Error-tolerant coverage control based on bio-inspired attractor selection model for wireless sensor networks

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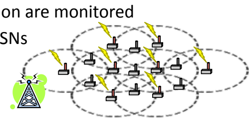
Coverage problem in wireless sensor networks

- Wireless sensor networks (WSNs)
  - Wide range of applications
    e.g. surveillance, environment monitoring and health care
  - Many sensor nodes (thousands ∼ tens of thousands)
  - Limited battery
- Coverage problem
  - Guaranteeing the target region are monitored
  - Prolonging the lifetime of WSNs



Existing coverage control proposals

- Estimation of a degree of coverage inside a sensor node's sensing area with a geometric algorithm
- Selection of sensor node's state, i.e. active or sleep, based on the degree of coverage inside its sensing area
- Unrealistic assumption
  - Accurate location
  - Circular sensing area

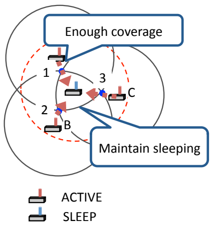
  ⇒ Decrease of performance suffering from error (e.g. short coverage and redundant active nodes)
- High overhead
  - Exchanging information required for the algorithm

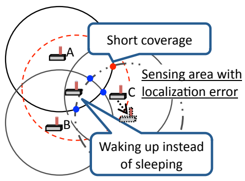
  ⇒ Reduced life time of WSNs

[3] X. Wang, G. Xing, Y. Zhang, C. Lu, R. Pless, and C. Gill, "Integrated coverage and connectivity configuration in wireless sensor networks," in Proceedings of ACM SenSys, pp. 33–72, August 2003.

CCP (Coverage Configuration Protocol)[3]

- For 1-Coverage, all intersection points between any sensor nodes' sensing area are covered by at least 1 sensor node.





Localization error causes sensor node's wrong state selection.

Research objectives

- Error-tolerant and low-overhead coverage control method
  - Nonuse of information of error-prone neighboring nodes (e.g. location and shape of sensing area)
  - A small number of message transmissions

⇒ Application of creature's autonomous state selection mechanism to sensor node's autonomous state selection

- Target application
  - Periodic monitoring

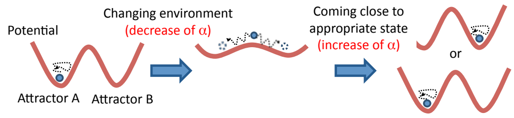
E.coli (Escherichia coli)
Excerpt from http://www.niaid.nih.gov/SiteCollectionImages/topics/biodefenserelated/e_coli.jpg

Attractor selection model for coverage control

- *E.coli*'s adaptive behavior to dynamically changing environment

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

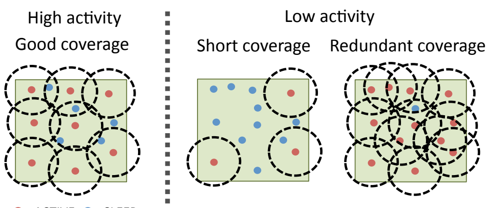
- $\vec{x}$: State
- $f(\vec{x})$: Potential function
- α : Goodness of the state (activity)
- $\vec{\eta}$: Gaussian noise



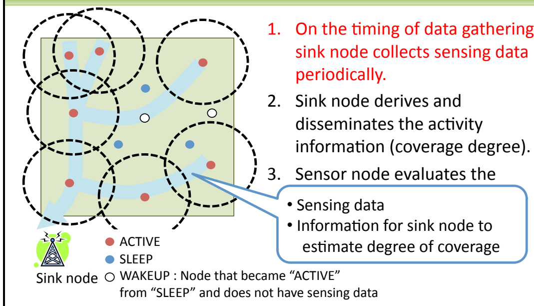
	Activity	Attractor A	Attractor B
E.coli	Growth rate	Folic acid	Glutamine
Coverage	Goodness of coverage condition	Active	Sleep

Activity for coverage control

- Activity α is defined as goodness of coverage condition.

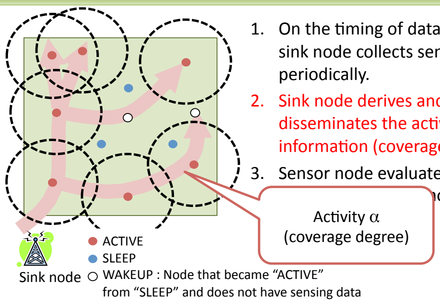


Overview of our proposal (1/4)



1. On the timing of data gathering, sink node collects sensing data periodically.
2. Sink node derives and disseminates the activity information (coverage degree).
3. Sensor node evaluates the

Overview of our proposal (2/4)



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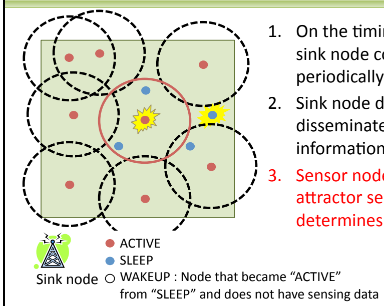
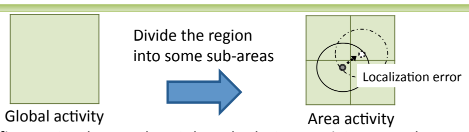
Overview of our proposal (3/4)



1. On the timing of data gathering, sink node collects sensing data periodically.
2. Sink node derives and disseminates the activity information (coverage degree).
3. Sensor node evaluates the attractor selection model and determines its state.

Overview of our proposal (4/4)



- For fine-grained control, a sink node derives activity per sub-area and sensor nodes use activity of a sub-area where they consider to be located.
  - A change of node state directly influences "Area activity" more than "Global activity".
  - Nodes with localization error may use an area activity of wrong sub-area.

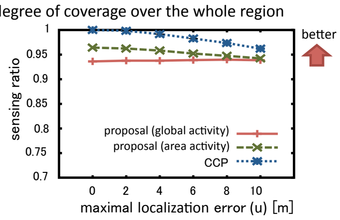
Simulation evaluation

- Examination of our proposal's localization error tolerance and low overhead through comparison with CCP
- Location error uniformly distributed between $-u$ [m] and $+u$ [m]
- 10,000 nodes randomly deployed in 500 × 500 [m^2]
- Global activity and area activity : 400 sub-areas of 25 × 25 [m^2]
- Gathering sensing data every 10 [s]

	Sensing area (radius of circle)	Communication range
Our proposal	10 [m]	large enough to keep connectivity
CCP	10 [m]	20 [m]

Simulation result (sensing ratio)

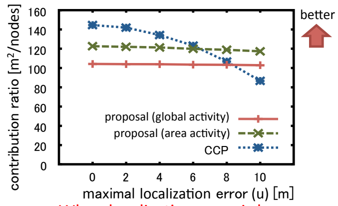
- Sensing ratio
  - The degree of coverage over the whole region



The global activity-based control keeps its coverage against different degree of localization error.

Simulation result (contribution ratio)

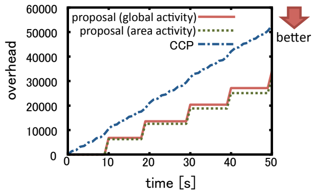
- Contribution ratio
  - The average area that an active node contributes to coverage



When localization error is large,
our proposal is more efficient than CCP.

Simulation result (overhead)

- Overhead
  - The total number of transmitted messages



Our proposal's overhead is less than CCP.

Conclusion and future work

- Conclusion
  - Propose bio-inspired coverage control method for WSNs
  - Confirm the error tolerance and low overhead
- Future work
  - Improve performance by introduction of other activity's definition
  - Evaluate energy consumption

Thank you for your attention.