BMBF – Project EIBONE: Efficient Integrated Backbone

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Abstract

The paper gives an overview on the activities and results of the BMBF funded project EIBONE. The consequences of broadband rollout with respect to new network architecture and requirements on transmission systems and components will be explained.

Importance of transport networks

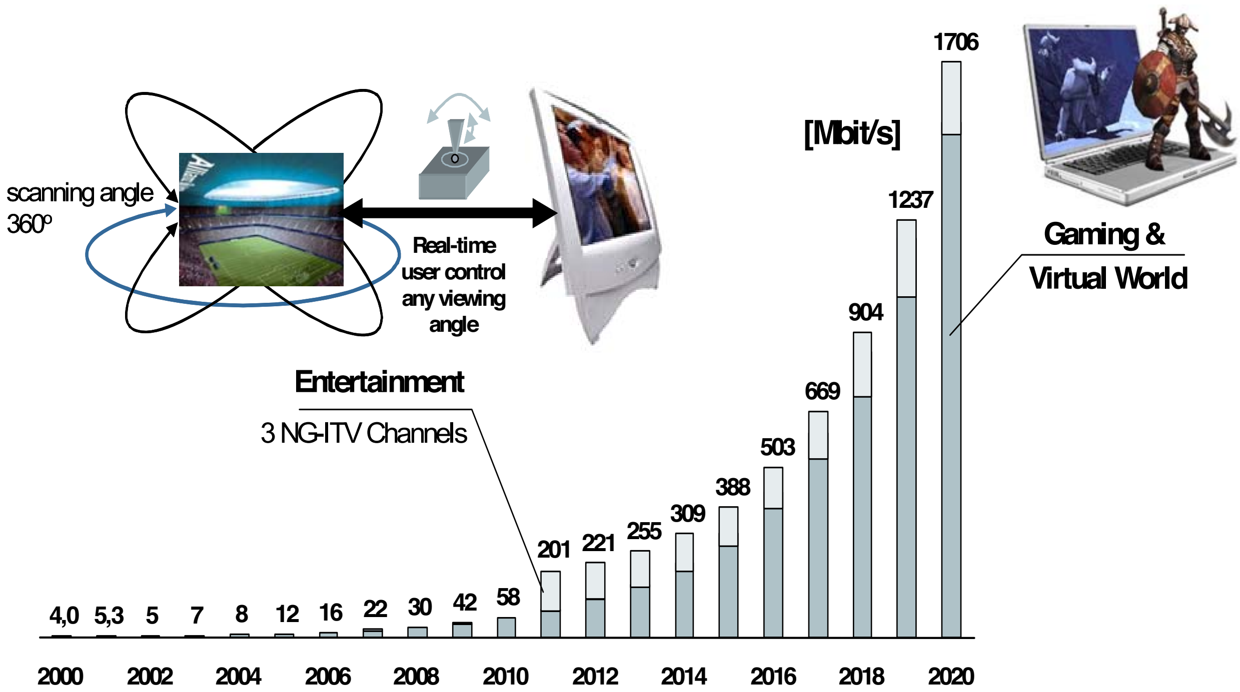

Figure 1: Evolution of end user application bandwidth demand

"Bandwidth for everybody" at school, at work and at home is a very important objective to ensure equal opportunities for everybody in an information- and communication-based society. Economy, science, and public administration require efficient and up-to-date data and communication networks. Data transport networks are the backbone of this communication infrastructure, providing the basis for services and applications in the Internet, in mobile and corporate networks. The transport network is structured according to the regional distribution and functionality in access, metro, and core networks.

Access networks cover the first mile from customers or enterprises to the network operator. In metro networks, the user or business data is aggregated and transported to gateway nodes. The core network builds the national or international data highways, similar to interstate highways. The doubling of data traffic every one or maximal two years presents a continuous challenge for the building and evolution of a cost-efficient transport network. This growth is supported by the deployment of fast optical access networks for residential customers as well as Virtual Private Networks (VPN) for business customers. For example, the broadband internet access speed of home users grew from 768 kbit/s to 16 Mbit/s in the last few years, and is aiming for speeds even higher than 100 Mbit/s using fiber access. This growth in data traffic has to be mirrored by the transport network.

Fuelled by growing access bandwidths, innovative end-user applications with high data volumes are emerging. These new applications like video sharing (e.g. YouTube) and peer-to-peer (P2P) sharing of large files depend on the deployment of high-speed access, metro, and backbone networks. In the area of the required transmission and networking technology, the German communication industry has a leading role in the international competition.

Data transport networks provide a critical infrastructure to all government and business segments. Many critical services are carried over transport networks with particularly high security requirements. An outage of the transport network would have a severe impact on our economy and our society. Therefore, efficient and robust resilience mechanisms must be used, which are able to cope with outage scenarios like large-scale power outages or terrorist attacks.

The BMBF – funded research project developed solutions for Backbone and Aggregation networks which can fulfil the demands of higher bandwidth, higher reliability and efficiency. EIBONE concentrated on network technologies, most importantly

- Carrier Ethernet
- Optical Transport Network (OTN) comprising SDH/SONET
- Wavelength Division Multiplexing (WDM) functionalities arranged in multi-layer architectures
- Questions of network optimization and operation.

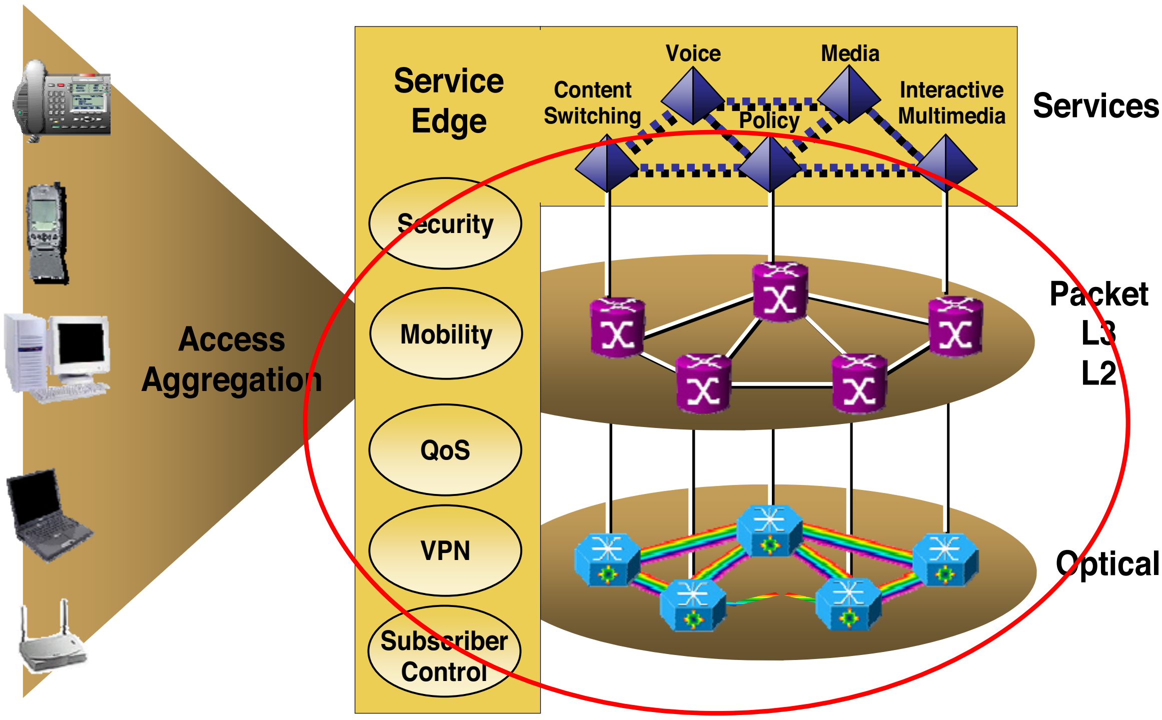

Figure 2*:* Technical focus of EIBONE

From a technological point of view, multi-layer transport networks with an integrated control can flexibly realize the different requirements and applications. On the one hand the multi-layer technology can offer different network services and may replace the “Internet Protocol” router technology within the network, which is then shifted towards the end user. On the other hand the integrated control offers an eased network operation. This requires the seamless integration of the service providers’ processes with the IT infrastructure for network management and operation. Key challenges are the cost-efficient design, planning, and operation of the multiple technologies in such multi-layer networks.

Evolution of data transport networks

The technological progress of transport network technologies in the past 15 years was characterized by a dramatic decrease in the cost of data transport, allowing Internet technologies to penetrate into many areas of life. Transport technologies establish the basis for all wireline and wireless services, also enabling cost-efficient mobile services to be available for the mass market. The essential network technologies in this context are the Internet Protocol (IP) for all Internet-based services, ISDN and GSM for voice services as well as SDH in combination with WDM for broadband transport.

Carriers worldwide strive to make high bandwidth available to the end customer. At the time of writing, significant investments are made in novel broadband access technologies. An example from Germany is the Very High-Speed Digital Subscriber Line (VDSL) technology deployed by Deutsche Telekom, which in a first step allows bit rates up to 50 Mbit/s in selected German cities. In the U.S. and Ja-

pan, competition is already based on fiber-based access solutions to the end customer (fiber to the home, FTTH). In a next step, broadband mobile services will be made available, requiring seamless interworking between wireline and wireless services (fixed mobile convergence, FMC).
High bandwidth in the access network and the convergence of network technologies will lead to a single network platform on which all services are provided. This development allows the provisioning of novel service bundles to the customers, e.g. the “multiple play“ of telephony, data, TV/video, and mobile applications using a single access line. A number of technical challenges arise from the combination of novel technologies, novel applications, and the change of user behavior. In the future, the requirements of three primary user groups have to be met:

- Residential customers will be offered a broad range of individual or bundled services, which are mainly in the areas of telephony, TV/Video and classic Internet. The broadband roll-out to residential customers will provide them with amounts of bandwidths previously available only to business customers. This implies that it will be used by the customer for yet unknown services, which impose new requirements onto the network. Examples are distributed storage systems and video platforms such as YouTube.
- Business customers: The classic leased line will disappear, which for many years provided business customers with point-to-point services. Especially low bit rate services (up to 34 Mbit/s) are envisaged to migrate to packet-oriented technologies such as IP and Ethernet, mostly using L3 and L2 virtual private network (VPN) services. Up-to-date solutions have to be less complex and less fragmented, providing intranet and extranet connections and support of mission-critical applications. Substituting technologies are expected to meet the same standards in terms of availability, protection and latency as classic leased-line services.
- Wholesale products will account for significant portions of the revenue for many tier-1 carriers, either through marketing or enforced through regulation. Such products will be produced on layers 1-3 with defined parameters regarding bandwidth and service levels.

Advances in mobile transmission standards (3G+, WLAN, UMTS, WIMAX) allow triple play content over wireless networks. The combination of multimedia content delivery with the wireless access option led to the terms of multiple or quadruple play. However, future wireline transport networks have to provide the required infrastructure to support new bandwidth-hungry mobile applications, i. e. high capacity interconnection of base stations.
Complementing the EIBONE activities on metro and core transport networks, the research project ScaleNet, also supported by the Federal Ministry of Research and Education, studies converged access network infrastructures and hierarchical broadband access networks, aiming for the scaleable and converged multi-access operator's network from tomorrow. ScaleNet focuses on the development of concepts for cost-effective, scalable, efficient and flexible integration of different wired and wireless access network technologies.
There exist a number of technological developments on layers 1-3 for the implementation of the different requirements in future networks, which allow novel solutions to problems in networking.

- IP: Next generation networks (NGN) will predominantly use the Internet Protocol (IP) suite of protocols for interfacing customers and provisioning of services, e.g. for VoIP or IPTV services. The continuation of the current architectural concepts requires the use of routers with throughputs up to several Tbit/s in the core. Such routers are interconnected using optical technologies. Specialized routers are located at the edge of the network for tasks such as video and TV signal distribution, SIP servers for VoIP and access control (AAA). The mere continuation of upscaling the IP network leads to an increased demand of IP routers with high throughput and specialized functionalities. Although such solutions seem technically feasible, it will challenge the overall router performance in terms of line card functionality, switching matrices, and power consumption/heat dissipation.
- Ethernet/L2 technologies: Originally designed for local area networks (LAN), now Carrier Ethernet is being discussed in increasingly larger networks on metro, national and global network scales (Metro Ethernet Forum, MEF). This development was made possible through significant efforts in standardization, pushing Ethernet technologies way beyond conventional LANs. Although the actual adherence to carrier-grade Ethernet - standards still needs to be proven in the field, Ethernet could bypass (on layer 2) a number of the IP-related problems stated above. In any case new interface rates (100Gbit/s), the new OAM and service specifications and the introduction of new virtualization techniques (Provider Bridges (PB) and Provider Backbone Bridges (PBB)) of Ethernet open the door fore wide applications of Ethernet in carrier networks. Besides the technical advantages, an important feature of Ethernet-related technologies is the possibility to address markets currently served by vendors of IP-equipment. U.S. based companies have traditionally been the market leaders for IP-equipment. Hence it would be of high strategic importance for European and German vendors to further develop carrier-grade layer 2 technologies in close cooperation with IP and transport functionalities.

- OTN- optical technologies: Progress in optical transmission techniques was a pre-requisite for the Internet boom since they led to a dramatic decrease in the cost per transmitted bit. The bandwidth available on optical fibers is used by layer-1 technologies such as SDH and SONET, with bit rates up to 40 Gbit/s. In the future the transport network evolution will migrate from SDH/SONET to the Optical Transport Network (OTN) developed by the International Telecommunication Union (ITU-T). OTN comprises an optical transport hierarchy (OTH), offering connectivity at bit rates of 2.5, 10, and 40 Gbit/s. Hence OTN becomes a key building block for provisioning transport capacity of all higher layers. A potential contender to OTN technology could be the development of 100 Gigabit Ethernet into a fully-blown transport technology.

- Last but not least, the key enabler of transport networks is the optical transmission technology and optically supported network configuration technology, i.e. optical add drop multiplexors (OADM) and optical cross connects (OXC). Optical technology was a strong enabler of the success of the internet in the last 15 years, because optical transmission enabled an extremely efficient transport of steadily growing, ultra high bandwidth at very low costs (Figure 3). Prices for network transport equipment and services have declined continuously [1] in the last decades. However this development is not fished yet. New modulation schemes and a drastic improvement of high speed electronics will enable very robust transmission over long distances at high data rates in the next years. EIBONE partners have investigated various new transmission formats with respect to impairment compensation, transmission distance and spectral information efficiency (for example [4],[5],[6]). Secondly, we can observe a remarkable progress in the field of optical switching technologies, like reconfigurable optical add drop multiplexor (ROADM) and optical cross-connectors. ROADM have been deployed in regional and metro networks, manly to overcome capacity and fibre limitations for broadband access and mobile backhaul.

A lot of new optical and electrical high-speed components are necessary to enable efficient transmission systems. To realize 100Gbit/s per optical wavelength, well developed modulators, receivers and electronic components are required. EIBONE has substantially contributed to the progress in the area of components. Especially new receiver modules and modulator have been developed. (Figure 4)

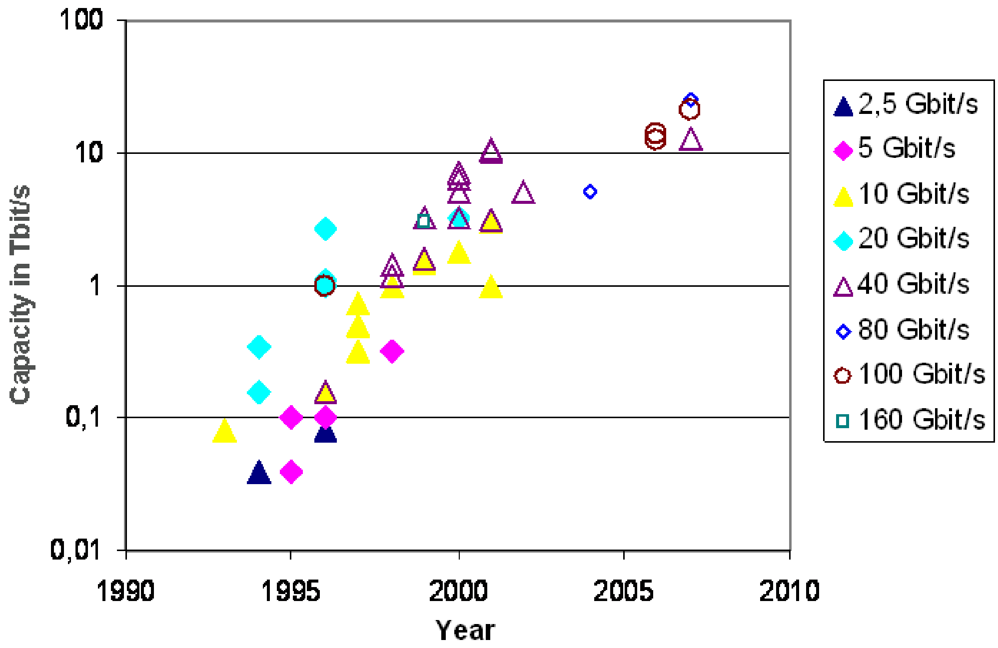

Figure 3: Total capacity per fiber of optical transmission experiments and data rates per channel

Summary

In summary, the evolution of transport networks will continue and provide carriers in the coming years with a number of alternative solutions to improve network operations, minimize cost and maximize revenue. This development is fuelled by the massive broadband roll-out in the access, as well as by the convergence of services for residential and business customers. The requirements in terms of reliability and scalability of such network architectures will be important design goals. It can be anticipated that there will

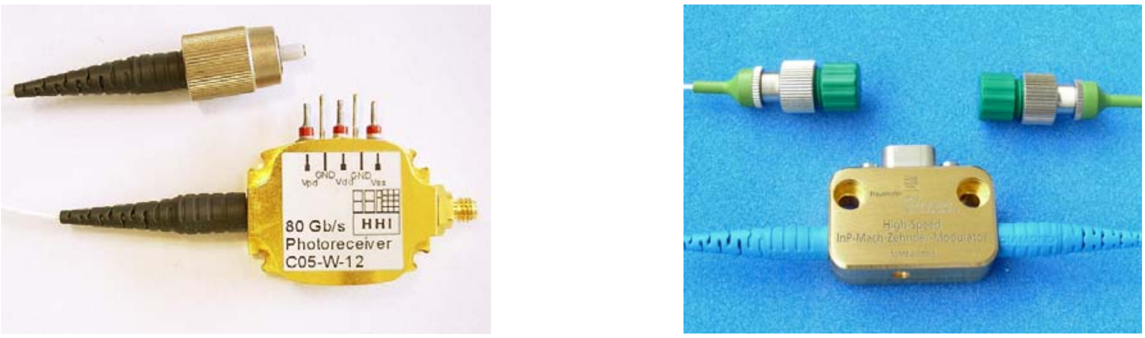

Figure 4: Components: Left A photograph of a pig-tailed OEIC 80 Gbit/s receiver module with 1mm RF output Right: 43 Gbit/s MZI-Modulator module with GPPO RF connector

not be a unique solution applicable to all network operators.

The solution currently being deployed will always be optimized to reflect the particular needs and carrier-specific boundary conditions (technical and economical). Whilst IP will provide essential address, routing and interfacing functionality, novel L2 and L1 technologies allow for alternatives to a pure IP backbone. The activities within the framework of the project EIBONE have bundled the activities of industry, universities and research institutes, and are providing a significant contribution in the short- and mid-term for the research and further development of transport network.

Upcoming new applications and subsystems, based on the Internet Protocol (IP) and IP Multimedia Subsystem (IMS), are driving the annual traffic growth at rates of 50-100%, in particular the wireline IP traffic in the metro and core transport networks. This emphasizes the importance of evolving transport networks towards a flexible, reliable and Quality-of-Service (QoS) supporting infrastructure fulfilling the requirements of IP based services, whilst also meeting tight cost and performance targets. The evolution starts from two different platforms: Existing synchronous, circuit-switched Synchronous Digital Hierarchy/ Synchronous Optical Network (SDH/SONET) networks on the one hand which are lacking the flexibility to handle efficiently packet based traffic and its highly dynamic traffic demands although offering high reliability and quality. On the other hand, packet-centric IP backbone networks which are well-suited for the dynamic IP traffic, but which face scalability issues and technology limitations due to the high complexity of the router hardware and protocols, and also provide reliability and quality only to a certain degree.

Various technical solutions for future multi-layer (layer 1 – 3) transport networks with an integrated control are studied in the German research framework EIBONE to provide an efficient, cost effective and automated infrastructure with optimized CAPEX (capital expenditure) and OPEX (operational expenditure). The studies are focussing on multi-layer architectures for core and metro networks. This includes considering new layer 2 packet transport concepts as a converged approach providing switching and forwarding of packets or frames and including layer 2 transport services as efficient solutions to the aforementioned challenges.

The control of these new multi-layer networks will make use of specific protocols like GMPLS (Generalized Multi-Protocol Label Switching) integrating all three lower network layers into a single control instance for automated, optimized usage of resources and for provisioning of end-to-end QoS in a multi-domain, multi-operator, and multi-layer environment. The architectural work in EIBONE is accompanied and supported by analysis and modelling of services and traffic profiles as well as architectural options to enable planning, dimensioning, and optimization of transport network solutions and to stimulate techno-economic studies in terms of performance and cost. Feasibility and implementation studies are investigating technological and functional options and will also provide lab demonstrations of selected node functions and its control.

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