Chapter 8

Software Networks at the Edge

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ABSTRACT

The chapter addresses the potential impact of technologies like Autonomic, Cognitive, and Software Defined Networking on future networks evolution. It is argued that said technologies, coupled with a wide adoption of virtualization, will bring an impactful disruption at the edge of current networks: in less than a decade developing distributed clouds of cheap edge nodes powerful enough to run virtualized network functions and services on standard hardware will be possible. This will improve network flexibility and programmability, creating the conditions for the development of new Telco-ICT ecosystems. The edge will become a business arena with multiple interacting networks and domains operated by diverse players. We are already witnessing this transformation, looking at the shift of value towards the users’ terminals. The chapter elaborates this vision, reports a brief overview of the state of the art of enabling technologies, describes some simulation results of a use-case, and concludes by providing future research directions.

INTRODUCTION

Socio-economic drivers and technology progresses (with their down-spiraling costs) are steering the evolution of current networks towards becoming a programmable environment of resources, dynamically interconnected by links that are created and destroyed to serve multiple applications.

Technology trends are progressing at an impressive rate: processing is continuing to follow Moore’s curve and it is doubling in capability roughly every 18 months; storage capacity on a given chip is doubling every 12 months, driving increases in connectivity demand for access to the network; and optical bandwidth is doubling every 9 months by increasing the capacity of a single
wave length and by putting multiple wavelengths of light on a single fiber.

These tendencies will impact dramatically the evolution of network architectures: future networks are likely to become less hierarchical and based on optical core infrastructures (with a limited number and types of large nodes) interconnecting different local areas (via optical and/or radio connectivity), populated, at the edge (in a range of few meters around Users) with a sheer number of heterogeneous nodes. The edge, where already we are witnessing already today the migration of “intelligence” will become the business area where a new galaxy of ecosystems will be created.

The performance of processing and storage technologies are making impressive progress, but software will be the true challenge. In fact, future networks will rely more and more on software, which will accelerate the pace of innovation (as it is doing continuously in the computing and storage domains). Already today, advances in resource virtualization are allowing the deployment, on the same physical infrastructure, of diverse coexisting and isolated virtual networks of resources, thereby best fitting, dynamically, a variety of service demands (just like having different OSs - Window, Linux - on the same laptop). This has multiple advantages: for example, the crash, or the misuse, of a virtual resource is confined in a virtual network (e.g., by applying fault recovery policies enforced by self-healing capabilities) and it has no impact on other virtual networks; it is possible to put in place, in each virtual network, specific logics and policies (e.g. to optimize the usage of allocated resources according to SLA); the use of physical resources is optimized, etc.

Software Defined Networking (SDN) (McKeown, 2009) can be seen as a further step in this direction. In particular, in SDN architecture network control and data planes are decoupled, so that network infrastructure is abstracted from business applications. SDN should not be confused with network virtualization, even if the two trajectories could intersect with interesting possibilities. Network virtualization is the second most-important trend allowing the set-up of virtual networks by connecting virtual IT and networking resources. This is expected to bring about programmability and flexibility: for example it will be possible to build multiple overlay networks (on the same physical infrastructure) offering multiple services.

On the other hand, this evolution is also bringing an increase in design and management complexity. Future networks will start exhibiting the characteristics of complex systems consisting of many diverse and autonomous, but interrelated software and hardware components. As known, complex systems cannot be easily described by rules and their characteristics are not reducible to one level of description: they exhibit properties (e.g. self-organization) that emerge from the local interactions of their parts and which cannot be predicted from the properties of the single parts.

Traditional management and control approaches will no longer be applicable. Networks should be able to self-adapt and self-configure themselves (with limited human intervention). These capabilities can be achieved by introducing cognition as a transformative software technology. As from the prior-art there are already technologies and solutions empowering cognitive networks with the ability to learn and to reason, which involve observations of network states, planning, decisions and actions while taking into account optimization goals. These kind of actions are intended to improve a network’s state with respect to these design goals and learning is a product of their accumulated knowledge about past actions and their results. Given these characteristics, we may even argue that the behavior of a cognitive network environment can be view as a sort of self-organization pursuing network-wide constrained optimization (CO). In fact, said behavior can be viewed as the result of a dynamic game, which is influenced by the local actions and the degree of coupling that may exist between the actions of different players (i.e., nodes) The coupling may
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