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Sink repositioning for enhanced performance in wireless sensor networks

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Abstract

Most of the energy aware routing approaches for unattended wireless sensor networks pursue multi-hop paths in order to minimize the total transmission power. Since almost in all sensor networks data are routed towards a single sink (gateway), hops close to that sink become heavily involved in packet forwarding and thus their batteries get depleted rather quickly. In addition, the interest in optimizing the transmission energy tends to increase the levels of packet relaying and thus makes queuing delay an issue, especially for real-time traffic. In this paper we investigate the potential of gateway repositioning for enhanced network performance in terms of energy, delay and throughput. We address issues related to when should the gateway be relocated, where it would be moved to and how to handle its motion without negative effect on data traffic. We present two approaches that factor in the traffic pattern for determining a new location of the gateway for optimized communication energy and timeliness, respectively. The gateway movement is carefully managed in order to avoid packet losses. The proposed approaches are validated in a simulated environment.

Keywords: Wireless sensor networks; Sink relocation; Energy awareness; Real-time data delivery; Timeliness

1. Introduction

Networking unattended wireless sensors is expected to have significant impact on the efficiency of many civil and military applications, such as disaster management, environment monitoring, combat field surveillance and security [1–6]. These systems process data gathered from multiple

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sensors to monitor events in an area of interest. For example in a disaster management setup large number of sensors can be dropped by a helicopter. Networking these sensors can assist rescue operations by locating survivors and assessing their medical conditions, identifying risky areas and making the rescue crew more aware of the overall situation. Such application of sensor networks not only can increase the efficiency of rescue operations but also ensure the safety of the rescue crew. In addition, the use of networked set of sensors can facilitate monitoring of forests for an early detection of fires and limit personal involvement in risky military reconnaissance missions. Security applications of sensor networks include intrusion detection and criminal hunting.

Sensors measure ambient conditions related to the surrounding environment and send the collected data, usually via a radio transmitter, to a command center either directly or through a gateway. Sensors used in many of the emerging applications are disposable and expected to last until their energy drains. Therefore, energy is a very scarce resource for such sensor systems and has to be managed wisely in order to extend the life of the sensors for the duration of a particular mission. Energy efficient data routing in wireless networks generally pursues multi-hop paths in order to minimize the total transmission power. Transmission power of radio circuits is generally proportional to distance squared or even higher order for environments rich with obstacles and interference sources. The basic idea of multi-hop paths is to shorten the distance so that significant power savings can be achieved. Therefore, the bulk of research on routing in wireless sensor networks mostly aims at maximizing the lifetime of the network, allowing scalability for large number of sensor nodes and supporting tolerance of sensor's damage and battery exhaustion [7–12].

The time for the first node to die is one of the most popular performance metrics for sensor networks. When it takes long for the first sensor to run out of energy, the network topology stays stable and data routing is performed efficiently. Since in almost all sensor networks data are routed towards a single sink, the gateway in our model, hops close to that sink become heavily involved in packet forwarding and thus their energy supply gets depleted rather quickly. When the gateway is stationary, hops that are further from the gateway have to be picked to substitute those close sensors, which are out of energy. Such scenario increases the total transmission power and gradually limits sensor coverage in the network and eventually makes the network useless. If the gateway has limited motion capability it will be desirable to relocate the gateway close to an area of heavy traffic or near loaded nodes in order to decrease the total transmission power and extend the life of nodes on the path of heavy traffic.

Gateway relocation can also be beneficial in applications involving real-time traffic. In such applications, data paths are carefully established so that certain end-to-end delay requirements are met [13,14]. The quality of service achieved in these applications can start to diminish with increased volume of real-time data and most of the packets can miss their specified deadlines. In order to enhance timeliness in such situations, one of the solutions is to explore gateway's ability to move to a location where the volume of real-time data is high. Gateway relocation in those circumstances can balance the traffic load among multiple nodes and hence decrease the miss rate of real-time packets. Examples of scenarios where relocation would be feasible are when the gateway is a laptop computer or other portable devices on the backpack of a rescue crew who is not expected to travel long distances.

Relocating the gateway during regular network operation is very challenging. The basic issues are when it would make sense for the gateway to be relocated, where the gateway should go and how the data traffic will be handled during the gateway's movement. The relocation of the gateway first has to be motivated by inefficient pattern of energy depletion or a non-tolerable increase in the number of missed deadlines when real-time packets are involved, even if it is the best possible network operation given the traffic distribution and network state at that time. Once the gateway detects such conditions, it should identify its most suitable location in order to enhance network performance. It is worth noting that in some setups it may also be desirable to continually adjust the