Chapter 12
Architectures and Information Signaling Techniques for Cognitive Networks

Dzmitry Kliazovich
University of Luxembourg, Luxembourg

Fabrizio Granelli
University of Trento, Italy

Nelson Fonseca
State University of Campinas, Brazil

Pascal Bouvry
University of Luxembourg, Luxembourg

ABSTRACT
The introduction of self-awareness, self-management, and self-healing into networks leads to a novel paradigm known as cognitive networking. This chapter overviews recent developments of this concept, discussing possible cognitive node structure and candidate cognitive network architecture. It explains the functionality of cognitive algorithms and discusses opportunities for potential optimization. Furthermore, the concept of cognitive information services is introduced. Information signaling techniques are then classified, reviewed in details, and compared among them. Finally, the performance of cognitive communication protocols is presented for a choice of examples.

INTRODUCTION
The evolution of communication technologies has brought networking a step closer to a service provisioning on an “anytime, anywhere” basis, yet ensuring instantaneous secure communications. However, such an innovation is limited by the constraints imposed by the original design of the Internet which leads to the inefficient configuration and management of networks (Georgakopoulos, Tsagkaris, Karvounas, Vlacheas, & Demestichas, 2012).

Self-awareness, self-management, and self-healing have all been proposed for the optimization of network operation, reconfiguration, and
management. The introduction of such “self-properties” contributes to an increase in network “intelligence”, as well as creating a new paradigm, known as cognitive networking, which is expected to be part of the 4th generation wireless networks (4G) (Maravedis, 2006).

Cognition implies the awareness of the network of its own operational state, as well as its ability to automatically adjust operational parameters to accomplish specific tasks, such as the detection of environmental changes. Cognition depends on the support of network elements (routers, switches, base stations, etc.), to host active agents which can measure network status and configuration parameters in order to drive its reconfiguration when needed.

The ability to think, learn and benefit from past experience requires interaction between cognitive agents. Cognitive networks are usually composed of a set of cognitive engines, which can reside in a protocol layer, between different layers, or be distributed among various nodes (Kliazovich, Granelli, & Fonseca, 2009). Each cognitive agent operates locally but contributes to the achievement of global goals by interacting with other cognitive agents. Indeed, the efficiency of the operation of cognitive networks depends on the communication among these agents. Depending on the communication scope, which can be inter-layer, intra-layer, or network wide, different technologies can be used, each imposing specific constraints on the speed and delay of information exchange. Such constraints cannot be neglected and should be taken into account during the design of cognitive network architectures.

Cognitive networking encompasses multiple wireless technologies and is designed to deal with the complexities of network configuration, as well as the support of user applications. Cognitive networks can increase the profit of wireless service providers by reducing costs and developing new streams of revenue as a result of the provisioning of heterogeneous wireless access solutions (Zhang & Hanzo, 2010). The benefits for service providers deriving from the adoption of cognitive networks include the following: the possibility of relying on common hardware and software platforms while coping with the evolution of radio technologies, the development of new services, the minimization of infrastructure upgrades, accelerated innovation, and the maximization of return-on-investment (Clark et al., 2003).

Cognitive technologies allow network operators to continuously analyze network configuration and its performance. Moreover, reconfiguration can be triggered by application requirements, policies, or billing plans. Furthermore, cognitive networking offers extended sets of operations, allowing new ways of interaction between network operators and end-users (Demestichas, Dimitrakopoulos, & Strassner, 2006).

In the following sections, we discuss a reference network architecture which can be used to enable cognition properties, with an emphasis on aspects related to interoperability and incremental deployment. We also provide an extensive survey of various techniques which can be used for cognitive information exchange; this is the key to the design and successful deployment of such cognitive optimization techniques. Finally, the chapter presents cognitive communication protocols for the transport and the link layers.

**BACKGROUND**

**Cognitive Node Architecture**

Designing the architecture of a node in a cognitive network requires a careful balance between performance and interoperability. Indeed, interoperability represents a stringent constraint in network research.

Cognitive node is a generic network node, such as user terminal equipment, which carries complete or partial implementation of TCP/IP protocol stack and is capable of running a cognitive process for the purpose of reconfiguration.
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