Chapter 10
Cognitive Cooperation in Wireless Networks

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ABSTRACT

In recent years, vertical handover (VHO) has been identified as the primary vehicle to provision seamless mobility and quality of service (QoS) transparency for end-user in composite network. This allows end-user to enjoy ubiquitous connectivity in the most efficient way, irrespective of time and place, commonly known as always best connected. In this chapter, the authors introduce the notion of cognitive cooperation as a means to provide optimized VHO opportunistically in order to exploit the inherent heterogeneity that exists within such composite network to improve radio resource usage. Through the cognitive cooperation, the chapter proposes a distributed load adaptation strategy (LAS) framework which exploits the benefits of joint optimization, particularly between link adaptation and load adaptation on-demand. The authors advocate that such synergetic interactions between the physical layer (PHY) and medium access control (MAC) layer have advantages over the PHY approach based only on link adaptation. Comprehensive performance analyses show that the LAS framework arbitrates a QoS-balanced system in which statistical QoS guarantee for multimedia traffic can be provisioned and overall system capacity can be maximized.

10.1 INTRODUCTION

Recent advancements in wireless network technologies have resulted in several new concepts and terms to support advanced radio system technologies. For instance, the composite network architecture has been defined in the IEEE 1900.1 standard (IEEE Std 1900.1-2008, 2008) as a type of wireless communication network that comprises of multiple radio access technology (multi-RAT) under a single or multiple network management control to support efficient commu-

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nication. Note that the key difference between a composite network and heterogeneous network, according to the IEEE 1900.1 standard, is that the former focuses on the sharing of resources while the latter does not. In similar context, the term 'cognition' central to cognitive radio has been dilated to cognitive network lately. Such cognitive network postulates the ability to optimize both user and network performances, as well as bring about better utilization of radio resources by adopting cognitive functionality, e.g., in the radio to exploit spectrum holes.

In fact, the IEEE 1900.1 standard states that cognitive functionalities may be applied to a composite network so that radio can select the best available option for communication. This is propelled by the fact that although cognitive radio can identify these spectrum holes, a parallel cognitive functionality is still required in the higher layer to harness any effective use of such additional spectrum. Given that the frequency spectrum is typically divided into multiple channels, the ramification of dynamic spectrum access supported by cognitive radio will manifest as the main challenge of managing these dynamically available heterogeneous channels which emanate from diverse parts of the spectrum with different propagation characteristics.

On the other hand, the fundamental problem of a composite network is imputed to the coordination of VHO between different radio access technologies (RATs). Recently, the research community is motivating the unification of cooperative and cognitive principles to exploit their highly complementary characteristics. According to (Fitzek & Katz, 2007), cooperation and cognition in wireless networks have significant inter-dependencies which intensify with the increasing heterogeneity of networks, terminals, and services. Although significant progress has been achieved in cooperative (Fitzek & Katz, 2006) and cognitive (Thomas, 2007) networks, their advancements are mainly autonomous. Therefore, it will be beneficial to explore the *cross-fertilization* of cooperation and cognition, which will become important as the heterogeneity of access networks, terminals, and services escalates. This elicits that cognition depends on the data acquisition of performance metrics through cooperation while cooperation depends on the awareness of surroundings through cognition. In particular, this chapter motivates that cooperation will become pertinent when there exists a mutual goal that requires the coordinated effort of more than one RAT. In this case, the mutual goal of a composite network is to harness overall system capacity and QoS improvements through optimized VHO fueled by cognitive cooperation.

For example, link adaptation or adaptive modulation and coding has been widely implemented across standards such as the 3GPP long term evolution (LTE) and IEEE 802.11xx wireless local area network (WLAN) to provide spectrally efficient and flexible data rate access while adhering to a target error performance over wireless channels. In general, it is known that the link adaptation of LTE system is more robust than WLAN. To be more specific, LTE system comprises of inner loop link adaptation which acts on channel quality information reported by the user equipment and (optional) outer loop link adaptation which relies on acknowledgment (ACK)/negative ACK (NACK) from hybrid adaptive repeat and request (HARQ) to correct systematic errors (Holma & Toskala, 2009). In contrast, most of WLAN's link adaptation are typically implemented based on the automatic rate fallback mechanism (Kamerman & Monteban, 1997), (Pang, Leung, & Liew, 2008).

Although link adaptation in LTE and WLAN systems has the ability to achieve optimum throughput by matching transmission parameters to the time-varying wireless channel conditions of a realistic wireless environment, it introduces an upper bound on the maximum achievable throughput due to the reduction of transmission rate in reality. This would inevitably affect users with bandwidth intensive and delay sensitive multimedia applications where QoS guarantee is extremely important. Such impact is especially

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