論文の内容の要旨

論文題目　A Study on Data Collection and Mobility Control for Wireless Sensor Networks
（無線センサネットワークにおけるデータ収集およびモビリティ制御の研究）

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In recent years, advances in wireless networking, micro-electro-mechanical system (MEMS) technology, embedded microprocessors, and micro-fabrication have enabled a new generation of massive-scale sensor networks suitable for a range of commercial and military applications. While these applications require high performance from the network, they suffer from resource constraints that do not appear in more traditional wired computing environments. The known resource constraints of sensor networks include memory storage, computational power, communication bandwidth, and energy supply. In particular, memory is scanty and most of them must be kept for sensed data, refraining the sensor nodes from maintaining a large routing table. Next only low-speed CPU can be assembled into tiny-sized sensors, prohibiting the sensor nodes from executing complicated calculations such as public-key algorithm. In addition, wireless spectrum is scarce, often limiting the bandwidth available to applications and making the packets dropped; the nodes are battery-operated, limiting available energy and making the nodes die eventually. Not only discharge of energy, the sensor nodes are also fragile and may be damaged by the harsh environment or by an enemy, reducing the number of available or alive nodes and limiting network connectivity. Moreover, the funneling effect, that is the many-to-one multi-hop traffic pattern, is likely to occur in sensor networks, making more packets dropped around a sink node even under light or moderate traffic loads.

My thesis is that this harsh environment with severe resource constraints requires a novel protocol designed for specific communication patterns and unique characteristics of sensor networks, rather than the conventional protocols developed for mobile ad hoc networks, to obtain the best possible performance. This dissertation supports this claim using detailed analysis, simulations, and experiments. The first study develops SCD (Scalable data Collection and Dissemination), a protocol for collecting and disseminating data in wireless sensor networks that uses proactive route discovery and reactive route maintenance together with extended security mechanisms to achieve practical implementation and good performance in terms of data delivery ratio, latency, path length (the number of hops), and the number of transmissions. In order to ensure that the nodes can be easily deployed in remote, hostile, difficult, or dangerous areas, network configurations composed of path discovery and maintenance are

autonomously done by each node without direct human intervention. One amongst the salient features of SCD is to initiate path discovery from a destination, instead of flooding control packets from all sources which incurs a numerous number of packets. This greatly decreases the amount of control traffics comparing to the previous approaches. Consequently, the proposed scheme improves packet delivery ratio and latency by an order of magnitude compared to the other protocols, especially when traffic load is high and the funneling effect occurs. Node and network lifetimes are also extended due to a fewer number of transmissions. Each node in SCD needs to maintain only trivial piece of routing information, thereby more memory spaces are available for keeping sensed data which is a main task of sensor nodes. As a unique feature, each sensor in SCD can find the nearest likely sink by itself, while other protocols need to know address of the nearest sink in advance.

The second study develops WISER (Wireless Interactive SEnsing Robot), a routing protocol for mobile sensor networks that discerns controlled mobility as a mean of data transfer, in addition to wireless transmission, to make data delivery possible in partially connected networks. WISER aims to minimize delay and energy consumption based on policy of each application by introducing an explicit collaboration of mobile robots and treating continuous data as a session instead of single packet. Since there is a tradeoff between delay and energy dissipation, WISER is divided into two main approaches. The first approach aims to minimize delay by including wireless link quality and path length when determining a path. This approach is further subdivided into three protocols (i.e., WISER/n, WISER/p, and WISER/c) depending on available location information because it may be difficult to have such information in some environments. Based on available location information, each node can change routing algorithm spontaneously and can calculate bounded delay in order to provide QoS guarantee required by some applications. The second approach, WISER/e, is designed to be an energy-efficient protocol by adopting transmitting power and remaining energy in path calculation. Friction of the surface is involved in path determination of both approaches when nodes must move to deliver data. In order to prevent conflicting movement controlled by other nodes, a locking protocol is proposed to reserve nodes physically. These approaches achieve good performance in terms of packet delivery ratio, latency, and energy dissipation claimed by the results from both experiments and simulations. The results demonstrate that WISER makes data delivery feasible in partially connected networks, and collaboration of robots increases performance of the network comparing to reclusive movement. These two protocols, SCD and WISER, show that a sensor network needs tailor-made protocol that considers its unique characteristics to achieve high performance in various scenarios and applications.