Bio-Inspired Autonomous and Adaptive Coverage Control for Wireless Sensor Networks

SeNAmI 2009 in Hiroshima

Takuya Iwai
Naoki Wakamiya
Masayuki Murata

Bio-Inspired Autonomous and Adaptive Coverage Control for Wireless Sensor Networks

Takuya Iwai, Naoki Wakamiya, Masayuki Murata

Coverage Problem in WSNs

Guaranteeing that the target region or objects are monitored
Prolonging the lifetime of a wireless sensor network

Assumptions of existing proposals

Need for accurate information on locations of nodes, sensing area (unit disk is often assumed), and sensing state

In actual situation

Accuracy of information are heavily affected by surroundings and characteristics of sensors.
→These proposals do not work well in realistic condition.

Exchanging these information consumes a lot of energies and bandwidth.
→These proposals are resource expensive.

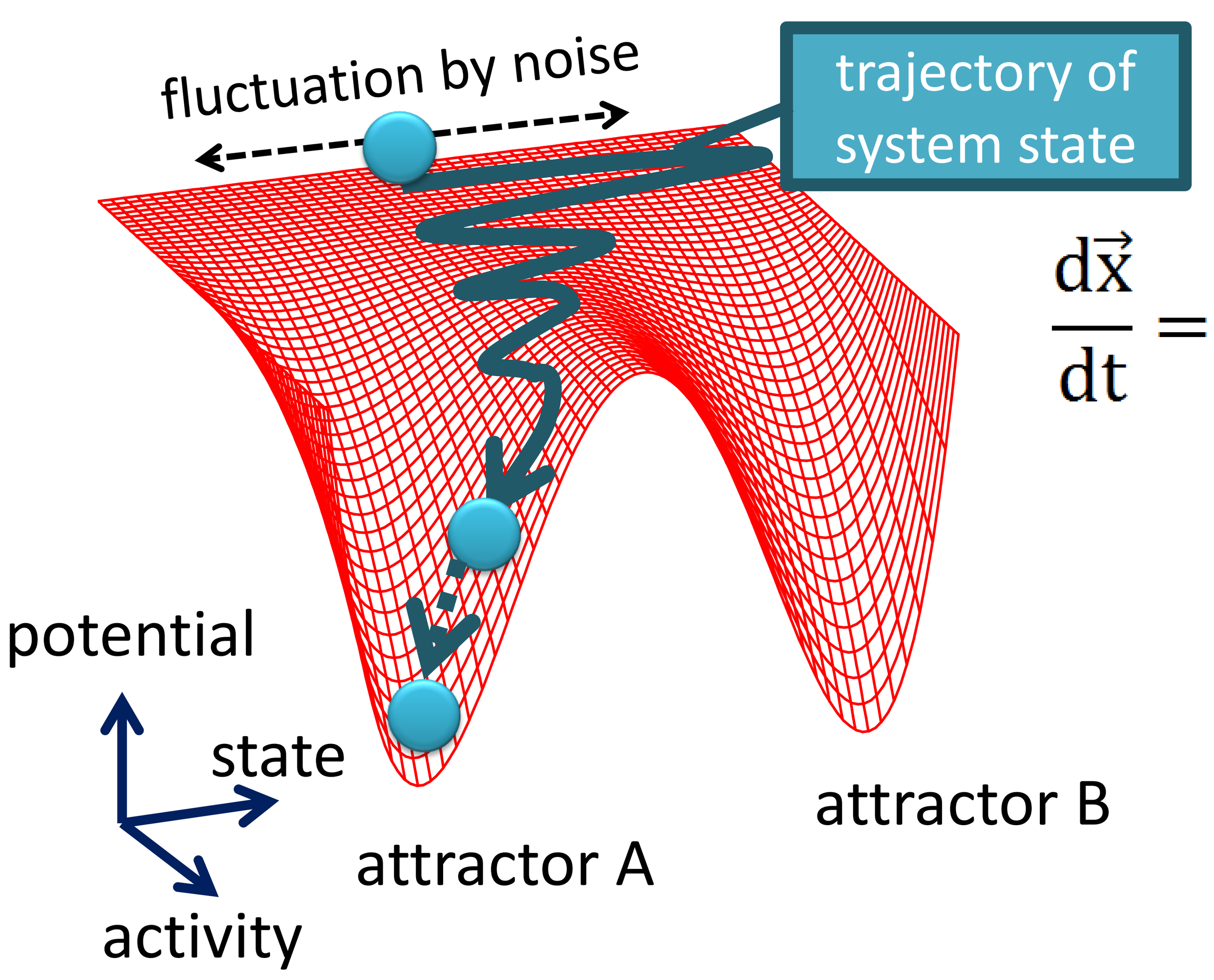
Characteristics of our proposal

Detailed and accurate information is not required.
→Based on the degree of coverage of the whole region, each sensor node determines its sensing state appropriately.

Key technique

Attractor selection model

The model of flexible and adaptive behavior of biological systems to dynamically changing environment
→Bacteria can adaptively choose nutrient to generate in accordance with the current living environment.



$$\frac{d\vec{x}}{dt} = f(\vec{x}) \times \alpha + \vec{\eta}$$

$\vec{x}$: system state
$f(\vec{x})$: potential function
α : activity
$\vec{\eta}$: noise

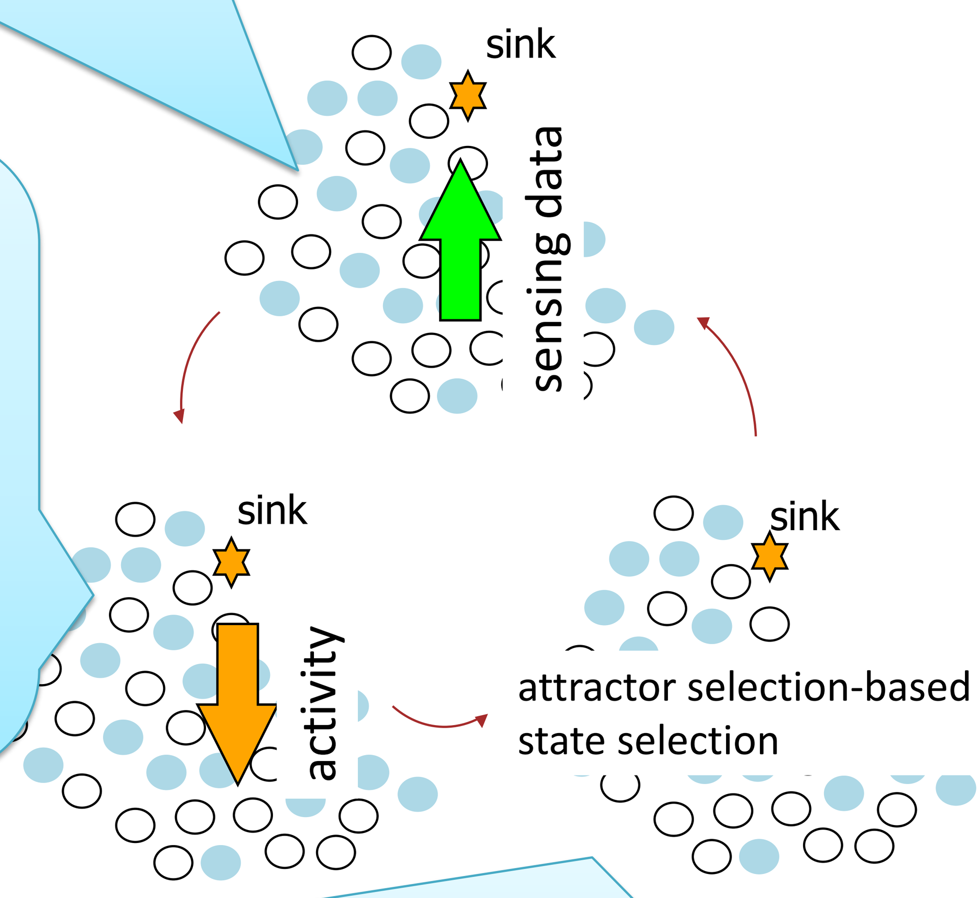
Image of the attractor selection (2-dimension)

Our proposal for periodic monitoring

1. At regular data gathering intervals, sensor nodes transmit sensing data to a sink node

2. Sink node evaluates the coverage of the whole region, and derives *activity*.
3. Sink node inform sensor nodes of new activity.

$$\frac{d\alpha}{dt} = \delta \times (\alpha^* - \alpha)$$



4. Receiving activity, each sensor node evaluates the attractor selection model and determines its state, i.e. active or sleep.

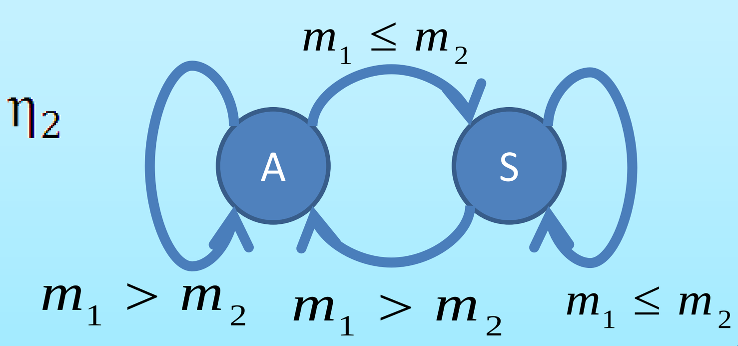
$$\frac{dm_1}{dt} = \frac{syn(\alpha)}{1 + m_2^2} - deg(\alpha) \times m_1 + \eta_1$$

$$\frac{dm_2}{dt} = \frac{syn(\alpha)}{1 + m_1^2} - deg(\alpha) \times m_2 + \eta_2$$

$$syn(\alpha) = \alpha \times (\beta^{\gamma} + \varphi^*)$$

$$deg(\alpha) = \alpha$$

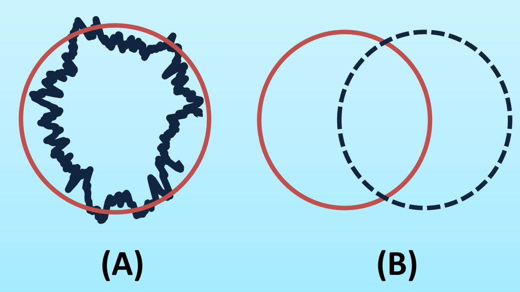
m_1: the goodness of active state
m_2: the goodness of sleep state



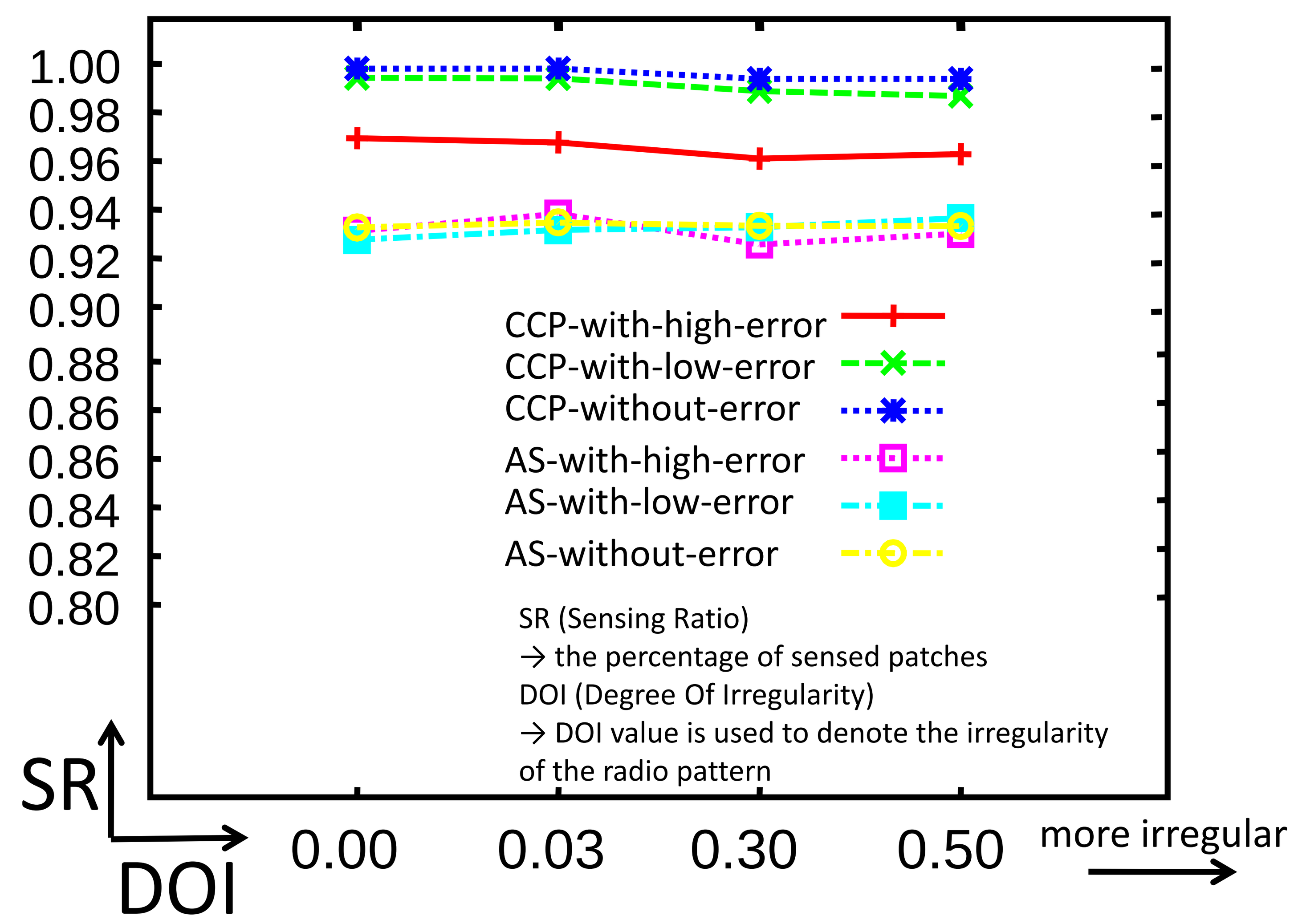
Simulation and evaluation

We compare tolerance to error with our proposal (AS) and CCP in terms of following 2 points.

A. Irregularity of sensing area
B. Error location of sensor node



In a 50×50 coverage region, 100 nodes randomly distributed.



Our proposal is less affected by error of individual information than CCP.
→It works well in realistic condition.
Each sensor node selects appropriate state with only one common value.
→This is beneficial for low overhead.