Network Virtualization: Isolation Problems and Scalability Issues

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1 Introduction

In today’s Internet, services are very different in their requirements on the underlying transport network. In the future, this diversity will increase and it will be more difficult to accommodate all services in a single network. A possible approach to cope with this diversity within future networks is to set up isolated networks for the different services on top of a single shared physical substrate. Network virtualization is considered as the key technology for future mobile and fixed Internet based networks supporting the establishment of such coexisting networks. Several different techniques to build virtualized network components have been proposed in recent literature [1, 2, 3]. These papers introduce virtual routers build on commodity hardware, the usage of specialized hardware components, and options separating the data path from the control plane. However, very little is known about the trade-off between isolation and performance and the scalability of these systems.

In this paper, we describe our approach to create analytical models of virtualized network components and give an outlook on which isolation and scalability problems we will address in future work.

2 Isolation of virtual networks

In order to operate virtual networks parallel to each other on the same physical substrate it has to be guaranteed that these networks are isolated, i.e., different virtual networks can not interfere with each other. In this context perfect isolation means that each virtual network is completely independent of all other networks running on the same substrate. On a single transmission medium this can be achieved by clearly separating the networks, in space, time, frequency, or code. However, if a network node is connected to different communication channels and running different parallel networks, perfect isolation might be difficult to provide. For example, Ethernet does not define a synchronization between transmitting hosts. If many virtual networks are run on the same ethernet substrate, perfect isolation can not be guaranteed, as simultaneous arriving packets for the same output port can not be handled without interference.

Figure 1: Virtual node queueing model

To save the cost of synchronizing virtualized nodes and reuse legacy systems, it is reasonable to lower the requirements and use some form of ‘weak isolation’. This means that if two parallel virtual networks demand the access to the transmission medium at the same time, statistical multiplexing is used to resolve the collision. Results by Baunach [4] in the field of CPU task sharing show that the overall performance of a system without preemptive multitasking can be improved if CPU cycles are not strictly round robin scheduled. In order to analyze the impact of different resource sharing and scheduling strategies, we propose the queueing model for a virtual network node as depicted in Figure 1. This model considers five different stages of processing a packet in a virtualized node, i.e., separation of virtual networks, pre-processing, switching, post-processing, and multiplexing. Furthermore, it contains the option of bridging physical as well as virtual interfaces. We integrated options to
model shared bottlenecks as well as processor sharing in order to analyze the performance and isolation problems of software based routers, hardware supported software routers, as well as concepts with an externalized control like OpenFlow [3]. In order to adopt the model parameters to the behavior of real systems, a performance analysis of many different virtual machine monitor implementations, including VM-Ware, Xen, KVM, OpenVZ, and Virtualbox has been performed.

3 Scalability of virtualized Networks

Careful planning and dimensioning can decrease the effects of ‘weak isolation’ on a single virtual node. However, a network is expected to comprise of many virtual nodes. Considering this, the effects of weak isolation get even harder to predict. Therefore, we need to find analytical models, which can be used to characterize the QoS, which can be achieved using a given virtualized infrastructure. An example for this is jitter estimation, as jitter is a reasonable effect of weak isolation. If we consider a network path spanning many virtualized components, at each hop the inter arrival and inter send times may differ because of statistical multiplexing. Hence, it is necessary to have an accurate jitter assessment, in order to guarantee for the maximum jitter a transmission between two nodes in this network will experience.

Another aspect, which has to be considered, is the implementation of the control plane. A network control which is completely distributed within the network might react in a different way and on a different time scale than a centralized network control. On the one hand, a local solution has the advantage that the control information is directly available and does not have to be transferred to a specific point in the network. On the other hand, a centralized solution is more aware of the global network situation and might therefore be able to solve problems caused by local overload or failure more effectively. Between these two extreme solutions many variants are reasonable. In order to deploy virtualized networks on a large scale, it is necessary to analyze the scalability of these control plane concepts and which concept fits best to scenarios like core networking, fixed and mobile access networks, and data centers. This aspect is especially interesting for systems like OpenFlow, which separate the control plane from the data plane by design. Based on the proposed queuing model we are able to simulate large virtualized networks and analyze the performance and scalability of different control implementations. OpenFlow enabled networks are of particular interest, as they are deployed in many research test beds. The question arises whether this concept is also sustainable for carrier grade networks?

4 Conclusion

Different virtual networks running separated on the same physical substrate are going to enable many use cases, which are too expensive to implement with current networks. In such a scenario, the isolation of networks is crucial. Perfect isolation is costly and therefore systems that allow parallel networks to influence each other up to a certain level have to be considered. We propose a model for a virtualized network node that enables us to assess the impact of weak isolation on a local as well as on a global scale. Based on this models and results of measurement studies, we will address scalability issues of different control plane concepts and analyze how techniques like OpenFlow can be used in carrier grade networks.

References


