Chapter 21

Cross-Layer Design in Wireless Sensor Networks

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ABSTRACT

New and diverse applications for Wireless Sensor Networks (WSNs) have led to new challenges. Cross-layer approaches have proven to be the most efficient optimization techniques for these problems, since they are able to take the behavior of the protocols at each layer into consideration to overcome the constraints for WSNs. Thus, this chapter focuses on identifying the core problems of WSNs and collects available cross layer solutions for them that have been proposed. The literature on cross-layer protocols, protocol improvements, and design methodologies for WSNs are reviewed, and a taxonomy is proposed in order to provide insights on the identification of cross-layer design in WSNs. The open issues are discussed in detail for future research, and precautionary guidelines for cross layer design to WSNs are indicated.

INTRODUCTION

Wireless sensor networks are an emerging technology consisting of small, low power, and low-cost devices that integrate limited computation, sensing, and radio communication capabilities. These sensor nodes can be deployed close to the detected area and used for continuous sensing, event detection, and local control of actuators. Therefore, wireless sensor networks can be widely applied into military, environment, healthcare, home, and commercial applications. Advance in low-power electronics design have made it possible to develop highly integrated, yet low cost, microsensor nodes, with the capabilities of sensing, processing, and wireless communications. These microsensor nodes can be deployed as Wireless Sensor Networks (WSNs) for close to

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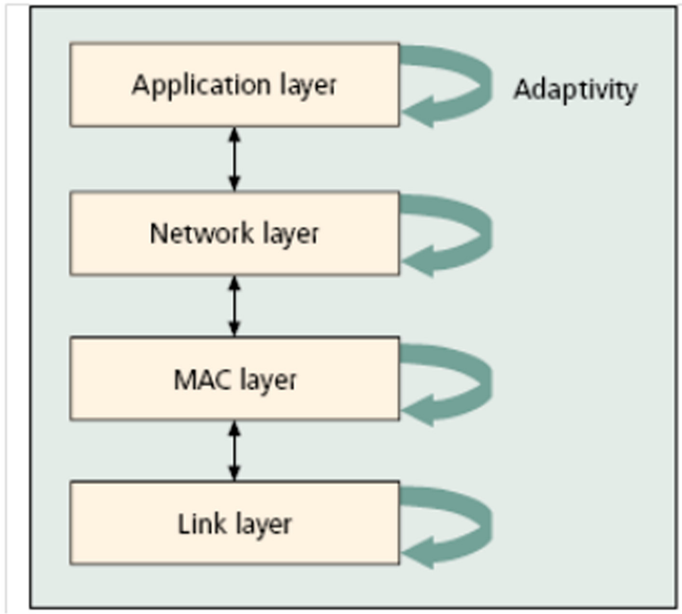
Figure 1. Traditional layered protocol stack for ad hoc network (from Goldsmith, et al., 2002)



the detected area and used for continuous sensing, event detection, and local control of actuators. Once deployed, a network of thousands of these low-power micro-sensor nodes is expected to operate over years. Due to a large number of potential civil and military applications, a growing research interest has been directed in developing energy efficient self-organizing protocols for wireless sensor networks

Sensor nodes are usually battery operated and their operational lifetime should be maximized, hence energy consumption at sensor node is a crucial issue for applications of WSNs. A large amount of research aims to improve the energy efficiency of communication in Wireless Sensor Networks (WSNs). However, most of the existing solutions are based on the classical layered protocol architecture, which is mainly based on the layered stack as shown Figure 1. This layered model makes a significant contribution to simplifying network design. Consequently, the layer structure leads to robust and scalable protocols. However, the design and operation of each layer in the stack are isolated, and the interface between layers is static and independent of the individual network constraints and application. While these protocols may achieve very high performance related to each of these individual layers, they are not jointly optimized to maximize the overall network performance. Therefore, inheriting such a stack will lead to poor WSN performance in which resources, especially energy, bandwidth, memory size, and CPU speed are greatly constrained.

In addition, since wireless media are used to transmit data, packets are subject to interference from other transmission, resulting in errors. This issue is closely related to energy constraints, since packet errors will cause retransmission, requiring more energy from the sensor. Moreover, retransmission will affect delay and data throughput, also affecting QoS. The use of error control techniques can prevent retransmission, however at the cost of introducing some transmission overhead, and thus increasing the sensors energy consumption. Hence, it can be seen that transmission errors, QoS constraints, and energy consump-