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Report No. 5939

Interneting and Packet Satellite Program: A Final Report for Contract No. MDA903-80-C-0353

Steven Blumenthal

July 1985

Prepared for:
Defense Advanced Research Projects Agency

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July 1985

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FINAL REPORT

As a means of utilizing valuable communications resources more efficiently, The Department of Defense Advanced Research Projects Agency (DARPA) has sponsored a program of research and development in the area of packet-switched data networks. In addition to more efficient utilization, packet switching systems with autonomous distributed control can be made robust and survivable. In support of this program, BBN has conducted research and development under contract MDA903-80-C-0353 in the areas of Interneting and the efficient use of broadcast satellite channels by packet-switched networks. Specific work performed under this contract involved the development of Internet gateways to interconnect many different types of dissimilar packet-switched networks, Internet protocols for data communication, and a Terminal Access Controller (TAC) utilizing these protocols for remote network-access to time-shared computer systems. BBN also continued the development of the Atlantic Packet Satellite Network, (SATNET) providing Internet connectivity between sites in the U.S. and Europe using a shared 64kb/s INTELSAT satellite channel, and the domestic Wideband Packet Satellite Network, providing high bandwidth communication among ten sites within the continental U.S.

*Additional keywords: Pluribus satellite;
Shipboard Communications; ARPA computer network.*

The work carried out in each of these areas has been presented in a number of Quarterly Technical Reports. The content of each of these reports is summarized in the remainder of this final report.

Quarterly Technical Report No. 17

BBN Report No. 4399, May 1980

SATNET:

A problem with the transfer of Test and Monitor (T&M) data from the PSP Terminal to the Satellite IMP was detailed. As part of providing ongoing operational service to European users of SATNET who need access to CONUS resources, software and hardware maintenance operations performed during this quarter were described.

INTERNET DEVELOPMENT:

Additions to the CMCC program were installed and documented. Two Rapicom 450 Facsimile systems and two DEC LSI-11/23 development systems were ordered for facsimile networking development and testing.

Quarterly Technical Report No. 18

BBN Report No. 4474, August 1980

SATNET:

The solution to the problem with the transfer of T&M data from the PSP Terminal to the Satellite IMP was described. As part of providing ongoing operational service to European users of SATNET who need access to CONUS resources, software and hardware maintenance operations performed during this quarter were described.

INTERNET DEVELOPMENT:

Details on the log file generated by the CMCC were presented. Service tests with Telenet on

the VAN gateway were conducted. Transfer of gateway functionality to LSI-11 machines was carried out.

TCP FOR THE HONEYWELL 316 TAC:

The Honeywell 316 TIP was converted to run as a stand-alone host on the ARPANET. Progress was made on the design of the TCP software module and data structures and on how TCP and NCP will be integrated in the TAC.

Quarterly Technical Report No. 19

BBN Report No. 4526, November 1980

SATNET:

A minimal Host-SATNET protocol for loading and dumping gateways was presented. As part of providing ongoing operational service to European users of SATNET who need access to CONUS resources, software and hardware maintenance operations performed during this quarter were described.

INTERNET DEVELOPMENT:

An overview of the performance-measure message formats in the CMCC was presented.

TCP FOR THE HONEYWELL 316 TAC:

A design document was written describing how the IP and TCP protocols will be implemented. This document was included in this QTR. The 1822 interface and packet core protocol software was converted to work with the new data structures.

Quarterly Technical Report No. 20

BBN Report No. 4609, February 1981

SATNET:

A deadlock condition encountered in the Host-SATNET Protocol was discussed, a few solutions were presented, and one solution was successfully implemented. The features of a new software release were documented, and several operational hardware problems encountered during the quarter were reported.

INTERNET DEVELOPMENT:

Problems encountered in the usage of the VAN gateways and recent progress in the TIP login system research and development were discussed. Progress was also reported on the Catenet Monitoring and Control Center (CMCC) software.

TCP FOR THE HONEYWELL 316 TAC:

Progress in the writing and testing of code to implement TCP was reported. An Internet Note, IEN-166, was published describing the design of TCP/IP in the TAC.

WIDEBAND NETWORK:

Integration of the PSAT with other elements in the Wideband Network was described. During January 1981, the Lincoln PSAT was able to lock onto and receive leader packets transmitted by the ISI PSAT for about 5 seconds; this represented the first successful instance of a cross-country PSAT-to-PSAT communication. Progress was made in SMI hardware debugging and the PSAT/ESI initial acquisition sequence were described in detail. The design of SMI test programs were described. Several issues related to the number and format of ESI statewords

were discussed.

Quarterly Technical Report No. 21

BBN Report No. 4679, May 1981

SATNET:

An automatic stream facility for gateway traffic was described. Software and hardware problems encountered during the quarter were also discussed.

INTERNET DEVELOPMENT:

Continued development and testing of the VAN gateway was reported. In conjunction with the DCA sponsored ARPANET Routing Study, the gateway group performed several informal experiments and fault-isolation investigations during this quarter.

TCP FOR THE HONEYWELL 316 TAC:

For the first time, all of the TAC software modules were assembled and run together during the quarter. These included the IP, TCP, NCP, Multiline-Line Controller (MLC), 1822 host interface and site configuration modules.

WIDEBAND NETWORK:

The major activity during the quarter focused on PSAT performance measurements and software tuning. Work was also done in the area of Wideband Network addressing.

Quarterly Technical Report No. 22

BBN Report No. 4761, August 1981

SATNET:

In preparation for the future expansion of SATNET, the software was reworked to support more than four sites. The capability to print traps directly on the SIMP terminal was added.

INTERNET DEVELOPMENT:

Operational support activities of the Internet gateways during the quarter were described. Plans for the development of a new gateway were discussed. The new gateway will be based on new computer hardware with a larger address space to work around the current limitations imposed by the PDP-11 architecture.

TCP FOR THE HONEYWELL 316 TAC:

TAC software was successfully tested with real users during the quarter and was also run for the first time in a BBN C/30 computer.

WIDEBAND NETWORK:

The major activities during the quarter continued to be the ongoing integration of the Wideband Network subsystems and enhancements to the throughput capabilities of the PSAT.

Quarterly Technical Report No. 23

*BBN Report No. 4825, November 1981***ATNET:**

C/30 interface for the COMSAT PSP Terminal was designed in preparation for the placement of the Honeywell 316 SIMPs with BBN C/30 computers. BBN began to investigate the possibility of controlling two independent 64kb/s INTELSAT satellite channels with a single C/30.

INTERNET DEVELOPMENT:

Responsibility for all gateway development was transferred from the BBN Information Sciences Division to the Computer Systems Division as the emphasis shifted away from the gateway as a research tool toward increased operational use. Plans continued to be made for a future gateway system which would have significantly higher performance.

TCP FOR THE HONEYWELL 316 TAC:

TAC software was completed during the quarter; the first operational TAC was installed; and TAC software for remote monitoring and control from the Network Operations Center (NOC) was completed. IEN-197 describing the TAC monitoring protocol was distributed. All work on the TAC under this contract was completed during this quarter.

WIDEBAND NETWORK:

A number of milestones were achieved during this quarter in support of packet speech experiments. Lincoln Laboratory received leader packets and datagrams transmitted by ISI, and channel stream and group were successfully created at both ISI and Lincoln. Integration

Work began with the Voice Funnel host based on BBN's Butterfly Multiprocessor. Work began the development of a PSAT SuperSUE Poller I/O controller for handling high speed I/O devices such as the satellite modem interface (SMI) and high speed host interfaces (HSMs). A preliminary discussion of future Wideband Network equipment was reported, calling for the elimination of duplication of functions by the current subsystems and the integration of the AT and Voice Funnel functions.

Quarterly Technical Report No. 24

BBN Report No. 4868, February 1982

TNET:

The first C/30 Satellite IMP was installed at COMSAT Labs, Clarksburgh, MD for integration with the COMSAT PSP Terminal. The dedicated satellite circuit between the SDAC ARPANET IMP and the NORSAR TIP (ARPANET Line #41) was permanently removed. Following the removal of this line, the only path connecting the NORSAR TIP to the Internet is via SATNET.

INTERNET DEVELOPMENT:

Internet gateways with software written in Macro-11, instead of BCPL, were developed as a replacement for the BCPL gateways. The Macro-11 gateways provided similar functionality with significant improvements in performance and packet buffering capability.

WIDEBAND NETWORK:

A major packet speech demonstration was held on November 18, 1981. Two simultaneous 64 kb/s voice calls were made between ISI and Lincoln Laboratory. During this period, the

and Network was operating at a data rate of 772 Kb/s. A summary of the Wideband network addressing issues was discussed and the PSAT internal host modules were described.

Quarterly Technical Report No. 25

BBN Report No. 5903, May 1982

ET:

C/30 microcode to support SATNET was completed and debugged during the quarter. IMP hardware and software maintenance activities during the quarter were described.

RNET DEVELOPMENT:

11 gateways began to be deployed and maintained during the quarter. BCPL gateways used to be maintained for Packet Radio Networks. The "stub" gateway protocol was used. The NU gateway monitoring system continued to be developed.

WIDEBAND NETWORK:

Preparation activities continued in preparation for a major packet speech demonstration in June. A fourth PSAT was installed at SRI on March 24.

Quarterly Technical Report No. 26

BBN Report No. 5129, August 1982

NET:

30 Satellite IMP for the Raisting, W. Germany site was constructed and shipped during the quarter. Work on the conversion of the SIMP software to allow it to use the C/30 Native Firmware system (NMFS) was begun. BBN began to investigate the use of HDLC-based

host interfaces for the SIMP to replace the VDH interfaces which were in use.

INTERNET DEVELOPMENT:

Macro-11 based Internet Gateways continued to be deployed and maintained. The last two remaining BCPL gateways were replaced with Macro-11 gateways. A new version of the Gateway software was released during the quarter. Progress was made in gateway performance measurements. A draft document describing the Internet Exterior Gateway Protocol (EGP) was distributed to the Internet community for comments.

WIDEBAND NETWORK:

The DARPA Packet Speech Project conducted a successful demonstration on June 3, 1982. The demonstration included PCM and LPC point-to-point and conference calls between Packet Voice Terminals (PVTs) on LEXNETs at Lincoln Laboratory, ISI, and SRI. In addition, calls were made between LEXNETs at Lincoln and ISI and the Packet Radio Network mobile van at SRI. Work began on the design of a new Satellite IMP based on the BBN Butterfly Multiprocessor.

Quarterly Technical Report No. 27

*BBN Report No. 5215, November 1982***SATNET:**

A SATNET C/30 SIMP was installed at Raisting, W. Germany. A new Internet gateway was installed at DCEC in Reston, VA providing a second access point into SATNET from the U.S. ARPANET line #77 between the SDAC IMP and London TIP was eliminated; SATNET was now providing the primary Internet connectivity between the U.S. and European sites. The Satellite NU Program running on BBN-INOC began to be used as the primary network monitoring and control system, replacing the TENEX-based system.

INTERNET DEVELOPMENT:

Macro-11 gateways continued to be deployed and maintained. Development and enhancement of the NU-based gateway monitoring system continued during the quarter. Work continued on the definition of the Exterior Gateway Protocol (EGP) and on the design of the VAN gateway.

WIDEBAND NETWORK:

Network monitoring and control was switched from the TENEX-based system running on BBNC to the NU system running on the BBN C/70 computer BBN-INOC. Wideband Network activities centered on operational support, ESI and satellite channel testing, and BSAT software development.

Quarterly Technical Report No. 28

*BBN Report No. 5286, February 1983***SATNET:**

BBN participated in the SHAPE Technical Center (STC) Internet demonstration during the quarter. The BBN SATNET gateway and the line between that gateway and the SIMP at Etam, W. VA were decommissioned. A new SATNET gateway was installed at the Center for Seismic Studies (CSS) in Arlington, VA. The CSS gateway and the DCEC gateway provided two parallel paths into the SATNET from the ARPANET in the U.S.; thus providing greater reliability.

INTERNET DEVELOPMENT:

The major activities during the quarter were the installation of the second SATNET gateway at CSS and participation in the STC demonstration. Another gateway was installed to support the Packet Radio exercise BRIM FROST.

WIDEBAND NETWORK:

Several satellite-channel related problems were investigated during the quarter. Probe Systems made a series of measurements at ISI during the week of January 17, and found that the source of the channel RF interference was due to signals from aircraft radar altimeters being aliased into the Wideband Network's frequency band by non-linearities in the Earth Terminal downconverter. A fifth PSAT was installed at RADC; however, no ESI was available for the site at that time. An analysis of the PSAT's utilization of memory buffer was described.

Quarterly Technical Report No. 29

BBN Report No. 5345, May 1989

SATNET:

Two C/30 computers were ordered to replace the Honeywell 316 SIMPs at Goonhilly, U.K. and Tanum, Sweden. Work continued on the conversion of the SIMP code to use the NMFS C/30 operating system. The NU Lightbox program was expanded to provide matrix displays of the frequency offset and AGC level Test and Monitor (T&M) data collected by the PSP Terminals. SATNET work on this contract was completed during the quarter.

INTERNET DEVELOPMENT:

A new version of the Macro-11 gateway was released during the quarter. Several additional Macro-11 gateways were deployed. Internet development work on this contract was completed during the quarter.

WIDEBAND NETWORK:

A Wideband Network meeting was held on March 16 and 17, in Washington, DC. BBN reported on an extensive series of channel and ESI measurements which identified several serious problems with the ESIs and the satellite channel. A task force was formed including representatives from BBN, Linkabit, Lincoln Laboratory, and ISI. The first task force working session was held at Lincoln during the week of April 25th. BSAT software development during the quarter concentrated on software for host interfaces and the BSAT synchronous I/O interface device drivers.

Quarterly Technical Report No. 30

BBN Report No. 5408, August 1983

WIDEBAND NETWORK:

Progress was made by the Wideband Network task force in correcting an ESI problem related to the processing of multirate coded bursts. The task force met at ISI during the week of May 16 to test out the Linkabit multirate coding fix and to install a bandpass filter in front of the ISI Earth Terminal's downconverter to correct the aircraft radar altimeter RFI problem. The task force convened for the third time at ISI during the week of June 27. A bug was found in the PSAT datagram fragmentation code. BBN supported the SRI/NTARE Internet speech exercise. A PSAT and Lincoln Packet-to-Circuit Interface (PCI) host were installed at Ft. Huachuca, Arizona during the week of June 20. The integration of the PSAT with the RCA Integrated Node speech host at RADC was completed on July 20 with a successful acceptance test of the Integrated Node. BSAT software development of the Host interface software continued during the quarter.

Quarterly Technical Report No. 31

BBN Report No. 5492, November 1983

WIDEBAND NETWORK:

The network operated stably throughout August at a channel data rate of 1.5 Mb/s. The network was tested at 3 Mb/s during a task force visit to ISI during the week of August 22. It was determined that the network could operate at that data rate if the control information in each burst were coded at rate 1/2 to correct bit errors. Work began on the design and coding of a satellite channel simulator for the BSAT with the simulator implemented in software

running on a Butterfly processor.

Quarterly Technical Report No. 32

BBN Report No. 5580, February 1984

WIDEBAND NETWORK:

The Wideband Network task force convened twice during the quarter. On November 14, at Lincoln Laboratory, an ESI problem related to the uplink delay was corrected. On December 5, the installations of a PSAT and an ESI were completed at Ft. Monmouth. The ESI was borrowed from the DCEC site. BSAT software development continued with work on the software-based satellite channel simulator, the datagram scheduling process, and stream setup code. A PSAT-translator program was designed to allow the BSAT to connect to and use the current ESI and ESI-A for debugging prior to the availability of the ESI-B which is currently being developed by Linkabit.

Quarterly Technical Report No. 33

BBN Report No. 5774, May 1984

WIDEBAND NETWORK:

During the quarter, the Wideband Network continued to operate at 3 Mb/s. Several additional sites were brought up on the channel, either for the first time or following a lengthy outage due to equipment unavailability, bringing the total number of sites up to seven. BBN's activities during the quarter concentrated on Wideband Network operations, task force working meetings, PSAT software work, BSAT software development, and PSAT-translator development. This QTR contained a detailed discussion of the satellite channel burst rearrangement algorithm used by the BSAT.

Quarterly Technical Report No. 34

BBN Report No. 5797, August 1984

WIDEBAND NETWORK:

During the quarter several serious network problems were uncovered. It was discovered that the ESI was not properly handling very short bursts, which are occasionally created as a result of the PSAT's fragmentation of messages to fit in the available channel space. This problem was corrected by Linkabit. A second problem was believed to be due to a PSAT software bug which would not allow the creation of more than four channel streams. The PSAT-translator was completed during the quarter and began to be tested at Lincoln Laboratory with an ESI-A and the BSAT software running in the Lincoln Voice Funnel hardware. The Wideband Network was down from July 27 to August 6 to allow for a changeover of the satellite channel from the WESTAR III to the WESTAR IV satellites.

Quarterly Technical Report No. 35

BBN Report No. 5883, November 1984

WIDEBAND NETWORK:

On August 9, BBN hosted a meeting of the Wideband Network community. At that meeting, it was decided to operate the network in a "quasi-operational" mode on Thursdays and Fridays of each week. BBN identified and corrected a PSAT software bug which had been preventing the network from operating with more than four channel streams. Two additional sites, at BBN and Linkabit, became operational during the quarter, bringing the total number of sites to nine. The BSAT software running in the Lincoln Voice Funnel hardware was successfully operated on a satellite channel using the PSAT-translator. A small Butterfly system was

shipped to Linkabit during the quarter, and progress was made in the integration of the BSAT with the ESI-B. In addition to the testing with the PSAT-translator and ESI-B, progress was made in other aspects of the BSAT software. During the quarter, BSAT code maintaining datagram reservation synchronization was implemented. This code was necessary to allow multisite BSAT testing to begin.

Quarterly Technical Report No. 36

BBN Report No. 5977, February 1985

WIDEBAND NETWORK:

The Wideband Network task force met at BBN during the last week of November to investigate a new source of satellite channel interference. The Wideband Network carrier signals were found to be amplitude modulated by a large square-wave signal. This square-wave modulation was determined to be caused by another TDMA network operated by the Department of Energy (DOE) which shares our satellite channel transponder. Each satellite channel transponder has only a limited amount of signal power available; the DOE network was operating at a considerably higher power level than the Wideband Network and was actually robbing power from the Wideband Network. The investigation team presented their findings to DARPA and Western Union on November 30, 1984. They recommended that either the Wideband Network or the DOE network be moved to a different transponder. Western Union was asked by DARPA to suggest a plan to solve this problem. BSAT software for datagram reservation synchronization was completed and tested. The BSAT/ESI-B Interface Specification document was officially released as *Wideband Network Note No. 39*.

Quarterly Technical Report No. 37

BBN Report No. 5992, May 1985

WIDEBAND NETWORK:

All technical work on this contract was completed at the end of January, 1985. Further integration of the Wideband Network into the Internet is continuing under contract MDA903-83-C-0131. A final report for contract MDA903-80-C-0353 was being prepared.

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