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Topology Control of Mobile Wireless Sensor Nodes based on Quality of Observation and Quality of Communication *

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1 Introduction

Sensor networks consist of sensor nodes with sensing devices and wireless communication devices. Sensing data achieved sensor nodes is gathered through sink nodes by using wireless multihop transmission. In case that costs for deployment, distribution, maintenance and removal of sensor nodes are not critical, and an observation area is not so large, by distribution of a much larger number of sensor nodes, whole the observation area are covered by sensing areas of the sensor nodes and sensing data is surely transmitted to the sink nodes. However, if the costs for sensor nodes are high and/or an observation area is large, it is difficult for the sensor nodes to be distributed in high density. Thus, by introduction of mobile sensor nodes [3], it may be possible to achieve better tradeoff among cost reduction due to lower density distribution of sensor nodes, shorter transmission delay and higher reach ability to the sink nodes of sensing data. Here, the mobile sensor nodes are required to follow mobility of an object in observation. In addition, higher connectivity and reliability between sensor nodes and a sink node is mandatory.

2 Related Works

Various methods for topology control in sensor networks have been proposed [2]. Some of them are for determination of locations of sensor nodes to cover whole the observation area and others are for scheduling of sleeping and waking up of sensor nodes distributed randomly in enough high density for reduction of battery consumption. Anyway, independently of the distribution of observation objects, sensor nodes are distributed in high density to cover the observation area and to keep high connectivity of the sensor network (Figure 1). Thus, all the objects are observed and all sensing data are surely transmitted. In [4], a method that mobile sensor nodes carry sensing data to a sink node. It is for sensor networks where the mobile sensor nodes are so sparsely distributed that most of them are usually unreachable to a sink node. Here, data messages may be gathered to a neighboring mobile sensor node for reduction of mobility cost and may be transmitted by a wireless multihop transmission to another node nearer to the sink node.

3 Proposal

This paper proposes a method to move sensor node for keeping observation objects included in sensing areas and for keeping wireless multihop transmission routes for sensing data available. A mobile sensor node is one of the following states: Thus, nodes observing an object should determine its location based on both quality of sensing data and quality of communication for transmission of sensing data it forwards. That is, a better tradeoff between the qualities realized by mobility of nodes is the goal of our proposal.

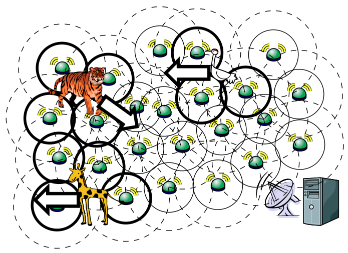

Figure 1: Conventional Dense Stationary Sensors.

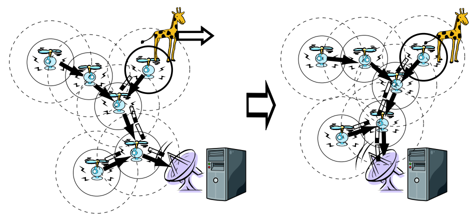

Figure 2: Proposal of Sparse Mobile Sensors.

3.1 Observation Quality

Observation quality is one of sensing data achieved by sensor node and is affected by various factors. A relative location of an observation object to a sensor node is one of the most important factors. As discussed in [1], observation quality is affected by the distance and there are various patterns of changes in observation qualities determined by nature of sensors. Each sensor node is needed to move to a location where higher quality sensing data is achieved by following mobility of objects.

3.2 Communication Quality

Transmission delay, sensing data throughput and loss ratio of sensing data are indicators of communication quality in wireless multihop networks for transmissions of sensing data to sink nodes. They depend on length of wireless communication links. Figure 3 shows a result of simulation experiments where wireless nodes M_i and M_j with 50m wireless transmission range are stationary and $|M_iM_j|$=60m, another node M_k is on $\overline{M_iM_j}$, and throughput of wireless multihop transmission from M_i to M_j through M_k is measured. It has a maximul value at a midpoint of $\overline{M_iM_j}$ and the almost the highest throughput is achieved if 20m≤ $|M_iM_k|$ ≤40m. Therefore, intervals between

*観測品質と通信品質に基づく移動無線センサネットワークのトポロジ制御手法
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successive sensor nodes in wireless multihop transmission route is desirable to be equal for achieving higher throughput and certain differences are allowed to achieve almost the highest throughput.

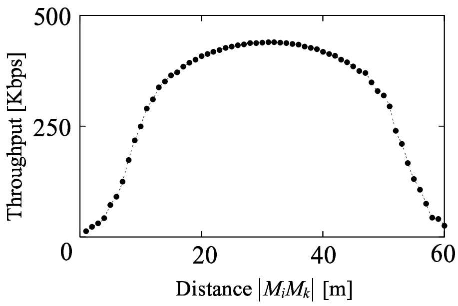

Figure 3: Throughput along Multihop Transmission.

In sensor networks, sensing data is transmitted from potentially all the sensor nodes to a sink node and multiple transmission routes join at some intermediate nodes. Here, a location of the joining intermediate node might affect communication quality. Consider 3 sensor nodes M_{s1}, M_{s2} and M_d on peaks of an equilateral triangle with 80m sides. Figures 4(a) and (b) show the total and the difference of sensing data throughput along $||M_{s1}M_iM_d\rangle\rangle$ and $||M_{s2}M_iM_d\rangle\rangle$. The highest throughput and the highest feasibility are achieved when M_i is at the circumcenter of $\triangle M_{s1}M_{s2}M_d$.

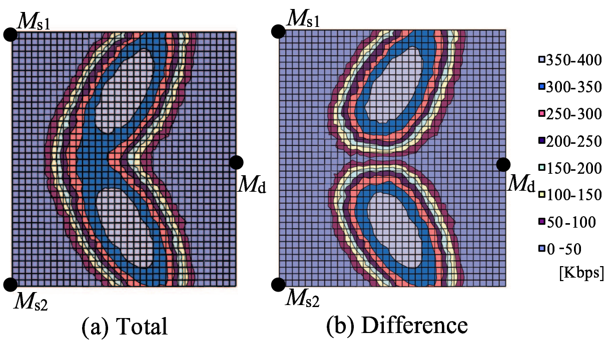

Figure 4: Throughput of Joining Routes.

3.3 Local Mobility Protocol

In case that an observation object moves and an observation quality degrades, the sensor node achieving sensing data of the object moves to improve the quality. Due to this mobility, it is possible for communication quality to be degraded since relative locations of successive neighbor nodes in a wireless multihop transmission route may be changed. Hence, to keep the communication quality higher than the required quality, other sensor nodes are also required to move. This section describes a topology control protocol. Let $Q_o(\boldsymbol{x}_i)$ and $Q_c(\boldsymbol{x}_i, \boldsymbol{x}_j)$ are observation quality at a location $\boldsymbol{x}_i$ of a sensor node M_i and communication quality of a wireless link between M_i and M_j at x_i and x_j respectively.

[Topology Control Protocol]

1) When a mobile sensor node M_i needs to move to keep observation quality higher than the required one or receive a mobility request message *Mreq* from its neighbor sensor node M_n at or moving to x^t_n to keep communication quality of a wireless link $\langle M_nM_i\rangle$, M_i determines a location $\boldsymbol{x}^t_i$ where $Q_o(\boldsymbol{x}^t_i)> RQ_o$ and $Q_c(\boldsymbol{x}^t_n, \boldsymbol{x}^t_i)> RQ_c$ are satisfied where RQ_o and RQ_c are the required qualities and $|\boldsymbol{x}^c_i\boldsymbol{x}^t_i|$ is the minimum where $\boldsymbol{x}^t_i$ is the current location of M_i. If such $\boldsymbol{x}^t_i$ is not achieved, M_i transmits back a negative acknowledgement message *Mnack* to M_n.
2) For each neighbor nodes $M_{n'}$ of M_i at $\boldsymbol{x}_{n'}$ except for M_n, if $Q_c(\boldsymbol{x}_{n'}, \boldsymbol{x}^t_i)> RQ_c$ is satisfied, M_i transmits back a positive acknowledgement message *Mack* to M_n. Otherwise, i.e., for a neighbor node $M_{n''}$ of M_i at $\boldsymbol{x}_{n''}$, if $Q_c(\boldsymbol{x}_{n''}, \boldsymbol{x}^t_i)< RQ_c$, M_i transmits *Mreq* to $M_{n''}$. If M_i receives *Mack* from all the neighbor nodes, M_i transmits back *Mack* to M_n. Otherwise, i.e., if M_i receives at least one *Mnack* from its neighbor nodes, M_i also transmits back *Mnack* to M_n.

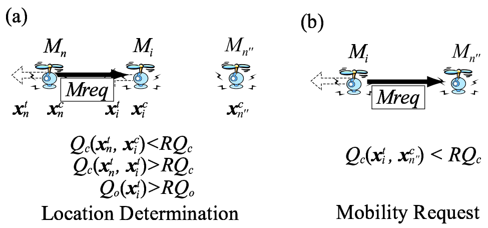

Figure 5: Mobility for Observation Quality.

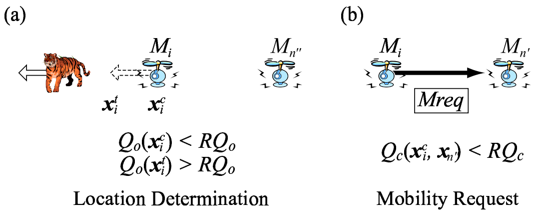

Figure 6: Mobility for Communication Quality.

4 Conclusion

This paper has proposed a method of topology control in sensor networks to keep observation and communication qualities even with mobility of observation objects. Performance evaluation of the protocol is our currently related future work.

References

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