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The Top Five Lessons Learned from the ARPANET Applicable to IPv6

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Internet History

First, let's look at Internet history. The launching of Sputnik caused President Eisenhower to form ARPA in 1957, to quickly create new technology, like the space program, which did not fit any current military necessity. It was created with a very broad and open mission and with a minimum of red tape. The people hired were top technology experts intended to stay for only a short period to fund research in their field. Dr. Licklider from MIT was the first Director of Information Processing Techniques (computers and communication) and quickly funded interactive computer research at key universities, greatly increasing the number of computer professionals in the US. Dr. Licklider convinced me to pursue computer networking in 1964. After a networking experiment at MIT which proved a new communications technology (packet switching) was required for linking computers, I was recruited into APRA in 1967 to make computer networking happen. My first plan was published in 1967; the first four nodes were installed in 1969, and 23 nodes were operating by 1973, using the initial ARPANET protocol, NCP. The ARPANET was a very inexpensive project by government standards, costing only $26 M over the first 5 years through 1973. However, a full demonstration at the ICC conference in 1971 had already shown the world the power of packet switching and the ability to interactively interconnect many computers. Traffic and users doubled each year starting in 1970 and continue at this rate today. When I left in 1973 to start the first commercial packet network, Telenet (now Sprint), Bob Kahn and Vint Cerf took over the ARPA program, developing the current Internet protocol, TCP/IPv4, and converting the network to TCP/IPv4 in 1983. It quickly became the worldwide standard. They eventually turned the Internet over to NSF, which later divested it, allowing commercial networks to take over.

Technical Problems

Second, let's look at Internet problems. Until today, the extant Internet protocol, IPv4, has served successfully for 22 years. However, due to extremely low cost (compared to TDM networks), both voice and video are now migrating to the Internet, and the current system cannot support real-time streams adequately. It has major delay variance and controls traffic through packet loss, both inappropriate for streaming media. Also, IPv4 does not support preemption priority, so that emergency services cannot be assured to function as they do on the PSTN. Security is an additional major problem, because IPv4 does not check the sender's source address, allowing anyone to send spam, viruses, worms, and denial of service attacks. Most of these problems could be solved by conversion to IPv6 from IPv4; however, the US is well behind the world in this process.

US Economic Issues

Also of great concern is the economic impact on the US. Clearly, the Internet has greatly accelerated the US economy, so that the majority of income is now generated by information services. However, the rest of the world caught up in the 1990's, and, through different government policies, many countries have passed the US in broadband installation, Internet traffic per person, conversion to IPv6, and are also well ahead in instituting video and voice services. Besides the negative impact on our balance of trade, the largest impact will be in the future, when countries like South Korea have a significantly better educated population due to the current widespread use of the Internet and its far advanced penetration of broadband into the home to provide video education. We clearly cannot depend on manufacturing for the US economy; we depend on our advanced education to lead in high technology products and services. This lead can evaporate quickly as other countries deliver education far more cheaply and for more hours to their children than we can.

The Five Lessons

1. **Protocol is important:** The original protocol, NCP, was designed for a small network and could not scale. IPv4 was a critical improvement in that it permitted nearly unlimited scalability and thus became a common protocol for all the computers in the world to intercommunicate. That scalability is now nearing its limit with the address space in IPv4, and IPv6 was designed many years ago to correct this limit. However, scalability is not the only benefit from IPv6 and is of less importance to the US, where most of the address space was assigned. Of far greater

importance are the improvements in security, QoS, and mobility.

2. **Technology Introduction:** When I was faced with a reluctant computer research community in 1969 that did not want their computer made available to others through the ARPANET, I used a stick and a carrot: no new computers without the network attached, and the promise of network research funding. Later, conversion to IPv4 was forced by DARPA in 1983; DARPA also used its significant funding of the computer community as a stick and carrot. Today, the DoD has announced its movement to IPv6, but there is no stick, nor much of a carrot (funding) even inside the DoD, and nothing outside the DoD. The government could become much more proactive here.

3. **User Groups Should Control Protocol Direction:** When I needed a protocol for the ARPANET, I appointed a committee of graduate students from all the user sites to design it. Similarly, IPv4 and IPv6 were created by Cerf and Kahn using the research community to review the design. When I designed the first commercial packet protocol, I went to the CCITT (now the ITU) to negotiate the protocol. The ITU is a collection of the user countries who all want to interoperate. Today, however, the IP protocol extensions required for things like the missing QoS signaling capability are mainly controlled by the product vendors dominating the IETF. Little progress can be made with such groups on innovations that might affect their product cycles. Thus, the current IPv6 QoS signaling protocol that could make possible secure quality video, voice, emergency services, and faster web access has been moved mainly through the user oriented standard committees, the TIA and the ITU.

4. **Security does not sell, it must be mandated:** Throughout history, security improvements have not been created by commercial demand, since one buyer cannot change the others. It has always required government direction or mandate to institute better security; this is true from police to networks. The security improvements in IPv6 could stop spam, viruses, DDOS, and worms due to the secure authentication of the sender. However, this helps no user unless all the others switch. Thus, it becomes a government issue to mandate the conversion to a secure protocol like IPv6, rather than leaving it up to user purchasing decisions.

5. **Broadband Penetration:** The ARPANET/Internet history proves that higher bandwidth to the user permitted many new services and opportunities. However, the US failed to create the correct environment for the rapid installation of broadband to the home, or even to businesses. In Korea, the government mandated high-speed service be made available, much like the US did with rural telephone service. Korea is now at over 90% penetration, while the US is in the 20-30% range. It will take 5 years to catch up to Korea, and the traffic per user lags by 17:1. This greatly inhibits new services like video education, which could very adversely impact the US economy. This oversight also was a major contributor to the failure of the US ISP industry, which was caused by a lack of edge access capacity, and, therefore, the expected traffic. Even though the introduction of DSL was flubbed by our public policy, action could be taken today to support all forms of broadband access, including municipal wireless. Instead, policies are being created by states to prohibit municipalities from supporting wireless. While Korea and Japan are rapidly moving to IPv6 to support their video and mobility for wireless, the US has no public policy on either broadband support or IPv6. Unfortunately, the economic impact from inaction could be huge in both education and exports.