ultra-high frequency (UHF) wireless network, which was designed with a simple but effective method for dealing with data-packet collisions. In addition, it led directly to CSMA, CSMA/CD, and CSMA/CA (collision avoidance), which were later incorporated into various generations of standards for Ethernet and Wi-Fi.

At the end of 1970, the ALOHAnet was complete. It connected the Hawaiian islands and was the world's first wireless packet-data network. In 1972, the ALOHAnet was connected to the ARPANET in North America using a satellite channel. In 1973, the first network to utilize random access packet transmission in a satellite channel was put into operation using the NASA ATS-1 satellite in an experimental network. It included the University of Hawaii, the NASA Ames Research Center in California, the University of Alaska, Tohoku University in Sendai, the University of Electro-Communications in Tokyo, and the University of Sydney. This network, called PacNet, operated at 9,600 bits per second (bps) on an ALOHA channel using low-cost satellite earth stations.

The ALOHA protocol is part of the Data Link Layer (OSI Network Layer 2) Protocol, which is different from a point-to-point protocol and is today classified as a medium access control (MAC) network protocol using a shared medium. It is based on the arbitration technology connecting plural network terminals first implemented in the ALOHAnet. Later, this protocol was optimized for wired systems and used for Ethernet by Metcalfe as CSMA/CD.

Ethernet was built on Abramson's ALOHAnet idea of wireless multiple access using randomized retransmissions and developed further as high-speed CSMA/CD for use in a LAN. Early Ethernets were able to run much faster than the ALOHAnet because they transmitted on copper cables instead of wirelessly. Decades later, Ethernet moved back to wireless (Wi-Fi) and today again looks much like the ALOHAnet. Ethernet in its many forms has now become the packet plumbing of the Internet.

While pursuing a doctorate in computer science at Harvard University, Robert Metcalfe worked on MIT's Project MAC and then at the Xerox Palo Alto Research Center (PARC) in 1972, where he developed a coaxial cable LAN system. He was a team leader for networking Altos to a laser printer and to the Internet. He invented the networking system initially called the Alto ALOHAnet. Ethernet randomized retransmission as in the ALOHAnet, but it improved packet throughputs under load with CSMA/CD. Together with David Boggs in 1976, Metcalfe published the article ''Ethernet: Distributed Packet-Switching for Local Computer Networks'' in the *Communication of the ACM*.[1]

Metcalfe encouraged Xerox to freely license its Ethernet patents and to cooperate with Intel and DEC to create a standard LAN system through IEEE. As a result, 10-Mbps Ethernet was submitted for the new IEEE Project 802 in 1980. IEEE subsequently standardized IEEE802.3 CSMA/CD in 1982. Afterwards, the 10-Mbps 10BASE-T Ethernet finally established its position as the global LAN standard. In his acceptance speech, Metcalfe expressed his thanks to the industries and people who contributed to put Ethernet to practical use and disseminate it.

Each year, C&C Prizes are awarded to no more than two groups. Recipients are given a certificate, a plaque, and a cash award (¥10,000,000 for each group). The foundation has awarded the prize to 88 people since 1985.

See additional details about the 2011 C&C Prize Ceremony at http://www.candc.or.jp/en/2011/ceremony.html.

Reference

1. R.M.Metcalfe, andD.Boggs, ''Ethernet: Distributed Packet-Switching for Local Computer Networks,'' *Comm. ACM,* vol. 19, no. 7, 1976, pp. 395–404.

Contact ***Akihiko Yamada*** *at a.yamada@computer.org.*

IEEE Packet-Speech Milestone Celebrated at MIT Lincoln Laboratory

In 1971 Jim Forgie of MIT Lincoln Laboratory experimented with the two-year old ARPANET to show the feasibility of sending speech over that first packet-switching network. At the time, in the context of traditional dial-up full-duplex telephone communications, many people doubted packetized speech, in which packets flow over varying network paths with varying time delays. In 1974 the Advanced Research Projects Agency (ARPA) began a multi-institution packet-speech program, lasting through 1982, that firmly demonstrated the utility of packet speech. This was the initiating technology of what we know today as voice over IP (VoIP) and capabilities such as Vonage and Skype.

The IEEE Milestone program is an IEEE History Committee activity administered through the IEEE History Center.[1] Milestones recognize technological innovation and

Figure 7. MIT Lincoln Laboratory packetized-speech project participants who attended the IEEE Milestone celebration. From left to right, Gerald O'Leary, Eric Evans, Mostafa Kaveh, Harold Heggestad, Peter Blankenship, Cliff Weinstein, Steve Blumenthal, Stephen Casner, Randy Cole, Earl Craighill, John Makhoul, Don Johnson, Peter Staecker, Robert Kahn, Joe Tierney, William Kantrowitz, Duane Adams, Connie McElwain, Carma Forgie, Gil Falk, Karen Panetta, and Bruce Hecht.

excellence and are proposed, nominated, and sponsored by an IEEE organizational unit and go through a rigorous vetting process. On 8 December 2011, a Milestone in packetized speech was recognized at the MIT Lincoln Laboratory, which had been the central player in the ARPA packet-speech program. The plaque read:

> **First Real-Time Speech Communication on Packet Networks, 1974–1982**
> In August 1974, the first real-time speech communication over a packet-switched network was demonstrated via the ARPANET between MIT Lincoln Laboratory and USC Information Sciences Institute. By 1982, these technologies enabled Internet packet speech and conferencing linking terrestrial, packet radio, and satellite networks. This work in real-time network protocols and speech coding laid the foundation for voice over Internet Protocol (VoIP) communications and related applications including Internet video conferencing.

This IEEE Milestone was sponsored by the IEEE Signal Processing Society and the Boston section of IEEE. The public dedication was attended by more than 100 people, including many of the 1974–1982 participants, several of whom came from across the country (see Figure 7). Welcomes were given by Karen Panetta, chair of the Boston chapter, Mostafa Kaveh, president of the IEEE Signal Processing Society, and Eric Evans, director of MIT Lincoln Laboratory.

Cliff Weinstein, leader of Lincoln Laboratory's Human Language Technology Group and a key member of the 1974–1982 research,[2] sketched the history of the effort, from Jim Forgie's early feasibility study, through the milestone years, to Bob Gray's July 2005 paper in the *IEEE Signal Processing Magazine*, which brought the 1974–1982 work to the attention of a 21st century audience (see Figure 8). Weinstein emphasized the multi-institutional composition of the research effort; they needed people at other locations to demonstrate long distance, packetized, two-person telephone conversations and teleconferencing, and the various institutions had different computers and end-user equipment and helped develop the necessary network protocols enabling communication among varied devices. Weinstein also played an audio tape from May 1978 of an early demonstration of voice conference among the Lincoln Laboratory in Massachusetts and USC Information Sciences Institute and Culler-Harrison, both in southern California.

Bob Kahn, the ARPA program manager when the packet-speech project was initiated, was the keynote speaker. He too emphasized that numerous people from many places participated in the program. He also noted that part of his purpose in creating the speech program was to show the importance of packet technology. ARPANET had been created to demonstrate packet switching, and it could transmit data of many types.

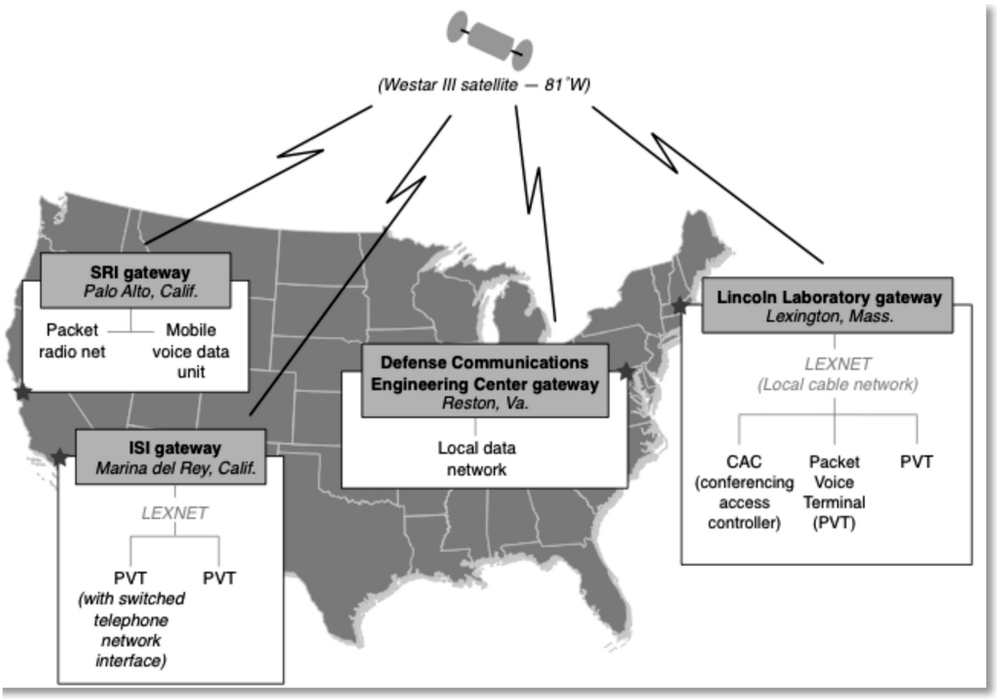

Figure 8. 1982 demo slide showing experimental wideband voice/data Internet.

However, communications such as file transfers between computers are not particularly visible to a wider audience. Voice, video, and other such communications were highly hearable or viewable, and Kahn noted Steve Casner's packetized video work took this idea beyond speech. Kahn also described changes that had to be made to the internal ARPANET algorithms and its external interface to allow high bandwidth, low-delay speech to be fully demonstrated (what Jim Forgie had predicted could be done). Also, the Transmission Control Protocol (TCP) originally contained both the TCP and IP functions, but it had to be split to enable applications such as packet speech (and its protocols) to communicate directly with IP. A goal was 1-kilobit-per-second (Kbps) speech (at a time when 4.8-Kbps or 2.4-Kbps speech were regarding as minimums), and this goal was reached, partly because packet speech did not require a full-duplex connection (saving 50 percent immediately). Packets also did not have to be sent during silences, which saved an additional significant percentage. Finally, Kahn explained that there are still possibilities for improving the way speech is transmitted over the Internet, and he envisions a time when speech may be the primary user interface to computers.

Danny Cohen, another major participant in the 1974–1982 research, was scheduled to be the second keynote speaker, but he was unable to travel, and Steve Casner presented Danny's amusing (as is Danny's way) slides.

The formal session ended with Peter Staecker, 2013 IEEE president, and Eric Evans, director of Lincoln Laboratory, unveiling the plaque and handing out 20 or so miniature versions of the plaque to participants in the 1972–1984 research.

The late afternoon session ended with a reception for everyone in attendance, again hosted by Lincoln Laboratory. Over hors d'oeuvres, old friends and colleagues continued to converse (as they had prior to the start of the event), remembering old times and providing updates on current activities. Younger attendees met with the pioneers who 40 years ago started the work that is so commonplace in our smart phones and other contemporary communication devices.

Reference and Notes

1. See http://www.ieeeghn.org/wiki/index.php/Milestones:IEEE_Milestones_Program.
2. C.J. Weinstein and J.W. Forgie, ''Experience with Speech Communication in Packet Networks,'' *IEEE J. Selected Areas in Comm.,* vol. SAC-1, no. 6, 1983, pp. 963–980.

Contact ***David Walden*** *at dave@walden-family.com.*