Network virtualization in G-Lab COMCON

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I. Introduction

Virtualization is a current trend in all areas of computer science and especially applied to computing and storage resources. The G-Lab COMCON (COntrol and Management of COexisting Networks) project transfers this paradigm to complete networks. With its consortium composed of Nokia Siemens Networks, Docomo Euro-Labs, and Infosim, as well as the academic partners University of Stuttgart and University of Würzburg, COMCON is well prepared for this challenge. The following sections present our achievements until now.

II. Transport Network Virtualization

Due to the huge increase in bandwidth demand, future transport networks will most likely be built with optical and coarse grained TDM technologies like OTN. The isolation of two operators sharing the same physical resources is the goal of (network) virtualization. For the data plane, this can be achieved e.g. by assigning different wavelengths or timeslots to the operators. The challenge for isolation here lies clearly on the control plane. Existing approaches, e.g FlowVisor [7], mainly target experimental networks. We have developed an approach that also encompasses protocols used in large, productive networks. It is based on centralized GMPLS and includes an optional path computation element (PCE) but also supports OpenFlow.

To develop, test, and demonstrate the necessary GMPLS and OpenFlow extensions, a simulation platform has been created. Selected components were also implemented prototypically. For automated topology discovery we rely on OSPF-TE. For virtual path setup and QoS signaling an RSVP-TE implementation has been developed. The calculation of the placement of virtual paths is performed by a PCE. For setup and manipulation of virtual nodes, a direct management interface has been chosen. For the data plane of this prototype, we integrated standard Linux computers as well as a Juniper router. For the latter we developed an OpenFlow compliant software extension that provides a standardized control interface.

Apart from such core network technologies, we also considered the access network and presented concepts for data plane isolation in passive optical networks [4].

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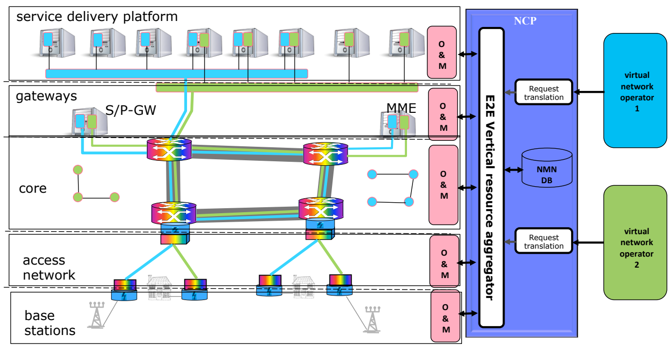

Fig. 1. The COMCON architecture applied to a mobile network.

III. Architecture and Marketplace

To be able to also virtualize a mobile network, we have evolved the COMCON virtual network reference architecture [3], [6], the result is depicted in Figure 1 [5]. While the generic reference architecture is suited for any transport network, additional network domains need to be considered if applied to the mobile network case. These domains reach from the base stations up to the service delivery platform. We are working on a step-wise introduction of virtualization technologies in these domains: 1) virtualization of the base stations, to be able to share base station hardware and sites among multiple operators, 2) virtualization of the mobile operator specific gateways that are responsible for mobility management and accounting, 3) virtualization of the service infrastructure, and 4) virtualization of the transport network, i.e. access and core network. For the virtualization of base stations and gateways, feasibility studies have been conducted. While the virtualization of the service infrastructure is still an open research topic, the isolation of operators in the transport network is most advanced as outlined in the previous section.

Besides mobile network specific extensions, we have also worked on interfaces for the case of multiple VNPs (virtual network providers) and PIPs (physical infrastructure providers). This is important if the resources for a virtual network are acquired on a marketplace and thus might span multiple, competing VNPs/PIPs. This encompasses the request of a virtual network of the VNO (virtual network operator), the comparability of different offers from competitors on the market place and the confidentiality of the PIP's network structure. These requirements are reflected in the procedures that take place during virtual network request and negotiation between VNO and VNP as well as VNP and PIP.

IV. Control and Role Interaction

Besides such economical aspects, the question how a virtual network operator can request resources and how this is controlled over the different network domains also occurs from the technical perspective. It has been answered by us with the creation of NCP, the network configuration platform. A VNO's (see Figure 1) request for resources is received by NCP which is responsible to reserve these resources. NCP acts as mediator that interacts with the operation and management systems of the different domains. With this, NCP is able to reserve a slice over the complete set of domains and is able to provide an end-to-end network slice to the virtual network operator.

To this end, the different parties have to converse about virtual networks, their components and properties in an unambiguous way. This communication has to cover the negotiation of potential virtual networks (VNs) as well as the description and reconfiguration of instantiated VNs. For this purpose, we examined existing description methodologies for virtual as well as physical networks and identified TM Forum's Shared Information Data (SID) as an appropriate candidate. For SID, we defined extensions to cover all relevant aspects and developed usage directives that allow an efficient and sound conversation on VNs.

V. Video Service and Monitoring

COMCON considers also the service perspective, i.e. the usage of virtual networks by application service providers. Such providers are interested in monitoring the network Quality-of-Service (QoS) and Quality-of-Experience (QoE) of their customers. On the one hand, they should be able to check if the virtual network provider stands to the contract and report an SLA violation if necessary. On the other hand, if the customers' QoE decreases, e.g., since too many customers are using the service, the provider may request additional resources from NCP to guarantee a certain QoE.

To be able to do this, QoE monitoring has been introduced for the example of video streaming based on the scalable video codec H.264/SVC. To this end, the impact of each frame's loss on the perceived quality is computed using an objective video quality metric. This information is distributed to the monitoring agents in the network. Thus, the agents are able to compute the QoE degradation based on lost packets and frames in real time with very low resource usage. The QoE and QoS values are reported to a control entity which either reacts by escalating an SLA violation to the neighboring layers in the architectural model or by requesting additional resources. If it is not possible to extend the resources of the virtual network slice, the service provider may optimize the usage of the available resources considering the application.

Software can be deployed on virtual routers, which enables the adaptation of the data streams in a network slice, e.g., with respect to QoE. For the video streaming service using SVC, bandwidth savings can be achieved by omitting enhancement layers. This controlled quality reduction disturbs QoE to a lesser extent than queue overflows that result in random packet losses. For this application-specific intra-slice resource management, different scheduling mechanisms have been investigated with respect to QoE influence and complexity.

VI. Demo

Based on the G-Lab-platform architecture, a selected set of the above concepts has been integrated in a demonstrator and presented in Euroview 2011 [1], [2]. It encompasses the control plane to reserve and provision virtual networks and uses video transmission via the enhanced SVC as showcase. For this project the performance management software StableNet® was enhanced for the monitoring of SVC QoE. Thus, not only can it be used to visualize the reservation of requested paths and link utilization, but also for QoE user experience. In the demo, a decision component uses the monitoring information to forward the video stream via multiple paths with differing quality.

For this years' Euroview, we have further evolved the demo to also include the negotiation phase based on a standardized network description in an extended TM Forum SID format. We also extend the scenario by including virtual machines, which are directly attached to MPLS tunnels. This demonstrates the feasibility of seamless integration of virtual hosts with virtualized links providing guaranteed QoS. The extended demonstration deployment now also includes a GMPLS-capable of-the-shelf router showing the advantage of using standardized and well-established technologies for virtualization.

VII. Conclusion

This abstract gave an overview on the G-Lab COMCON project. We discussed transport and mobile network virtualization, looked at the control architecture, presented monitoring approaches with a focus on video transmission, and outlined the demo.

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