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

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In the forthcoming ambient information society, it is expected that information devices embedded and distributed in the environment monitor the environment and people in the region and provide people with information services, which are appropriate for the time, place, occasion and people's demands. For this purpose, information devices such as wireless sensor nodes need to keep monitoring the region while prolonging the lifetime of the system. There have been many proposals on the coverage problem in wireless sensor networks (WSNs) [1]. However, most of them adopt geometry formula or graph theory to evaluate the degree of coverage for each node to determine its state, i.e. active sensing or sleep. As such, they assume the complete location information and the regular and homogeneous sensing area. However, in an actual situation, location information is not accurate enough and the shape and size of sensing area of each node are heavily affected by surrounding condition and characteristics of sensing devices.

In this paper we propose a novel coverage protocol which is free from the above mentioned unrealistic assumptions. Each node does not need to know the shape and size of sensing area, the location of itself and neighbours, and the state of neighbours. In particular, each node decides its state in accordance with the feedback from a sink node. Although it is possible for a sink to determine an optimal schedule with the complete information of a WSN if available, but it is impractical. Instead, in our proposal, a feedback message disseminated through a WSN only informs nodes of the degree of coverage, i.e. how much the region is monitored by active nodes. The degree is a single scalar ranging from 0 to 1. If the degree is low, a sleeping node considers that it should wake up to contribute to the coverage. If the degree is still low, it tries sleeping and sees how the degree changes. Once the degree becomes high enough, it keeps the same state for convergence and stable control.

Such autonomous and adaptive state selection is accomplished by the nonlinear mathematical model, i.e. attractor selection model, which explains non-rule based adaptation of biological systems to dynamically changing environment. A bacterium moves between two states, in which it generates different nutrients. If the environmental condition is neutral where two nutrients sufficiently exist, it stays in one of states. However, once the environment changes and one nutrient is exhausted, it chooses an appropriate state to generate missing nutrient to live and grow larger. However, there is no if-then type of inherent rule. By adopting the model, a node can autonomously and adaptively choose an appropriate state based on the simple feedback.

We will show the performance of the proposal in comparison with CCP [3], in terms of the number of active nodes, control overhead, time to convergence, and resilience against node failures.

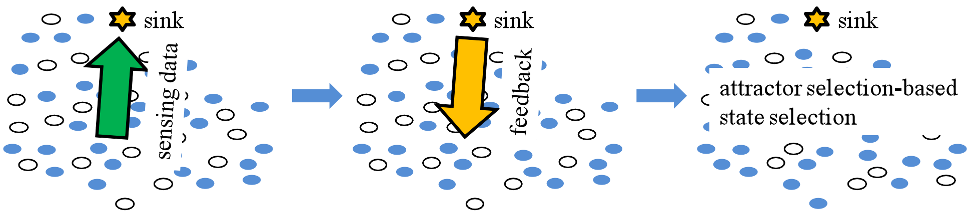

Figure 1. Left: sensing data obtained by active nodes are sent to a sink. Middle: the sink evaluates the degree of coverage and disseminates it to the whole WSN. Right: each node evaluates the attractor selection equations and decides its state.

References

[1] Ghosh, A. and Das, S. K., Coverage and Connectivity Issues in Wireless Sensor Networks, Mobile, Wireless, and Sensor Networks, 2006, John Wiley & Sons, Inc.

[2] Kashiwagi, A., Urabe, I., Kaneko, K., and Yomo, T., Adaptive Response of a Gene Network to Environmental Changes by Fitness-induced Attractor Selection, PLoS ONE, vol. 1, no. 1, 2006.

[3] Xing, G., Wang, X., Zhang, Y., Lu, C., Pless, R., and Gill, C., Integrated Coverage and Connectivity Configuration for Energy Conservation in Sensor Networks, ACM Transactions on Sensor Networks, vol. 1, no. 1, pp. 36-72, 2005.

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