Internet Protocol – Perspectives on consequences and benefits by introducing IP

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The Internet Protocol (IP) has been subject to an overwhelming interest during the last decade or so. One may raise the question of why this has been the case. Broadly, the answer can be that IP represents a shift in the philosophy of telecom business besides being a fairly easy and widespread protocol. This article makes some reflections on issues related to IP development – mostly based on technical aspects, but also linking these to a broader business perspective.

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1 Introduction

The Internet Protocol (IP) has been around for several decades, formally managed by IETF (Internet Engineering Task Force). Just 10–15 years ago the commercial interest for this protocol emerged from the telecom provider's side. Several factors took place to support such a development: i) the volume of IP implementations in different terminal equipment (PCs and host computers); ii) the development of web browser applications providing an intuitive user interface for accessing information; iii) email applications taking the step into the residential sphere; iv) gradual deployment of the IP suite in other terminals than computers; v) a growing political and commercial interest for broadband service offerings. Naturally, other factors also contributed in different regions. Overall, it seems too simple to claim that a single event or factor resulted in the huge interest for IP-based services. Therefore, one may wonder whether it was the *open arena* for discussing IP-related work progress provided by IETF, the range of *deficiencies* seen for the IP suite, or the growing commercial interest – and potential *return on effort*, that inspired this huge effort. Possibly the actual explanation is a combination of all these as well as a few others.

Making a distinction between IP as a protocol and the "Internet movement" is essential. Principally, IP is just a protocol defining a set of header fields and capabilities. However, no Internet offering is seen without the presence of IP. Hence, IP and Internet are these days considered to go hand-in-hand. On the other hand, IP-based networks are also implemented that do not allow for public traffic. Examples are enterprise-internal networks, e.g. within and between enterprise sites. Networks for management activities are also regularly realised by IP.

For a future-looking strategy one has to be open for the introduction of other protocols – complementing and/or replacing the IP suite. Although during the last years several other candidates have been promoted for different areas, the IP suite now seems to be the undisputable winner at the network layer. In fact, as its sheer volume and momentum grows the challenge grows for alternative solutions to take over that position.

Objectives of this article are to place the IP deployment into a commercial context and to outline trends and potential benefits. Some technical aspects will be treated as well, as the commercial opportunities follow from the technical possibilities.

As several papers have described the IP history the following chapter will rather briefly outline some of the events. The intention is to provide a basis for further descriptions in subsequent sections. Chapter 3 gives an outline of the IP suite, giving a general overview of protocols and mechanisms related to IP and found in IP-based networks. Then, current trends for implementing IP-based networks are described in Chapter 4, together with drivers and consequences as seen today. No perspective article would be complete without reflections on what is next to come. This is the topic of Chapter 5; both discussing next steps related to the IP suite and issues that may ask for radical changes or even replacement of IP. An efficient operation of networks and systems requires that past, current and future(s) are linked in a smooth manner. This is treated in Chapter 6, also giving concluding remarks.

2 Take a look over your shoulder – reflecting on the past

2.1 IP key characteristics

Returning to the conception of IP, one of the main goals was to provide a protocol that was able to transport the information to its destination. This was an essential requirement even during failure situations. Hence, emphasis was placed on the eventual arrival at the destination, less on strict real-time delivery. Without entering the discussion of whether this was originally intended for having a network surviving a nuclear attack, a nuclear power plant accident, reaching vessels under various conditions, or some other

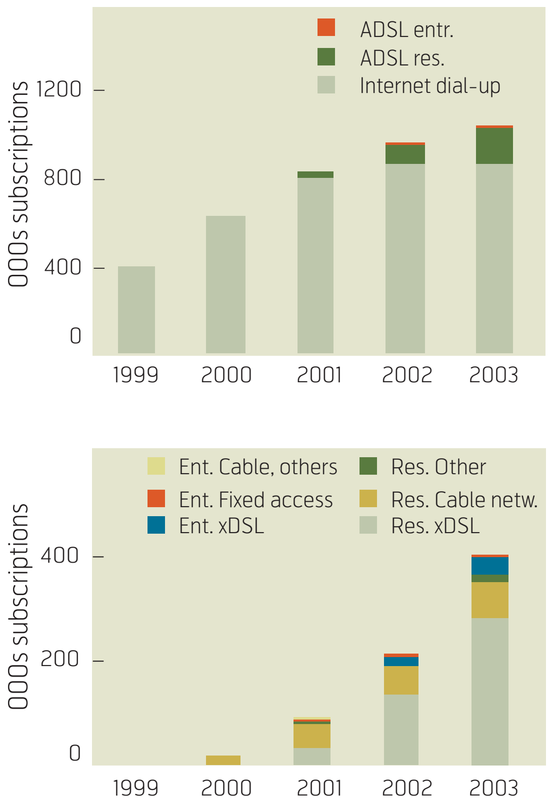

Figure 1 Top – Telenor Internet subscriptions Norway – dial-up and ADSL access (from the Telenor Annual Report 2003); Bottom – Broadband access growth in Norway (from Norwegian Post and Telecommunications Authority)

cases, it seems clear that the robust transport capability was given high priority amongst the requirements.

This is also reflected by the two *key characteristics* that identify the IP format:

- Each packet carries the addresses of its destination and source;
- Each packet can be forwarded individually, independent of routes of preceding and following packets.

2.2 Volumes and industry events

Preparing the foundations in the late 1960s, the IP principles being elaborated in the early 1970s have survived for several decades. The more rapid growth came after the establishment of WWW (World Wide Web) in the beginning of 1990s. The intuitive user interface “click and get” dramatically lowered the threshold for information collection. Emails accompanied the usage, although such message transfer capabilities had already been proposed in the 1960s. However, other phenomena allowed such a growth, like the relative price reduction of computers and the information made available by different sources.

In the late 1990s, however, it seemed as if the telecom industry was becoming too optimistic in their estimates of traffic volumes and revenue potentials in this area. The so-called bubble-burst left several companies out of business and others going through drastic downscaling. This also influenced the progress of IP-related developments. As pointed out in [RFC3869], more recent events in different parts of the world have led to increased insecurity and renewed interest in having dependable telecom infrastructure. The players pulling through the bubble burst also seem to have more sensible expectations to the industry. It is still necessary to join forces in order to make progress in the IP-related areas. This is also a motivation for the organisations and initiatives, such as ITU, IETF, ETSI, 3GPP, DSL forum, Infranet initiative, and so on. In later years a steady increase in the traffic has accompanied the users’ interest in the Internet. Figure 1 illustrates the situation regarding Internet subscriptions and broadband accesses in Norway.

2.3 IP on-time to meet a need in service portfolio

Considering the outset and initial motivation, one could raise the question of how this protocol has managed to maintain its position. That position is manifested not only during the transition from a single-class (best-effort) to a number of differentiated classes, but also during the shift from academic and internally controlled environments to commercial operations with a range of players involved.

One explanation for the success of IP may be that it belongs to a simple solution that was presented to the market at the right time. In the early 1990s there were few services around providing information collection and messaging to private persons. Then, the combination of browser and email neatly covered that demand. This was accompanied by more affordable PCs and higher modem bit rates.

The commercial interest in IP came around a time when broadband systems were defined. As such, there was a recognized need for having a system and protocol suite supporting these services. Several of the telecom providers had therefore joined forces to specify B-ISDN (Broadband Integrated Digital Network). In a fairly traditional (telecom) manner one started out by defining services and control regimes. As an outsider to this the IP suite had a simple implementation, requiring neither parallel signalling nor traffic declaration schemes. As we all know, it turned out that the relevant applications were actually wellmatched with the simple best-effort regime offered by the IP suite.

Some may claim that several of the proposals related to IP (see following chapter) are to "repair" the *initial deficiencies*. Hence, one could ask whether it would not be better simply to find a replacement. Still, it is a fact that the IP formats have broadly maintained their interpretation for several decades. In fact, this may well be one of the causes for its popularity; it would be more discouraging to have to adapt to different versions and protocols that were developed and steadily changed.

On the other hand, one cannot neglect all the suggestions that have been made related to improving certain aspects of having an IP network. In retrospect, it seems nice that IP as the core protocol has been left unchanged, and most of the suggestions might be seen as modules that could be added on to the core protocol. Such a *modular-based philosophy* supports the flexibility of proposing new modules replacing others to allow for more services, more efficient network operation, and so forth.

3 The IP suite in a broader perspective

3.1 IP features

The most fundamental IP service is to offer an *unreliable, best-effort, connectionless packet transport* between a source and a destination. The service is called unreliable as delivery of the packet is not guaranteed (no verification of correctness taken care of by IP). Connectionless comes from the fact that each packet is treated independently from other packets in the same flow. Best-effort comes from the fact that no packet is assumed to be discarded or distorted on purpose.

A protocol stack is used when transferring information between two points. IP is commonly referred to the network layer as packets can be inspected in intermediate routers between the sender and the receiver. Version 4 of IP is the one most applied today. This adds a 20 byte packet header to the information, see Figure 2. The packet header contains sufficient description for the packet to arrive at its destination and for the information flow to be reconstructed by the receiver. Some pieces of the header also allow packets to be favourably treated (priority field) and avoid that packets stay in the network following too long routes (time-to-live field).

IP version 6 is also promoted by several sources. A basic argument is that more addresses are supported (128 bits address fields compared to 32 bits for IPv4). However, an effect of this is that the header of IPv6 packets has grown to 40 bytes. On the other hand, the header supports more flexibility and enhanced options.

Error and control messages are incorporated at the IP layer. These allow routers and terminals/hosts to exchange operational and maintenance information. One motivation is to inform that a destination is unreachable, which could be detected by the time-to-live header field being decreased to zero.

3.2 Transport protocols

Above the IP layer, two transport protocols have found their place; one for fast un-acknowledged transfer – UDP (User Datagram Protocol), the other for acknowledged transfer – TCP (Transmission Con-

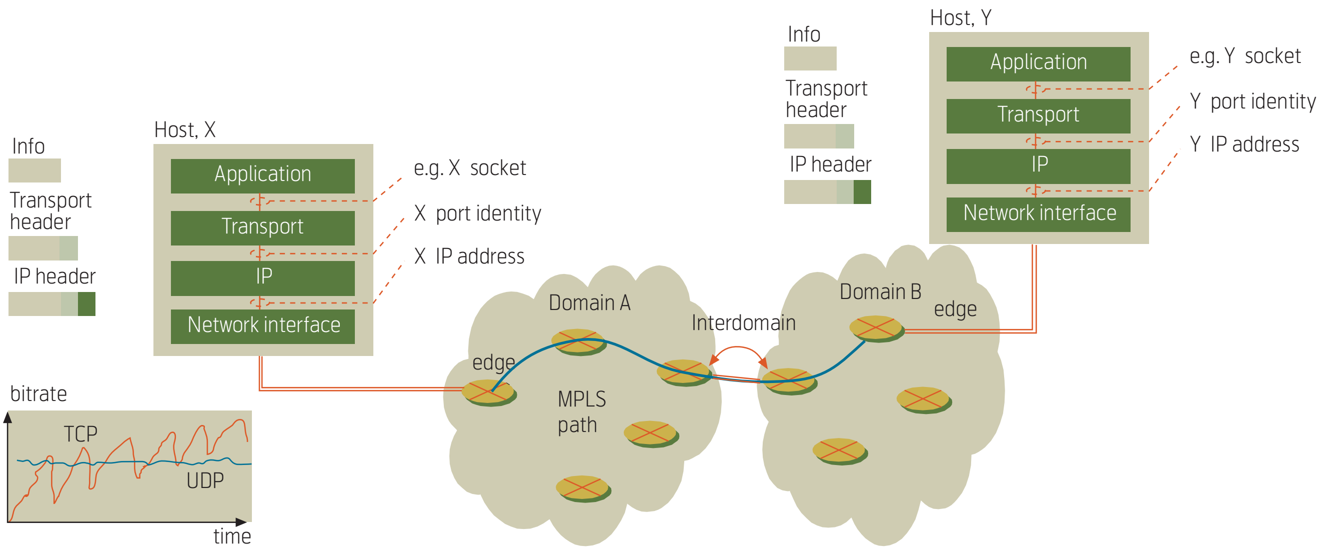

Figure 2 Illustrating IP suite

trol Protocol). The former is commonly applied for transferring data having strict real-time requirements, where retransmission for correcting an erred or dropped packet is not relevant as that is assumed to arrive too late. Examples are transfer of real time voice and video. TCP is widely deployed for transfers of data where correct information is requested. Hence, it has been used for file transfers, email transfers, web browsing, and so forth. In order to support this a connection between the end-points has to be established and acknowledgements have to be exchanged.

Due to an initial idea of IP that end-systems are in charge of the information transfer, it is a challenge to find the appropriate transfer rate (kbit/s) for a host/application. TCP has an incorporated mechanism for estimating the proper rate to apply (slow-start and rate adjusting by increasing and decreasing factors). In principle, the inherent TCP mechanism would pursue the proper rate by increasing its transmission rate until a packet is lost (or arrives too late). Measurements have shown that this may result in an oscillating transfer rate. However, a maximum window size can assign an upper limit of the information unacknowledged and thereby a maximum transfer rate. This maximum window size is utilised in some systems, e.g. for UMTS (Universal Mobile Telecommunication System) to avoid the oscillating behaviour of TCP.

3.3 Underlying protocols

The IP layer may utilise several underlying protocols, including PPP (Point-to-Point Protocol), MPLS (Multi-Protocol Label Switching), and Ethernet. In fact, one of the advantages of IP is its ability to make use of different link protocols. In the core network, MPLS appears as a current main candidate. This protocol assists to separate traffic flows by offering a tunnelling mechanism. Hence, MPLS tunnels can be managed by intermediate nodes relieving the IP routing and processing capacity. Commonly MPLS is used to implement VPN (Virtual Private Network) services.

Several people have investigated relations between IP and high-capacity systems, e.g. optical networks. This deals with questions like:

- Architecture, e.g. should the IP layer and the optical layers interact as peers exchanging information as between equal parties, or should IP simply be an overlaying client?

- Which framing protocol should IP use – if any – as container when carried by an optical network?

- Should redundancy and protection schemes on IP and optical layers co-operate or carry out their actions independently?

3.4 Routing and naming

Different routing protocols are often applied – with a division between the domain-internal protocol and the protocol used between different domains. Here, a domain may represent a set of routers (a single operator may define a number of domains). A main difference between the intra- and inter-domain routing protocols is the detailed information exchanged. Between domains this information is limited not to reveal too much on the domain internal structure. In addition, limiting the information also results in less data to be exchanged and stored in the routers. Between domains, BGP (Border Gateway Protocol) provides mechanisms for aggregating routes and ranges of IP address prefixes. This supports efficient connection between networks.

There is also a distinction between routing and forwarding; the former used to describe the exchange of routing information (by routing protocols), and the latter used for sending IP packets according to the routes. When MPLS is used as tunnel, the IP forwarding is by-passed, allowing those packets to travel along different paths to what the routing would tell. Today, this mechanism could be used for load-balancing a network.

There are different sets of addresses and identifiers in a network. The IP address gives a source or a destination referring to the IP layer, see Figure 2. Then, transport protocols, e.g. TCP or UDP give a port identity. Between a transport layer and an application, a socket identifier is commonly applied. This will then point to the application, such as a file transfer application. A hierarchy of applications can also be used; for example the web browser can invoke the file transfer application. An example of identification at the application layer is URI (Universal Resource Identifier). A DNS (Domain Name System) service is applied to translate between URI and IP address, such as from www.telenor.com to 129.134.11.24. Then, clicking on a link (described by URI) can be converted to an IP address (and the server) where the information is found.

3.5 Traffic handling

Different traffic handling mechanisms are also defined for IP. DiffServ (Differentiated Services) is a way of defining a number of traffic classes where IP packets in the different classes receive different priorities. The result is that high priority IP packets may be forwarded before low priority packets. An argument is to give flows with strict real-time requirements, e.g. voice, higher priority to limit the delay, and delay variation. The mechanisms also mean that packets must be classified, the corresponding flows monitored and queueing disciplines have to be implemented.

To fully support ensured services, however, additional mechanisms must be installed. Examples are admission control and resource reservation. Commonly statistical guarantee can be promoted where some of these mechanisms are more loosely applied.

3.6 Related protocols

The traffic handling is motivated by combining high resource utilisation at the same time as requirements from applications are fulfilled. Typically, these mechanisms are fully deployed on the edge of the IP network. An example is the service edge routers where IP packets are inspected after being generated by a DSL (Digital Subscriber Line) user. PPP may for example be utilised as security means for each user – offering a tunnel between the residential and the service edge router. To provide an IP address and authentication of the user equipment, RADIUS (Remote Authentication Dial-In User Service) could be used between the service edge router and an authentication server. Other protocols are also proposed for service control and management, such as SIP (Session Initiation Protocol) and COPS (Common Open Policy Service). SIP, including some enhancements, has currently much support for controlling services for both fixed and mobile/wireless access.

A quick visit to the IETF web pages gives an impression of topics that occupy those who are engaged in that forum. However, there are also other organisations working on essential aspects of running IP-based operations. Examples are requirements described by ITU and implementation and interoperability issues described by a number of fora such as the DSL forum.

4 Current implementation trends and consequences

4.1 IP central in all strategies

Every major operator is currently deploying broadband – and narrowband – services utilising IP. Most operators see IP as an essential element in their network and system development. This should therefore be carefully planned and implemented as part of the strategic plans, not as an isolated activity.

Looking more closely at the operators' strategies, we see that a wide range of services utilising IP are to be provided. Examples of services are TV broadcasting, video-on-demand, voice/telephony, Internet access, VPNs. There is also a clear trend that IP is introduced in all major network areas. Besides the wired/fixed network, bodies working on mobile systems and broadcasting systems introduce IP to take a growing position.

The steady growth of IP-based networks is motivated by a *number of drivers*:

- New applications and user groups; these place additional requirements on network capabilities. One example is that low-revenue users also want access to networks and information, requesting sponsored or low-cost solutions.

- New technologies; more technical solutions are developed related to IP-based networks, supporting efficient configuration and operation as well as supporting more user demands and application types.

- Increased load and network expansion; increasing the broadband offering in a region commonly asks for more distribution of equipment. For example, when the access rate on copper lines increases, shorter lines are often used implying that equipment is located closer to the users.

- Higher network dependency and more providers involved; steadily more actors are depending their businesses on available IP network services. The up-time requirements are therefore becoming stronger. At the same time, the number of players involved in some of the services is growing, requesting arrangements between the players to sort out duties and responsibilities.

This could be taken as proof that IP has matured from simply a best-effort solution to being able to support business-critical applications and differentiation of services.

4.2 Consequences accompanying IP suite

Broadly, one could recognize two *"schools of thought"* driving the IP development: i) those wanting to introduce ensured and differentiated services, and, ii) those wanting to keep a single IP transport service class. On a generalized level, this could also be seen as the battle between keeping most of the service control (referring to IP transport service) within the network as for school i), and keeping the control in the end-system as for school ii). In case school ii) should be the right one to follow, this may be argued on the grounds that basic IP transport services are the only ones asked for. That is, these services must be incorporated into the portfolio – a sub-argument is that faced with possible performance bottlenecks, more capacity should be added. Some may also claim that this is less expensive than implementing advanced traffic handling mechanisms. However, most providers lean towards school i). They mainly apply the following arguments:

- Differentiation: a range of different users and applications is to be supported. These have different requirements (such as delay, loss and availability), intuitively asking for different services.

- Cost reduction: being able to support differentiated services in a common physical network allows for cost savings. That is, it should be less expensive to invest in and operate a common network supporting a range of services, compared with having different physical networks. A principle scale argument as known from traffic studies supports this argument. Applying traffic theory also shows that better resource utilisation can be achieved when service differentiation is implemented.

- Support on new service packages: having a common IP network should alleviate developing and offering of so-called converged services. That is, service packages crossing different traditional network accesses are more swiftly available with a common IP network as basis. The cost and speed of service offering is an important argument. In several of today's incumbent operators' system portfolio, the level of complexity due to interaction between different systems seems to dramatically slow down the service development speed.

Summarised, two main groups of argument are driving the IP deployment from an operator's perspective; the *cost saving* and *the option to offer new service packages*. The former is further backed by the observation that "IP type of equipment" has been falling faster in price compared to others. This is expected to continue; driving deployment of IP into new areas of telecommunications. The second, new service argument is also a trend expected to continue. In some respect services currently provided by other platforms are implemented on the IP platform, e.g. voice/telephony. There are also more services added; on-demand, gaming, multi-party messaging. Even if some of these are introduced by other access forms (e.g. mobile), the network-internal implementation is commonly based on IP.

The availability of an "IP interface" also lowers the threshold for other parties to offer services. This is therefore a driver for other providers to get access to an IP-based interface, being able to provide the services to users in an easy manner.

From the outset, users might not care about technical implementations. However, the Internet and IP philosophy has also accompanied the wide deployment of personal devices such as mobile handsets and computers, as well as other devices. Therefore end-users also benefit from the wide spread of IP-enabled devices. Naturally, security mechanisms must also be installed avoiding non-authorized intrusion and revealed personal information.

4.3 Some technical deployment trends

In most IP core networks, MPLS is utilised as a tunnelling mechanism. There is also a push towards introducing DiffServ for service priority and efficient resource utilisation. Underlying Ethernet interfaces are argued for because of cost-savings. The overall principle is then a common physical network allowing for virtual separation of traffic classes. The shift from IP version 4 to version 6 has not found a definite answer in Europe and USA. One cause is that the address space is not that restricting in these regions. There are growing interests in finding beneficial solutions which can explore capabilities of IP version 6 – other enhancements supported in addition to greater address space.

For service and session control, several international bodies have promoted SIP. Similar solutions have been promoted for future releases of mobile systems.

On the access side, alternatives to PPP are investigated. One argument is to arrive at functionally similar solutions for all access forms, whether based on cable or air.

Incumbent operators evaluate how their network portfolio should evolve. 4–8 years ago there seemed to be a hype that every service would be based on IP fairly soon. These days, however, a more healthy view is observed; that only services efficiently realised on IP-based networks should be produced in such a way. This does not however pose too many obstacles for the rapid growth of IP traffic. Still, to satisfactorily meet the accompanying requirements, more solutions must be implemented – some described in the following.

5 So, what's next?

5.1 Overall issues

As part of the strategy work, it is always reasonable to ask questions as to which trends that dominate the evolution, as well as to which phenomena are challenging the current way of running the operation.

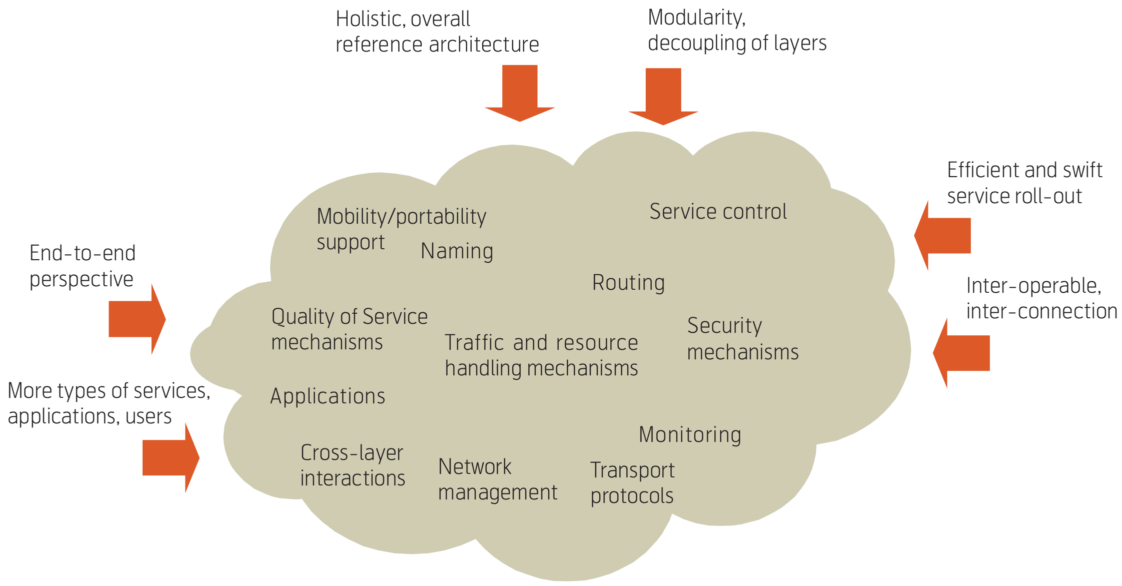

Figure 3 Samples of some topics and mechanisms to be addressed during further work on IP-related development

Therefore, it is sensible to look at both the *evolution within the IP suite* and which factors may lead to *replacements of parts of the IP suite*.

Addressing the former question, work is on-going in several organisations. Examples are the next generation networks activity in ITU and the "all-IP" target in 3GPP, ref. Figure 3. IETF is also pondering on issues that should be researched to ensure a sane evolution of the IP suite.

Considering that so-called next generation networks are based on IP, a number of related trends and corresponding challenges are:

- Holistic perspective: Providers want to offer more "advanced" services on IP. This implies that a reference architecture must be in place. Finding which components to apply for the different modules in the architecture has not been completed. Protocols and mechanisms elaborated in IETF must be put together in an efficient manner. As part of this area, interworking with other networks has to be solved. However, it is essential that the IP network does not import the complexity such interworking could lead to.

- Separation, or decoupling, of control and bearer/transport functions: This allows for defining service platforms to some extent independent of the underlying IP network. A clear interface definition has to be in place, though. The decoupling of bearer and service control supports a modular-inspired architecture. One of the service platform candidates is a solution developed by 3GPP; IMS (IP Multi-media Subsystem). This solution has been promoted by several organisations and operators to potentially offer services on most access types, both fixed and wireless. This requires that requested functionality is supported by the IP-based network.

- Offer a wider range of services and applications: The types of applications assumed to be supported by an IP-based network are steadily growing wider. Real-time and business-critical applications are placed on the network in addition to web browsing, email and file transfers. This intensifies the dependability, performance and security aspects. Features such as multicast, mobility, unified access for users, community networking, and so forth, must be supported at IP layer for efficient realisation.

- The end-to-end perspective: Considering the applications, an IP network is utilised for more demanding purposes. For commercial operations, the users require ensured service levels to justify the payments involved. For example, breaking a real-time video presentation is not acceptable when it is paid for. Hence, mechanisms for ensured service delivery is required. This implies invocation of traffic and QoS management.

5.2 Some technical issues

On the more technical level, several issues have been identified, e.g. ref. [RFC3869], [ITU_IP]. All of these have relations with the four areas i) overall architecture/functionality, ii) traffic/performance, iii) security, and, iv) network evolution. The efficiency and scalability must also be taken into account. Some of the issues to address are:

- Naming: allocation of IP addresses, domain names, and others (e.g. ENUM, Electronic Numbering), has to be co-ordinated on a global level. Discussions are on-going including ITU, IETF and others. A transition from version 4 to version 6 of IP is also considered.

- Routing: Protocols for routing may need to be enhanced or replaced considering the new needs emerging from commercial operations. Examples are more routing metrics including business matters, faster routing convergence to recover from unexpected events, interconnections between domains, multi-homing of devices, and mobile/ad-hoc environments.

- Network management: The growing traffic and users require that a (logical) network perspective must be supported for efficient management. Otherwise, the complexity cost would likely outgrow the scale gain. This also includes monitoring and measurement arrangements. How and what to measure are essential questions – balancing the accuracy and scalability aspects. Management and control of customer equipment would also be requested allowing end-users to be relieved of intricate configurations. Management of any intermediate system (sometimes referred to as middle-boxes) should also be supported. Autonomous procedures would likely be efficient in this manner, naturally also asking for performance and security aspects to be solved.

- Quality of service: How the different mechanisms actually influence the real end-user experience is not understood. The user sees the effect of the total system, asking for understanding of the overall architecture, likely involving several domains and actors and different combinations of equipment configurations (such as queueing disciplines).

- Efficient resource utilisation: An example is congestion control mechanisms. In-built features of TCP have been utilised to avoid congestion. New applications and new environments (e.g. wireless) demand other control mechanisms. A new transport protocol is under development, DCCP (Datagram Congestion Control Protocol). Besides such a protocol, information exchanges across layers could also be utilised. For example, intermediate IP routers could signal load levels to the end-systems.

- Application capabilities: Higher requirements are placed on intuitive user interfaces. Depending on the services provided by the IP network, easily comprehended feedback to users can also be required. An example is to inform a user that a load situation somewhere (within the user network, access network, server side, etc.) results in a degraded service level.

5.3 Challenging IP's position?

Then, one may ask whether there are any candidates to replace IP. It is a broad opinion these days that no strong candidate exists. On the other hand, a number of issues may motivate for not using IP in all circumstances:

- Lack of holistic overall architecture. If such an architecture is not defined, solutions will likely lead to inefficient configurations.

- The overhead added by the IP protocol suite. In case the protocol features are not utilised, low capacity links do not favour this overhead.

- No coherent mechanisms for ensuring services. The strictest requirements place rather tough demands on the network solution, where other networks currently may meet these demands in a more efficient way.

- Security matters may inspire for increased use of "hidden" identifiers. That is to avoid that attacks and information not asked for can be distributed.

... and, in principle, any other solution that allows for more cost-efficient operation offering timely services. The combination of inexpensive solutions and easy installation has an urge of deciding the winning technologies. The sheer volume of IP-based devices and applications, however, make if difficult to believe that any alternative would gain significant position in the medium term. Naturally, increased traffic volume, simple transport network functions and treatment of aggregated traffic mean that the IP level may not be inspected by all intermediate nodes.

6 Present questions – bridging past and future

6.1 Immediate challenges

Based on the current status for commercial operation of IP-based networks, there are several challenges to face in the short term in order to prepare for the future. These challenges are mostly formulated from a network operator's perspective. In broad terms they are grouped into:

- *Business* concerns: Although perhaps provocative, it is fair to say that few of the major operators have really incorporated processes and systems for swift offering of IP-based services. Several of the newcomers seem to be much more streamlined, though. These processes refer to every phase from defining customer-related systems, deciding on pricing structures, allowing bundled services, supporting self-service variants, and so forth.

- *Service* concerns: Communicating what service is actually provided seems to be challenging. SLA (Service Level Agreement) could be elaborated correspondingly. This also asks for monitoring apparatus documenting that SLA conditions are met. Offering more value-added services is also expected to be on the operator's wish list. Then, it is necessary to integrate service control and management. A particular aspect is that several systems and players may contribute to complete the service delivery. Additional mechanisms are also required to allow this to take place in a controlled manner.

- *IP transport* concerns: Interplay between different systems, within and partly outside an operator's domain requires (standardised) protocols. In some areas these are in place, such as routing between domains. For interacting with customer equipment, several options are currently proposed. Configuring IP resources is also a challenge on the same level, in particular in view of multiple services assumed to be supported. Monitoring is a challenge on the IP network layer. It is not much of a problem defining a monitoring scheme collecting huge amounts of data. But to define a scheme, which captures the traffic and performance in an efficient way, is still an unresolved issue. Defining and tuning traffic handling mechanisms is also a necessity to deliver ensured services.

6.2 … and, in summary

The steady growing presence of IP in almost all telecom operations is evident. No matter which access networks and services that are looked at, IP-based implementations are seen in the current or future roadmaps. This *IPfication* is an expression of the packet-oriented implementations of telecom services. No operator/provider should neglect this trend and proper steps should therefore be prepared in a timely manner. A basic argument for an incumbent operator is that these steps should also assist when reducing its internal complexity, which likely has grown for several years. That is, the *IPfication* allows a drastic cleansing of an operator's system portfolio. This implies reduced cost base and more swiftly service offerings. The whole telecom industry is currently very occupied with finding means to lower costs and allow for enhanced service portfolio. Society as a whole would also benefit from the lower cost base and improved service offerings. In fact, the technical solutions fuel the so-called global information and knowledge-based society as defined by United Nation's bodies.

Major challenges rest within areas of defining an overall reference architecture, traffic and resource handling, security and efficient evolution schemes. Target reference architecture allows for describing modules that should be in place to support service offerings. The modular architecture corresponds with trends of introducing open interfaces and decoupling different layers. This is also a competitive edge considering the growing heterogeneity and dynamics foreseen for service environments.

In some respect the *IPfication* could be considered as Internet philosophy brought into a commercial context. Here, a principle of "good enough" seems to be dominating. That is, not too much, neither too little. What is then "good enough" in a more specific interpretation? Well, that is a multi-billion question continually examined by most players involved.

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