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From World-Wide Web to Information Superhighway

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Abstract

This paper reviews the origin of the information superhighway paradigm and the many resulting national initiatives or plans, including the US NII and the world-wide GII. The guiding principles are quoted, and a list of possible future services is presented, together with an overview of the major technological avenues. Then, the paper discusses the current prototype of the future universal information infrastructure, that is the Internet and its killer application, the World-Wide Web. It discusses which requirements are currently satisfied by the Internet plus WWW combination, and which capabilities are not yet provided. It concludes by presenting a possible scenario of evolution.

Several parts of this article are reproduced from the book "Understanding Networked Multimedia", François Fluckiger, Prentice Hall 1995 [1].

I. Origin of the Highway paradigm

The term Information Superhighway was coined by US vice-president Al Gore, as a metaphoric reference to an infrastructure transportation program launched many years before by his father. Initially, the metaphor referred in practice to a national initiative called the *National Information Infrastructure (NII)* which aims at "building a nation-wide system that will allow all Americans to take advantage of our rich resources in information, communication and computing technology". A few months after the initial US NII ideas had been laid down, a number of other countries decided to initiate comparable programs.

However, the information highway concept and its implications remained particularly obscure for most people. Three international surveys presented at the G7 summit which took place in Brussels at the end of February 1995 showed that half of the people in European Union (EU) member states are unfamiliar with the terms Information Superhighway and Information Society. The terminology itself is far from stabilised. An analysis made available by the end of 1994 showed that the following expressions appeared in the print media in 1994. They are ranked by frequency of occurrence: Information Superhighway (59%), Information Highway (36%), Info Highway (3.5%), Infobahn (1.3%), I-Way (0.2%). We briefly review in the next chapter the various national initiatives or programs before trying to identify common characteristics.

II. Several national initiatives

II.A. Information highway in Japan

In June 1994, the Japanese Ministry of Post and Telecommunications (MPT) announced a series of measures to launch an ambitious information superhighway program. The goal is to achieve by 2010 the connection by optical fibres of 75 million Japanese homes. The necessary investment is estimated to range from Y33 000 billion to Y55 000 billion ($300 billion to $500 billion), to which Y42,000 billion ($430 billion) should be added if the network is entirely underground.

One of the strategic objectives of the program is to help in resolving the problem of the saturation of conventional communications infrastructures in the country (road and public transportation) and to possibly contribute to de-congestion of the towns.

II.B. Information highway in Germany

In Germany, discussions on the information superhighway are directly connected to the deregulation of the telecommunications sector. At the time of writing, a number of industrial groups including Veba and RWE Energie have indicated their interest in participating in the future German highway, though no clear plan exists yet at the national level. Several regional initiatives have been launched, however. In the Eastern part of Germany, the OPAL program aims to connect 1.2 million homes with optical fibre.

II.C. Information highway in France

In France, a report issued in June 1994 estimated that FF150 billion ($28 billion) will be necessary to construct the infrastructure capable of connecting each of 30 million homes with an optical fibre. The report indicates that the cost in software development, will be three times that of the infrastructure. That is, the total capital cost of the national superhighway program, including infrastructure and server development should reach FF600 billion between 1995 and 2010. For the infrastructure, the superhighway program would imply extending the internal optical fibre infrastructure from 820 000 km to 2 million km by the end of the 1990s.

An initial base for the development of services and markets over the future French superhighway is the Minitel service. Already 7000 servers are active, accessed by 7 million terminals and a user population estimated at 15 million individuals. The turnover of the Minitel sector in 1994 was in the order of FF7 billion ($1.2 billion).

II.D. Information superhighway and European Commission programs

In 1994, the European Commission launched several studies to evaluate scenarios for launching a concerted program at European level and a proposal was submitted to the European Parliament. In parallel, a panel of industrialists, the European Round Table of Industrialists (ERT) published a report [2] which provided an evaluation of the market potential and a list of proposed actions (European Round Table of Industrialists, 1994). These initiatives have created awareness of the challenges Europe is facing and pushed national programs. Several new technological programs, such as the Trans-European Network (TEN-IBC), have been adapted to integrate information superhighway items.

II.E. The US National Information Infrastructure

The US NII estimates that of the order of $200 billion will be invested by telecommunications, cable TV, and possibly wireless cable operators in the coming 10 years to build the network infrastructure. The vision is to create a seamless web of interconnected and interoperable information networks, computers, and consumer electronics to link together homes, workplaces, and public institutions.

The National Information Infrastructure not only addresses home consumers. Public administrations will also be heavy users. Several large-scale regional initiatives exist, including the North Carolina Information Highway (NCIH) program, started as early as 1993. The NCIH expects benefits in education (additional classes, more equity in education, opportunity for team teaching, shared libraries, ...), health care (remote consultation and diagnosis, better medical continuing education, ...), criminal justice (video arraignments, interactive video for remote inmate education, law enforcement training, ...), economic development, government (reduced paperwork, videoconferencing , electronic town meetings, ...), and libraries.

However, the NII is not a monolithic network nor a single grand plan. Rather, it is presented as series of components, including a collection of networking technologies and a series of concerted actions. The NII Advisory Council has defined it as "the vision of a nation-wide, invisible, seamless, dynamic ***web*** of transmission mechanisms, information appliances, content, and people".

The relationships between the US National Research and Education Network (NREN) program —focusing on the development of information networks for education and research— and the wider NII have been addressed in several report including in [3].

Several guiding principles have been suggested for the NII, including:

- *Universal services,* that is, services available by 2005 "to all people with adequate facilities at reasonable cost".
- *Open access*; commercial and competitive initiatives should be the driving forces, though fair access and pricing to all companies should be guaranteed.
- *Privacy and security*; personal privacy, including information, transactions and communications must be protected, though such protection may be balanced by concepts of legal accountability.
- *Intellectual property;* where appropriate, amendments and clarification to existing US copyright law may be advisable.
- *Market place*; the NII must provide an information market place, and promote the principles of free enterprise.

The first report of the Advisory Council details each of these principles. In particular, the "universal access" principle contains the following sub-principle: "All individuals should be able to be both consumers and producers of information and services". This is a rather new principle, and we shall see that it is particularly relevant when we discuss the World-Wide Web.

III. The Global Information Infrastructure (GII)

Though no broadband national information infrastructure exists at the time of writing, the concept of a world-wide superhighway has already been launched. It has been coined by the US Administration as the Global Information Infrastructure (GII). Since none of the national components exist yet, and countries have distinct legal, cultural, and social visions and traditions which will lead to a variety of implementations, the GII is still a concept. However, Vice President Al Gore has recommended the following 5 fundamental principles:

1. encourage private investment;
2. promote competition;
3. provide open access to all information providers and users;
4. create a flexible and regulatory environment that can keep pace with rapid technological and market changes;
5. ensure universal services.

We can see that most of these principles are borrowed from the NII. They were discussed in February 1995 at the G7 summit on the information society, which, as a first step, adopted 11 pilot projects, ranging from electronics libraries to global emergency management.

IV. The 4 basic components of the superhighway initiatives

As explained before, the status and vision varies considerably from country to country. Whereas the USA have set up advisory and industrial committees, laid down the guiding principles, and tried to clarify the respective roles of the government and the private sector, other countries have just started a reflection on the scope and goals of their future national information highways. However, in most countries, it seems that the future information infrastructure will be based on 4 fundamental components.

1. *High-speed local loop to residential users*
   The idea is that high-speed digital connections should not be reserved for business environments. The exact bit rate requirement for the final home link varies from program to program. Intermediate phases based on the use of voice-grade telephone cables or analogue cables installed for CATV are often considered. In most countries, the final objective is, however, to eventually connect every home with an optical fibre cable. Tree topologies would be used to aggregate several subscriber fibres through hubs internal to the network. Other intermediate phases may in fact combine over a single cable conventional analogue transmission as used for cable TV distribution and digital transmission for newer interactive digital services. This is called the hybrid approach.
2. *A very high-speed backbone digital transport network*
   Of course, a backbone network is necessary to carry the traffic among subscribers, and between subscribers and information servers. The technology and the required speed of this backbone are generally not fully determined. The ATM technology is the most frequently mentioned.
3. *A network of information servers*
   The various programs aim at:
   - Integrating public servers of information already available on the Internet —some of these servers may not remain fully free of charge.
   - Promoting a new industry of profit-oriented servers to open new economic sectors.
4. *An integrated choice of services to the subscriber*
   The idea is that a single home connection will carry all conventional and new high-speed data services. In fact, this is the concept of "broadband integrated services digital network", but generalised at the level of every home, like electricity distribution.

V. Superhighways: the services to residential subscribers

The nature of the services that will be provided to residential subscribers over their access to national information superhighways will depend on the evolution of the technology, but will also be dictated by the industrial policies of governments. The services that *may* eventually be available to residential users over the superhighway termination links include:

- *Conventional telecommunications services*
  - Plain old telephone service (POTS) and telefax
- *Improved communications between people*
  - Videophony via existing TV or personal computers
  - Multimedia electronic messaging or on-line forums for residential subscribers
- *Healthcare*
  - Access to patient record and diagnosis information
  - remote consultation and diagnosis
- *Entertainment*
  - TV broadcasts in analogue mode (hybrid approach)
  - TV broadcasts in digital mode, often referred to as the "500 channels" program
  - High-definition TV broadcasts
  - Pay-per-view digital video programs on demand
  - Full movies-on-demand with VCR-style control
  - Remote computer games possibly multiplayers and with three-dimensional effects
- *Education and culture*
  - Generalised access to public Internet-like servers, via simple user interfaces
  - Customised and multimedia-based learning
  - Access to cultural information, exploration of museums
- *General information*
  - Topical or general static information on demand (administrative data, geographic information, ...)
  - Topical or general news on demand (sports, finance, weather, ...)
- *Transactions*
  - Teleshopping
  - Telebanking
  - Teleticketing (booking at a distance)
- *Advanced presentation of information*
  - Virtual reality advertising (remote exploration of virtual kitchens, houses, buildings)

When consulted early this year by the Eurobarometer, 55% of the people in the EU member states said they would like to consult a doctor from heir home. However, only half thought that the information society would improve their quality of life, and 70% thought the new services will not bring citizens closer together. Only 30% believe that these technologies will help reducing the various inequalities in Europe and other developed countries.

VI. Superhighway Technology

Not only the various national or regional initiatives differ in terms of scope, objective, industrial policy, or planned services, but the underlying technology is far from being universally agreed. Part of the reason stems from the fact that many essential components are at the fore front of current technologies. In this section, we list the major technological avenues currently considered.

VI.A.High Speed Carrier Backbone

Most medium or large scale pilot projects plan to use the ATM technology, which seems well suited for handling a variety of applications with differing requirements. However, for distribution applications, a broadcast or multicast functionality —that is, a facility supported by the network by which a source transmits a single information stream, which then reaches multiple destinations via appropriate replication mechanisms— is required. ATM networks do not yet support multicasting satisfactorily.

VI.B.Tail connections

As explained above, the trend is to connect homes with systems which can support a complete range of digital services, and not only movie-on-demand and broadcast TV channels. A number of options are proposed by operators or alliances of companies to build the internal transport network and to connect to the home. Many options for the final connection include the provision of both video- or movie-on-demand services and analogue broadcast channels. In such cases, the target is generally to offer in the order of 500 channels, including analogue broadcast channels, digital broadcast channels and digital video- or movie-on-demand channels. The list of options include:

- *Satellite transmission*
  The fibre cable approach —or other intermediary solutions based on copper cables— is not supported by the entire telecommunications industry. A number of industrial initiatives rely on wireless solutions, usually based on satellite transmissions and the use of small dishes. As an example, a small dish (18 inch) may cost as little as $700 and offers in the order of 150 digital TV channels.

- *Adapted cable TV infrastructure*
  The cable TV (CATV) operators may use their cable infrastructure to deliver services such as video-on-demand. But the simple-tree cable TV infrastructure has to be enhanced with some form of switching capability. Traditionally, cable TV operators have delivered TV to the home over coaxial cables that terminate in set-top devices. In several countries, CATV operators will benefit from their wide coverage. In the USA, their networks pass the door of over 95% of the homes.

- *Conventional copper telephone wires*
  Asymmetric Digital Subscriber Loop (ADSL) is a digital transmission technology designed to work over the regular 2-wire copper telephone loop. It supports two VCR-quality channels —that is, a bit rate of 3 Mbps— over about 3 km, and one such channel —that is, T1 speed— over 5 km. This is in the direction from the network to the home. The return channel, used for commands and user input, operate at a lower speed. This is why the technology is termed asymmetric.

- *Optical fibre infrastructure*
  Fibre-in-the Loop (FITL) is another option where optical fibre is used all the way to the home or to a very close pedestal. The latter case is called Fibre-to-the-Curb (FTTC). The optical fibre may be exploited in digital mode only. In such cases, the ATM technology is generally considered. In practice, both the cable TV and telecommunications operators are also considering hybrid infrastructures where the homes are connected with mixed fibre/coax cables.

- *Optical fibre infrastructure exploited in hybrid analogue/digital transmission*
  Another solution lies in the combination of analogue and digital transmission over an optical fibre, using two distinct wavelengths, one for each type of transmission. An example of this approach is called ATM over PON (APON).

In all interactive applications, a return channel for the user to input information has also to be provided. For systems which are of a broadcast nature such as satellite or cable TV, a simple solution is to use a separate network. The switched telephone network and ISDN can be used, and touch-tones can serve to code the requests. Another solution is to use radio transmission in specially allocated frequency bands.

VI.C.End-user systems

In professional environments, it is usually agreed that the end-systems accessing the information highway services will be powerful multimedia personal computers or workstations. The prediction is less clear for residential subscribers. One type of applications is called *interactive television (iTV).* Interactive TV is multipurpose interaction with servers using a regular TV set. The information displayed is not necessarily of the motion video type, and may be text only or still images. But in practice, both TV sets and personal computers may be adapted, enhanced or upgraded with external boxes —called set-top-boxes, to be the device of choice for information highway applications. Since the computer industry does not intend to remain inactive in this sector, the question is then whether the device of the future will be a TV set turned into a computer or a computer turned into a TV set.

VII. Internet and Word-Wide Web

Pending the deployment of a broadband world-wide Global Information Infrastructure (GII) a number of planned services are already available on the world-wide Internet through its major application: the World-Wide Web for the exchange and share of multimedia information.

World-Wide Web is the name given to a cooperative project, initiated in 1989 at CERN, Geneva, Switzerland, under the leadership of Tim Berners-Lee, to design and develop a series of concepts, communication protocols and systems to support the interlinking of various types of information according to the hypermedia concept [4]. The result of the CERN project is a series of protocols and specifications which have been endorsed by the Internet community and widely adopted outside their original organisation. Thus, the initial project evolved into a world-wide initiative, the success of which is largely due to the hundreds of contributions made throughout the world, and in particular, to the development and support by the National Centre for Supercomputing Applications(NCSA) of a family of popular user-interface systems known under the collective name MOSAIC. Early in 1995, CERN decided to re-focus its WWW involvement in those areas which are relevant to its prime mission. Since then, the development of the WWW standards is carried out through a consortium led by MIT and INRIA, thus maintaining a strong European involvement.

In computer industry jargon, a killer application is an application that makes its supporting hardware sales skyrocket. Probably, the WWW is the first killer application for Internet connections.

VIII. WWW guiding principles and main features

The design of the WWW followed three guiding principles:

- The abolition of the centralised information store concept, managed by dedicated information specialists. As a result, anybody can create and make available information.
- Geographical independence, via the specification of mechanisms to unambiguously locate distributed documents.
- The concept of a simple uniform interface, that hides the details of both the formats and the protocols involved in transferring the documents.

The WWW supports a simplified form of hypermedia applications. We say simplified, as the current implementation does not support the specification of timing relationships between components of a document, such as the display of an image synchronised with the playout of a sound. However, it allows navigation through multimedia documents, including text, images, sound and moving picture sequences. In its standard implementation, the WWW operates in the downloading mode —that is, sound or video sequences are first transferred, then played out. This implies that continuous media sequences are short, to avoid excessive delays. The regular WWW implementations do not support real-time transmission of audio or video. However, they are sometimes used as a user interface to real-time applications such as desktop audio-videoconferencing.

Another important feature is the facility for WWW servers to access any existing database, and not only to deliver WWW conformant documents. Finally, one of the most fundamental features is the support of transactions. Thus, not only passive consultation, but real interaction can be provided. This facility is essential for the support of commerce over the Internet. Security and privacy is however often felt insufficient, though considerable progress has been made over the last months.

IX. Internet and WWW technologies

We only briefly summarise those aspects of the Internet and WWW technologies which are relevant in the context of the information highway.

The Internet is a network of networks, based on a connectionless packet switching technology.

- The base Internet technology, IP, spans almost entirely the range of available speeds (from 300 bps to more than 100 Mbps) and access mode. It can run over any existing transmission technology, including ATM.
- A universal mechanism exists to uniquely give names to connected systems, and to automatically transform these names into physical addresses (DNS).
- The IP protocol supports multicasting, and can emulate a broadcasting facility by mechanisms of free membership to distribution groups.
- The Internet technology is not yet well suited for guaranteeing grades of service.

The WWW technology is currently formed of three distinct components: the specification of a format for (simplified) hypermedia documents (HTML), a protocol to transfer such documents or others (HTTP), and a format for specifying the location of objects in the network (URI and URL).

- The HTML format does not support timing relationships between parts of a documents.
- The HTTP protocol is said to be a stateless protocol. In practice, the user does no "connect" to a remote system. All the exchanges between the end-user's client system and the remote server

are asynchronous, and are performed by means of small messages which resemble electronic mail messages.

- Interactivity, such as needed by transaction applications, is also supported by the asynchronous exchange of messages: when a user fills a form, clicking on the "send" button triggers a message to be sent to the remote server. Note that the WWW concept of *stateless access* to servers —where requests are served without prior explicit declaration to the server by means of a user session— follows the same logic than the Internet *connectionless* concept —where packets can be sent without prior explicit declaration to the network by means of a connection.
- In many developments, the WWW is used as a universal interface to launch other applications. Examples include access to video-on-demand servers, or initialisation of desktop videoconferences.

X. Meeting GII requirements

Clearly, the combination of the Internet transport network and the WWW applications satisfies some of the guiding principles laid down for the Global Information Infrastructure. In other areas, they do not yet provide the desired information highway capabilities.

X.A. Internet carrier service

Internet, as a carrier network, fulfils the following GII requirements:

- *World-wide coverage*. In particular, its scalable technology is particularly well suited for less developed countries.
- *Open, non-discriminatory* access.
- *Universal service* for both companies and people. Due in particular to the wide range of connection speeds, including the regular telephone.
- Unique technology for *multicasting*, and for *universal naming* of connected systems.

The areas where the Internet carrier service does not yet provide the desired capabilities include:

- *Guaranteed grades of service* (in particular to support digital broadcast-quality motion video, which typically requires from 2 to 4 Mbps end-to-end).
- *Integration with/linkage to POTS*.
- *Hybrid* access for the support of *analogue* TV broadcast.
- Support of *digital HDTV* (which requires from 12 to 25 Mbps guaranteed end-to-end).
- *Ubiquity*. Not all potential users can yet readily take advantage of the Internet, which requires at least a home personal computer.
- *Integrity and privacy*.
- Detection and prevention of *fraud and abuses*.

X.B. WWW and other Internet applications

The WWW, together with other applications running atop the Internet carrier service meet partially or totally the following GII requirements:

- Support of *invisible seamless, dynamic web of information and people*.
- Partial support of improved *communications between people* (through desktop audio or videoconferencing, email, ...)
- Full support of *educational and cultural* strengthening.
- Anyone can be both *consumer and producer* of information.
- Full support of *"participatory democracy"* and access to general public information.
- Partial support of improved *healthcare* (insufficient support of motion video and fast transfer of very high resolution images).
- Partial support of *commercial transactions* (security and integrity to be improved).
- Provision of an *information market place*.

The areas where the WWW and other applications do not yet provide the desired capabilities include:

- *Ease of use*. The "point-and click" user interface is felt by some specialists to be too complex for many potential users. However, this point is contested by others.
- *Ubiquity*. The WWW currently requires a personal computer.
- *POTS*, though it is unclear when it will be a required capability.
- *Broadcast-quality digital TV* in distribution, pay-per-view or on-demand mode.
- Support of true *hypermedia* applications with full intermedia synchronisation.
- *Virtual reality* with immersion. Such applications usually require less than 100 ms for the round-trip delay.

Possible services (to residential and business users)	Supported today by Internet+World-Wide Web
Conventional services	
Plain old telephone service	□
TV broadcast in analog mode	□
Improved communications between people	
Videophony	▒
Multimedia electronic messaging	■
Entertainment	
TV broadcast in digital mode (500 channels)	□
High Definition TV Broadcast	□
Pay-per-view digital Video-on-demand	□
Remote computer games	▒
Education, culture, general information	
Access to scientific, technical, commercial information	■
Customized multimedia-based learning	■
Access to cultural information, exploration of museums	■
Transactions	
Tele-shopping, banking, ticketing from home	■
Commercial advertising and transactions	■

▒ Partially
■ Fully

XI. Conclusions

The combination of the Internet as a transport system and the World-Wide Web as a powerful but simple to use technology to exchange information of any type, already covers a significant fraction of the GII objectives.

- The Internet has a universal coverage and its technology can satisfy the requirements of companies to attach powerful computer centres over high speed links as well as those of residential users connecting cheap home personal computers via telephone calls.
- The World-Wide Web allows any individual at home or in a company to access remote servers of multimedia information from any regular personal computer. It supports transaction-oriented applications such as teleshopping or telebanking, commerce, inter-personal communications, audio-video cooperative work, or tele-education. It also provides a simple way for any individual to be not only an information consumer, but also an information producer by turning its computer into a server, and making available its reflections, knowledge or art work.

However, the current Internet and WWW combination can not support plain old telephone services, nor most of the entertainment services envisaged on the future broadband GII. It lacks ubiquity, high integrity and privacy, and protection against fraud. It will nevertheless constitute over the coming years, the major world-wide undertaking providing immediate and tangible results towards the information society. Analysts predict that the Internet will connect half a billion people before the end of the decade.

In the coming years we may expect two parallel processes to develop. On the one hand, the Internet and its major applications will try to overcome their shortcomings: better guaranteed grades of service and more security for the Internet, full support of hypermedia and real-time transfer, improved privacy for WWW and other applications. A reputed analyst has even predicted that over 100 million people will view the 2000 Olympic Games over the Internet. On the other hand, medium speed —e.g. based on the ADSL technology— and high speed infrastructures —mostly fibre and ATM based— will connect thousands of homes through pilot projects. The challenge will then be to progressively turn the many isolated pilots into a seamless integrated system offering world-wide services. At this stage, part of the Internet/WWW technology and concepts —those which ensure the current universality— may offer attractive overlay options —that is, running atop high speed infrastructures— for the necessary world-wide unification of services.

Why not support only ATM (plus a transport protocol) in each end-system? Experts are debating. Probably the IP technology or something equivalent will still be needed for a couple of decades as the unifying end-to-end layer. There are technical reasons for this, including addressing and network services such as name servers. But more importantly, the network which is envisioned for the next century should operate indifferently at 100 Mbps or more in certain countries, and at 300 bps in others. ATM-like and fibre technology will not reach all continents for many years. There will remain segments of IP routers interconnected by a variety of means. Thus, facing the diversity of data communications development, an approach may be to build gateways between the regions with less advanced infrastructures and the parts of the world already enjoying the ATM-based superhighway services. Instead of gatewaying two distinct worlds, with the risk of widening the technological fracture, we consider it preferable to unify the very diverse underlying technologies by using on top of them a common universal end-to-end technology.

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He is the author of more than 30 articles in data networking, has contributed to a number of international projects or activities including THORN, RARE, EARN, BETEL, or COSINE of which he is a co-author of the specification documents. He is a regular lecturer of multimedia networking at professional conferences. He has more than 20 years of experience in design, development and management of data networks.

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