THE FRANKLIN INSTITUTE

PHILADELPHIA, PENNSYLVANIA

Hall of the Institute
Philadelphia, 26 April 2001

Investigating the work of

PAUL BARAN

of

ATHERTON, CALIFORNIA

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Committee on Science and the Arts

The Franklin Institute, acting through its Committee on Science and the Arts, has considered carefully those workers in the applied or theoretical sciences, without regard to country, whose efforts have done the most to advance our knowledge of physical science or its application and has selected as the recipient of the award of the Bower Award for Achievement in Science for 2001:

PAUL BARAN

of Atherton, California

For his seminal invention of packet switching – the foundation of modern communications networks and, in particular, the Internet.

Simply stated the technology of packet-switching, allows pieces of information to be divided into small packets or "envelopes" of information that are addressed, sent using multiple available routes to a specific destination, then reassembled. This technology - a post office-like system - revolutionized the telecommunications industry. Originally devised during the cold war for a military communications system survivable in the event of nuclear attack, packet switching became the foundation of computer networks including the Internet and truly has altered the world in which we live.

Introduction

Telecommunications advances have contributed to changes in geopolitical structure, increased access to Information and education for millions of previously disenfranchised persons, and improved the world economic condition. Communications systems worldwide are converging on standards that will dictate the mode of information exchange for the foreseeable future. We are on the threshold of ubiquitous high-speed access and terabit speeds for network link capacities.

The scope of the 2001 Bower Awards for Telecommunications included:

1. Underlying technologies and concepts enabling telecommunications -including fiber optics systems, digital signal processors, electronic switches, and network routers;
2. Technologies and concepts that allow the synthesis of these building blocks into highly integrated networks spanning the entire globe.
3. Technologies and concepts that have led to the convergence of computing and communications, first within the telephone system itself (voice and data communications), and now blending in the Internet technology; and
4. Standards and protocols utilizing the underlying telecommunications structures that have enabled applications that could not have existed before and which are changing our society and economy, including health care, education and commerce.

Nominations were received from industry, as well as academe in several nations.
Baran's concept of distributed communications networks using a technology now called packet switching fits in the above four categories and has become the foundation for the Internet.

Before his work all voice and what little data that existed was transmitted over switched circuits set up for the duration of the call or by permanently dedicated circuits (e.g. leased lines for military communications and control). Reliability was achieved by alternate routing of calls and protection against nuclear attack proposed by buried cables and a few "hardened" switching sites. - an expensive partial solution.

Commercial data network users (banks, insurance companies etc) complained to the telephone companies over high tariff rates and slow service (installation and circuit peed limits). Packet switching arrived to offer these users improved and more economical service.

Paul Baran's contribution

(with notes selected from Matrix News March 2000)

In 1962, the Department of the Air Force asked the RAND Corporation to study the design parameters of digital data communications networks. In 1964, RAND issued a dozen reports by Paul Baran (with some collaborators) under the group title *On Distributed Communications*. In his first report Baran wrote:

"Although it is premature at this time to know all the problems involved in such a network and understand all costs, there are reasons to suspect that we may not wish to build future digital communication networks exactly the same way the nation has built its analog telephone plant. There is an increasingly repeated statement made that one day we will require more capacity for data transmission than needed for analog voice transmission.

If this statement were correct, then it would appear prudent to broaden our planning consideration to include new concepts for future data network directions. Otherwise, we may stumble into being boxed in with the uncomfortable restraints of communications links and switches originally designed for high quality analog transmission.

New digital computer techniques using redundancy make cheap unreliable links potentially usable. A new-switched network compatible with these links appears appropriate to meet the upcoming demand for digital service. This network is best designed for data transmission and for survivability at the outset."

So a drastic change was proposed in a series of reports listed below:

I. Introduction to Distributed Communications Networks, Paul Baran, RM-3420-PR.
Introduces the system concept and outlines the requirements for and design considerations of the distributed digital data communications network. Considers especially the use of redundancy as a means of withstanding heavy enemy attacks. A general understanding of the proposal may be obtained by reading this volume and Vol. XI.

II. Digital Simulation of Hot-Potato Routing in a Broadband Distributed Communications Network, Sharla P. Boehm and Paul Baran, RM-3103-PR.
Describes a computer simulation of the message routing scheme proposed. The basic routing doctrine permitted a network to suffer a large number of breaks, then reconstitute itself by rapidly relearning to make best use of the surviving links.

III. Determination of Path-Lengths in a Distributed Network, J. W. Smith, RM-3578-PR.
Continues model simulation reported in Vol. II. The program was rewritten in a more powerful computer language allowing examination of larger networks. Modification of the routing doctrine by intermittently reducing the input data rate of local traffic reduced to a low level the number of message blocks taking excessively long paths.

IV. Priority, Precedence, and Overload, Paul Baran, RM-3638-PR.
The creation of dynamic or flexible priority and precedence structures within a communication system handling a mixture of traffic with different data rate, urgency, and importance levels is discussed. The goal chosen is optimum utilization of the communications resource within a seriously degraded and overloaded network.

IV. History, Alternative Approaches, and Comparisons, Paul Baran, RM-3097-PR.
A background paper acknowledging the efforts of people in many fields working toward the development of large communications systems where system reliability and survivability are mandatory. A consideration of terminology is designed to acquaint the reader with the diverse, sometimes conflicting, definitions used. The evolution of the distributed network is traced, and a number of earlier hardware proposals are outlined.

VI. Mini-Cost Microwave, Paul Baran, RM-3762-PR.
The technical feasibility of constructing an extremely low-cost, all digital, X- or Ku - band microwave relay system, operating at a multi-megabit per second data rate, is examined. The use of newly developed varactor multipliers permits the design of a miniature, all-solid-state microwave repeater powered by a thermoelectric converter burning L-P fuel.

VII. Tentative Engineering Specifications and Preliminary Design for a High-Data-Rate Distributed Network Switching Node, Paul Baran, RM-3763-PR.
High-speed, or "hot-potato," store-and-forward message block relaying forms the heart of the proposed information transmission system. The Switching Nodes are the units in which the complex processing takes place. The node is described in sufficient engineering detail to estimate the components required. Timing calculations, together with a projected implementation scheme, provide a strong foundation for the belief that the construction and use of the node is practical.

VIII. The Multiplexing Station, Paul Baran, RM-3764-PR.
A description of the Multiplexing Stations which connect subscribers to the Switching Nodes. The presentation is in engineering detail, demonstrating how the network will simultaneously process traffic from up to 1024 separate users sending a mixture ofstart-stop teletypewriter, digital voice, and other synchronous signals at various rates.

IX. Security, Secrecy, and Tamper-Free Considerations, Paul Baran, RM-3765-PR
Considers the security aspects of a system of the type proposed, in which secrecy is of paramount importance. Describes the safeguards to be built into the network, and evaluates the premise that the existence of "spies" within the supposedly secure system must be anticipated. Security provisions are based on the belief that protection is best obtained by raising the "price" of espied information to a level which becomes excessive. The treatment of the subject is itself unclassified.

X. Cost Estimate, Paul Baran, RM-3766-PR.
A detailed cost estimate for the entire proposed system, based on an arbitrary network configuration of 400 Switching Nodes, servicing 100,000 simultaneous users via 200 Multiplexing Stations. Assuming a usable life of ten years, all costs, including operation, are estimated at about $60M per year.

XI. Summary Overview, Paul Baran, RM-3767-PR.
Summarizes the system proposal, highlighting the more important features. Considers the particular advantages of the distributed network, and comments on disadvantages. An outline is given of the manner in which future research aimed at an actual implementation of the network might be conducted. Together with the introductory volume, it provides a general description of the entire system concept.

There is also his IEEE paper, "On Distributed Communications Networks," *IEEE Transactions Of The Professional Technical Group On Communications Systems,* Volume CS-12, Number 1, March 1964.

RESUME OF THE RECIPIENT PAUL BARAN

EDUCATION

Born in 1926 in Poland, coming to the USA at the age of 2, the Barans settled in Philadelphia. He obtained his BS in EE at Drexel University in 1949, and his MS in Engineering at UCLA in 1959.

EMPLOYMENT

Eckert Mauchly Computer Company in 1949 as a technician on world's first commercial computer, the Univac. Went to Raymond Rosen Eng. Products Co. in 1950 where he designed the first telemetering equipment for Cape Canaveral. Joined Hughes Aircraft Co. in 1955 in the Systems Group of the then Ground Systems Department in radar data processing and later in Studies and Analysis. He went to the RAND Corporation in 1959 where he wrote the series of 13 reports describing the key concepts underlying packet switching in 1964. While at RAND he also designed the first doorway gun detector, and was at the time the first computer scientist to testify to the U.S. Congress on the impending problem of computer privacy.

COMPANIES STARTED

In 1968 he co-founded the Institute for the Future, a not-for-profit research organization to develop longer range planning methodology. In 1972 he formed Cabledata Associates, initially a consulting firm. Cabledata's initial contract was a study of the divestiture of the ARPANET for ARPA. Later, Cabledata Associates developed new technology in its own behalf and launched new companies. The first was Comprint, an early low cost computer printer.

The next was Equatorial Communications Co., using technology allowing very small antennas. It was the first V SA T company, which later became a public company and subsequently was acquired by Contel.

A third company started by the Cabledata Associates group was Telebit, based on a technology invented by Baran, now called ODMT --orthogonal discreet multitone modulation using an ensemble of hundreds of tones sent simultaneously creating the highest performing modem of its time - the Trailblazer. Telebit was acquired by Cisco 1996. Baran started Packet Technologies in the early 1980's, a company designing equipment for interactive TV control and high-speed transmission of packetized voice and data over T1 links. Part of the Company was exchanged for equity in what was Stratacom, a public company acquired by Cisco in 1996.

In about 1985, Baran started Metricom, Incorporated. It became a public company initially focused on remote electric utility meter reading using unlicensed radio frequencies. Later it changed its changed its focus to become a wireless Internet provider. And most recently with major investment from MCI and Paul Allen, becoming a large national network for connecting laptop computers to the Internet. Note: the genesis in his RAND report VI. Mini-Cost Microwave Baran also started Interfax, based on interactive fax retrieval, and later sold to Cardiff software. Baran then founded Com21, Inc. in 1992, where he is now the Chairman of the Board. This company is now the largest supplier of cable modem systems in Europe and number three in the United States.

OTHER PRESENT ACTIVITIES

Baran also serves on the Technical Advisory Boards of Geocast Networks and of Metricom.

His present not-for-profit activities includes serving as a Member of the RAND President's Council, as a Trustee of the IEEE History Center, and most recently as a Trustee of the Charles Babbage Institute at the University of Minnesota.

HONORS AND AWARDS

Silver medal (for the design of the Trailblazer Modem), PC World 1986.

The Edwin. H. Armstrong Award, IEEE Communications Society 1987.

The UCLA Advanced Computer Technology Act-One Pioneer Award 1989.

The ACM Special Interest Group in Communications, First Annual Award, 1989.

The IEEE Alexander Graham Bell Medal, October 1990.

The Marconi International Fellowship Award, June 1991.

Communications Week, Top 25 Visionaries Award, January 1992.

Drexel University Centennial Drexel100 Medal, June 1992.

Data Communications 20th Anniversary Issue --Top 20 People, September 1992.

Electronic Frontier Foundation, Pioneer Award, March 1993.

Life Fellow, Institute of Electronic and Electrical Engineers, January 1993.

Fellow, American Association for the Advancement of Science, September 1994.

U.S. National Academy of Engineering, act. 1996.

Computers and Communications Foundation Award (NEC-Japan)
(with Vinton Cerf and Tim Berners-Lee), Nov. 1996.

Honorary Dr of Science degree in Engineering, Drexel University, June 1997.
Entrepreneur of the Year, Technology Award Silicon Valley Business Journal, Aug. 1999

IEEE -First Annual Internet Award
(with Donald Watts Davies, Leonard Kleinrock and Lawrence G. Roberts), June 2000

Honorary Ph D degree in Policy Analysis, The RAND Graduate School, June 2000

IEEE -Centennial Medal, Nov. 2000

Recent popular press articles:

August 2000, Claire Furia Smith, *Inquirer Philly Tech.*

May 5, 1999, Reid Kanaley, *Philadelphia Inquirer* .

BOWER AWARD FOR ACHIEVEMENT IN SCIENCE

LEGACY

BOWER AWARD FOR ACHIEVEMENT IN SCIENCE

1991	Paul C. Lauterbur	(Chemistry & Bioengineering)
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1995	Chen Ning Yang	(Physics)
1996	Frederick P. Brooks, Jr.	(Computer Science)
1997	Ralph L. Brinster	(Physiology)
1997	Sir Martin Rees	(Astronomy)
1998	Ralph Cicerone	(Earth and Environmental Science),
2000	Alexander Rich	(Structural Biology)

RECIPIENTS OF THE BOWER AWARD FOR BUSINESS LEADERSHIP

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1999	P. Roy Vagelos
2000	William Rutter

Now therefore, for his seminal invention of packet switching – the foundation of modern communications networks and, in particular, the Internet, THE FRANKLIN INSTITUTE AWARDS its BOWER AWARD FOR ACHIEVEMENT IN SCIENCE FOR 2001 to PAUL BARAN of ATHERTON, CALIFORNIA.

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