Keynote

Bottom-Up Information Infrastructure and the Internet

by Anthony-Michael Rutkowski
Executive Director
Internet Society

I am pleased and honored to be here at the University's Founder's Day - this year focused on the Internet.

We should note at the outset that on the global map of Internet network density, Pittsburgh ranks 21st in the world with 235 registered networks as of the middle of last year, including of course, the University of Pittsburgh and Carnegie Mellon with the Pittsburgh Supercomputing Center, the Software Engineering Institute, and the US Computer Emergency Response Team. Even a casual query of the WHOIS directory service also reveals smaller institutions like the Pittsburgh Regional Library, the *Post-Gazette*, and Pittsburgh OnLine. It was rather irresistible yesterday - as well as fun and informative - to have "visited" several of these sites via the World Wide Web prior to actually coming here.

I even garnered what must be a local trivia factoid - that PittState is NOT in Pittsburgh PA, but in Pittsburg, Kansas!

Last year, Fortune magazine covering Internet developments dubbed locations like Pittsburgh as "Netplexes" - something equivalent to virtual metropolitan areas on the world's Information Infrastructure. Fortune magazine writer Rick Tertzelli was fascinated with the seeming irony that a technology that could support complete diffusion of people and institutions could at the same time produce these concentrations. The answer, of course, is that in the final analysis, it is people and local environments that spawn cybercities, not technology or machines.

Along these lines, therefore, I thought it useful today to discuss not only the Internet - its metrics and directions - but also the more profound meta-revolution that has only recently been recognized and called “bottom-up infrastructure.”

Bottom-up Information Infrastructure

The last decade has profoundly transformed the way we conceptualize and create information infrastructure. The "old world" was oriented around highly structured monoliths of the telco and early computer worlds that were planned and operated by big government and corporations. The national telecom and information policies and plans flowed "top-down" from millions of hours of huge formal meetings and literal mountains of paper which purported to chart the future of information infrastructure for decades to come. They provided a plethora of abstractions that no one quite understood, under the aegis of never quite defined nor accepted concepts like ISDN, OSI, and next generation mainframes. Enormous directed monies were to flow into these projects pursued by national monoliths, and trickle-down information infrastructure would eventually settle into place.

The Information Superhighway metaphor was an unfortunate throwback to this old pattern - which is why the Clinton Administration switched quickly to "infrastructure."

However, top-down just did not happen as planned. Instead, a combination of VLSI, PCs, workstations, Local Area Networks, routers, and elegant user friendly software found an enormous marketplace that motivated individual initiative and investments. At the same time, long haul transport technology offered increasingly cheap bandwidth, and national governments allowed facilities-based competition among telecoms and deregulated value-added services. Under combined pressures from rapid technological change, competition, and affordable new systems, the world of information infrastructure began a speedy transformation.

Washington policy makers began to get the picture several years ago - quite literally. I remember visiting the FCC Chairman’s office in 1990 and watched his assistant excitedly show two charts he had just put together. He said, “look at this graph from our Common Carrier Bureau that shows investment in the telecom infrastructure which the Commission monitors.” It was at the several billion dollar level and growing modestly and linearly - as it had for many decades. He grabbed another and said "look at this one - from the Commerce Department, looking at overall network infrastructure." It began at about the level of the telecom investment a few years earlier, and was rising exponentially to double the telecom investment by the late-80s. He noted "this enormous growing unknown gap represents investment in information infrastructure which we know nothing about."

At just the right time, robust TCP/IP technologies were available to serve as the universal intelligent interface among computers. As a result, enterprise networks, distributed network management and applications, and the global Internet became universally implemented. Massive bottom-up infrastructure happened, proliferated, and a new paradigm prevails.

Information infrastructure is no longer what you get handed from the telephone or big computer companies - or the PTT if you live in other country. Today, the most significant information infrastructure is what you put in your shopping basket at the local computer supermarket, and then connect, boot, and operate yourself.

This has been a remarkable decade-long learning experience - discovering what information infrastructure is all about, and in nurturing its development. It's discovery time in cyberspace, and we are constantly learning about what works and what doesn't. This is not to say that all top-down activities are frivolous - no more than asserting that all bottom up activity will produce meaningful infrastructure. Similarly there is a lot more to information infrastructure than just the Internet.

These experiences provide some invaluable models and lessons about key components of national and global information infrastructure. The most prominent of these lessons is that bottom-up infrastructure succeeds most efficiently and spectacularly!

The Internet Global Mesh

Constant Evolution: Three Stages

The Internet and internet technology has been growing and evolving constantly since its inception in Vint Cerf's imagination and first articulation more than 20 years ago on the back of an envelope in San Francisco. At the outset, it had multiple facets that addressed real needs: a means to share information system resources across multiple diverse platforms, a highly robust self-healing network that could operate across almost any medium to survive nuclear holocaust, and a way to bring together experts spread across the world in "collaboratories" to create, innovate, improve and produce in many different research areas.

It is now into the third stage of that evolution. The first stage was the early years under the aegis of the US DOD ARPA and the province of a relatively small closed community. Those people not only developed the technology, but the cooperative mechanisms and institutions that allowed it to scale and for further innovation to occur. The genius of it all can still be appreciated at major Internet meetings which typically bring together a significant cross-section of world's most highly motivated and innovative computer networking communities in every country.

Following DARPA's divestiture of the network and the technologies in the mid-80s, the second stage unfolded. It represented a period of major development by: 1) vendors for a growing enterprise internet market, 2) the USA National Science Foundation, NASA, and Dept of Energy and their counterparts in other countries who scaled the network to support open global academic and research activities, and 3) early innovators in the business sector who began providing public access services and using the capabilities. Interop itself was a key part of this second stage as it fostered massive investment in private open systems infrastructure.

The third stage is now unfolding as almost everyone, everywhere who provides, uses, promotes, or funds information systems and infrastructure becomes involved in the growth and use of the Internet, its technologies, and applications. If the first stage took us to 2000 hosts over the first ten years, and the second state scaled the connectivity from 2000 to 1 million over eight years, the third state of Internet growth is now marked by host counts that will likely proceed from 1 million to 100 million over the next five years. The growth of the attached networks is now publicly announced every three days, and we are literally watching it grow before our eyes.

Dimensioning Internet

The Internet is generally dimensioned two different ways. The core portion consists of the subset of registered internetworks that are known to have IP connectivity among themselves; while the larger Matrix Internet popularized by John Quarterman consists of the core Internet plus all the networks known to be connected to it by some lowest common denominator application like messaging.

The Core Internet and its metrics

As of the end of January, there were 569,915 allocated network addresses, 61,843 registered at the global Network Information Center, and about 46,318 known to have connectivity among themselves. For the last several years, the most widely used backbone network - the NSFNet - has provided a useful reference point for making consistent measurements.

Total networks increased at the rate of 97 percent last year; 98 percent outside the USA. As of 1 Feb, IP traffic is being routed to networks in 90 different nations. It's known that the European CERN backbone usually sees more reachable networks, and with the emergence of commercial public Internet backbones as well as the termination of NSFNet in April, the total number is likely to increase even faster.

Another major trend - in addition to globalization and the rapid increases - is revealed in analyzing the kinds of new networks attaching. Most are commercial in nature.

Specific focus on both the Asia-Pacific and European regions shows that about a year ago, the number of networks in most countries with significant GNPs began to scale significantly with about 2000 connected networks in each country. The trend seems unabated.

In addition to dimensioning the Internet in terms of networks, it is also possible to do so by computer hosts reachable. Since the earliest days of the Internet, Mark Lottor has been executing an Internet Walk script over several weeks to produce an actual list of every machine reachable. The results are generally released every three months. As of the end of January, the number of hosts was 4.852 million. The count increased 119 percent over 1994. Lottor's hosts reachable dimension of the Internet is regarded as particularly significant because of the Internet's most basic function is providing connectivity among machines.

The most profound indication of the changing nature of the internet is reflected in the registered domain statistics. As of 19 Feb, there were 34,900 .COM domains, 3490 .ORG, 2040 .NET domains, 1770 .EDU domains, 340 .GOV.

Internet traffic is also highly important in understanding usage patterns among countries and among the hundreds of technologies employed as services on the Internet. Traffic on the NSFNet backbones has been doubling every year and was no different. However, that statistic is becoming increasingly irrelevant as the NSFNet is being phased out. Many smaller local backbones have experienced regular traffic increases of 20 percent per month. Outside the USA, many nations have experienced initial annual traffic increases measured in the thousands of percent.

The most interesting new service from a metrics standpoint is the World Wide Web which has grown spectacularly to account now for 17.6 percent of the entire NSFNet backbone traffic at the end of January. Web traffic grew at the unprecedented rate of 341,000 percent in 1993, and 1,151 percent in 1994. New Web servers have been added so fast that virtually every organization of any kind with a significant Internet connection now has a site. If this growth pattern persists, some have calculated that in three years it will exceed the total world voice communication traffic.

The Matrix Internet

The core Internet's massive size, high performance, and open connectivity has proved a magnet to nearly every other kind of computer network. As a result, many other large and extensive networks have attached themselves to the core Internet's periphery. This includes networks based on specific platforms like BITNET, FidoNet, AppleLink, Minitel, and UUCP networks, as well as specific application networks for Email - for which there are numerous examples like X.400, AT&T mail, MCIMail, SprintMail, CompuServe, etc.

These peripheral networks create a larger Matrix Internet that currently reaches 168 countries, and provide many millions of people with lowest common denominator Email connectivity. In this capacity, the Internet is truly the world's universal electronic messaging backbone.

Open Collaboration & Development

Just as the Internet is technologically a virtual matrix among up to 4 billion computers and 64,000 process ports on each of those computers, so is it also a matrix among 20-30 million people who are directly or indirectly using those computers and processes. This is an enormously empowering capability that allows almost instant creation of workgroups, discussion groups, and audiences of all kinds. The capability transcends time zones, national and organizational boundaries, and in the near future even language. In its ultimate extrapolation, it is the ultimate open society where anyone, anywhere can provide or receive any information to anyone within seconds.

From its inception, the Internet was intended as more than just a computer network, but as a means of facilitating collaboration and development at great speed - sometimes described as technology transfer among disparate groups with different strengths like academics, industry researchers, and business entrepreneurs. This activity has taken two forms: 1) research and development of new distributed network techniques and applications, and 2) innumerable user populations employing the Internet and its technologies as tools to significantly enhance their specific professional activity or pursuit.

An entire new engineering and research discipline has been cut out of whole cloth - distributed autonomous networking - complete with its own development dynamics and methods. Mosaic, httpd, Gopher, Archie, Veronica, Collage, Eudora, POP, SMTP, Netfind, Knowbots, NFS, NNTP, VAT, and SNMP are examples of some of the more popular client-server products to come out of the Internet innovation "soup."

With amazing rapidity, ideas for a new application or service get vetted on a discussion group or at IETF "BOFs" and proceed through a standards working group. At the same time, the code is placed on a network server. In the process, innumerable users employ the code, grow the market, refine the code, and a large commercial market emerges in a matter of months that is finely tailored to end user needs. Even commercial proprietary code is being distributed on the network to test and grow the marketplace - as is the case currently with 32-bit versions of Microsoft Windows operating system code being distributed concurrently with new versions of Mosaic. This process of developing running, standardized code through the Internet has been highly successful.

It is the more general user populations, however, who are embracing the tools in vast numbers across the planet. The enormity of the implications are just beginning to be understood. For example, it's asserted that 80 percent of all the scientists who ever lived are on the Internet today! And in each of these fields, the people "networked" constitute the majority of early adopters and innovators.

Transforming Enterprises, Institutions, and Professions

The effects of large-scale networking of enterprises, institutions, and people are now being realized. Certainly traditional barriers whether they are reporting hierarchies, institutions, country or geography are being obliterated. There is also a certain "compelling" effect that beyond a certain point promotes ever larger numbers of people to become networked. Not having an Internet mail address today has become a major liability in many businesses and professions.

The result has been to transform old institutions, create new network based enterprises, and bring about programs to implement these transformations. The best known of the latter is the Clinton Administration's Reinventing Government initiative. However, on a smaller scale, efforts are now underway in Canada, Chile, Argentina, France, and Poland - as well as many international organizations.

Some major older corporations like IBM and Chrysler have embarked on well-known efforts to get Internet technologies introduced among their employees to purposely break down both internal and external barriers. In an increasingly competitive environment, lacking network connectivity and employees with skill sets to effective use the network tools, is a major liability that's quickly reflected in either diminishing market share or lost opportunities.

An entirely new and potentially massive new field is now emerging around the Internet and distributed networking. Getting connectivity is only one component. More significant (and perhaps more difficult) is obtaining and retraining people to effectively use these tools in many different enterprises. This daunting task involves not only equipment, but cultures and attitudes. And, it also pervades every office in a corporation or institution, from the CEO to the average staff member in every department.

Not suprisingly, there is a focus on developing these skills now at the elementary and secondary school levels so that children at an early age are able to comfortably use and create information on computers, to discover and make available networked information resources, and to collaborate seamlessly across networks with their peers. These are the survival skills of rapidly emerging global internetworked environment.

The Future

It seems meaningless to talk about "what's after the Internet" anymore than to talk about what's after the telephone. As long as we have computers speaking to other computers via distributed networks, we will have internets. Indeed, a hundred years from now, history may well record the emergence and implementation of an Internet protocol as a profound turning point in the evolution of human communication - of much greater significance than the creation of the printing press.

No other form of human communication other than actual meetings allow people to actually interact with each other in a collaborative fashion in short time-scales. It is this capability of rapid, large scale, low-cost interaction of people and sharing of information that are unique Internet properties - which have profound implications across a broad spectrum of human activities.

It's difficult to predict where all the different facets of the Internet are leading us. In the near-term, we can look at events currently underway to chart likely developments in the coming months.

Business on the net

The Internet use most likely to scale really dramatically seems likely that of business transactions. The arrival first of WWW-html forms, then of safe and simple monetary transaction mechanisms, are the bellwether for what is projected by some to be a trillion dollar a year Internet-based marketplace. Even the names of these new mechanisms capture the imagination: CyberCash, DigiCash, NetCash, First Virtual, and NetCheque. The microtransaction costs of some of these techniques should make possible an entire new realm of enterprise opportunities.

Ubiquity

Other major indicators include both the ubiquity of the access, as well as the ease of setup and use by ordinary people. Access involves the diversity of the media being employed (such as local dialup, freephone dialup, CATV LANs, N-ISDN, and VSATs), and the ever-expanding number of service providers - especially major carriers and local resellers. Resellers are especially important in this phase of internet evolution because of the frequent significant level of interaction with customers in using the technology. However, some of the newly emerging software for PC environments is so object oriented and self configuring that only minimal computer skills are required.

The Challenges and Promises

No electronic network mesh has consistently grown on the scale at the speed of the Internet. As a result, it has throughout its history been constantly challenged to develop new technologies, standards, and administrative techniques to provide greater bandwidth and additional services to more users through ever more complex architectures. However, each order of magnitude scaling becomes more difficult.

Problems associated with addressing and security seem largely transitory - with a combination of technology, new standards, and administration providing effective solutions.

The next few years will likely witness nearly every computer in the world being potentially connected to an internet. This seems well within the realm of feasibility. However, what numbers are actually connected to the Internet or accessible - through the Internet and at what bandwidths or time periods - depends largely on the available underlying infra-structure and cost of service.

Bandwidth seems destined in the long-term to approach zero within and among most metropolitan areas of the world, but the increasing complexities of managing ever larger numbers of Internet networks is going to drive operation and maintenance costs up. The result for end users may mirror the computer world where the performance just keeps on increasing at relatively constant cost. In fact, the evolution of computers and computer networks is sure to proceed hand in hand. And collective innovative Internet genius will doubtlessly produce an endless stream of imaginative applications and tools.

It is at the human and institutional levels that major unknowns arise - but also offer the greatest promise. The autonomous, heterogeneous, flat model of the Internet seems intrinsically a good one. It will be constant discovery time in Cyberspace, but a world of shared minds that transcends the accidental boundaries of history, the distance of geography, the machinations of institutions, and the mischief of manipulation, is potentially one filled with discovery, fulfillment and fascination for all peoples - individually and collectively.

The Internet Society as the international organization for the Internet is dedicated to help make this happen.

›››šśš