Chapter 6
Cross-Layer Design for Network Security Enhancement

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ABSTRACT

Cross-Layer Design is useful for wireless communication to improve the performance and efficiency. On the other hand, Cross-Layer Design is also helpful in enhancing network security. With the help of cross-layer information and interactions, the security overhead can be reduced and the security efficiency can be improved. In this chapter, the authors review the existing literature and provide a taxonomy based on their methods and applications. According to their survey, these cross-layer security enhancements could be classified into four categories: 1) security protocol; 2) security policy; 3) key management; 4) intrusion detection. The authors hope to attract more applications and research attention in this direction.

INTRODUCTION

The traditional Open System Interconnection (OSI) layered protocol stacks have been used for a long time. In OSI, the function of each layer is defined clearly that could reduce the complexity of network implementation and increase the flexibility. In the layered OSI architecture model, the protocol at each layer is designed independently for the different layers. The layered architecture does not allow direct communication between nonadjacent layers. Communication between adjacent layers must follow the pre-defined interfaces through procedure calls and responses. However, for the next generation wireless networks and mobile systems, the traditional layered network design cannot satisfy the user requirement on performance and efficiency (Chao, et al., 2009). Because of the nature of wireless communications such as time varying transmission of the wireless channel and the dynamic resource requirements of

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different applications, the mobile communication is meeting the challenge of architectural design.

Cross-Layer Design (CLD) is still a hot research topic that actively exploits the dependence and interaction between different protocol layers to obtain performance gains. Srivastava and Motani have made a detailed survey on cross-layer design and depicted main reasons to motivate designers to violate the layered traditional architecture. Under the wireless environment, these problems include some unique problems created by wireless links such as the possibility of opportunistic communication on wireless links and the new modalities of communication offered by the wireless medium (Srivastava & Motani, 2005). For instance, a classic problem of wireless link is that TCP sender may mistake a packet error and believe that network congestion happened. Network element can cooperate with others or collect more information from different layers to improve the communication quality. Cross-Layer Design is a novel and practical mode for wireless communications in protocol or mechanism design (Zhou, et al., 2009; Zhou, et al., 2011; & Chang, et al., 2010).

In the aspect of network security, cross-layer design is helpful for improving the performance of existing protocols and enhancing the efficiency of existing mechanisms. For instance, due to the limitation of traditional layered architecture, application or protocol cannot communicate or cooperate with other nonadjacent ones. It may cause redundant processes to degrade the performance such as multiple encryptions in network security. We can utilize cross-layer design to deploy appropriate configuration for tradeoff between performance and security. Moreover, cross-layer information and interaction is also useful for designing security mechanisms such as key management and intrusion detection.

In this chapter, we will introduce the background of cross-layer design in next section. The background includes cross-layer design categories, methodology, signaling, and features. According to our survey of cross-layer design for network security, we classify these cross-layer security enhancements into four categories and describe them in order.

BACKGROUND

An important cross-layer design aspect is the management of cross-layer interaction that can guarantee the system operation. Such cross-layer entities (i.e., functions, programs, or protocol layers) may reside within the stack, in which case it is considered as an internal cross-layer entity or an external network node as shown in Figure 1 and Figure 2 (Foukalas, et al., 2008). Internal entity may be either an inter-layer entity that coordinates the operation of all protocol stack layers or an intra-layer entity that is located within a protocol layer. The external entities may be centralized by a specific network node or distributed over several network nodes.

Another important issue in cross-layer design is the signaling mechanism. Foukalas et al. (2008) performed a well-studied survey of different kinds of cross-layer signaling mechanisms and protocols. The ways of exchanging and indicating information are hints and notifications. A hint is the message sending from higher layer toward lower

Figure 1. Internal cross-layer entities