Key Technologies for the next-generation Internet

Khaled Fuad Elsayed
Dept. of Communications and Electronics
Faculty of Engineering, Cairo University
Giza, Egypt
kelsayed@alpha1-eng.cairo.eun.eg

Abstract

In this paper, we take a glimpse into the evolution of the Internet. Some key applications are identified as the main driver for evolution of the Internet. New technologies are needed to cope with the new requirements of the Internet. We review some of these exciting new technologies and illustrate how they can be used to move the Internet into new frontiers.

I- Introduction

It is not an exaggeration to say that we are currently living in the “Age of the Internet”. In the past few years, the Internet has witnessed a phenomenal growth and affected the average man’s life in no ways that were predictable or even dreamed of when the initial designers of the Internet started working on ARPANET (the early conception of the current Internet) in the 60’s. The growth in the number of Internet connected site and the number of people who have become Internet users (or addicts in some case) represents a unique phenomena in the history of new technologies.

This spectacular growth in the years from 93-97 can be attributed to the emergence of the World-Wide Web (WWW) and the related applications that enabled everyone who knows how to click a mouse to take advantage of a wealth of services and information available on the net. This growth has led to a new crisis in the Internet that WWW is now considered a synonym for World-Wide Wait! So, where is this growth taking the Internet? Will the Internet service quality deteriorate with time as more people and enterprises jump in to take advantage of the net? Would the companies taking advantage of the Internet be still able to attract more users? In the coming years, the Internet would be a much better place to be thanks to key new technologies and applications. This article is about the new applications that will be dominate the net, their implications, and how the Internet community is preparing to take advantage of new technologies to enable these applications and make the net even better.

II- Next Killer Applications

There may not be a single next-killer application that can identified as the sole source of driving evolution of the Internet and its technology. However, we can point at five applications and services that will place more demands on the Internet.

<u>1- Webcasting</u>
Webcasting is the integration of TV broadcasting and WWW technology: you would be watching a specific broadcast and on the screen you get some related network sites for more information. For example, you would be watching the evening news with some news about the space mission to MARS, a display of a set of web sites that are related to that will pop-up on the screen and there you can click your mouse and get more information about it, watch a previously recorded related news or just save the links for future reference.

Webcasting can be implemented in two ways: Either TV broadcasting would get some web content or the net would get TV broadcasts. In the first case, modified TV sets would be needed and net connections would be either wireless or through cable (if it is available). It is expected that every TV set in the world would get a built-in IP address for this purpose. The other way, which is currently available for demonstration, is getting live video broadcasts on the net integrated with web browsers. The current demonstrations of the technology broadcast low-quality video integrated with web-content and displayed via your normal browser (e.g. navigator or explorer) or via special applications such as Microsoft’s NetShow or Progressive’s RealPlayer.

Once webcasting is a reality and spread out in usage, it would place a tremendous burden on the Internet bandwidth. In order to distribute TV-broadcast high quality video, one needs at least 1-2 Mbps using Mpeg encoding. In addition, the net must be capable of providing quality of service guarantees for video/audio content. Ultimately, the entertainment and computing industries would be integrated and the Internet would be there to take advantage of this fruitful marriage.

To sample this technology, you can point your browser to [1] for audio/video broadcasts, to [2] for a list of broadcast events and their schedule, to [3] for exciting broadcasts of sports and for demos of webcasting, to [4] and [5] for a sample of webcasting and other multi-media applications.

2- Push-technology Applications

Another category of applications that are similar in essence to webcasting is push-technology applications. The difference is a bit subtle and one may argue that both types are really the same but I would argue that they are different. Normally a web user follows hyper-links leading from one site to another and "pulls"-in the required information. In the "push" world, a user would subscribe to specific services that are of interactive/live nature, such as stock quotes, latest news (related to a specific country or a particular event for example), or weather updates .. etc. When the price of a stock changes, a news item of particular interest to the user is placed on the news-wires, or a major weather cautionary is advertised, this information is "pushed" to the user desktop without the user explicitly requesting it. The user can control things as the refresh rates, how and where the information will be displayed and so on.

A very popular application is pointcast. Pointcast technology is being used extensively nowadays in Internets and Intranets. Pointcast is a very popular that many network managers in many corporations wish it never existed since it consumes a lot of bandwidth and it is very popular among corporate workers. To download a free copy and try pointcast, point your browser to [6], and to sample various flavors of push-technology go to [7].

3- Internet Telephony, Video-conferencing and Distributed Workgroup Applications

Many net users are familiar with on-line chatting through IRC, FreeTel, Yahoo and Excite Chat Rooms .. etc. Surprise (or maybe not to some readers), equipping your computer with a multi-media kit, possibly a digital video camera (you can get low video-quality/cheap camera for little money), and the right software tools, you can use your Internet-connected computer to do full-fledged live conversations and video-conferencing.

Not only this, but you can even make a dial a regular phone number, bypass the PSTN (the telephone network, you would still use the PSTN to connect to your ISP), make the connection through the Internet and pay much less than you would pay for the same phone call if it went through the PSTN. This is great for international and long-distance calling. It is projected that many carriers are now making plans to either adapt and enhance this technology or try to de-regulate it since it is definitely a threat to their business. However, at the current state, you would not do the phone call through the Internet unless you know the other party quite well and the other party knows somehow that you are calling through the Internet since the quality of the voice/video may be not what you get from the PSTN service. The Internet is still in large a best effort service that does not provide any guarantees on quality-of-service (QOS). The IETF (Internet Engineering Task Force) has introduced the Integrated Services model to handle application that need specific QOS from the net.

To get a feel for some of these applications try Intel Video Phone [5], Microsoft NetMeeting [8], and FreeTel [9]. To try making a free phone call on the net, check net2phone [10].

4- Virtual Private Networks over the Internet

An application which may not be as end-user-driven as the previous two examples is virtual private networks (VPNs) for large (international) corporations over the Internet. Large corporations with world-wide offices pay dearly to get their own private data/voice network to connect various sites. With the advent of encryption and formidable security firewalls, corporations can effectively construct their data VPNs overlaid on the Internet. Phone calls can still be transported if voice quality is not very important and the company wishes to save on international/long distance phone bills. This would definitely change with the Internet evolution towards the Integrated Services model.

When more corporations with to Internet-based VPNs, more bandwidth and QOS guarantees would be demanded from the net. To sample products, issues, and future direction of this topic, the reader can refer to [11].

III- Demands from the Internet for the Next Generation

The projected growth of the user/corporation base and the penetration of the next wave of killer applications will place certain demands on the Internet. In order to accommodate these demands, networking technology offers a variety of neat solutions. The demands from the next generation Internet and the technologies that can be used to accommodate them can be summarized as follows:

A backbone that is orders of magnitude faster then the current backbone. This is clear from the growth rate and the demands of the new applications. The solution is the usage of FiberOptics links, ATM Switching, and fast IP routers.

An increased pool of IP addresses. The current version of IP (IPv4) allows 2^32 addresses. This number is certainly a very large number. The problem, however, is that IP divides addresses into a subnet address and a host address. With the increased number of corporations that are requesting their own subnet address, it would not be too long before there is an IP address crisis. The solution of this problem is IPng (IP next generation) also known as IPv6.

Scaleable multicast-capable backbone. Multimedia application, webcasting and remote workgroup collaboration can make use of multicasting routers to reduce the overall bandwidth consumed by these applications. The solution is the usage of IP-multicast-capable routers and efficient multicast protocols.

Quality of Service Guarantees. Real-time and multimedia applications would require minimum guarantees from the network. The current best-effort model for the Internet can not accommodate multimedia applications with hard bounds on delay and packet delivery. The solution is the Integrated Services model, the Resource Reservation protocol, enhanced transport protocols (for example RTP), and effective usage of ATM networks.

Faster (and cheap) links to home and corporate users. Internet users are already complaining about that modems are too slow, ISDN is not very wide-spread and if it exists, is mostly expensive. Even with 56 kbps modems, home users would ask for more in the near future. In the mean time, corporations pay a lot of money for fast leased-lines connections to the Internet. The solution is xSDL technologies.

The following section highlights each of the above technologies and the way they can help the networking community build a better Internet for the next generation.

IV- Key Technologies for the Next-generation Internet

<u>ATM backbones for more Bandwidth</u>

ATM stands for Asynchronous Transfer Mode. It is a blend of packet switching (as in X.25 and ARPANET) and circuit switching of the POTS (Plain Old Telephone Service). In the (pure) packet switching model, no resources are reserved for the connections along the path from source to destination. In circuit switching, it is the reverse, enough resources are reserved to each connection to guarantee a minimum acceptable service quality. Packet switching is efficient but it provides no service quality guarantees to the users. Circuit switching on the other hand, will only admit new connections if their service requirements can be met but it can waste a lot of unused resources in doing this. ATM tries to achieve both efficiency through statistical multiplexing and quality of service through sophisticated signaling and congestion control mechanisms.

ATM is available on link speeds ranging from 64 Kbps to 622 Mbps. The most important feature of ATM is the marvelous speed at which network switches may route ATM packets. This is because an ATM packet (called a cell) is of fixed-length (53 octets) and because each connection is setup before actual transfer is done, therefore only a small identifier (called the VCI) is used to route the packets.

This enables the construction of very fast switches with simplified architectures as compared to packet switches with variable packet sizes. Another important feature of ATM is its ability to provide various classes of service. For example, provide service with delay bounds and guaranteed packet delivery while other classes can tolerate delays and packet loss. Since the Internet is IP based and ATM was not specifically built to handle IP traffic and IP routing, a myriad of techniques are proposed to route IP traffic using ATM switching efficiently and in wire-speed (native ATM speed). These techniques are collectively known as Layer-3 (IP) switching (as compared to currently available Layer-3 routing). The next generation of routers, called router/switch would have this functionality.

Currently, in the USA, NSF (National Science Foundation) sponsored the Very-high-speed Backbone Network Service (VBNS). This is a system composed of ATM switches and super-fast IP routers and links of capacity 155 Mbps interconnecting selected research labs and educational institutions. To get more information, go to [12]. Two more initiatives are the Internet2 project [13] and the Next-Generation Internet [14] are aiming at implementing a very-high-speed backbone to the Internet. The Internet2 project has stated one of its objectives as building an Internet that is 1000 times faster than the current Internet! For more information about ATM and IP switching, check [15] and [16].

IPv6 for Increased pool of IP addresses

Up until recently, the Internet has been largely used by universities, high-techs, and government. With the explosion of the demands to get connected, the integration of computing and entertainment industries with the projection that every TV set comes with an IP address, with millions of people roaming with wireless portables and wanting to keep in contact with their bases, and with Bill Gates hopes that every home appliance will be controlled through a home-area network (HAN) with IP being the protocol used, it is not surprising that the current pool of IP addresses will not be sufficient.

Sensing this trend, the IETF started working in 1990 on a new version of IP. Its major goals were to support billions of hosts, simplify and increase routing efficiency, provide better security, pay more attention to quality of service, and support mobility. Various proposals were submitted to IETF, and a combination was selected to strike a balance between efficiency, enhanced functionality and simplicity. Surprisingly, IPv6 is not compatible with IPv4, but it is compatible with other Internet protocols such as TCP, UDP, ICMP, IGMP, OSPF, BGP, and DNS. Two of the main features of IPv6 is that the address is 16 bytes instead of 4 in IPv4 and that the header has only seven fields instead of 13 in IPv6. The reduced number of header fields enable faster routing of IP packets and improves throughput.

Multicasting: Bandwidth scalability for group communications:

The IP protocol provides a native mechanism for multi-receiver multi-sender (or group) communications. IP has reserved a set of addresses (called class D in IP terminology) for group communications. This mechanism is referred to as multicasting. Multicasting is very useful for applications such as webcast and push-applications (single sender/multi-receiver) and multi-media group conferencing (multi-sender/multi-receiver). Consider for example a webcast application consisting of a single senders and N >> 1 receivers. The N receivers are distributed in M subnets, where M typically less than N. Without multicasting, the application and network would send each receiver a unique packet. With multicasting, there is only a need to send K less than or equal M (depending on the actual network topology) to the destination subnets. The routers in the destination would then multicast the packet to all the receivers it its subnet. This example shows how multicasting can make the Internet more scaleable specially that some of the killer applications would by nature make use of multicasting.

Multicasting is managed in IP networks through the IGMP (Internet Group Management Protocol). Multicast routing is implemented via modified versions of RIP and OSPF called (DVMRP and MOSPF respectively). PIM and SRM are being proposed to allow scaleable and more reliable multicast protocols.

MBONE, a testbsed for multicasting hardware and software has been operational since 1989 as a service over non-multicast capable routers. The key in building MBONE was to encapsulate multicast IP packets in regular IP packets through a technique called tunneling. MBONE enabled the research community to explore multicasting capabilities and a wave of multi-media applications(such as vat, nv, ivs, wb, and sd) emerged to make use of it. To get more information about multicasting and MBONE, check out [17] and [18].

Quality of Service on the Internet

All applications running on the Internet receive one type of service: best effort. For example, when you send out an e-mail message, there are no bounds on the time it might take the net to deliver the message to its destination. While this is acceptable for non-interactive applications like message delivery and file transfer, it is not suitable for the type of service applications like video-on-demand, web-casting, telephony and other real-time and interactive applications. These applications usually need a minimum bandwidth and certain bounds on the delay and assurance of packet delivery so that they would operate in a manner acceptable to the end-user. For example, if voice packets suffer from excessive loss, the received voice would not be understandable. On the other hand, if voice packets are not received within a specific interval, the phone conversation would be cumbersome. In essence, in the current model of Internet, every application might get some portion of the bandwidth but not as much as it might wish.

To resolve this problem, the IETF came up with the ReSource reserVation Protocol (RSVP) and a new model for the Internet known as the Integrated Services model. RSVP is a signaling mechanism through which applications can request specific QOS from the net. RSVP defines three classes of service: guaranteed service, controlled-load service (statistical) and best-effort. Best-effort service would make use of bandwidth and resources, remaining after satisfying the requirements of the first two classes, in the same manner as in today's Internet. For example, video and webcasting may be mapped to guaranteed service, interactive web browsing to controlled-load service and file transfer and e-mail to best-effort service. To get more information about RSVP and the integrated services model check out [19] and [20]

XDSL: high bit rate to home and corporate users

One is maybe very happy that his/her ISP is supporting 34.4 kbps or 56 kbps modems. This is probably the highest possible speed on telephone lines, right? WRONG, an amazing new family of modulation techniques collectively known as xDSL (digital subscriber loops) can get speeds of 1.5 Mbps (and more) over the normal copper wire connecting homes and local telephone exchanges for distances upto 5 Km. The key in xDSL is that, while modem technology use the 8 KHz bandwidth for the voice channel, a copper wire can carry frequency upto a range of 1.2 MHz. Using sophisticated modulation techniques, it is possible to provide a bit rate of 1.5 Mbps up to 8 Mbps depending on the length of the copper-loop (the longer the length the smaller the bit rate). The interesting fact is that, one can still carry normal phone conversations in the normal manner since xDSL does not touch the 8 KHz voice channel.

This is all good, the catch is xDSL modems are expensive and some equipment is needed at the local exchange. That means extra effort is needed since local carriers will be involved. Many carriers plan to offer xDSL service by the end of the decade. It costs about $1200 to install xDSL equipment at the user premises and the central office while for a 56 kbps the cost is only $200. However, as xDSL technology penetrates the market, the cost will go down (exponentially) to reach very reasonable levels as companies start to produce economic quantities of the equipments. At the current level, xDSL is still much cheaper than leased high-speed lines in the range of T1/E1 speeds. xDSL will offer comparable bandwidth at the fraction of the cost. Comparing xDSL with ISDN for faster connections, xDSL is much better. ISDN can offer a maximum of 128-144 kbps for 2B+D service which may cost comparably with xDSL. For more information about xDSL check out [21] and [22].

V- Conclusions

An exciting new set of technologies is ready to take the Internet to new frontiers. Thanks to these technologies the Internet would provide better services to a much wider user base and in an enhanced style. The impact on the society and workflow of organizations and corporations must be carefully studied. Organizations and corporations should put strategic plans to make use of the good opportunities the Internet has brought.

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