

Constraint-Minimizing Logical Topology for Wireless Sensor Networks

by

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Abstract

Wireless sensor network (WSN) is currently one of the most promising areas in the field of information and communication technologies (ICT). This new technology has unlimited potential for numerous applications in different areas, including environmental research, medical application, military, transportation, entertainment, crisis management, homeland defense, and smart spaces. However, several constraints of the sensor nodes are the main obstacles for designing efficient protocols for WSNs. The major constraints of WSNs include energy consumption severity, low quality of communication, limited computational resource, and scalability.

So far, in developing various application protocols for WSNs, such as data collection, dissemination protocols, routing protocols, security or synchronization protocols, researchers have primarily focused on reducing the aforementioned constraints of WSNs. Their approaches tend to focus primarily on developing protocols first, and then to use them on different topologies to implement the protocols. This thesis, however, proposes a novel approach for protocol design paradigm. To contend with the constraints of WSNs, this thesis argues that the logical topology needs to be built first before protocols are designed, because logical topology inherently defines the communication abstraction among the sensor nodes, and thus logical topology governs protocol design. An optimized logical topology facilitates the designers to design efficient protocols, which allow the sensors to communicate with each other with little overheads, consume lower energy, lengthen lifetime of sensor nodes, and reduce latency. It is thus more intuitive to approach the constraints-minimizing problem of WSNs from the topological point of view, and to design topologies according to the conservation requirements. Moreover, the use of logical topology is inevitable when the sheer number of sensor nodes, their unattended deployment, and hostile environment preclude reliance on physical configuration or physical topology. In such circumstances, designers need to rely only on the logical topologies. Hence, this thesis aims to design an efficient logical topology/structure, with which other application protocols can be designed.

Starting with a discussion on the influences of logical topology on different constraints of WSNs, this thesis proposes how sensor nodes should be connected and

managed in an efficient way, so that the WSNs are able to provide connected coverage and at the same time overcome different constraints. A hierarchical multi-chain oriented logical topology is proposed. This topology exploits the advantages of chain-oriented topology, and at the same time, overcomes the problems of chain-oriented topology. The proposed logical topology restricts the sensors to communicate only with their successive nodes along the chains, which saves vast energy, and thus helps to lengthen the lifetime of sensor network. To make the proposed logical topology more efficient, three adaptations to the basic multi-chain oriented topology, namely i) scheduling the chain members, ii) creating localized chains, and iii) employing mobile data collectors are proposed and designed. The first adaptation proposes a scheduling method, which allows a considerable number of deployed sensors to be turned off by sacrificing only a negligible amount of coverage area. The second adaptation proposes a localized chain construction method using Voronoi tessellation technique. This scheme not only saves energy, but also reduces interference in the network. The third and final adaptation describes an efficient data gathering scheme for energy conservation, network connectedness, and reduced latency. Extensive simulation experiments are performed to evaluate the performance of each of the adaptations.

Furthermore, to test the proposition on logical topology, a number of application protocols are designed using the communication abstraction of the proposed logical topology. All the applications, one for data collection, one for data dissemination, and the other for data transfer in WSNs, showed promising results in respect of energy consumption, network lifetime, as well as latency.