

09072 Executive Summary

Bandwidth on Demand

— Dagstuhl Seminar —

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Abstract. This paper is the executive summary of the Dagstuhl Seminar 09072 “Bandwidth on Demand” which was held from February 8-11, 2009, in Schloss Dagstuhl – Leibniz Center for Informatics.

Keywords. Bandwidth on demand, bandwidth provisioning, bandwidth trading, network economics, resource allocation, network virtualization, wireless mesh networks, peer-to-peer networks, business modeling, telecommunications, market mechanisms, regulation, legislation

Motivation

The rapid technological progress in the area of network virtualization, mainly driven by new optical fiber technology and virtual router infrastructures, is generating a new trend for “on demand” provisioning of bandwidth or even whole networks for applications that require short-term bandwidth assignments at large scale, such as large sporting events or cultural open air activities. Network virtualization, in addition to numerous benefits that it offers in terms of security, flexibility, and reliability, enables the transparent sharing of physical network equipment between different customers of the same network provider. The current trend is backed by new optical network management systems which enable the provisioning of end-to-end light-paths across multiple independent optical network domains.

At the same time, the proliferation of wireless technology has enabled users “to be connected” anytime and anywhere in the world. What’s more, wireless devices allow users to offer network connectivity to each other, *e.g.* via mobile ad-hoc networks or neighborhood wireless mesh networks. The support of bandwidth allocation in a fully decentralized manner, such as based on emerging peer-to-peer (P2P) concepts, shows further advantages in terms of robustness and scalability for large-scale systems.

Despite (or due to) these recent technical advances, the provisioning of the right amount of bandwidth at the right location and at the right time remains a challenge. Suitable business models for “on demand” bandwidth services have not yet evolved. Moreover, the design of resource allocation policies and incentive

mechanisms for cooperation in this context are very challenging and interesting research questions. Resource allocation mechanisms should aim, ideally, to maximize the overall social welfare of the system. However, participants may not have the incentive to disclose truthfully their private information. Auctions are a standard way to achieve such objectives, but the distributed environment and the different types of resources involved poses significant challenges on their design and implementation.

Wireless technology enables interesting new business models such as FON and Boingo. However, suitable incentive mechanisms are required for such systems to operate efficiently and avoid free riding and other types of undesirable behavior in terms of resource sharing and the overall distributed management of the system, which depends on the cooperation and resource contributions of all participants. These incentive issues reduce the overall value that could be generated thanks to the positive externalities that appear in P2P systems. It is of interest to study the potentials and limits of P2P bandwidth sharing systems and understand to what extent they could harm the ISP business. In addition, legislative and regulative issues related to these concepts have to be tackled.

Therefore, the purpose of this Dagstuhl Seminar on “Bandwidth on Demand” was to bring together researchers and practitioners from different disciplines to discuss and develop partially technical, economic, and regulatory mechanisms for the provisioning of bandwidth on demand services. The key topics tackled by this seminar included but were not limited to:

- The technical design of scalable, robust, and cost-effective bandwidth allocation and provisioning schemes, including fully decentralized and market-based mechanisms such as auctions
- Economic studies and modeling of market and business models in carrier and service provider networks, including cost and revenue models as well as game theoretical bandwidth on demand models
- Resource allocation and provision in non-profit systems such as neighborhood wireless mesh networks and network testbed infrastructures like GENI or PlanetLab
- Industrial developments of new technologies that facilitate or create impediments to bandwidth on demand, including network virtualization technologies and wireless mesh networks
- Legislative and regulatory issues related to the Telecom Act and in comparison to other commodities markets such as the electric grid, as well as legal issues of P2P trading infrastructures

Programme – Day 1

The three-day seminar started with two keynote sessions. In the first session on “Technologies and Bandwidth Provisioning”, Shigeo Urushidani gave a presentation on “Resource Allocation and Provision for BoD” which provided an

overview on the support of bandwidth-on-demand in the SINET3 network in Japan. In his talk, Shigeo presented some interesting figures about their BoD service, *e.g.*, they have a setup time of 5 minutes and a minimal duration of 15 minutes. The talk was followed by a presentation of Aiko Pras on “Management of Lambda-Connections in Optical Networks”. Aiko predicted that there will be plenty of bandwidth available in the future and questioned whether there would be a demand for bandwidth at all. He argued that users demand applications and, therefore, are only willing to pay for the application, not for bandwidth.

The second keynote session then looked into “Economic and Legal Studies, and Business Models”. In this session, Panayotis Antoniadis gave a talk on “Resource Allocation and Provision in Non-profit Networks” in which he analysed different federation policies among networking testbeds like PlanetLab. Following this talk, Jochen Dinger addressed the legal aspects of BoD. In his presentation on “Techno-Legal Bandwidth on Demand Perspectives” he addressed the issue of network neutrality, and raised the question whether there are any rules needed.

After the keynote sessions, the seminar continued with four brief statements of participants. First, Georg Carle gave a short talk on “Multihoming in Heterogeneous Wireless Access Networks”, followed by a presentation of George Huitema on “Energy on Demand: Learning from the telecoms world”. George argued that ICT is now widely applied in telecoms, however, only little has been done related to ICT in the context of energy. Isabelle Hamchaoui in her talk on “Bandwidth on Demand: an ISP Point of View” then claimed that Bandwidth-on-Demand is not necessary, since VPNs (virtual private networks) without reserved bandwidth would be sufficient in practice. Customers search for QoE (Quality-of-Experience), and the bandwidth is only one factor in that, which is typically overlooked. Finally, Zoran Despotovic asked about the “Value of Decentralized Reputation Management for BoD”.

The brief statement session was followed by a brainstorming on BoD topics of interest. The collected topics were classified along the categories: (1) Wireless BoD / mesh networks; (2) Peer-to-Peer BoD, measurements; (3) BoD applications, BoD versus bandwidth no demand; (4) Legal issues, environmental and social/regulatory aspects; and (5) Economic mechanisms, service aspects, and resource management. Those categories were further combined in three topics which were finally used to form the working groups.

Programme – Day 2

The next day, the seminar started with another brief statement session. Burkhard Stiller opened the floor with a presentation on “RoD, BoD, CoD, ..., PoD, SoD, ... And XoD”. He argued that naming the problem is important. A generalization of mechanisms may be possible, but we have to make sure to focus on problems which exist. Athanassios Androutsos went on with a talk on “Bandwidth Externalities & QoS Growth: A Long-run Economic Approach”. He

presented a model to explain the source of QoS and bandwidth growth and concluded that an increase of bandwidth per capita will increase the rate of QoS growth.

Christian Hoene then presented a position statement on “Buying Bandwidth only if you need it”. He claimed that BoD systems need a performance metric and mechanisms to automatically negotiate the legal terms of a BoD contract. Moreover, the transaction costs must be low for a BoD system to be successful. His talk was followed by a presentation on “Network virtualization providing Bandwidth on Demand” by Martina Zitterbart, discussing the technological impact of network virtualization in the BoD context.

Martin Waldburger, in his talk on “Bandwidth on Demand Contract(s)”, showed that a BoD contract can be highly complex. He concluded that the risk assessment for such contracts will be very challenging. Fernando Beltran went on with a talk on the “Analysis of aggregation strategies in BoD markets”, in which he identified problems that users and sellers would face in such markets. He was followed by David Hausheer who argued for “Virtual Networks on Demand”. Bandwidth is only one parameter among other important ones, like delay and jitter. What customers want is end-to-end connectivity. At the same time, virtualization enables the sharing of network equipment among several customers and improves the efficiency. The session was concluded by Torsten Braun with a talk on “QoS Support for Overlay Multicast”. He found that different applications have different needs of bandwidth on demand. But many of those could be supported with appropriate QoS extensions for overlay multicast.

After lunch, a third session with brief statements was held. Hannes Hartenstein introduced the session with a talk on “Two Challenges: Wireless and As-a-service”. He claimed that BoD in wireless vehicular communication is a serious research issue for the next 10 years. Adrian Farrel followed with a statement on “Convergence without Conflation - IETF Perspectives”. He identified common misconceptions in network provisioning, and presented the requirements which were defined in the IETF. The talk concluded with a presentation of a solution toolkit for bandwidth on demand. It was followed by a talk on “Self-managed inter-domain pricing: a discussion of possible approaches” by Bruno Tuffin, discussing relevant properties of inter-domain pricing mechanism.

Finally, Peter Reichl, in his statement on “The User Knows Best: A QoX-based View on *oD”, asked what BoD really means for the end user. It can only mean Quality-of-Service, which has evolved into the term Quality-of-Experience (QoE, QoX) recently. Thus, QoX-on-Demand (QoD) is what the user is really caring about. The session was concluded by Giancarlo Ruffo with a talk on “Privacy on Demand: A Difficult Challenge in a Highly Connected World”, arguing for privacy in the BoD context.

The day continued in the afternoon with an external visit to the museum of ceramics of Villeroy & Boch in Mettlach and ended with a visit and dinner at the abbey brewery in the same village. People report that the brewery gave a totally new meaning to the term “BoD”.

Programme – Day 3

The last day started with the presentation of results from the different working groups. The first working group on “BoD Applications and BoD versus Bandwidth *no* Demand” was attended by Adrian Farrel, Hannes Hartenstein, Aiko Pras, Burkhard Stiller, Shigeo Urushidani, and Martina Zitterbart. They questioned which applications and customers BoD would be good for and what time-scales “on-demand” would refer to. The group found that end-to-end connectivity supported by ISP-to-ISP relationships would be the core application area. Moreover the economic, technological, and privacy aspects of a BoD service were analysed. The group concluded that the provision of bandwidth on demand is a chicken and egg problem, therefore, the problem is not a technical one. BoD will be a business advantage, but it is not clear yet when the right time for it will come.

The second working group focussed on “Economic Mechanisms, Service Aspects, and Resource Management” and was formed by Athannasios Androutsos, Panayotis Antoniadis, Fernando Beltran, Georg Carle, Zoran Despotovic, Isabelle Hamchaoui, George Huitema, Peter Reichl, and Bruno Tuffin. They discussed different BoD scenarios including user-to-ISP and ISP-to-ISP and analysed main economic problems such as resource allocation and interconnection policies. The group questioned whether BoD is really a new concept or just an updated interest on network economics with a new keyword.

Finally, the third working group dealt with “Legal, Social, Ecological, ... Issues” and was composed of Jochen Dinger, Martin Waldburger, Torsten Braun, David Hausheer, Giancarlo Ruffo, and Christian Hoene. They first discussed who would be the user of a BoD service and concluded that it would be the end-user since the access link is the bottleneck, while bandwidth would not be an issue in the backbone. The discussion went on about service level agreements (SLA) for BoD, including SLA monitoring tools as well as respective regulations. A key question addressed was the number of BoD providers a user would face: One for all, a separate one for multimedia content, or one for each application? The group concluded that one bandwidth share for each application would be the best solution in terms of simplicity, responsibility, and efficiency.

The working group feedback session ended with an ad hoc presentation by Christian Hoene on the idea of a “Bandwidth Station”, in which he showed the similarities and differences of a bandwidth station with a gasoline station.

Discussion and Conclusions

A closing discussion was held at the end of the seminar to draw conclusions. The discussion was opened by Fernando Beltran. He thought that Bandwidth on Demand becomes more feasible in wireless than in wired areas, because of the uncertainties in mobility, since users are generators of unpredictable service demand. But he argued that an agreement on standards would be needed. In

the future he envisions that agents may be working for us, *e.g.*, driving around looking for the best service.

Peter Reichl enjoyed that the topic brings together different aspects. But he asked what “on demand” would really mean. He argued that BoD will not differ so much between fixed and wireless networks, since the key difference is between user-to-ISP and ISP-to-ISP relationships. Later on, Martin Waldburger opposed that the most important question is whether we address consumers or businesses. The Kindle example shows that making it work is the way to go.

Aiko Pras found that BoD is similar to a water-pipe, but end customers are not interested in capacity, they are interested in data. With optical networks there is the possibility to provide bandwidth on demand, but we should look mainly at big customers. Torsten Braun agreed that users request for service on demand. Therefore, it is more important to focus on services than on bandwidth, and network providers must care how these services can be provided. However, the future importance of virtual networks is unclear.

Athanasios Androutsos believes that bandwidth is an important input to the QoS provisioning process. However, appropriate pricing models are needed to allocate bandwidth in an efficient manner. For example, long-term bandwidth provisioning could reach a cheaper price. Architectural frameworks should be considered to enforce a certain pricing model, but enforcing mechanisms are needed in order to support Self-* and dynamic SLA provisioning. Shigeo Urushidani added that we need more user experience. Without it could be difficult to improve network provisioning. The critical mass of users that use BoD service has to be increased and they are only willing to pay, if they get addicted. However, Burkhard Stiller was concerned that a viable business model may not be achieved. It could be applicable to services, resources, and bandwidth, but protocols may be different. The key is to standardize the BoD interface.

Panayotis Antoniadis had the impression that the BoD discussion is about the future of the Internet, *i.e.* we try to predict the scenario of the future. But it is unclear to what extent there will be scarcity, therefore, we don't know the type of problem. Bruno Tuffin added that it is clear now that it is not clear what BoD is. But he observed that much more tools are available for the user-to-ISP than for ISP-to-ISP relationship. Isabelle Hamchaoui initially thought that academic people were happy about BoD. She emphasised that BoD is not a main issue for the customer, but it is important for the ISP-to-ISP relation and, thus, there is a need for new solutions in the inter-domain context. She was surprised to see discussion about signalling protocols like GMPLS and new things like energy networks, which shows that academic people are open to operator problems. George Huitema replied that energy on demand is different compared to bandwidth on demand for telcos. In the energy sector it is more interesting to look at the user to energy provider interaction.

Adrian Farrel thought initially that BoD is applied down in the network. But he is now convinced that we should have Qo*, and part of this is Quality of Business. The relation between Qo* and *oD is important. The users know best what they mean by Qo*, but they don't understand *oD. Hopefully, this can be

parameterized. Giancarlo Ruffo believes that the problems can be solved with a layered architecture, rather than with peering. But contracts between ISPs and national governments are necessary. Consumers are at the end of the value chain and cannot be cut off, since they are part of the long-tail that contribute to the service. In that respect, he still sees many problems at different levels.

In summary, the seminar was very successful. With 25 attendees it did lead to many fruitful discussions and scientific exchange. Figure 1 shows the participants of the seminar in front of the Dagstuhl library. A future BoD workshop is planned to be organized again in colocation with a large conference.



Fig. 1. Participants of the Dagstuhl Seminar on Bandwidth on Demand

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