Chapter 15
Cross-Layer Protocols for Multimedia Communications over Wireless Networks

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ABSTRACT
In the last few years, the Internet throughput, usage, and reliability have increased almost exponentially. The introduction of broadband wireless mobile ad hoc networks (MANETs) and cellular networks, together with increased computational power, have opened the door for a new breed of applications to be created; namely, real-time multimedia applications. Delivering real-time multimedia traffic over a complex network like the Internet is a particularly challenging task since these applications have strict quality-of-service (QoS) requirements on bandwidth, delay, and delay jitter. Traditional Internet protocol (IP)-based best effort service is not able to meet these stringent requirements. The time-varying nature of wireless channels and resource constrained wireless devices make the problem even more difficult. To improve perceived media quality by end users over wireless Internet, QoS supports can be addressed in different layers, including application layer, transport layer, and link layer. Cross layer design is a well-known approach to achieve this adaptation. In cross-layer design, the challenges from the physical wireless medium and the QoS-demands from the applications are taken into account so that the rate, power, and coding at the physical (PHY) layer can be adapted to meet the requirements of the applications given the current channel and network conditions. A number of propositions for cross-layer designs exist in the literature. In this chapter, an extensive review has been made on these cross-layer architectures that combine the application-layer, transport layer, and the link layer controls. Particularly, issues like channel estimation techniques, adaptive controls at the application and link layers for energy efficiency, priority based scheduling, transmission rate control at the transport layer, and adaptive automatic repeat request (ARQ) are discussed in detail.

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INTRODUCTION

As the wireless networks evolved from circuit-switched voice traffic based 2G networks to an all-IP based packet-switched network catering to a mix of high speed real-time traffic such as voice, multimedia teleconferencing, online gaming etc., and data-traffic such as WWW browsing, messaging, file transfers etc., there has been a dramatic change in the quality-of-service (QoS) requirements in terms of transmission accuracy, delay, jitter, throughput and so on. In order to achieve a successful and profitable commercial market for future wireless technology, network service designers and providers need to pay much attention to efficient utilization of radio resources due to fast growth of the wireless subscriber population, increasing demand for new mobile multimedia services and consequent diverse and more stringent QoS requirements. Traffic on wireless networks is becoming increasingly complex with a mix of real-time traffic such as voice, multimedia teleconferencing, gaming, and data-traffic such as WWW browsing, messaging and file transfers etc. All these applications require widely varying QoS guarantees for different types of traffic. Of late, various mechanisms have been proposed in the literature to support these QoS requirements. However, providing a robust QoS support for multimedia applications over wireless networks is a very challenging task due the following reasons (Jiang et al., 2005).

- Different applications have different QoS requirements. Real-time media such as video and audio is delay-sensitive but capable of tolerating a certain degree of errors. Non-real time media such as web data is less delay-sensitive but requires reliable transmission.
- Wireless channels have high packet loss rate and bit error rate (BER) due to fading and multi-path effects. Resulting packet loss and bit errors can have an adverse effect on the multimedia applications.
- Wireless channels have bandwidth limitation and fluctuations of the available bandwidth, packet loss rate, delay and jitter.
- Traditional transport layer protocols perform poorly in wireless networks since they assume congestion to be the primary cause for packet losses and unusual delay in the network. These protocols reduce the transmission rate whenever they observe packet loss. In wireless networks, the packet may be dropped due to channel errors, thereby resulting in unnecessary reduction in end-to-end throughput.
- The mobile devices are power constrained. Maintaining good media quality and minimizing average power consumption (for processing and communication) are two conflicting requirements.
- Receivers in multimedia delivery systems are quite different in terms of latency requirements, visual quality requirements, processing capabilities, power limitations, and bandwidth constraints. Moreover, multimedia may traverse different types of networks, e.g., wire-line networks, cellular networks, and wireless local area networks (WLAN). Each of these networks has different characteristics such as reliability, delay, jitter, bandwidth, and medium access control (MAC) mechanisms.

In view of the above constraints, a strict modularity and protocol layer independence of the traditional transmission control protocol (TCP) / Internet protocol (IP) or OSI stack will lead to a sub-optimal performance of applications over IP-based wireless networks. For optimization, we require protocol architectures that require modification of the reference layered stack by allowing direct communication between protocols at non-adjacent layers or sharing state variables across different layers to achieve better performance. The
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