Study on Network Virtualization Scenarios

Shivanand B Lamani[1], Ravikumar K[2]
[1]Faculty in Computer Science Dept, Akkamahadevi Women's University, Vijayapur
[2]Computer Science Department GFGC, Gangavati, Karnataka, India

Abstract: Virtualization has been extended from wired to wireless networks. It improves efficiency and utilization and enables customized service and multi-tenancy. New architectures involving virtualization have been proposed in the major wireless domains such as WiFi, cellular network and wireless application in Internet of things (IoT). Additionally, the use of Software Defined Radio (SDR) gives more and better options for virtualization. Despite the fact that the architectures are not yet mature enough to be deployed in large scale, the preliminary results reveal the promising future of virtualization in wireless networks.

Keywords: LINP, virtualization, WiFi, network interface virtualization, load balancing, SplitAP, cellular network, Network Virtualization Substrate (NVS), Long Term Evolution (LTE), Internet of things (IoT), wireless sensor networks.

I. INTRODUCTION

Network virtualization is a technology which enables combining computer network resources into a single platform appearing as a single network. In this form of virtualization all hardware and software in the virtual network appear as a single collection of resource. There is another form of network virtualization in which logically isolated network partitions are created over the shared physical network infrastructure. Such logical partitioning, as shown in Figure 1, resulting in multiple heterogeneous virtual networks can coexist simultaneously over the shared infrastructure.

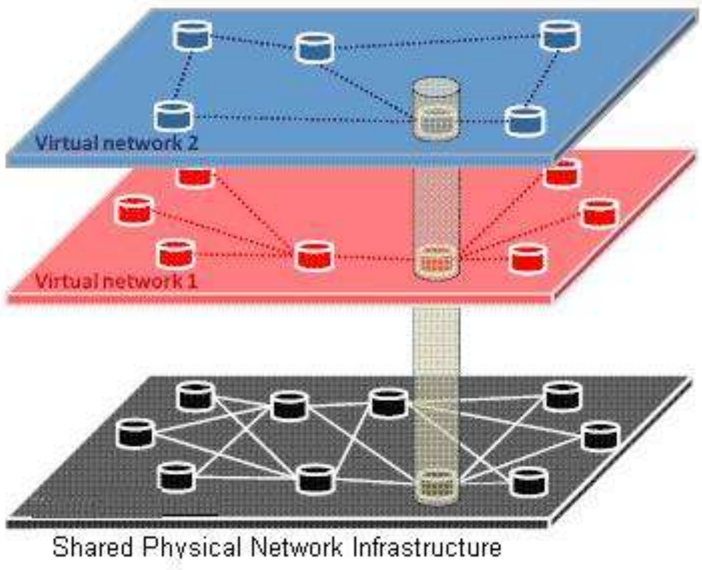

Figure1: Logical Network partitions on a shared network infrastructure

Network virtualization is a useful technology to achieve better utilization of infrastructures in terms of reusing a single physical or logical resource for multiple other network instances, or to aggregate multiples of these resources to obtain more functionality. These resources can be network components, such as routers, switches, hosts, virtual machines, etc. Hence, Network virtualization can reduce the total cost by sharing network resources.

Shared Physical Network Infrastructure

Although virtual networks are only logically isolated networks, over a common infrastructure, but each such virtual network can provide the user, of logical virtual network, network services similar to those provided by the common infrastructure as a non-virtualized network. Network virtualization is not an completely new concept but it has been in use to limited extent such as virtual private networks (VPNs) & virtual local area networks (VLANs).

Virtualization in the Wireless Part of Internet of things (IoT)

Internet of Things is expected to connect everything together. Wireless networking is the fundamental for IoT because it can integrate almost anything into networks in an efficient way. Sensor networks are by far the most widely deployed IoT related wireless network. Effort has been made on this part.

The need for wireless virtualization in IoT

IoT has its unique demand for wireless networks. Most of the objects expected to be connected are limited in functionality, size, cost and power. With such constrained resources and the enormous business scale, sharing becomes even more significant. Table 1 highlights the major differences between wireless networks in current Internet and in the future IoT.

II. KEY FEATURES OF NETWORK VIRTUALIZATION

Some of the key features of network virtualization are given below:

- **a) Partitioning:** Network virtualization allows creation of logical network partitions with a programmable control plane so that users can use protocols, network topologies, and functions as per their requirements. The re-configurability capability of Network virtualization make the logical partitions capable of easily and rapidly creating network topologies and reconfiguration according to users' requirements, the status of networks, policies of resource owners, etc.
- **b) Isolation**: The network virtualization technology is capable of providing the isolation, among logical network partitions, so that there is no interference which may affect network performance. This includes the isolation to deterioration of the performance of a logical partition due to exhaustion of network resource by a malicious logical partition.
- c) **Abstraction**: In a logical network partition the network elements should be controlled as abstractresources, in which a given virtual resource need not directly correspond to its component resources. Network abstraction allows hiding the underlying characteristics of network elements from the way in which other network elements, applications, or users interact with those network elements and separates infrastructure instances and control frameworks of network virtualization.
- **d) Aggregation**: Network virtualization makes it possible to provide high performance resources for users by logically aggregating multiple resources into single resource.

To illustrate some of the key features, we may take Server Virtualization as an example. Server virtualization software allows the user to run multiple guest computers on a single host computer with those guest computers believing they are running on their own hardware. By doing this, user gain all the benefits of any type of virtualization such as portability of guest virtual machines, reduced operating costs, reduced administrative overhead, server consolidation, testing & training, and disaster recovery benefits. Examples of server virtualization products are VMware Server, Workstation, Player, and ESX Server, Microsoft Virtual PC and Virtual Server, Xen, Virtual Iron, etc. Following are the different levels of server virtualization commonly offered:

Full virtualization: guest OS is unmodified and believes it is running on the same hardware as the host OS.
Para virtualization: guest OS is modified.

Emulation: guest OS is unmodified but it is running on a software emulated CPU.

III. BENEFITS OF NETWORK VIRTUALIZATION

Virtualization technology offers a unique opportunity for organizations to improve efficiency and scalability and reduce overall operational costs and complexity. It provides an efficient way to centrally manage network resources, simplifying provisioning and maintenance tasks.
Virtual Networks attempt to better utilize networking infrastructure by reusing individual routers or links (i.e., either physical or logical networking resource) for multiple concurrent network instances, or to aggregate multiple such resources to obtain increased capabilities. These resources can be any network component, including routers, hosts, links, and services, (e.g., name mapping services). Increased capability can refer to aggregate capacity provided by bundles of links or groups of routers, or increased fault tolerance of a cluster of primary and backup service systems.
Network virtualization when done at the device level reduces the number of physical network devices, or when done at the network level, by creating multiple logical networks, enables full utilization of one physical network.
In brief, following are some of the benefits of network virtualization:

- It helps in de-ossifying the current network architectures.
- It allows multiple virtual networks to coexist over a shared physical infrastructure.
- It provides paths to the future networks approaches.
- It allows the deployment of new business roles and players.
- It reduces/shares cost of ownership.
- It optimizes the resource (network infrastructure) usage.

IV. ARCHITECTURE OF NETWORK VIRTUALIZATION

Network virtualization is required to be capable of providing multiple partition of network appearing to be isolated from each other. These partitions, also referred to as Logically Isolated Network Partitions (LINP), may be created over the single physical infrastructure. Figure 2 shows multiple LINPs created in a network virtualization framework. Each LINP is isolated from each other and is programmable to satisfy the user's demand on the functionality and amount. Users' demand is conveyed to an entity known as LINP manager which coordinates infrastructures resource so that appropriate LINP is provided to the user as per the user's demand.

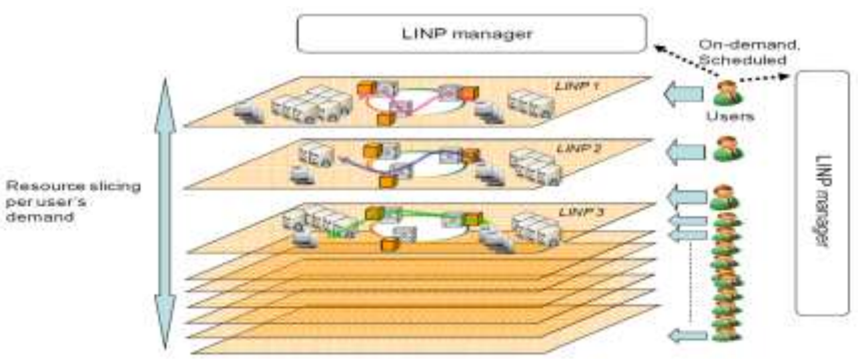

Figure 2: Network virtualization

V. Implementation Examples

Some of the implementation examples of network virtualization are given in the following paragraphs:

5.1 Router architecture for virtualization support

To support virtualization capability, the router architecture has three layers viz. router hardware, router software, and control framework layers.

Figure 3 shows the functional architecture of a router, which supports virtualization.The router hardware typically consists of a switching component for packet forwarding and flow table. The router software performs router's main operations such as running routing protocols and building routing table. The router software may include virtualization layer in order to support virtualization in router. The virtualization layer typically creates and manages logically isolated virtual systems, which can run various components on the native hardware. Thus, the virtualization layer can support virtualization of router hardware resources by creating the isolated virtual systems, i.e. virtual router. The virtual router is a software implementation of a router that executes the same operations as a physical router. It is an isolated partition of a real router. Multiple virtual routers can coexist over the virtualization layer and each virtual router is completely isolated from the others. In order to provide the management of virtual routers, the virtualization layer can include the virtual machine monitor or hypervisor function. The control framework performs the interaction between the virtual or physical router and other network entities. Control framework defines interfaces, message types including basic protocols and required functions, message flows between router and network entities.

The network entities may include networking elements such as routers, switches, and so on. It also may include logical entities such as registry for managing of LINPs, network resources, and user information. Each LINP and virtual routers are managed by resource manager that are implemented in the control framework of the physical router. The resource manager is in charge of creating and managing LINPs and virtual routers in the physical router.

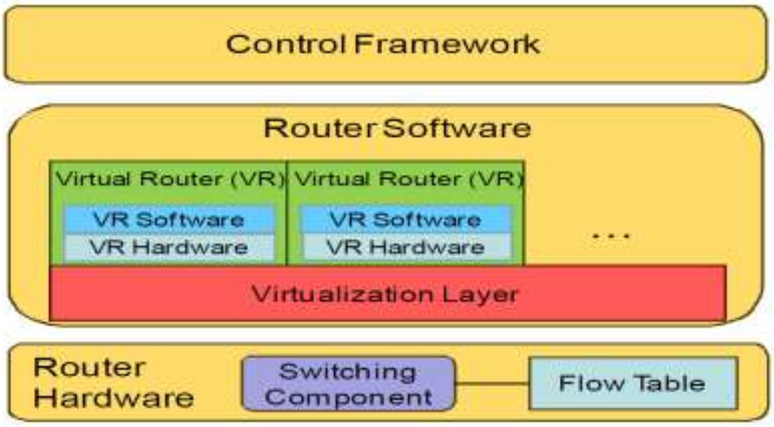

Figure 3: Functional architecture of virtualization support router

5.2 Application virtualization

Figure 4 shows an example of relation between applications and LINPs. Each application accesses the LINP to control the functionality of the LINP, such as routing. Multiple applications may access the same LINP.

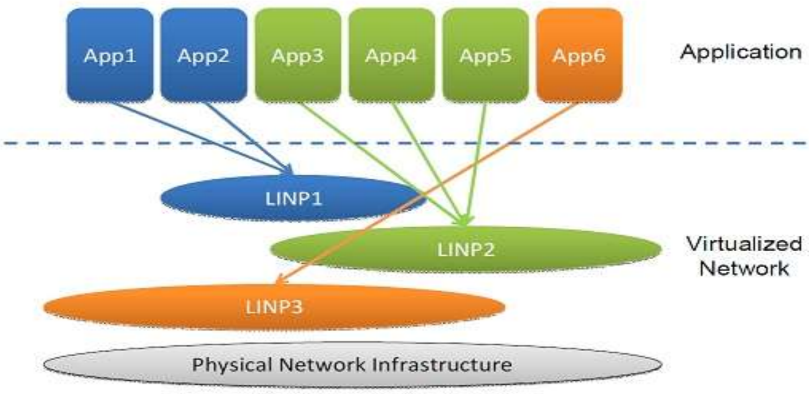

Figure 4: Relationship between application and LINP

Figure 5 shows another example of relation between applications and LINPs. Here, application platform is introduced. The task of Application platform is to receive requests from the application, to access LINP to control the functionality of the LINP, and to access virtualized network management to reconfigure LINP.

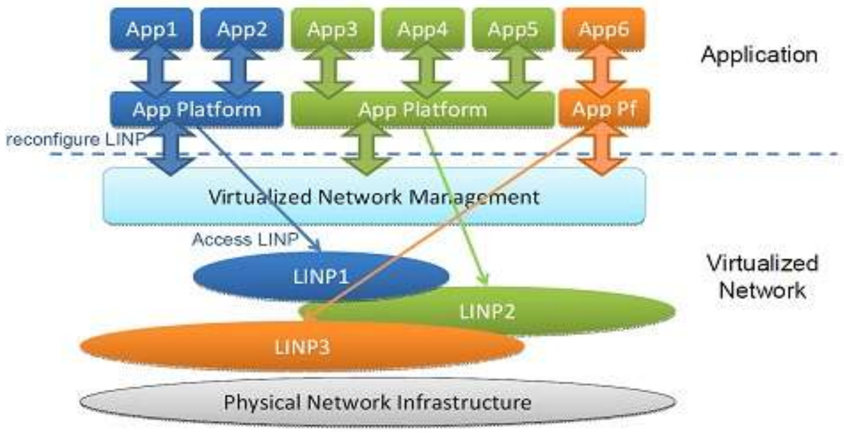

Figure 5: Relationship between application and LINP

VI. Areas of Concern

Following are some of the issues or challenges which need to be taken care of to avail the benefits of network virtualization are given below:

a) **Isolation:** Providing secure isolation among the network services is an important issue. The isolation has various aspects including performance isolation, management isolation, and so on. For example, as multiple network services coexist over shared physical infrastructures, performance problems in a service may spread out over the whole network and may cause performance degradation of other services. Hence, it is to be ensured that Network virtualization provides complete isolation of any LINP from all others, minimizes the impact of behaviour of LINPs to other networks, and supports diversity of application, service and architectures.

b) **Flexibility:** In network virtualization, users should be provided with the flexibility to use arbitrary network topology, forwarding or routing functions, and protocols.

c) **Management:** Since each virtual network is independent from other virtual networks, it has to be managed independently from other virtual networks. At the same time, the management system for the virtual network has to collaborate with the management system of physical infrastructure. It is therefore necessary to carefully define which part of management can be done by the management system of the virtual network, and how to align it with that of physical infrastructure. Moreover, if the isolation is not perfect, alignment with the management systems of other virtual networks also becomes necessary.

d) **Security:** Network virtualization should ensure that complete isolation among logical network partitions so that the failure or malfunction or security problem in one service or in one of the logical network are not spread over the other logical networks.

VII. Conclusion

Network virtualization has been accepted as a key technology for the Future Internet and has been recognized as a powerful tool that can bring significant benefits for the enterprises that deploy it. For network operators, it brings new business scenario where it can sell infrastructure to third parties, diversify infrastructure for private purposes, minimize the cost of ownership, and provide network infrastructure as a managed service. The business incentives to deploy network virtualization are clear.

However, implementation and deployment of the network virtualization needs to satisfy its requirements, characteristics and design goals such as manageability, scalability, reliability, isolation, security, etc. Although these requirements will ensure an open, flexible, and heterogeneous networking environment, but it is not so easy.

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