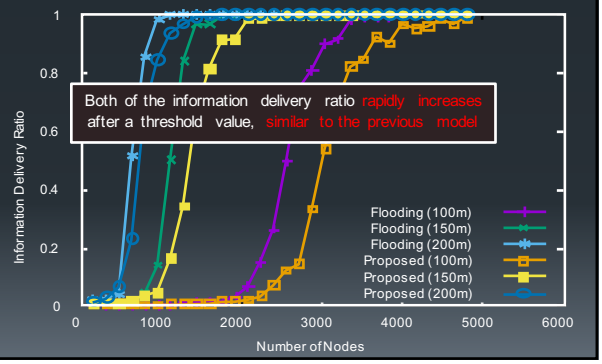


Performance Evaluation: Randomly locate nodes

- Previous network model: nodes are arranged in square lattices
- Randomly locate nodes in square region
  - Sides of length 4,000 [m]
- The configuration of the nodes is the same as previous one
- Propagation loss of the radio waves follows free space loss model

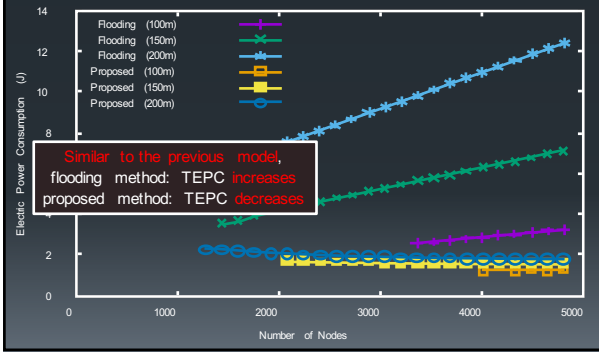
Simulation Results: Information Delivery Ratio

Both of the information delivery ratio rapidly increases after a threshold value, similar to the previous model



Simulation Results: Total Electric Power Consumption (TEPC) when the information delivery ratio is at least 95%

Similar to the previous model, flooding method: TEPC increases proposed method: TEPC decreases



Conclusion

- Proposed an information dissemination method that considers electric power consumption
  - Based on the flooding method
  - Controls broadcast times according to strengths of received signals
- Showed the proposed method can disseminate information in an energy efficient manner when the transmitting power becomes large

Future Works

- Evaluate the proposed method with other propagation loss models
  - two-ray ground model
- Evaluate proposed method in an experimental network
  - Crossbow MICAz motes
- Analyze the proposed method by applying percolation theory from statistical physics

Thank You