Chapter 5
The Transport Layer

5.1 Introduction

In the communication protocol stack, the transport layer is in charge of the transmission of segments on an end-to-end basis. The transport layer, which interfaces with the application layer, currently provides two types of services: a reliable and an unreliable service.

The User Datagram Protocol (UDP) and the Transmission Control Protocol (TCP) are the transport layer protocols of choice in the current Internet. It is very well known that UDP provides neither message delivery reliability nor includes a mechanism for flow and congestion control. As a result, UDP has been utilized by those applications that need a continuous delivery of segments and can tolerate some losses, such as streaming applications, like voice over IP, or video applications. TCP, at the other side of the spectrum, provides a very reliable service and includes mechanisms for flow and congestion control. TCP has been the protocol of choice for data-oriented applications that do not send data continuously but cannot tolerate packet losses, such as transactions over the web, file transfers, telnet sessions, and the like.

Unfortunately, wireless sensor networks have different constraints compared to wired and even other wireless networks. Also, wireless sensor network applications differ from Internet-like applications in many aspects. As a result, these two factors make current transport layer protocols, such as UDP and TCP, inappropriate for wireless sensor networks. This chapter first presents a general view of the functionality of the transport layer. Then, wireless sensor network applications and their characteristics are described with the goal of identifying which of those transport layer functions are needed to support each type of application. Finally, the chapter describes some of the most important transport layer protocols available in the wireless sensor networks literature.
5.2 Transport Layer Functions

The transport layer of the communication protocol stack is in charge of flow and congestion control and error control functions on an end-to-end basis. Different transport layer protocols are then designed including both functions, only one of them or even none of them. For example, TCP includes flow and congestion control and error control while UDP includes none.

Flow control is the mechanism that guarantees that the sender will not overwhelm the receiver with more data than it can receive and process. Congestion control, on the other hand, is the mechanism that guarantees that the network is not overwhelmed by more traffic that it can handle. As a result, it is clear that flow control is an end system issue while congestion control is a network issue. In this chapter, we will only consider the congestion control issue, as it is more relevant than flow control in wireless sensor networks.

Congestion control has three main components: congestion detection, congestion notification, and congestion reaction. Congestion detection is the mechanism used by the transport layer protocol to detect congestion. This mechanism can act in a proactive or a reactive manner. A proactive mechanism can be used to prevent or avoid congestion while a reactive mechanism usually acts once congestion has taken place. Mechanisms widely used to detect congestion are repeated acknowledgments, sender timeouts, and buffer size measurements. Once congestion has been detected, a notification needs to be conveyed to the sender so it can act upon it. Congestion notification can be explicit, by sending a message to the source indicating the location and level of the congestion, or implicit by means of measured end-to-end delays or acknowledgments. Finally, once the source knows that the network is congested, it has to react accordingly. This is the congestion reaction component and there are many different mechanisms to change the source’s transmission rate in response to the congestion notification received. The most widely known congestion reaction is the Additive Increase Multiplicative Decrease (AIMD) strategy used by the TCP protocol, which increases the transmission rate in an additive manner if transmissions are successful, and reduces the transmission rate in a multiplicative manner on error conditions.

Error control is the function in charge of detecting and recovering from missing or corrupted segments. Error control consists of error detection and error correction mechanisms. While missing packets are usually detected using sequence numbers, corrupted packets are detected by means of error checking mechanisms. Error correction mechanisms are usually based on end-to-end retransmissions.

5.3 Wireless Sensor Network Applications

In order to design appropriate transport layer protocols for wireless sensor networks it is important to know the type, characteristics, and requirements of the most common applications utilized over these networks. Figure 5.1 shows the domain space for wireless sensor network applications, based on whether the applications send one or multiple packets, and the level of reliability that they need.