Grand Challenges in Network Research 27.8.2010

In layman's thinking, the Internet has won, it will take care of all communications services of the future and all we need is more capacity and some lightweight engineering. When one takes a more careful look at the matter, it turns out that networks are crying for new solutions and that instead of more "all-IP" songs we need groundbreaking fundamental research.

There are several long term drivers of change for the technology. The basic components used to build new network devices are digital and they use the semiconductor technology that is available at the time of design. (1) The development of semiconductor technology follows that Moore's law starting from 1960's and the trend is expected to continue for many years to come. This has opened and continues to open huge opportunities that we can exploit in networking technology. (2) While the technology capabilities have grown, software implementation of new functionality has continued to grow in importance. Software makes products flexible, i.e. it makes products capable of meeting new, even unforeseen, user needs. (3) Improved network capability has led to deepening penetration of networks and network based services into our lives and the business life. An ever broader set of users and user needs means new requirements for the networks to be met. What are then the grand challenges the fundamental research needs to address now?

As the bandwidth and throughput of networks have grown, power consumption of the network devices has become an issue. Researchers have estimated that if the Internet traffic volume in Japan continues to grow on its current trend and the demand is met using the present router technology, in 2020 the routers in Japan will use as much electrical energy as the whole of Japan in 2005. At the same time we are expected to cut CO_2 emissions, not increase them. Improvements of the technology are possible but the physical limit comes with the minimum voltage needed by a single transistor. Although we may be able to build the devices for transferring 100 –times more traffic than today, we cannot afford to use the devices. More generally, the basic operation in the network nodes is switching or forwarding. Switching may take place optically or electronically. It depends of the protocol stack how much processing and thus how much energy are consumed for switching one unit of data. The higher in the protocol stack switching takes place, the more energy is consumed. When the Internet architecture has deteriorated more and more, switching has tended to move up in the stack: more and more often even the application layer needs to get involved in the decision what to do with the packet at hand before the packet is pushed through the stack again to the next hop. Conversely, the lower level switching can be used the less energy is needed. We can reformulate the problem more positively as a challenge: let us target carbon free networking.

Over the past few years, wireless broadband has started to grow globally very rapidly. The wireless broadband subscriptions have already surpassed the number of fixed broadband subscriptions. With the available cellular mobile broadband technology it is profitable to build networks to cover the developed countries and large cities in the emerging markets. We can conservatively expect that the number of Internet users will grow by a Billion from the present 1.8B in a few years. This growth will require ever improved access technology. Efficient and robust wireless communication is very challenging. Wireless grows not only because of affordability, it is also user friendly: the operator takes care of all network devices and everything the user needs can be integrated in the mobile device or mobile computer. The challenge in mobile broadband is heavy protocol stacks and high access delay. Both in access and end-to-end, high delay destroys performance. So, as the bandwidth of networks grows, new structures are needed in order to make the capacity usable by the end users. Let us set the target that the network should respond so rapidly that the user does not perceive any network delay.

The third grand challenge is that we own an ever larger number of gadgets that we would like to connect to a network. This requires more addresses. The official solution is IPv6 with its 16 octet long addresses. In this column I have said that at least I do not need the 50 000 quadtrillion addresses for my own use that in principle IPv6 can offer. We want to hide from the world most (>90%) of the few hundred or thousand connected devices that we may possibly own on average sometime in the future. We want to restrict their direct use to ourselves, members of the family and possible agents we trust and contract to look after some aspect of our household or business. Because of ease of deployment and use, most of these devices are likely to wireless. IPv6 is a wrong solution to this need.

Thinking about those challenges, it looks as if we need to re-design the whole architecture of data networks and re-invent many fundamental algorithms that form the basis of the networks that we use today. We should target a network that can meet growing user needs in a sustainable and cost-efficient manner. It should be possible to deploy the new technology smoothly. How does the Finnish or European research funding respond to this need for fundamental research? Unfortunately, very poorly. Almost all public funding is targeting short term gains that are achievable tomorrow. Neither is European networking industry eager to give support to research in areas where it is used to looking into California for solutions. Light seems to rise from Asia. There operators and vendors are ready to try new solutions. It is high time to wake-up in Europe.