Future Mobile Communications, LTE Optimization and Mobile Network Virtualization

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I. Abstract

This paper presents the concepts of network virtualization, focusing specifically on wireless virtualization of the LTE mobile communication system. A novel wireless virtualization framework is proposed and developed, which allows mobile network operators to share the wireless spectrum, as well as, the infrastructure (i.e., hardwares equipment). The framework targets the concepts of wireless virtulization applied within the 3GPP Long Term Evolution (LTE) system. LTE represents one of the new mobile communication systems that is just entering the market. Therefore, LTE was chosen as a case study to demonstrate the proposed wireless virtualization framework. The framework is implemented in a LTE network simulator and analyzed, highlighting the many advantages and potential gain that the virtualization process can achieve. Within this work two potential gain scenarios that can result from using network virtualization in LTE systems are studied and analyzed: Multiplexing gain coming from spectrum sharing, and multi-user diversity gain.

II. Virtualization

Virtualization is the process of creating virtual versions of physical resources that emulate the same physical characteristics. It is often used in the IT context, to partition a physical resource into several virtual ones, for example, virtual memory, hard disk partition, virtual machine. The virtualization concept [1] was first introduced at the beginning of the 1960s, when Christopher Strachey published a paper entitled ``Time Sharing in Large Fast Computers" that focused on multi-programming. Then came the IBM M44/44X Project in the mid 1960s, where the term Virtual Machine (VM) was introduced for the first time. The creation and maintenance of such virtual machines is what is known today as ``Server Virtualization". The idea at that time was to create several virtual machines out of one mainframe computer, to enable multi-tasking, i.e., running simultaneous applications and processes in one computer, since such computers were very expensive at the time.

The virtualization concept can be applied in different areas. But, from what can be seen in today's IT interest, three main areas emerge that adopt the use of virtualization, and these are:

- Storage Virtualization
- Server Virtualization
- Network Virtualization

A. Network Virtualization

Network virtualization is the process of combining different -virtual- network resources, into a Virtual Network (VNet). Individual virtual networks can contain operator-specific protocols and architectures, which could be totally different from other co-existing virtual networks. In addition, network virtualization also provides full administrative end-to-end control, for the operators over their VNets.

Many research activities focusing on the Future Internet architecture, have been launched around the world, for example 4WARD [2] in Europe, VINI [3] and GENI [4] in the U.S. and AKARI [5] and AsiaFI [6] in Asia.

In spite of all these major research projects, one very important piece of the puzzle is still missing, that is, “Wireless" Virtualization”. Wireless virtualization, according to the best of our knowledge, has not yet received the appropriate attention entitled to, and only little work has been done in this field.

B. Wireless Virtualization in Mobile Communication

Mobile networks are one of the fastest growing technologies that are influencing major aspects of the way we communicate and access information. The virtualization of mobile networks is a subset of the wireless virtualization. Virtualizing mobile networks and sharing their resources, will bring a more efficient utilization of the scarce wireless resources. Furthermore, network virtualization can reduce the amount necessary base station equipment, and thus reduce the required energy to run wireless networks, as well as, reducing the overall investment capital required by mobile operators to setup their own infrastructure.

Network virtualization also enables completely new value chains. Small players can come into the market and provide new services to their customers using a virtual network. Furthermore, the idea of being able to share the frequency resources among multiple operators is very appealing. This gives operators the flexibility to expand, or shrink their networks and the air interface resources they use. This will lead to more efficient overall resource utilization and reduced energy consumption.

LTE is the next generation of mobile communication. In this work it is chosen as a case study, to demonstrate how network virtualization is applied in mobile networks, and what benefits can be achieved. Virtualizing the LTE network, means that the infrastructure of the LTE system (including eNodeBs, routers, Ethernet links ...), has to be virtualized, so that multiple mobile network operators can create their own virtual networks, depending on their individual requirements and goals, while using a common infrastructure. The main technical challenges faced are how to virtualize the physical infrastructure to support such scenarios, and what kind of architectural changes are required in the current LTE system. Two different categories of the virtualization processes are mainly foreseen, these are:

- Physical infrastructure virtualization: the infrastructure of the LTE network (i.e., nodes and links), has to be virtualized, so that different virtual mobile operators can create their own network.
- Air interface virtualization: being able to virtualize the LTE spectrum, i.e., the physical spectrum resources can be shared by different virtual mobile operators.

The latter case is the focus of this work, because the first part can be broken down into node (routers and servers) virtualization, as well as, link virtualization, which have been extensively studied in the literature as mentioned before; while virtualizing the air interface of the LTE system is a completely new concept.

[1] A. Singh. An introduction to virtualization. http://www.kernelthread.com/publications/virtualization/, January 2004.

[2] 4WARD. Fp7 european project. http://www.4ward-project.eu/. last accessed on April 2012.

[3] A. Bavier, N. Feamster, M. Huang, L. Peterson, and J. Rexford. In vini veritas: realistic and controlled network experimentation. In Proceedings of the 2006 conference on Applications, technologies, architectures, and protocols for computer communications, SIGCOMM '06, pages 3–14, New York, NY, USA, 2006. ACM.

[4] GENI. Global Environment for Network Innovations. http://www.geni.net/.

[5] AKARI. New generation network architecture akari conceptual design (ver 2.0). http://akari-project.nict.go.jp/eng/concept-design/AKARI_fulltext_e_preliminary_ver2.pdf, May 2010.

[6] AsiaFI. Asia future internet forum. http://www.asiafi.net/.