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PAUL BARAN – The Beginnings of Packet Switching (RAND Corporation)
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How the author of packet switching (foundation of modern communications), sees his work after 40 years.



Interviewed September 27, 2003 in Atherton (CA)

Born on April 29th 1926 in Grodno, Poland (now Belarus) and moved to the USA at two years of age, *“the best decision I’ve ever made”* :-)

Received a B.S. in Electrical Engineering from Drexel Univ. in 1949 and an M.S. in E.E. from UCLA in 1959. Worked for Hughes Aircraft Company and joined the RAND Corporation¹, where working on a system for U.S. telecommunications infrastructure to survive a "first strike,"² conceived the ideas that became foundations of the Internet and digital packet switching.

<http://www.rand.org>
<http://www.com21.com>

Since the 1970s, as an entrepreneur and private investor, he started seven³ Silicon Valley companies, of which five became public companies. At the time of the interview he serves as a trustee-director for several non-profit organizations including the Charles Babbage Foundation, the IEEE History Center, and the Marconi International Fellowship. He holds 30 US patents and has received numerous professional honors.

¹ RAND was established by the US Air Force to preserve the operations research capability created by the Air Force in World War II and to work on issues of national security. According to Baran, the freedom of the staff to choose projects, try novel approaches, and disagree with the bureaucracy is difficult to imagine in the present environment.

² This was in URSS-USA Cold War times. He was flying continuously from Santa Monica (CA) to Washington, and said that he did a large part of his work on the plane.

³ *Cabledata Associates* (to create new technologies), *Comprint, Inc.* (low cost computer printers); *Equatorial Communications Co.* (first VSAT company); *Telebit, Inc.* (highest speed telephone modems for bad lines); *Packet Technologies* (broadband digital services to the home Via TV cable); *Stratacom* (sold to Cisco) & *Com21* (ATM based cable TV modems).



Do you remember when you had your first contact with a computer?

I worked on the first commercial computer, the Univac 1⁴, as a technician at the Eckert Mauchly Computer Company (whose founders built the first large electronic computer, the ENIAC). Among my jobs was calculating lifetimes of the components, at which time I concluded that computers would be too unreliable to be economic.

After that I worked for two electronic companies, and in 1955 I moved from New York to California with my wife Evelyn Murphy, where I joined Hughes-Aircraft and started taking after hours classes at UCLA⁵.

What was your first contact/experience with Internet or ARPANET? My work in this field was primarily pre-ARPANET. After Hughes-Aircraft, I joined the non-profit RAND Corporation in 1959. RAND received its money from the US Air Force once a year and we were given remarkable freedom to pursue our choice of subjects to research. As a result of my experience in radar information processing at Hughes I became concerned about issues of vulnerability and command and control.

In the late '50s the Cold War was heating up and the major problem facing the country and the world was that both sides⁶ were planning to build highly vulnerable missile systems. RAND studies showed that the US strategic command and control systems would be destroyed by Soviet missiles aimed at the US counter weapons. I felt that this was a major problem and one where I could contribute toward a solution. I then came up with the idea of a system design based on a distributed network of nodes. In my frequent visits to the Pentagon while serving on a Department of Defense committee I came to increasingly appreciate the need for a "survivable network."



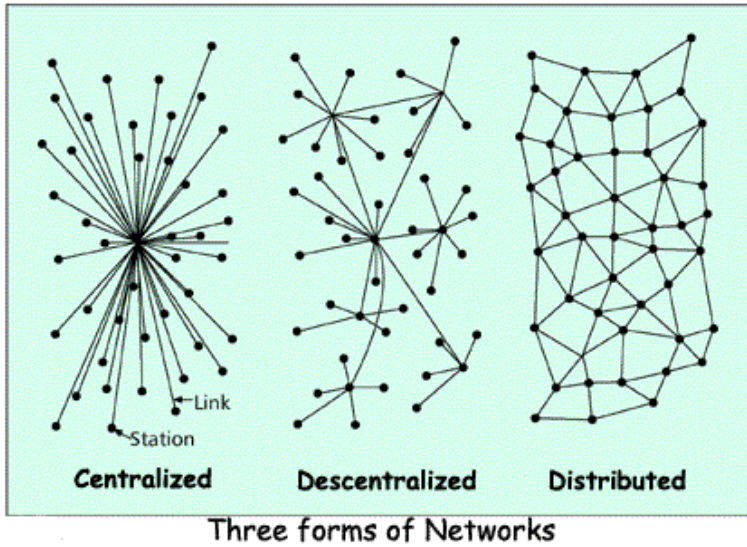
My basic concept was *Parallelism* in communications (Many parts had to fail before no path existed between any two nodes). This required the use of *Digital Signals* and packetization or what I then called "Message Blocks". I proposed *Hot Potato Routing*⁷ now called deflection routing.

⁴ Delivered to the U.S. Census Bureau, was the first commercial computer to attract widespread public attention.

⁵ He received an MS in Engineering degree from UCLA in 1959.

⁶ Former URSS & USA

⁷ The main idea is that you have to maintain a "carbon copy" of the message sent to the next station until you know the message has arrived without errors.



Most of my work was done in the period 1960-62. I gave the briefings to the military, to government agencies, to research laboratories, to commercial companies and to universities. As I gave more than 30 briefings, I refined my ideas every iteration. I published a number of papers from 1960 onward and a relatively final set of memoranda in 1964⁸. In 1965 the RAND Corp.

sent a formal recommendation to the Air Force to build the network. Finally the funding was approved. But due to an impenetrable barrier to understanding the ideas in the assigned agency⁹, we decided to wait for better times to implement it.

ARPANET did not become a reality until the very late '60s (1969). That network, was proposed by Robert Taylor of the ARPA IPTO¹² office to connect terminals to multiple computers. Larry Roberts led the project. He chose to use packet switching instead of circuit switching as he originally contemplated. I became peripherally involved when Roberts (1967) recruited me to advise the ARPANET planning group.



The main goal of the ARPANET was not military; It was to interconnect remote users to multiple computers. And, the detailed analysis for my work in distributed communications was applicable.

⁸ All this work was unclassified and spread and told everywhere we could. We believed that "was better if the fate of the world relied on more robust communications networks".

⁹ The interviewed is referring to the Defense Communication Agency (DCA) with "no digital experience".

¹² ARPA stands for Advanced Research Project Agency and IPTO for Information Processing Techniques Office.



In your opinion, what are the key characteristics of Internet and the most important milestones?

It is not easy to define because it is a multidimensional issue, but first I would say:

- Distributed Networks ,where the Intelligence is dispersed within the Net
- A simple routing policy replicated at each node.
- Cooperative Implementation – an open system.
- Avoidance of centralized management and control.
- The work of people independently generating “Requests For Comments” to consider various ideas and selection of the better ones after a broad community review, as exemplified by the work of Jon Postel¹³.

How did you contribute to the development of the ARPANET?

My work was done years prior to the creation of the ARPANET. The ARPANET growth has been a collective effort. From time to time I have been assigned credit for all sorts of things that I haven't done. For example, I am not responsible for the ARPANET. Its initiator was Robert Taylor, and it was project managed by Larry Roberts. I became involved when Roberts recruited me to advise its ARPANET-planning group, on distributed communication and packet switching.

*“The ARPANET group was exposed to the ideas of Baran and Donald Davies (NPL¹⁴), and they became convinced that packet switching and distributed networks would be both feasible and desirable for the ARPANET”.*¹⁵

A detailed description of my role can best be found in the 2002 paper listed at the end of this chapter.

Who were some key people in the early activities of the development of Internet?

The Arpanet grew through the effort of many, including many graduate students, who transformed the initial and rudimentary BBN packet switching network into a computer communication network. We do not recognize nearly enough of the many people who made it happen. I think that it is appropriate to give credit to those who had a major role in that early activity. For example, **Robert Taylor** is one not fully recognized. His contributions to the ARPANET project tends to have been markedly underreported.

But in answer to your question about the names that come to mind, I would include but not limited to:

- | | | |
|-------------------|---------------|---------------|
| • Vint Cerf | Larry Roberts | Danny Cohen |
| • Steve Crocker | Howard Frank | Frank Hart |
| • Bob Khan | Len Kleinrock | Elmer Shapiro |
| • Severo Ornstein | Jon Postel | JCR Licklider |

¹³ RFC Request For Comments series of standards. The first is dated April 7, 1969.

¹⁴ NPL stands for National Physics Laboratory of London. Authors of the term “packet switching”.

¹⁵ Janet Abbate. “*Inventing the Internet*”. MIT Press, 1999. pp 36-37.



What do you think about the future of Internet?

Spam and virus dissemination without a rapid ability to pinpoint and eliminate the sources of the mischief is a symptom of a fundamental problem. The Internet is too easy to misuse because of a paranoiac fear of the loss of anonymity. If we eliminated this requirement, mischief makers would no longer have the same freedom for making trouble as today. The Internet is too valuable a system to be allowed to be messed up this way.

The key benefit of the Internet is its growing ability to allow anyone on the earth to access all the world's information at a very low cost and allow low cost communications include international voice and video transmission. It is likely to replace much of today's voice telephone systems.

Do you see any technological trends?

The major trend of in communications is toward ever reducing costs. The main building blocks are fiber and satellites for the long haul and, and radio for the tails. (Radio is suitable for last mile short distances as spectrum requirements are minimal because of allowable frequency reuse) The competitor to radio tails in the urban area is today's hybrid fiber coax cable TV transmission, capable of carrying over 5 gigabits/sec when operated in the all-digital mode.



ADDITIONAL READING

D.W. Davies, 2001 "An Historical Study of the Beginnings of Packet Switching." British Computer Society Journal. Vol 44. Nº 3, 2001. pp. 151 to 162.

P. Baran, 2002 "The Beginnings of Packet Switching: Some Underlying Concepts". IEEE Communications Magazine. July 2002. pp. 42 to 48.

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Bartlett, K. Davies, D. Scantlebury, S. & Wilkinson, P. 1967. *A digital communication network for computers giving rapid response to remote terminals.* ACM Symp. Operating Systems Principles, October. ACM Press.