Internet evolution scenarios

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Abstract

A review of the state of the Internet in terms of traffic and services trends covering both the Research & Education and the Commercial Internet will first be given with particular emphasis on green ICT and mobile technologies. The problematic behind the IPv4 to IPv6 migration will be explained, a short review of the ongoing efforts to re-design the Internet in a clean-slate approach will then be made. Last, an overview of the main organizations involved in Internet Governance will be presented

Keywords: Internet, GÉANT, FIND, FP7, GENI, IAB, ITU, IPv6, LTE, "clean-slate", "green ICT".

1 Introduction

This article attempts to address the evolution of Internet and, more generally, relevant ICT technologies with special emphasis on Mobile, Green, Grid and Cloud computing technologies.

One major concern is to keep the Internet together throughout this very complex and fast evolving technological process, hence some plausible evolution scenarios will be sketched.

As the exhaustion of the IPv4 address space is getting closer i.e. 2011-2012, as the wide adoption of IPv6 is still lacking, as the Internet continues to grow at a annual rate greater than 20%,, the Internet is at a crossroad with two competing approaches, evolutionary or clean-slate.

While a clean-slate approach bears lot of promises it does not provide a realistic alternative in the short to medium term given the time to standardize new architectural proposals that both solves the numerous problems of today's Internet while also providing a more stable foundation for the "Internet of the Future" encompassing new needs and requirements (e.g. mobility, security, sensor networks, Radio Frequency Identification (RFID), Personal Area Networks (PAN), Vehicle Area Networks (VAN), etc.).

2 Main Sources

This article is an updated version of an article that was originally published in the NEC'2007 conference proceedings[2] and is also derived from the presentations I made at CHEP'2009[3] in Praha and at NEC'2009[4] in Varna.

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[1] Olivier.Martin@ictconsulting.ch
[2] www.ictconsulting.ch/reports/NEC2007-OHMartin.doc
[3] www.ictconsulting.ch/presentations/CHEP09-Final.ppt
[4] www.ictconsulting.ch/presentations/NEC2009.ppt

3 Internet Traffic & Infrastructure

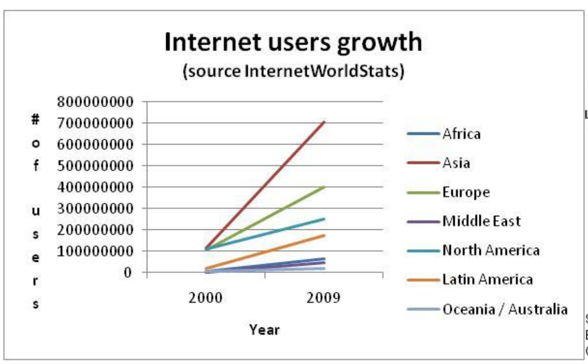
There are really two Internet branches that, apart from the fact that they are obviously interconnected, have very little in common namely, the Commercial Internet and the Academic & Research Internet exemplified, in Europe, by the pan-European GEANT backbone interconnecting National Research & Education Networks (NRENs), in the USA by Internet2[5], the Energy Science Network (ESnet[6]) and the National Lambda Rail (NLR[7]), etc.

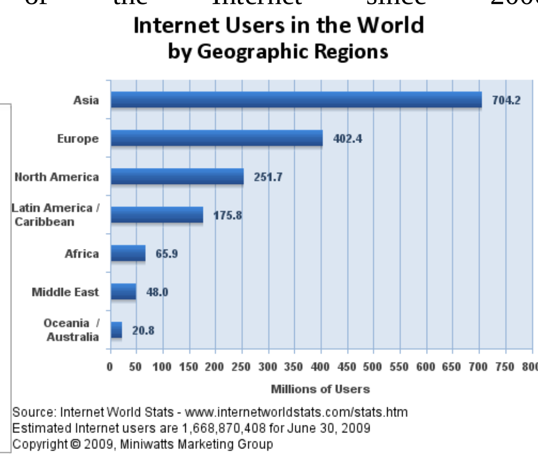
3.1 Internet Traffic

There are many sources of Internet statistics, e.g. Akamai State of the Internet[8], Atlas Internet Observatory[9], CAIDA[10], Cisco Visual Networking Index[11], Internet World Statistics[12] (IWS), Ipoque[13], Pinger[14] (SLAC), RIPE[15], etc.

Despite the numerous technical problems the Internet is faced with, all available statistics indicate that it is growing very rapidly and does not show any signs whatsoever of a brutal slowdown, indeed, the Internet is, in a sense, "victim" of his own success. According to Internetworldstats, the worldwide Internet user penetration is approaching 25%, i.e. 1.7 billion users off a world population of 6.8 billion persons mid-year 2009, with an increase in the number of Internet users of more than 200.000 since mid-year 2008, when the Internet penetration was only 21.9%.

Internetworldstats is monitoring the number of Internet users per world region and has also been tracking the development of the Internet since 2000.





Not surprisingly, Asia with 650 Million users and Europe with 390 Million users are now well ahead of North America with only 247 Million users. However, these figures are somewhat different when one looks at the penetration of the Internet with respect to the

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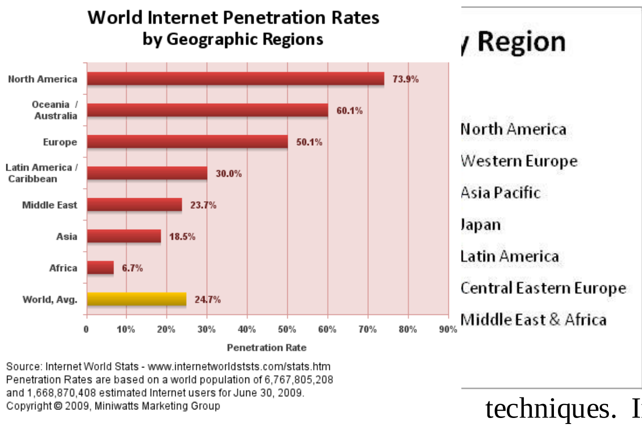
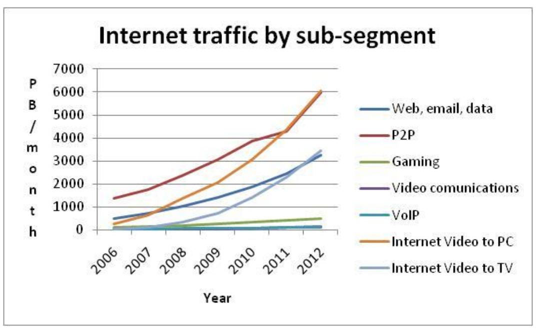
5 http://www.internet.edu
6 http://www.es.net/
7 http://www.nlr.net/
8 http://www.akamai.com/stateoftheinternet/
9 http://www.arbornetworks.com/en/atlas.html
10 http://www.caida.org/home/
11 http://www.cisco.com/en/US/netsol/ns827/networking_solutions_sub_solution.html
12 http://www.internetworldstats.com/stats.htm
13 http://www.ipoque.com/resources/internet-studies
14 http://www-iepm.slac.stanford.edu/pinger/
15 http://www.ripe.net/ttm/



population of the various regions with North America still being well ahead of Asia and Europe.

Another source of information is the Internet traffic studies conducted by Ipoque in collaboration with 8 ISPs around the world and 3 universities, using deep packet inspection (DPI) techniques. In their last 2008-2009 report[16] covering 1.1 Million users (i.e. 0.7/1000 sample) producing 1.3 Petabytes of data, it is stated that "*BitTorrent and eDonkey downloads have been analyzed to classify the transferred files according to their content type. Some of the key findings are: P2P still produces most Internet traffic worldwide although its proportion has declined across all monitored regions – loosing users to file hosting and media streaming; regional variations in application usage are very prominent; and Web traffic has made its comeback due to the popularity of file hosting, social networking sites and the growing media richness of Web pages.*"



The traffic projections made by Cisco in their Cisco Visual Networking Index are also most interesting, however, they must be taken with a grain of salt as it is clearly in Cisco's own interest to predict too high rather than too low compound annual Internet growth rate; nonetheless the Cisco predictions appear to make a lot of sense as everyone can observe the clear move towards more access to multimedia content over the Internet.

Both Cisco and Ipoque agree that Peer to Peer (P2P) traffic is the dominant source of Internet traffic worldwide, up to 40-50% depending in some regions. So, one essential fact is that the Web traffic, that used to be the prevalent source of Internet traffic, is only representing 20% to 25% of that traffic today; however, due to the increasing popularity of Web 2.0 & social networks, Web usage appears to be growing again. In the longer term, Cisco predicts that by 2012, with a compound annual growth rate of 97%, "Internet video to PC" will surpass P2P traffic.

Given its high impact on the overall performance of the ISPs, in particular transit ISPs, the P2P traffic sometimes raises network neutrality issues, that is discrimination against specific types of traffic (e.g. encrypted, P2P, traffic) by using traffic shaping, also dubbed "traffic throttling", techniques, thus potentially causing major performance losses under high load conditions.

[16] http://www.ipoque.com/resources/internet-studies/internet-study-2008_2009

3.2 Towards a "green" Internet

An unfortunate consequence of the high-penetration of the Internet into (almost) everybody's home, in particular, and, more generally, spectacular advances in Information, Communication and Computing Technologies is the impact on worldwide CO2 emissions. According to Bill St.Arnaud's "Green Broadband" Web site[17] "It is estimated that the CO2 emissions of the ICT industry alone exceeds the carbon output of the entire aviation industry."

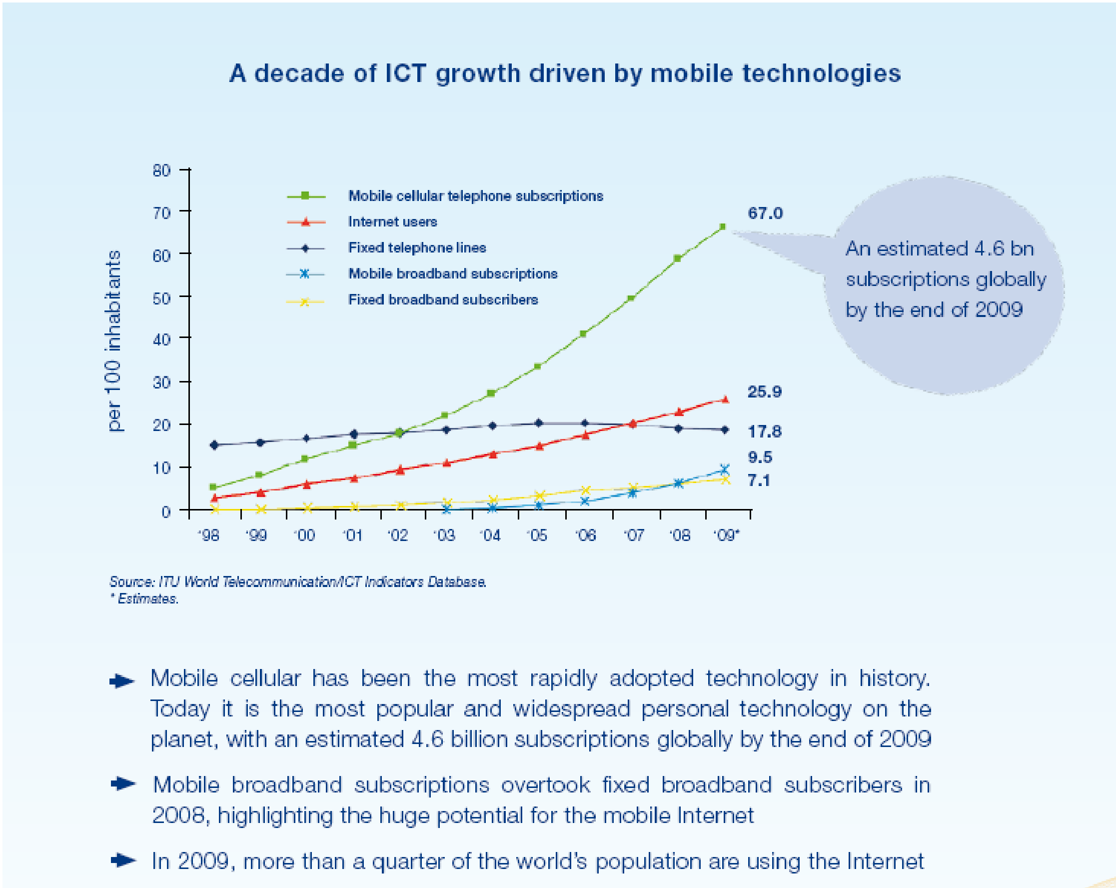
So, "green computing" has thus become a major topic and is the subject of many conferences, reports and projects. Like with cars and many home appliances, energy-aware network ICT products bear a lot of appeal and low energy consumption coupled with smarter energy management strategies have become excellent selling arguments. In the not too distant future we are therefore likely to see a sharp increase in the use of self-powered sensors and renewable energy.

In any case, Information and Communication Technologies (ICT), in general, and the Internet, in particular, will, no doubt, become "Greener"; in other words, an energy aware, Internet will appear sooner rather than later as energy consumption of new data centers becomes both very expensive but also extremely problematic to deliver. Given the urgency as well as the potential savings, rapid progress can be expected.

3.3 The growth of ICT

The ITU has been tracking the growth of ICT technologies, in general, and the role of mobile technologies, in particular. On the occasion of Telecom World 2009[18], the ITU published a report titled "The world in 2009, ICT facts and figures[19]". As shown in the following diagram, ITU estimates that the total number of mobile cellular subscriptions will reach 4.6 billion by the end of 2009 and that the total number of mobile web users[20] also dubbed "mobinauts" grew past the total number of desktop computer based internet users for the first time in 2008.

[17] Green IT/Broadband and Cyber-Infrastructure: December 2007
[18] http://www.itu.int/net/TELECOM/World/2009/newsroom/index.aspx
[19] http://www.itu.int/net/TELECOM/World/2009/newsroom/pdf/stats_ict200910.pdf
[20] http://en.wikipedia.org/wiki/Mobile_Web



3.4 Access and Backbone Technologies

Broadband access needs are increasing in order to support new applications, therefore wired as well as wireless access speeds will evolve from Mb/s to Gb/s and will become nearly ubiquitous in a very fast evolving technology framework, but fixed access will not disappear (ADSL, FTTH, GPON, Cable TV, leased lines, etc.).

Wide-scale commercial 40Gb/s deployments that really started in 2008 (e.g. ATT, NTT) are expected to continue, however, "commodity" 10Gb/s circuits will also continue to be increasingly widespread as 40Gb/s technology is still too expensive for most ISPs. Although it is too early to say, it could well be that 100Gb/s will overtake 40Gb/s technology as an interconnection technology (e.g. Internet Point of Presences (PoP), Internet Exchange Points (IXP), high performance LAN environments). Indeed, a number of 100Gb/s deployment have been announced, e.g. the deployment of CIENA's 100Gb/s equipment[21] during 2010 in the NYSE (New York Stock Exchange) Euronext data centers in New-York and London. This announcement comforts my long held belief that the commercial Internet is actually well ahead of the academic and research Internet despite the commonly held view.

There is, in fact, little doubt that the major evolutionary trend in the last years has been the pervasiveness and the ubiquity of wireless technologies, be it Wi-fi[22] or Cellular phones.

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[21] http://www.ciena.com/news/news_nyse.htm
[22] http://en.wikipedia.org/wiki/Wi-Fi

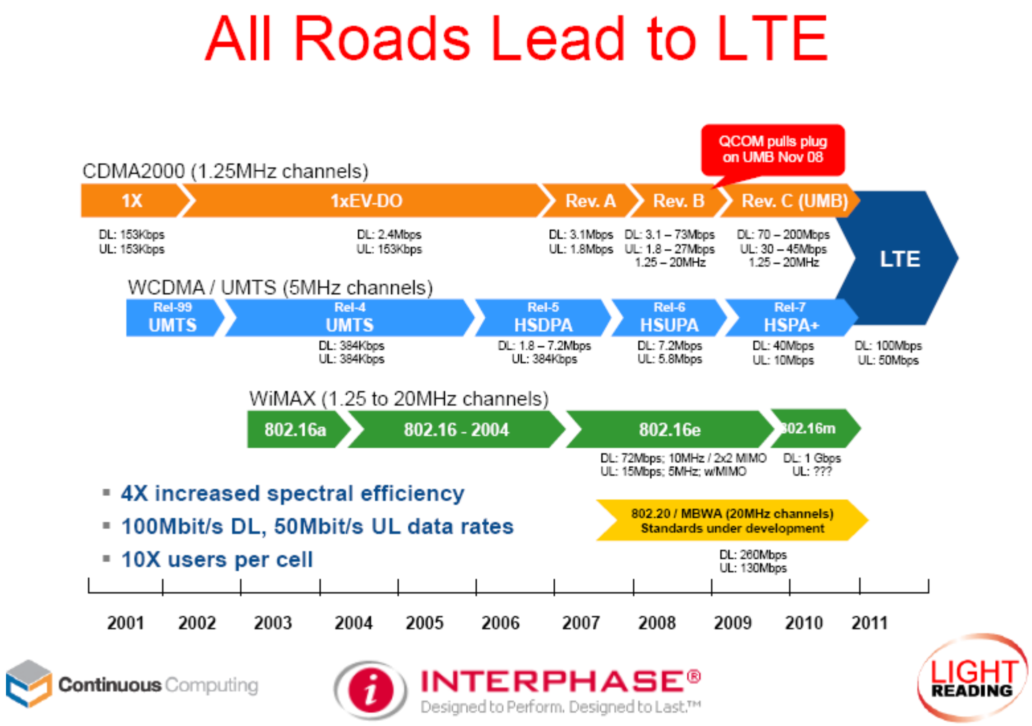
The first full internet service on mobile phones[23] was "*i-Mode"* introduced by NTT DoCoMo[24] in Japan in 1999 that immediately met an overwhelming success. Shortly afterward the "*Blackberry*[25]*"* (1999, 2002) was introduced. However, it is only after the extraordinary successful introduction of Apple's "*iPhone*[26]*"* in 2007 which features, among other things, a new ergonomic user interface with a touch sensitive screen, that a new category of mobile phones[27] called "*Smarphones*[28]" started to invade the mobile telephony and mobile Internet market. One reason behind the success of iPhone is the ability to purchase & download applications from a very large online marketplace called *Appstore*[29]

Thus, it is the iPhone "mania" that really paved the way to a whole new generation of "smart phones" and to a new, potentially "dangerous", way to access the Internet, in general, and live Internet services, in particular. The danger lies in the way Internet traffic is charged to users, as behind the apparently "*unlimited"* there are usually a number of "exception" clauses, e.g. "*roaming*" but also various ceiling in monthly and/or daily traffics that look line *"devious"* ways to re-introduce *"pay per view"* style services. In that respect a recent case with an Orange customer[30] in France is rather instructive.

Google could not stay inactive, of course, so it first made available a new "*open*" operating system for smart phones called Android[31] and it is also announced that its own smart phone "*Nexus One*[32]*"on January 5, 2010.* This is actually quite worrying as the dangers of living in a "Google" centric world may actually be even greater than those of a Microsoft centric world!

The following chart[33] was extracted from a Light Reading Webinar delivered on Thursday, September 10, 2009 and titled " LTE[34] (Long Term Evolution) Technology and Components" :

23 http://en.wikipedia.org/wiki/Mobile_phone
24 http://www.nttdocomo.com/
25 http://en.wikipedia.org/wiki/BlackBerry
26 http://en.wikipedia.org/wiki/IPhone
27 http://en.wikipedia.org/wiki/Mobile_phone
28 http://en.wikipedia.org/wiki/Smartphone
29 http://en.wikipedia.org/wiki/App_Store
30 http://www.geekwithlaptop.com/french-customers-run-up-astronomical-bill-for-3g-internet-access
31 http://en.wikipedia.org/wiki/Android_(operating_system)
32 http://blogs.zdnet.com/BTL/?p=28432&tag=nl.e539
33 http://www.iphase.com/downloads/LTETechandCompwebinar.pdf
34 http://en.wikipedia.org/wiki/3GPP_Long_Term_Evolution



CDMA[35], a proprietary standard designed by Qualcomm in the United States, has been the dominant network standard for North America and parts of Asia, whereas GSM[36] technology, that includes UMTS[37] and HSPA[38], is also known under the name WCDMA[39]. HSPA is a family of mobile telephony protocols including HSDPA[40] (up to 7.2 Mb/s downlink speed enhancement), HSUPA (up to 5.8 Mb/s uplink speed enhancement) and HSPA+[41] also known as Evolved HSPA with up to 40Mb/s downlink and 10Mb/s uplink. Note that CDMA and WCDMA are incompatible.

Do all roads really lead to LTE in the short term, i.e. a convergence of CDMA and WCDMA? Some specialists, e.g. Dan Warren of the GSM Association, have doubts[42] "*With LTE set to become a short-term reality, rather than a long-term vision, it is easy to overlook the extraordinary impact of another young technology – HSPA. Now a standard feature in smartphones, netbooks and many laptops, HSPA is spreading mobile broadband services across the world and, in tandem with HSPA+, could ultimately emulate the longevity and widespread usage of GSM. For both GSM and CDMA mobile operators, all roads will eventually lead to LTE, but many will travel there via HSPA and HSPA+. The dilemma in the current economic climate is whether to move rapidly to LTE or focus near-term capital spending on HSPA and HSPA+.*"

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[35] http://en.wikipedia.org/wiki/Code_division_multiple_access
[36] http://en.wikipedia.org/wiki/GSM
[37] http://en.wikipedia.org/wiki/Universal_Mobile_Telecommunications_System
[38] http://en.wikipedia.org/wiki/High_Speed_Packet_Access
[39] http://en.wikipedia.org/wiki/W-CDMA_(UMTS)
[40] High Speed Packet Access - Wikipedia, the free encyclopedia
[41] http://en.wikipedia.org/wiki/Evolved_HSPA
[42] http://www.rcrwireless.com/article/20090929/FRONTPAGE/909289993/reality-check-all-roads-lead-to-lte-eventually

3.5 Internet Infrastructures

A more extensive version of the following sections article is available from http://www.ictconsulting.ch/reports/CHEP2009.doc

3.5.1 Academic & Research Internet

Over time, DANTE (Delivery of Advanced Network Technology to Europe), thanks to massive European Union funding and continued support of European NRENs, successfully managed to build, mostly over leased dark fibers, the very impressive pan-European GEANT backbone with many interesting features and services, connections to the academic world in Africa, America, Asia, Caucasian (Black Sea) and Mediterranean countries.

It is interesting to note that thanks to the deployment of dark fibers and the resulting availability of cheap 10Gb/s light-paths, GEANT evolved from a single global pan-European backbone into multiple Mission Oriented Networks, e.g. DEISA, JIVE, LHC[43], i.e. back where the scientific community was some 30 years ago with mission oriented networks like HEPnet[44], MFEnet[45], NSI[46], which is actually a very good thing!

In the USA, Internet2 deployed a "High-Performance Data Transfer for Dynamic Circuit Networks" capability over its production network infrastructure dubbed PHOEBUS[47]. This new service can be activated from outside or inside the network; in the latter case it can be seen as a regular traffic engineering tool, the innovation being its automatic activation in the case of high bandwidth flows. While ESnet uses OSCARS[48] (On-demand Secure Circuits and Advance Reservation System) to support production traffic. The main user community is the High Energy Physics (HEP) community with 21 out of 26 long term, i.e. static, virtual circuits[49] activated in October 2009, which is very similar to what can be seen in Europe over GEANT where the LHC community is, by far, the main user of dedicated "lambdas". What is more intriguing is the fact that short-term dynamic VCs have been used across ESnet on a "significant" scale, i.e. nearly 5000 successful VC reservations during the period between 1/2008 through 10/2009; however, most of these VCs have been initiated by BNL's TeraPaths[50] and FNAL's LambdaStation[51] with middleware that was precisely developed with the goal of demonstrating the use of dynamically established VCs. What is more "spectacular", in a sense, is that ESnet received ~$62M in ARRA[52] funds from the Department of Energy (DoE[53]) for an Advanced Networking Initiative (ANI) aiming at:

- building an end-to-end prototype network in order to address DoE's growing data needs while accelerating the development of 100 Gb/s networking technologies
- providing a network test bed facility for researchers and industry.

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[43] http://en.wikipedia.org/wiki/Large_Hadron_Collider
[44] High Energy Physics Network
[45] Magnetic Fusion Energy Network
[46] NASA Science Internet
[47] http://e2epi.internet2.edu/phoebus.html
[48] http://www.es.net/oscars/
[49] 3 VCs for Climate related projects (GFDL, ESG), 2 VCs for computational astrophysics (OptiPortal)
[50] https://www.racf.bnl.gov/terapaths/
[51] http://www.lambdastation.org/
[52] http://en.wikipedia.org/wiki/American_Recovery_and_Reinvestment_Act_of_2009
[53] http://www.energy.gov/

While there is no doubt that there are classes of data intensive scientific applications that absolutely require large amounts of bandwidth in order to operate successfully (e.g. HEP, astronomy, climate) and while the availability of large amounts of unallocated bandwidth in research infrastructures allows the development and deployment of new innovative Bandwidth on Demand (BoD) architecture and services, the question of whether these new types of services make real sense in a commercially driven Internet is, in my view, a sensible question to ask. Indeed, it is rather unclear whether there are sound commercial prospects for a mass market?

The answer maybe is to make an analogy with the commercial airplane industry where the cheapest way to fly is usually through hubs, i.e. local airport to hub, hub to hub and then hub to destination which is similar to the general purpose Internet; in contrast, direct, usually regional, flights allow shortcuts from local to destination airports, which is similar to end-to-end Internet circuits, whereas on-demand bandwidth solutions can be compared to private jet services. For once, the big science community would be travelling 1st class but are there real needs?

I contend that most needs can be satisfied with static circuits, either native, e.g. 10 Gb/s lambdas/optical circuits or emulated, e.g. with MPLS for fractional 10Gb/s circuits, i.e. typically 1Gb/s, above or below and my understanding is that this is the solution used by some research networks (e.g. RENATER) and commercial Internet Service Providers.

Grid computing was very fashionable some years ago, and funding agencies worldwide made considerable investments in Grid middleware and infrastructures. In addition a significant standardization effort has been put into defining open Grid protocols through the Open Grid Forum (OGF[54]). Despite all this, the commercial world, as exemplified by Amazon's EC2[55] service, is going into the direction of "cloud" computing. In an excellent article[56] authored by Judith M. Myerson[57] titled *"Cloud computing versus grid computing: Service types, similarities and differences, and things to consider*", the author outlines the evolution of the grid towards cloud computing very well. Cloud computing is seen by some people[58] as the "Anti-Internet[59]", in other words the return of proprietary applications which is rightly seen as the negation of openness and interoperability! Unlike the Grid, there is a glaring lack of cloud computing standards and, in particular, inter-clouds interoperability.

3.5.2 Commercial Internet

The commercial Internet is faced with a number of very serious challenges that are threatening its long-term stability. By far the most serious problem is the IPv4 address space exhaustion which is predicted to occur within the next 2-3 years and the lack of IPv6 uptake by the commercial Internet. There are also known DNS weaknesses (cache poisoning) that should be cured by the expected large scale deployment of DNSSEC in 2010, numerous security issues, lack of guaranteed Quality of Service (QoS), especially inter-domain QoS, poor mobility support and worrying growth of the routing table due to the fragmentation of the Internet and the increased use of Provider Independent (PI) addresses.

[54] http://www.gridforum.org/
[55] http://aws.amazon.com/ec2/
[56] http://www.ibm.com/developerworks/web/library/wa-cloudgrid/
[57] jmyerson@bellatlantic.net
[58] Michel Riguidel/Telecom Paris
[59] http://www3.informatik.uni-wuerzburg.de/euroview/2009/data/slides/Session3-Riguidel-slides-handout.pdf (page 19)

Lack of serious IPv6 operational deployment by commercial ISPs is clearly a direct result of the highly competitive Internet market situation with slimming profit margins; indeed, even assuming near-zero Capital Expenditures (CAPEX), the IPv6 deployment related Operational Expenditures (OPEX) will, no doubt, be fairly high.

While the common "wisdom" says that the academic and research community is still the major contributor to new major Internet technology innovations, I can only observe that, during the last decade or so, most innovations have actually come, in the form of new applications and services, through the commercial Internet, e.g. Web 2.0, sophisticated data dissemination techniques (e.g. Akamai, BitTorrent, Google, Yahoo), Web caches, content engines, network appliances, Network Address Translation (NAT[60]), Application Level Gateway (ALG), Firewalls, Intrusion Detection System (IDS), IP Telephony[61] (a complex mixture of IETF and ITU standards), Skype, Triple Play[62], Streaming media proxies, ultra sophisticated search engines like Google, Peer-to-peer[63], etc.

MPLS (Multi-Protocol Label Switched), IPSEC and SSL based VPNs (Virtual Private Network) are flourishing within the commercial Internet and are a major source of revenue in a market where, as already observed, profit margins are extremely low.

Internet TV over VDSL[64] is becoming increasingly popular and represents a serious threat to cable TV as well as terrestrial and satellite TV operators.

4 The predicted end of IPv4 and the long expected advent of IPv6

An IPv4 Address report is auto-generated by a daily script and is available from: http://www.potaroo.net/tools/ipv4/index.html

The report generated on 13 December 2007 predicted November 2010 as the date of the exhaustion of IANA's Unallocated IPv4 Address Pool and November 2011 as the date of the exhaustion of the RIR[65] (Regional Internet Registries) Unallocated IPv4 Address Pool. According to the December 14th report, these dates have now been pushed back to September 2011 and 2012 September respectively.

In a reason driven world the migration to IPv6 would appear to be unavoidable, however, the sad reality is that IPv6 deployment is still in its infancy and may even never happen as there is still a very strong resistance and alternative solutions/kludges, like carrier grade NATs, could extend the life of IPv4 indefinitely. In addition, translators providing a convenient way to interconnect the IPv4 and the IPv6 Internet will become widely available soon; even though it is rather obvious that a healthy Internet cannot rely on the massive use of translators, be they "carrier grade", these are likely to have a big impact.

One problem is that the time horizon of ISPs is much shorter that those of the Internet architects; indeed, Internet Service Provision is driven by short term economic incentives and the profit margins are very low due to the highly competitive business environment; hence, the business case for IPv6 seems to be nearly impossible to make and the proliferation of NATs (Network Address Translators) is likely to continue until the Internet becomes completely

[60] http://en.wikipedia.org/wiki/Network_address_translation
[61] http://en.wikipedia.org/wiki/Voice_over_IP
[62] http://en.wikipedia.org/wiki/Triple_play_(telecommunications)
[63] http://en.wikipedia.org/wiki/Peer-to-peer
[64] http://en.wikipedia.org/wiki/Very_high_bitrate_digital_subscriber_line
[65] http://en.wikipedia.org/wiki/Regional_Internet_Registry

impossible to manage and the case for IPv6 becomes both appealing and compelling. In any case, very interesting new ideas are already emerging from the various clean-slate Internet initiatives around the world therefore on can reasonably expect that some of these more radical design approaches, e.g. a content-centric rather than a host-centric Internet using self-certifying names, can be fitted into the existing Internet.

Therefore, it is extremely difficult to predict whether real IPv6 uptake will happen in 2010, e.g. in Network World 20/3/09 *"Business incentives are completely lacking today for upgrading to IPv6, the next generation Internet protocol, according to a survey*[66] *of network operators conducted by the Internet Society (ISOC)."*, whereas the Special Network World Executive Guide sponsored by NTT (21/1/09) is titled ***"IPv6: Not If, When***[67]?"

Although one can only concur with the above prediction, the sad fact, however, is that large scale IPv6 deployment by major ISPs around the world did not happen in 2009, what about 2010?

In any case, there appears to be, at least, a growing consensus that the IPv4 to IPv6 migration will not happen as originally thought out back in 1994, if only because of the forthcoming shortage of IPv4 addresses that will make it increasingly difficult to comply with the "canonical" dual-stack[68] transition strategy.

In a recent IETF panel[69] it was admitted by Internet developers that the ***"Biggest mistake for IPv6: It's not backwards compatible"***:

"Our transition strategy was dual-stack, where we would start by adding IPv6 to the hosts and then gradually over time we would disable IPv4 and everything would go smoothly," says IETF Chair Russ Housley, who added that IPv6 transition didn't happen according to plan. In response, the IETF is developing new IPv6 transition tools that will be done by the end of 2009.

Similarly, when asked the question ***"are NATs for IPv6 a necessary evil?"*** Russ Housley answered*:"They are necessary for a smooth migration from IPv4 to IPv6 so that the important properties of the Internet are preserved…we need to be pragmatic!"*

The above statements are very welcomed signs that paradigms are changing in the right direction, e.g. "end to end" is no longer a dogma, NATs are no longer evils, communication between IPv4 only and IPv6 only hosts is no longer deemed impossible. One can therefore hope that the IETF will soon specify the much needed new standards that could greatly facilitate a graceful transition towards IPv6.

5 Short Review of Internet "clean-slate" initiatives

Given the "stalled/ossified" state of the Internet and its inability to move forward in a coherent manner, some of the key players, e.g. the US National Science Foundation (NSF) through GENI and FIND, the European Union (EU) through the "Future Networks[70]" and "Future Internet Research Experimentation (FIRE[71])", Japan's National Institute of Information and Communication Technology (NICT[72]) through the Akari[73] project, but also some of the

[66] http://www.isoc.org/pubs/2009-IPv6-OrgMember-Report.pdf
[67] ksc.exportcenter.go.kr/_common/download/download_file.jsp?fileSeq=9999989979692
[68] http://www.rfc-archive.org/getrfc.php?rfc=1671
[69] http://networking-world.blogspot.com/2009/03/developers-admit-biggest-mistake-on.html
[70] http://cordis.europa.eu/fp7/ict/future-networks/
[71] http://cordis.europa.eu/fp7/ict/fire/
[72] http://en.wikipedia.org/wiki/National_Institute_of_Information_and_Communications_Technology

prestigious Universities that contributed the most to the Internet concepts and architectural principles, e.g. Cambridge University (UK), MIT & Stanford University (USA), have launched their own Internet "clean-slate" design programs.

NSF's GENI**[74]** (Global Environment for Network Innovations) is basically a flexible and reconfigurable network "test-bed" allowing multiple slices to be allocated to different user groups to validate their new architectural proposals. The GENI Research plan[75] is an evolving document which is most interesting to read as it very well describes a number of new "disturbing" concepts like "buffer-less[76]" routers, for example. The FIND**[77]** (Future Internet Design) program solicits "clean slate process" research proposals in the broad area of network architecture, principles, and design, aimed at answering these questions. "*The philosophy of the program is to help conceive the future by momentarily letting go of the present - freeing our collective minds from the constraints of the current.".*

It is, in fact, very surprising to find that so few public results are coming out of the GENI and FIND initiatives, despite all the "*hype*" that accompanied their launch. It is also very disappointing to observe similar "*opacity*" from Stanford University and MIT's (Communication Futures Program***[78]***) clean-slate projects. As a matter of fact the perceived "opacity" relates more to the results of the FIND/GENI projects than to the definition of the projects as well as the funded research. As a result of an external review[79] was commissioned by the NSF which concluded that although the FIND funded projects were quite interesting and addressed many meaningful areas, the project was leading nowhere, hence a refocusing through the new Future Internet Architecture (FIA) solicitation with a consolidation of the needed research in 4-5 large Integrated Projects. In fact, an approach very similar to the one taken by the EC with, for example, 4WARD.

It is actually a pity that the new NSF FIA solicitation clashes with EC's FIA ("Future Internet Assembly") initiative.

In contrast, the European Union FP7 programs like "The Network of the Future[80]" and "Future Internet Research & Experimentation (FIRE[81])" have not gained much visibility inside and outside Europe, despite the fact that these projects are not only very interesting but also very open, i.e. most deliverables are public. Indeed, the EU initiated a number of extremely challenging projects, e.g. 4WARD[82], ANA[83], Ambient[84], PSIRP[85], TRILOGY[86]. The 4WARD project is particularly interesting as it is driven by the Wireless World initiative (WWI[87]) that aims to contribute to a clean-slate Internet design from a global, including mobile and wireless, perspective.

http://www.parc.com/work/focus-area/networking/

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73 http://en.wikipedia.org/wiki/AKARI_Project
74 NSF's GENI
75 http://www.geni.net/GDD/GDD-06-28.pdf
76 http://www.sigcomm.org/co-next2007/papers/papers/paper15.pdf
77 NSF's Future Internet Design (FIND) Program
78 MIT's Communication Futures Program
79 http://www.nets-find.net/FIND_report_final.pdf
80 http://cordis.europa.eu/fp7/ict/future-networks/
81 http://cordis.europa.eu/fp7/ict/fire/
82 http://www.wireless-world-initiative.org/Innovation%20Day%202007/FP%207%20plans%20pa3.pdf
83 http://www.ana-project.org/
84 http://www.ambient-networks.org/
85 http://www.psirp.org/
86 http://www.trilogy-project.org/
87 http://www.wireless-world-initiative.org/

There are, however, some good news, for example, PARC[88] "*recently released an early version of open source infrastructure software and protocol specifications for their "Content-Centric Networking (*CCN*)" architecture*" with the stated goal "*to enable experimentation in the network research community and establish a foundation of open core protocols for content networking.*"

Van Jacobson[89] also delivered a very interesting lecture[90] titled "*Introduction to Content-Centric Networking*" at the FISS 09 conference in Bremen (Germany) in June 2009 and there is a very informative paper titled "*Networking Named Content*[91]" that has, however, ACM copyrights and cannot, therefore, be redistributed.

5.1 The growing controversy over publicly funded Internet "clean-slate" research

Not surprisingly, some, usually strongly IETF connected, Internet experts like Brian Carpenter[92] (BC) and Jon Crowcroft[93] (JC) are very skeptical about the flurry of "clean-slate" Internet initiatives worldwide, here are some quotes:

BC: "*Although the related work is extremely interesting it is potentially dangerous as it could create an even worse political delusion than the "IPv6 cures everything" delusion.*"

JC (excerpts from "Future Internet Exasperation[94] (FIE)": *"I'm so Bored of the Future Internet (FI). There are so many initiatives to look at the Internet's Future, anyone would think that there was some tremendous threat like global warming, about to bring about its immediate demise, and that this would bring civilisation crashing down around our ears. The Internet has a great future behind it, of course. However, my thesis is that the Future Internet is about as relevant as Anthropogenic Global Warming (AGW), in the way it is being used to support various inappropriate activities. Remember that the start of all this was not the exhaustion of IPv4 address space, or the incredibly slow convergence time of BGP routes, or the problem of scaling router memory for FIBs. It was the US research community reacting to a minor (as in parochial) temporary problem of funding in Communications due to slow down within NSF and differing agendas within DARPA."*

Although there is definitely some truth, also much wisdom, in the above statements, I think it is fundamental to avoid entertaining the illusion that "clean-slate" Internet projects are, by their very nature, "*revolutionary, i.e. eradication of the past*"; on the contrary and as pointed by many proponents of a "*clean-slate*" approach they should be seen as a "*clean(er) architecture-wise evolutionary approach*" as opposed to continue "*patching*" the Internet with half layers in horizontal as well as vertical dimensions, in order to solve the most urgent problems.

6 Internet Governance

This chapter was originally developed in the "State of the Internet & Challenges ahead" article and then updated in "Where is the Internet heading to?"

88 http://www.parc.com
89 mailto:van@parc.com
90 http://www.comnets.uni-bremen.de/typo3site/uploads/media/vjCCN-FISS09.pdf
91 http://www.parc.com/content/attachments/networking-named-content.pdf
92 http://www.cs.auckland.ac.nz/~brian/
93 Jon Crowcroft's Personal Home Page
94 http://www.cl.cam.ac.uk/~jac22/out/fie.pdf

This chapter was never meant to be exhaustive given the huge number of actors and its only intent was to clarify the roles of the Internet Corporation for Assigned Names and Numbers[95] (ICANN), the Internet Society[96] (ISOC), the Internet Architecture Board[97] (IAB) the Internet Engineering Task Force[98] (IETF), the Internet Governance Forum[99] (IGF), the OECD[100], the ITU and the European Union. The ITU and EU sections being fairly new and having been updated recently are reproduced here.

Regarding ICANN there has been a major policy change in September 2009 where ICANN announced the signature of a new 'Affirmation of Commitments' allowing it to break free from the US Government and be that long-sought-after international body. However, ICANN has confirmed that it will continue to be based in the United States.

6.1 ITU

For various reasons the ITU does not have a very good image in the Internet community, maybe because of its role in establishing the IGF, maybe for other reasons, e.g. failed standards like X.400, I personally believe that this poor image is largely undeserved given that the ITU has been very active on many fronts, e.g. QoS, Next Generation Networks (NGN) and a simplified version of IETF's MPLS, i.e. without dynamic signaling, called T-MPLS which is currently being reworked by the IETF under the name MPLS-TP in order to meet ITU's transport network needs.
More recently, ITU has started an annual Kaleidoscope event[101] *"aiming to increase the dialogue between experts working on the standardization of information and communications technologies (ICTs) and academia"* and a new Focus Group on Future Networks (FG-FN[102]).

However, reusing acronyms can be very confusing! For example, ITU's NGN only refers to the migration of the legacy telephone network and the new cellular phone networks over an IP based infrastructure and, although it claims to be a step beyond the existing Internet because of the built-in QoS, which is obviously necessary in order to support real-time delay and packet loss applications, it is not meant to address the future Internet as rather clearly shown in the following figures extracted from Tomonori Aoyama's (Keio University, NICT) presentation[103] at ITU's Kaleidoscope event in Geneva[104] (June 2008). The same remark can also be made about T-MPLS.

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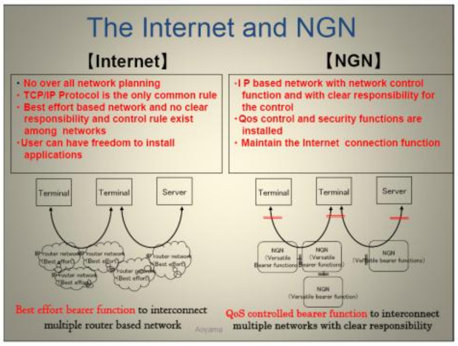
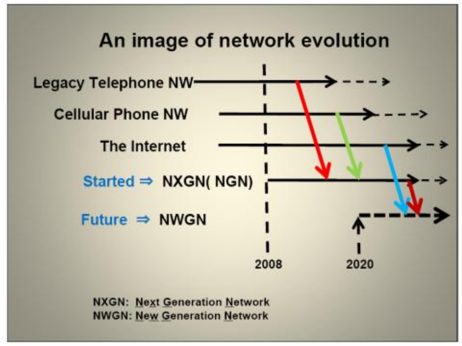
[95] http://www.icann.org/
[96] http://www.isoc.org/
[97] http://www.iab.org
[98] http://www.ietf.org
[99] http://www.intgovforum.org/index.htm
[100] OECD's Science Technology and Industry Directorate http://www.oecd.org/sti/
[101] http://www.itu.int/ITU-T/uni/kaleidoscope/
[102] http://www.itu.int/ITU-T/newslog/Group+To+Track+Global+Future+Network+RD.aspx
[103] http://www.itu.int/dms_pub/itu-t/oth/29/01/T29010010010001PDFE.pdf
[104] http://www.itu.int/ITU-T/uni/kaleidoscope/2008/programme.html





6.2 European Union

The EU has made numerous, rather unsuccessful, attempts to influence directly or indirectly the deployment of Internet or stated differently to counterbalance the influence of the US government. However, a Future Internet Assembly[105] (FIA) that is due to meet twice a year has been successfully started under the auspices of the EU in Bled (Slovenia) and continued in Madrid (Dec. 2008), Praha (May 2009) and Stockholm (November 2009).

7 Internet evolution scenarios

The uncertainties around the wide adoption of IPv6 as well as the possible impact of the clean-slate programs are such that even the best Internet specialists are very unsure about the evolution of the Internet, but at least three scenarios are possible:

1. no changes (i.e. the Internet remains largely IPv4 based with increased use of NATs)
2. migration to IPv6 (for sure IPv6 use will continue to grow but how fast and when can one reasonably expect the Internet to become IPv6 based with only residual IPv4 islands?)
3. clean-slate (i.e. radical new design). Even the clean-slate proponents all agree, I think, that a clean-slate Internet will need to coexist and interwork for many years, if not for ever, with the existing Internet, be it IPv4 or IPv6 or both.

Likewise, campuses will have to choose between:

1. Full IPv6 migration (i.e. dual stack everywhere) which is, in practice, very difficult because of old legacy equipment
2. Status quo (i.e. IPv4 as today) an unlikely though plausible scenario with connectivity to the IPv6 world through external gateways
3. Mixed (i.e. partial migration), implies some partitioning of the campus, e.g. dual stack servers, desktop PCs, printers, etc. unchanged

At first sight it looks like the deployment of IPv6 in the commercial Internet is somewhat easier, despite the fact that most, if not all, academic and research Internet backbone are already dual stack. Indeed, the commercial Internet is driven by commercial incentives, so, as soon as the business case becomes compelling, IPv6 deployment is likely to happen very quickly. In

[105] http://www.future-internet.eu/

particular, it appears somewhat simpler to deploy new IPv6 aware ADSL routers with new firmware than converting very large campuses.

In any case, ICT, in general, and the Internet, in particular, will, no doubt, become “Greener”.

Wired as well as wireless broadband access (i.e. Mb/s→Gb/s) will become nearly ubiquitous in a very fast evolving technology framework.

Use of MPLS will most certainly continue to increase. Although overly complex according to some, because of its connection oriented features and the associated signalling, MPLS has many interesting properties for Internet Service Providers, namely: traffic engineering, QoS delivery, provision of layer 2 or layer 3 Virtual Private Networks (VPN), departure from the destination based routing paradigm, implementation of the “routing at the edges, switching in the core” principle in order to remove complexity from the network core and push it at its edges. There are several MPLS variants: IETF’s MPLS/VPLS including “Pseudo Wires” (PWE3), ITU’s, a simplified version of IETF’s MPLS without dynamic signalling, currently being reworked by the IETF under the name MPLS-TP in order to meet ITU’s transport network needs, IEEE’s PBB-TE (802,1Qay), Provider Based Transport, which was initiated by Nortel and is similar to T-MPLS but is Ethernet based.

Regarding streaming and QoS, will streaming technology overcome P2P technology or the other way round and will inter-domain QoS ever become a reality?

8 Concluding remarks

The conclusions of this article are essentially copied from the previously quoted "Where is the Internet heading to?" article.

There is little doubt that the most urgent problem is the exhaustion of the IPv4 address space. Strangely enough, this is not currently seen as a high priority item by most ISPs; however, IPv6 looks unavoidable some day, especially if one adopts the “conventional” view that all Internet capable devices, e.g. mobile phones, sensors, home appliances, RFIDs, etc., must be directly accessible, but, is this really desirable or even sound? In any case, the IPv4 Internet cannot continue to grow “as is” beyond 2012 or so, therefore, increased deployment of IPv6 looks “almost” unavoidable. What is much less clear, though, is the level of seamless interoperability that will really be achieved between these two Internet as well as their relative importance during the years to come. In the meantime, NAT like solution, even so considered as “kludges”, are likely to continue to flourish and could even slow down considerably, if not prevent, the deployment of IPv6. Whether an IPv4 trading market will really develop and how it may impact the operational deployment of IPv6 is also impossible to assess at this stage.

The next most urgent problem is to solve the continuous growth of the routing tables that is endangering the growth and the stability of the Internet, but this should be much easier to handle as the core Internet routers market is still largely dominated by Cisco and Juniper. The proliferation of security threats and the associated “degeneracy” of the Internet, i.e. the deployment of patches/bandages, will no doubt continue as the time horizons of the Internet Service Providers and the clean-slate Internet architects are so different. Even though it is badly needed, the future of inter-domain QoS, remains very unclear!

The last major Internet architectural change was the introduction of MPLS, will it be the last one given the operational flexibility it brings, in other words will there ever be a "clean-slate" Internet? The increasing lack of "network neutrality" as well as the increase of copyright infringements and the related attempts to regulate the Internet in a lawful manner are also very preoccupying.

New business models will be necessary anyway, a mostly "free" Internet cannot go on forever, but are Internet customers ready to pay more?

9 Acknowledgments

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[106] http://www.slac.stanford.edu/

[107] Information Society & Media, Directorate D "Converged Networks & Services/Future Networks"