Impacts of Duty-Cycle and Radio Irregularity on HCRL Localization in Wireless Sensor Networks

Ziqi Fan[1], Yuanfang Chen[1], Lei Shu[2]*, Lei Wang[1], Takahiro Hara[2], Shojiro Nishio[2]
[1]School of Software, Dalian University of Technology, China
[2]Department of Multimedia Engineering, Osaka University, Japan
Email: *lei.shu@ieee.org, lei.wang@dlut.edu.cn, hara@ist.osaka-u.ac.jp, nishio@ist.osaka-u.ac.jp

***Abstract*—This paper focuses on studying the impacts of two important factors that have been once ignored in localization: 1) duty-cycle of sensor nodes and 2) *DOI* (degree of irregularity) in radio irregularity. It reveals the fact that a smaller *DOI* can help to increase the localization accuracy in Distance-Vector (DV) based localization, e.g., HCRL. But, waking up more sensor nodes cannot always help to increase the localization accuracy, which actually is different from our intuitive thinking: more awake nodes can help to increase the HCRL localization accuracy.**

***Index Terms*—Distance-Vector Based Localization, Duty-Cycle, Radio Irregularity, HCRL**

I. THE RESEARCH PROBLEM

The Hop-Count-Ratio based Localization (HCRL) [1] has two outstanding features: 1) low congestion and 2) energy-saving, which make it better than other Distance-Vector (DV) based localization algorithms, e.g., DV-Hop [1]. However, in the HCRL studied network model, two important factors of nodes are ignored: 1) Duty-Cycle [2], sensor nodes normally switch between sleep/awake modes for saving energy; 2) Radio Irregularity [3], a degree of irregularity (DOI) normally exists in radio range which can cause asymmetric link connectivity in network. Thus, in this paper, we are extremely interested in seeing the execution performance of DV based localization algorithm, i.e., HCRL, in WSNs with duty-cycled and radio irregular sensors. Particularly, our interests fall into the following two aspects:

- The relationship between the number of sleeping neighborhood sensor nodes and the localization accuracy;
- The relationship between the *DOI* and the localization accuracy.

II. THE CKN SLEEP SCHEDULING ALGORITHM

In [2], Nath *et al*. proposed a Connected K-Neighborhood sleep scheduling algorithm, named as CKN, for duty-cycle based WSNs. CKN algorithm aims at allowing a portion of sensor nodes in the WSN to go to sleep but still keeping all the awoken sensor nodes connected. The number of sleeping nodes in the WSN when applying CKN algorithm can be adjusted when changing the value of K. For example, as shown in Fig. 1, when the K increases from 1 to 7, the number of sleeping nodes in the same WSN decrease.

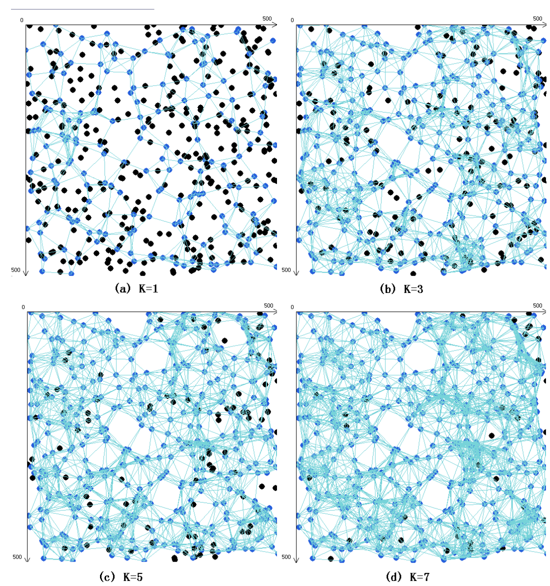

Fig. 1. When K = 1, a large number of sensor nodes can turn to sleep mode, but when K = 7, almost all sensor nodes have to be always-on. Here, the black color and unconnected sensor nodes are sleeping nodes.

III. STUDYING METHOD AND OBSERVATION RESULTS

In order to check the impacts of duty-cycle and *DOI* on HCRL localization algorithm, we implemented HCRL algorithm which combines CKN and *DOI* into our NetTopo WSNs simulator [4].

To quantify the influence made by the factors on localization accuracy, we use *Error* to denote it, which is defined as the average bias between an unknown node's real coordinate and calculated coordinate divided by sensor radius. When duty-cycle works in WSN, network topology changes from one *epoch* to another *epoch*, but is stable during each *epoch*. The specific length of one *epoch* is decided by different applications, so we do not assign it explicitly in this paper.

Our WSN is deployed with 400 sensor nodes and the network size is 500*500m^2. The transmission radius R for each node is 60m, when DOI is set to 0.0. In the first experiment, the value of K for CKN is changed by the order 1, 3, 5, 7. At the meantime, the *DOI* is kept unchanged as 0.0. For each K value, we collect the average localization *Error* for

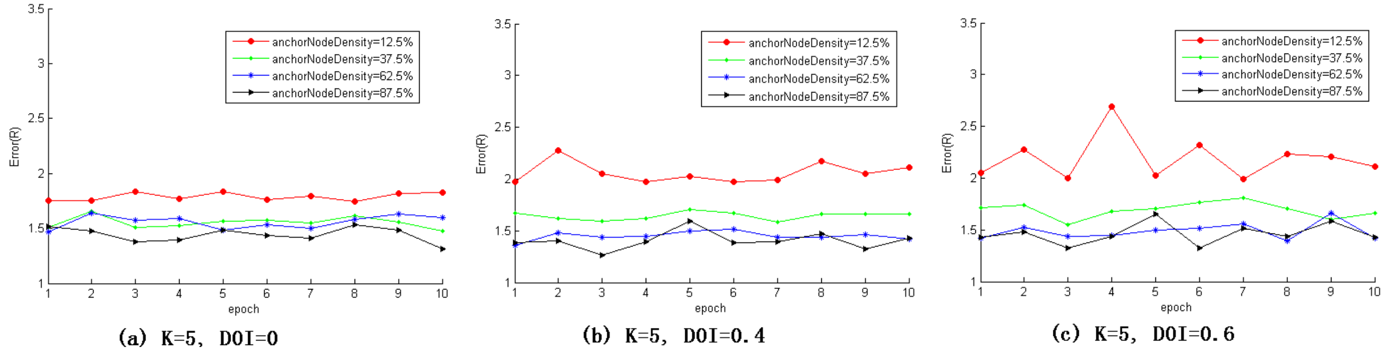

Fig. 4. *Epoch* vs. *Error* as *DOI* changes from 0.0 to 0.6

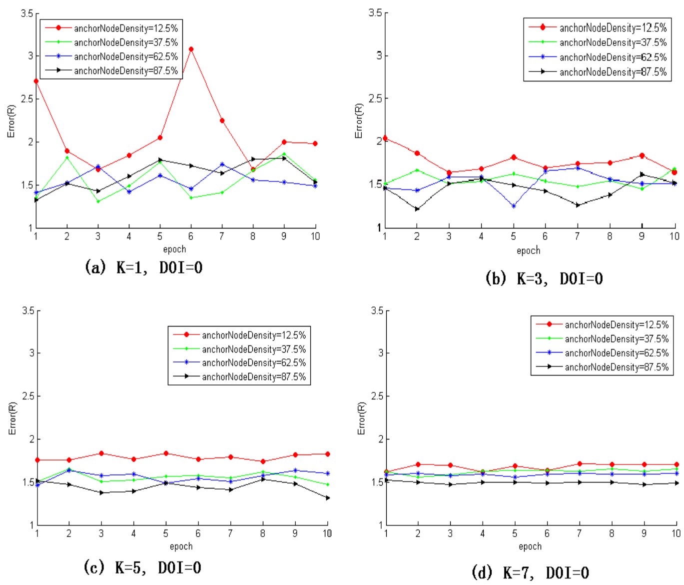

Fig. 2. *Epoch* vs. *Error* as *K* changes from 1 to 7. The anchor node density can be calculated by the number of anchor nodes divided by the sum of anchor nodes and unknown nodes. And, the *Error* can be calculated by formula $Error = \sum_{k=1}^{n} \frac{\sqrt{\Delta x_k + \Delta y_k}}{nR}$.

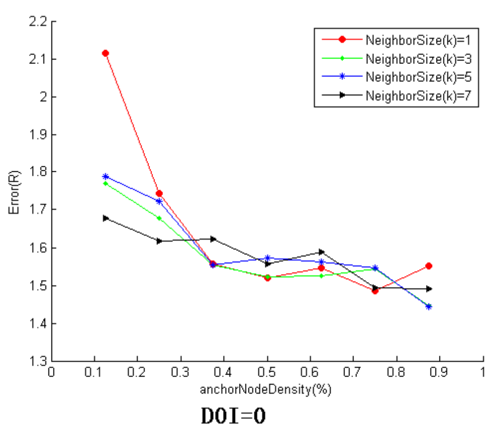

Fig. 3. Anchor Node Density vs. *Error*

ten *epoch*s, and the results are shown in Fig. 2. From these results, we can conclude that: When the number of awake nodes is large, decreasing the number of anchor nodes will not result in serious losing on HCRL localization accuracy. Fig. 3 reveals another fact: In general, increasing the number of anchor nodes can help to increase the localization accuracy, but, when the number of anchor nodes is fixed, increasing the number of awake nodes may not help to increase the HCRL localization accuracy (decreasing the *Error*). In other words, for a specific network configuration, probably, there is an optimal value of *K* and an optimal anchor node density can help to minimize network energy consumption without losing much of the localization accuracy.

In the second experiment, the *K* is set to 5, which means that the number of awake nodes is unchanged. But the *DOI* is changed in order as 0.0, 0.4, 0.6, as shown in Fig. 4. Results in Fig. 4 reveal that: 1) When the number of anchor nodes is fixed, having larger *DOI* in the network will result in lower HCRL localization accuracy (the *Error* will increase); 2) When the network's *DOI* is fixed, increasing the number of anchor nodes can help to increase the HCRL localization accuracy (decreasing the *Error*).

IV. Conclusion

This research confirmed that both 1) Duty-Cycle and 2) Radio Irregularity can really affect the localization accuracy of Distance-Vector (DV) based localization algorithm, i.e., HCRL. And, new localization algorithms should be proposed by taking these two important factors into consideration.

Acknowledgment

This research work in this paper was supported by Grant-in-Aid for Scientific Research (S)(21220002) of the Ministry of Education, Culture, Sports, Science and Technology, Japan.

References

[1] S. Yang, J. Yi, H. Cha, "HCRL: A Hop-Count-Ratio based Localization in Wireless Sensor Networks", In Proceedings of the IEEE SECON 2007.
[2] S. Nath, P.B. Gibbons, "Communicating via fireflies: Geographic Routing on Duty-Cycled Sensors". In Proceedings of IPSN 2007, pp.440-449, New York, NY, USA, 2007.
[3] Z. Gang, H. Tian, K. Sudha, J. Stankovic, "Models and Solutions for Radio Irregularity in Wireless Sensor Networks", ACM Trans. on Sensor Networks, 2(02):221-262, May 2006.
[4] L. Shu, C. Wu, Y. Zhang, J. Chen, L. Wang, M. Hauswirth, NetTopo: beyond simulator and visualizer for wireless sensor networks. In ACM SIGBED Review, Vol. 5, No. 3, October, 2008.