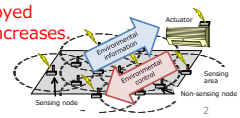
Proposal for dynamic organization of service networks over a wireless sensor and actuator network

○Takuya IWAI, Naoki WAKAMIYA, Masayuki MURATA
Osaka University, Japan

Background

- Wireless sensor and actuator network (WSAN)
  - Network consisting of nodes with sensors and actuators
    ex. thermal sensor, illumination sensor, heater, light
  - Control environment based on environmental and personal condition
    ex. Illumination control, HVAC, Home security
- Construction and management in application-oriented manner to answer specific requirements of each application
  - Deployment of dedicated nodes for each application

Nodes will be redundantly deployed as the number of applications increases.

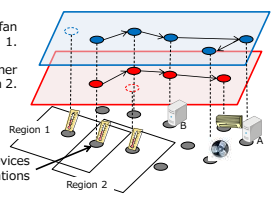


Research objective

- Mechanism to realize a behavior of an application by combining nodes with sensors & actuators (devices)
  - Select nodes which provide more applications with devices and have more residual energy
  - Autonomous and decentralized manner

Node A controls a ventilation fan based on the information on region 1.

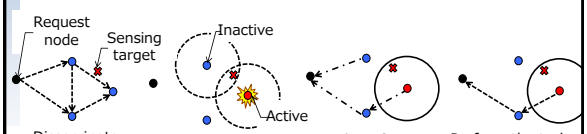
Node B controls an air-conditioner based on the information on region 2.



We call the network composed of nodes to realize the behavior a *service network*.

Proposal : Overview

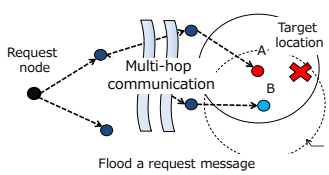
- Organize a service network satisfying App's requirements
- Repeat 4 steps while a service network is operating
  - Request node disseminates request message.
  - Node selects whether to provide a device or not.
  - Active/Inactive node sends notification message.
  - Active node performs a task if necessary.



Proposal : Step1

- Dissemination of the request message
- Decision on whether to provide a device or not
- Transmission of the notification message to report the result

ex. Monitoring of a coordinate (x,y) by thermal sensor
Assumption 1 : All nodes have one thermal sensor.
Assumption 2 : Node A has been monitoring for other service networks.

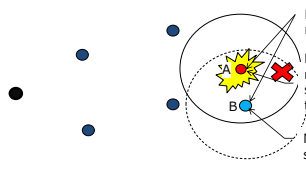


Example of a request message
- coordinate : (x,y)
- device : thermal sensor
- demand : s ($\geqq 0$)

Proposal : Step2

- Dissemination of the request message
- Decision on whether to provide a device or not
- Transmission of the notification message to report the result

ex. Monitoring of a coordinate (x,y) by thermal sensor
Assumption 1 : All nodes have one thermal sensor.
Assumption 2 : Node A has been monitoring for other service networks.



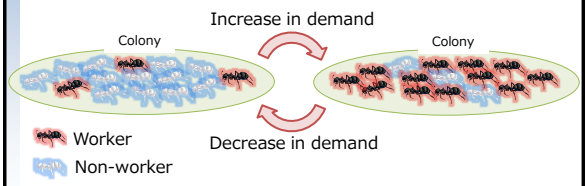
Decision on whether to monitor or not

Node A has already been monitoring and it can provide the service network with sensor data, too.

Node B keeps own thermal sensor inactive.

Response threshold model [2]

- Mathematical model of division of labors in social insects
  - Autonomous decision of individuals
  - Two groups of workers and non-workers
  - Adjustment of group size based on the demand of task



Response threshold model [2]

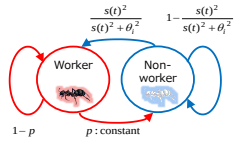
- Demand $s(t)$ of a task at time t

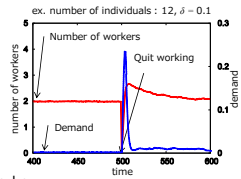
$$s(t) = s(t-1) + \delta - \frac{\text{number of workers}}{\text{number of individuals}}$$

If there are not enough workers, the demand increases.

δ : constant relating to the size of group

- Stochastic decision of individuals





θ_i : hesitation of individual i in becoming worker

Group size is adjusted based on the demand.

Extended response threshold model

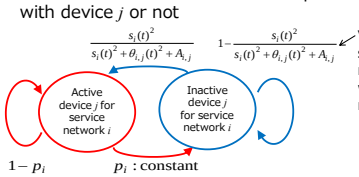
- Device j provided to service network i is considered as worker.
- The demand of service network i in disseminating t –th request message

$$s_i(t) = s_i(t-1) + \delta_i - \frac{N_i}{M_i}$$

N_i : number of active nodes iin service networks i

M_i : number of active/inactive nodes in service networks i

- Stochastic decision on whether to provide service network i with device j or not



Variable $A_{i,j}$ becomes small as a node provides more service networks with device j and has more residual energy.

~SKIP~

Definition of variable $A_{i,j}$

Term of a node with providing as many service networks as possible with device j becomes near 1.

$$A_{i,j} = W_c \times \left(1 - \frac{F_j}{S_j - 1}\right)^n + W_e \times \left(1 - \frac{1}{1 + e^{-g \times (P_{res}/P_{full} - b)}}\right)$$

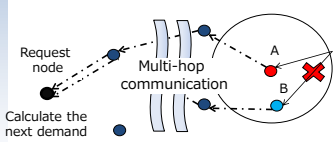
Term of a node with more residual energy becomes near 1.

Name	Description
S_j	number of service networks the node can provides with device j
F_j	number of service networks the node provides with device j
P_{res} / P_{full}	ratio of residual energy
n, g, b	constant
W_c, W_e	weight

Proposal : Step3

- Dissemination of the request message
- Decision on whether to provide a device or not
- Transmission of the notification message to report the result

ex. Monitoring of a coordinate (x,y) by thermal sensor
Assumption 1 : All nodes have one thermal sensor.
Assumption 2 : Node A has been monitoring for other service networks.



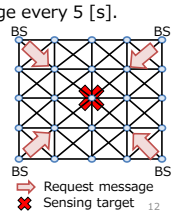
Report on whether to provide the device or not to the request node

Transmission of the notification message

Simulation evaluation

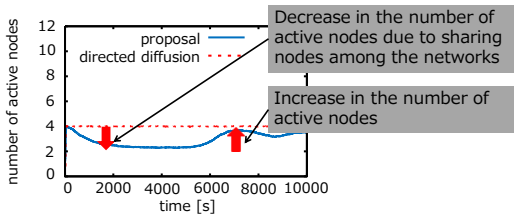
- To verify service networks are organized with nodes which have more energy while sharing nodes among the networks
- Simulation setting
  - In 40 [m] × 40 [m], 25 nodes form a grid.
  - 4 service networks to monitor at a coordinate (20,20)
  - Each service network's base station located at each corner disseminates a request message every 5 [s].
  - Comparison with directed direction [7]
  - Averaged results of 500 runs

Parameter	Value
δ_i of service network i	0.1
Communication range	15 m
Sensing range	20 m
Amount of battery	200 mAh
Energy consumption in Active / Idle	20 mA / 0.1 mA



Simulation result

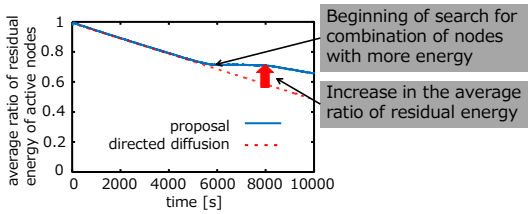
- Number of active nodes
  - active node : node providing service networks with devices



Nodes are shared among service networks

Simulation result

- Average ratio of residual energy of active nodes
  - active node : node providing service networks with devices



Service networks consist of nodes with more residual energy

Conclusion and future work

- Conclusion
  - Propose the mechanism to organize service networks
  - Confirm the effectiveness through simulations
- Future work
  - Improve the mechanism to share relay nodes
  - Improve the mechanism to solve feature interaction
  - Evaluate robustness, scalability, and adaptability

Thank you for your attention !!