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**Command and Control Related Computer Technology:
Packet Radio**

**Quarterly Progress Report No. 19
1 June 1979 to 31 August 1979**

February 1980

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COMMAND AND CONTROL RELATED COMPUTER TECHNOLOGY:

Packet Radio

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1. INTRODUCTION

An important component of the Packet Radio project is the station software, providing a variety of control, coordination and monitoring functions. BBN's role in developing this software is to specify, design, implement and deliver programs which perform these functions.

Progress during this quarter centered on the Labeler process and on TOPS20 monitor internet code. The Labeler, which receives reports of network connectivity and status, has responsibility for controlling the network, primarily through assignment of routes. A new Labeler to support version 5 of the Channel Access Protocol (CAP) has been completed and is now running. This is reported in section 3, along with other Packet Radio network issues.

The Internetwork Protocol effort has made version 4 of internet facilities, integrated into the DEC TOPS20 operating system, available. This and other internetwork items are covered in section 4.

Section 2 deals with meetings, including a Packet Radio Working Group (PRWG) meeting this quarter, and with publications and negotiations. Section 5 covers hardware efforts during the quarter.

2. MEETINGS, TRIPS, PUBLICATIONS

2.1. Meetings and Trips

During this quarter BBN was involved in several meetings, both for debugging and for negotiations. Collins Radio personnel visited BBN facilities for debugging of PR hardware (see section 5), but also a visit was made for software debugging. With their help, we diagnosed a serious flaw in the SPP protocol used to communicate between the station and PRs. This is discussed further in section 2.3.

BBN Personnel visited SRI this quarter for on-site debugging of CAP 5 station and PR software and testing of its performance. Some bugs in the Labeler were found and fixed. Another on-site visit was scheduled for early August, for mobile testing, but was postponed in favor of resolving continuing difficulties locally at BBN, Collins and SRI, and cross-net when appropriate.

BBN hosted a June 21 meeting on source notification. This established a forum for various discussions on how and when sources of internetwork traffic should be informed of error conditions. Such conditions include the destination host or network being down or unreachable; traffic being refused by the destination host, destination network, or an intermediate network; and traffic being discarded by gateways when congestion occurs. Another aspect of the source notification issue involves identifying which traffic handling element should generate the notification. Meeting minutes were prepared and made available.

BBN personnel attended the July 11-12 meeting of CAP 5 implementers at SRI. Major topics of discussion relating to station software were the SPP oscillation problem and consideration of eventual conversion to the "SPP2" protocol; placing a value in the "type" field of acknowledgement packets generated by the station which matches that of the packet being

acknowledged; fast labeling and route assignment for coming use and demonstrations at Fort Bragg; potential need for a PDP-11/23 miniature station at Fort Bragg in 1980; priority of LROP generation in PRs (which had been low enough that network control algorithms were not working well); and possible expansion of the design of the PR down line load process, to permit delivery of PR code to the station via FTP, with supervision and direction from an operator. All of these issues constitute useful improvements to the overall PR network design and capabilities.

2.2. Publications

This quarter four Packet Radio Temporary Notes (PRTNs) were released by BBN, two on theoretical issues and two on design specifications. We also sent a station documentation package to Fort Bragg. The PRTNs are summarized in the paragraphs below.

PRTN 271, "SPP Heterostate Diagram"

This paper explains and motivates the SPP protocol. The intention was to publish this document some time ago, in conjunction with PRTN 177, "SPP Definition". While PRTN 177 is technically complete, the complexity of SPP is more easily grasped when it is broken down into constituent pieces. Each piece solves a different constraint problem relevant to the operational environment in which SPP must operate. In addition to this decomposition, PRTN 271 also provides a simple graphical notation (the "heterostate diagram") to convey all the major aspects of SPP. This paper is published now largely in response to the ongoing negotiations over SPP and the proposed simplified SPP, SPP2. These arose in turn because of the SPP oscillation, triggered by Performance Data Packets originated by PRs with both "open" and "close" SPP indications asserted.

PRTN 272, "SPP Oscillation"

This paper documents and describes the oscillation diagnosed this quarter by BBN and visiting Collins staff. It is due to each end device alternately executing the required opening and closing of a connection on which it has not transmitted, but which has been closed by the remote end. This oscillation is inherent in SPP, but was not known or experienced until CAP 5, in which PRs first take the initiative to generate traffic. This note also discusses solution alternatives, including the timeout we have adopted in station software. It also discusses why the Transmission Control Protocol (TCP), a more robust, internet protocol, is not subject to this type of oscillation.

PRTN 276, "Specifications of New Packet Radio Down-line Loader"

This document presents the capabilities of the new PR down line load process (PRLOAD). In particular, both Experimental and Improved types of Packet Radio units (EPRs and IPRs) will be serviced, with easy expandability to Low-cost and Ultimate varieties (LPRs, UPRs). In addition, the station operator, through terminal dialog with PRLOAD, will specify a service host and file name from which PRLOAD will FTP new PR code, placing it on station disk.

PRTN 277, "A Simple Fairness Algorithm"

This paper presents a solution to a task scheduling problem in PRs. The PR control structure is a loop consisting of successive tests of whether various tasks can be performed. When a ready task is found, that task is serviced, after which control returns to the top of the loop. If tasks tested early in the loop are ready often enough, tasks later in the loop will never be tested, not to mention serviced. The paper proposes suppressing each particular task on certain passes through the

loop, thus guaranteeing all tasks at least some level of service.

2.3. Negotiations and Informal Documents

The most significant negotiations this quarter revolved around the oscillation possible in the Station-to-PR Protocol, SPP. We found that the CAP 5 station and PR would sometimes enter an unending cycle of sending empty (textless) packets back and forth. This was particularly easy to reproduce in the BBN PR net, where packet printing is presently performed on a ten character per second terminal, which is slower than elsewhere. Down line loading the non-station PR would precipitate the sequence of events, which would so congest the connection process that the down line load in effect ceased. On-site debugging by Collins staff helped to clarify the PR's role in this sequence, and the conclusion was reached that the oscillation is a potential problem inherent in the design of SPP. This, and the 20-second timeout, or deaf period, used to quench the oscillations in the station, are discussed at length in PRTN 272, "SPP Oscillation" (see section 2.2).

Other negotiations this quarter were of relatively minor significance. One bug in connection handling in the PR was found and reported to Collins personnel, who quickly fixed it; a second bug, concerning LROP priority, was suspected and became the topic of a discussion at the CAP 5 Implementers' meeting (section 2.1).

We also negotiated with other PRWG contractors on the best way to ensure repair of failed routes; on whether route limitations should be resolved by increasing the route length in packet headers or by implementing transfer points; and on the applicability of modelling work at Probe Corporation to issues of network design and PR deployment. No strong consensus arose out of these negotiations, but in the last week of the quarter we participated in negotiations with Collins which promise to arrive

at a format for IPR down line load command packets which is convenient to both station and PR.

3. THE PACKET RADIO NETWORK

3.1. Station Programming and Testing

3.1.1. Connection process and STACON

We designed and implemented modifications to the SPP protocol in the station connection process. These modifications correct a problem in the protocol, the SPP "oscillation". This problem allowed a PR and the station to have different notions of the state of connections between them, when acknowledgements (ACKs) to synchronize (SYN, open) packets were lost or delayed (for example, due to packet printing). We delivered this to SRI, where it was used in CAP 5 testing, and again later for regular use. The modifications were fully described in PRTN 272 (see section 2.2).

Changes were made to the station operator's terminal control process, STACON, to permit process output streams to be directed, by default, to particular terminals. The previous version cycled through the existing terminals and processes, assigning them in an arbitrary, cyclic order. SRI had requested this modification so that certain physical terminals in their station room would always perform certain functions. For instance, packet printing would always be performed on a high-speed scope terminal line, and the operator's terminal would always be a particular hard copy terminal. Hardware problems and scheduling contingencies prevented delivery of the new STACON to SRI this quarter, but we anticipate delivery early in the coming quarter, when conditions permit.

3.1.2. Labeler and network testing

The Labeler was enhanced and extensively tested and debugged this quarter. Additional CAP 5 labeler commands were designed, written and tested, to allow the station operator to perform several new functions. These functions refer specifically to

important aspects of CAP 5, and most do not have any counterpart in earlier CAP versions. They are as follows.

- a) Examine the neighbor information reported in the most recent PDP -- for a particular PR or for all PRs.
- b) Examine the reported link qualities and age of links between the specified PR and its neighbors -- for a particular PR or for all PRs. The age is the duration of time the link has been usable for routing assignment.
- c) Examine the time since a PDP has arrived -- for a particular PR or for all PRs.
- d) Tell the station to generate a PDP request -- for a particular PR or for all PRs.
- e) View the station's current notion of the best route between any two PRs.
- f) Change the threshold values used in determining good neighbor status, for experimental purposes. (This was requested at the SRI meeting July 11-12.)

The vast majority of station debugging was centered on the new CAP 5 Labeler, so efforts in that domain are included in this section. Progress was very good this quarter, resulting in a station (and network) with no known bugs by the end of August. At that time, activity had become mostly one of load testing -- determining what amount of traffic and connectivity change (primarily due to mobile operation) could be supported. Problem areas encountered in network testing this quarter included the following.

- 1) SPP oscillation, as noted in section 2.3. Initially avoided by turning off (disabling) the packet printer at BBN, or by running at SRI. Later treated by a modification to the connection process (see section 3.1.1).

- 2) A long-standing (years old), infrequent bug started cropping up more frequently, due to new control structures in the Labeler and to the way it exercises the operating system. The timer queue in the BCPL library routines was losing the Labeler's refresh interval timer, so routes would not be refreshed. The bug was laboriously tracked down and fixed. For a time, it looked like a hardware problem, since it was seen only in the PDP-11/40 and not in any PDP-11/34. Before the problem was found, we masked it by an additional cross-check, counting the times when the timer had been erroneously removed from the queue. This permitted mobile testing for the interim. The cause was a mismatch between library and Labeler understandings of whether part of an argument field was ignored.
- 3) Another long-standing bug started to appear frequently, and had to be masked (while still counting instances) for mobile testing before it was fixed. This is the "ACK but no packet sent" problem, an intermittent problem regarding the cleanup of an SPP connection, between the Labeler and the connection process. The connection process would occasionally signal the Labeler that an acknowledgement had been received, but the Labeler had no record of sending any packet to which this could be an acknowledgement. A coding error was finally found and fixed.
- 4) Use of the station-resident gateway led to unacceptable levels of congestion in the station PR, contaminating results of tests (especially mobile runs). The exported gateway software had been released for some time, but PR net testing was using the resident gateway due to scheduling conflicts with Fort Bragg CAP 4.9 software work, which required one of SRI's PDP-11s. The solution was to wait awhile and install the

exported gateway as soon as project priorities permitted, which was late in August. Hardware unavailability due to a PR hardware failure at SRI, and to IPR software development, also contributed slightly to delay in mobile testing.

- 5) Under staffing has been somewhat of a problem in the intense testing this quarter. Even SRI's more generous staff size has been stretched with Fort Bragg preparations, continuing TIU work, and CAP 5 testing. The TOPS-20 command file we prepared (see QPR 18) helps SRI staff to capture ELF crashes for later diagnosis, but occasions when station processes themselves crash are examples of when BBN personnel must be immediately available, or the crash data will be lost. Unfortunately, SRI scope does not permit their staff to learn XNET debugger commands to capture the data; nor does BBN scope permit guaranteed availability of a knowledgeable person on call.
- 6) As the quarter progressed, an increasing amount of time and effort, on the part of Collins, SRI and BBN, was drained by attacks on the "bad ID" problem. Somehow information claiming the existence of various PR ID numbers, to which no actual PR corresponds, is entering the net. This causes extra control traffic as PRs report these bad IDs to the station, and as the station attempts to label these phantom PRs. The extent of damage to network performance is not yet clear, and the origin of the bad IDs is even less understood. This remains a serious problem as the quarter ends.
- 7) A serious problem was observed in PDP generation. The station PR did not respond to a PDP request within 12 minutes, and had not sent a PDP within 45 minutes. The suspected cause is congestion in the station PR. BBN prepared a document (PRTN 277; see section 2.2) describing a simple fairness algorithm, and suggested it be implemented in the PRs. This would insure

servicing of all routines in the "grand loop" (PR scheduling algorithm) at some minimum rate. A somewhat different fairness strategy was obtained through restructuring of the grand loop by Collins staff, and this appears to work satisfactorily.

- 8) A problem with buffer allocation in the Labeler was found when the system was placed under load. It was fixed.
- 9) Confusion over configuration, scenario, traffic level and effects to be monitored slightly hampered some testing efforts this quarter. BBN took temporary responsibility for scheduling on-site mobile testing for the remainder of the quarter, and drew up mobile test plans.

A number of severe tests were used to gain confidence in the correct operation of CAP 5 station and PR software. Besides normal tests, including mobile internet user traffic and SRI's "PMON" monitor program, we employed the following tactics.

- + Intermittently turning on (enabling) the slow packet printing in the BBN net, thus causing delay and congestion in the station's connection process.
- + Initiating down loads of PRs.
- + Temporarily halting, or completely restarting, PRs or the station.
- + Sending garbage information to the Labeler. (Specific efforts were not necessary to accomplish this. The PR net generates bad IDs, for example, and PR software bugs over the course of development have sent other garbled data to the Labeler.)
- + Cause repeated connectivity changes, forcing the reassignment of routes of several traffic streams.
- + Run heavy amounts of traffic internet, intranet forwarded by the station, and intranet point-to-point.

The results of this extensive testing have been a very robust Labeler, plus the progress on design issues and suggestions to other contractors identified above. It also proved possible to adjust timing intervals in the station for more efficient network performance, as a result of insights gained into network behavior from mobile testing. Use of the exported gateway, however, will be the biggest improvement in this area.

3.1.3. PR down line load process

As mentioned in section 2.3, we negotiated this quarter with Collins regarding a format for IPR down line load command packets. The criteria here are compactness of packets, to minimize radio channel load; resemblance to IPR assembler output, to minimize complexity of reformatting and consequent potential for errors; and similarity of format for loading all PRs, again to minimize complexity, chance of error, and implementation and maintenance cost. We also received TIU loader server information from SRI, relating to possible use of that facility to load the IPRs. The TIU mechanism, however, uses a different format (XNET debugger packets) and protocol (internet protocol), plus it is ARPANET-based rather than station-based. For these reasons it has been decided that the IPR and TIU loader server mechanisms will be completely distinct. The exact format of the IPR down load packets is still in discussion as this quarter closes.

We also delivered a new PRLOAD down line loader process (for EPRs), which accepts new connection open failure codes installed in the connection process this quarter. Also, PRLOAD is now compiled with the "/X" switch, resulting in the "finish" command compiling a process freeze instead of a halt instruction. This is compatible with new ELF switch conventions, which, without this change, would preclude debugging a process which simply halted. The documentation was updated accordingly.

3.1.4. XRAY cross-radio debugger

A new version of XRAY, the cross-radio debugger, was delivered this quarter, incorporating a small change to accept new connection open failure codes from the connection process.

3.2. Support

During this quarter progress was made in several PR network support areas. We modified the internet bootstrap to use 96-bit leaders. Use of 96-bit leaders, as opposed to 32-bit leaders, is necessary in order to communicate with a bootstrap running in a machine attached through a port expander. The modified bootstrap was installed on the disk at UCL. In the future, this 96-bit format bootstrap will also be used on other gateways and on Packet Radio stations.

We also made a design decision on XNET debugger protocol under version 4 Internet Protocol: there will be no change except for conversion to the new header format. This will minimize conversion costs.

We delivered various station software to assorted disks at SRI, including two deliveries of station software for Fort Bragg. We also wrote a PDP-11/34 bootstrap and complete station software on a disk sent to us by Collins. On this disk we also placed two IMP11-A interface diagnostics, one configured for the station-ARPANET interface and one for the station-PR net interface. This disk has been shipped to Collins, where we expect it will permit the Collins station to be brought up early in the following quarter. An initial plan to write only the bootstrap on disk was expanded because of indications from Collins that their ARPANET connection might not be working, which would prevent delivering the rest of station software that way.

Earlier hopes that documentation and training would permit SRI staff to reformat and deliver to their own disks PR code for down line loading have not been realized. There is an issue of operational complexity, but apparently a more significant issue is the limitation of SRI scope. This apparently prevents SRI staff from using XNET, the cross-net debugger, which is essential to such delivery of PR code. As a result, although we aided SRI in placing one version of PR CAP code on disk, we have continued to perform this task this quarter. The table below summarizes the deliveries made during these three months.

CAP version	to SRI	to BBN	comments
-----	---	---	-----
5.0.4	X		
5.0.5	X		
5.0.6	X		
5.0.7	X		
5.0.8	X		
5.0.9	X		
5.1.0	X	X	
5.1.1	X		version 1
5.1.0	X		backup
5.1.1	X		version 2

4. INTERNETWORKING

4.1. Transmission Control Program (TCP)

Three major advances in TCP status occurred this quarter: testbed availability to users, delivery of Fort Bragg monitor software to ISI, and testing against TIU software.

As this quarter opened, monitor TCP and TELNET were made available for Packet Radio group users to test them. Users were encouraged to schedule testing time with BBN personnel, so any problems could be immediately tracked.

The Fort Bragg PR net will be using host computer facilities at ISI. These will be accessed via TCP version 4, so our efforts to provide this system software have direct application in the Fort Bragg project. During this quarter we received from ISI a list of TOPS20 Release 3A monitor parameters for the Fort Bragg system. We built such a system from standard DEC sources, with the following exceptions:

1. BBN's 96-bit NCP was used.
2. TCP version 4.0.1 was included.
3. Internet 4.0.1 was included, with Internet user queues.

We sent this Release 3A monitor image with Internet Protocol (IP), TCP, 96-bit NCP, and monitor TELNET to ISI. The TCP files and modifications to DEC files were sent on magnetic tape to ISI so their staff can merge in their local changes as well. ISI found two bugs in the NCP during installation, and a user program uncovered a bug in the TCP. These have been fixed, resulting in a running system at ISI ready for Fort Bragg use.

In addition, a program which samples the program counter has been used to watch the Internet, TCP and TELNET code. The analysis of its results has not yet been completed, but already it has shown that a certain hash table in the free storage package was overflowing. This resulted in considerably

inefficient operation. The problem has been corrected and the updated files given to ISI.

In the third area of TCP progress this quarter, SRI's new version 4 Terminal Interface Unit (TIU) program was tested in conjunction with the TOPS20 monitor TELNET. Problems were discovered on both ends. Updated files for TOPS20 will be sent to ISI early in the next quarter, and testing will continue.

4.2. Gateways

Previous testing with Lincoln Lab staff of their software to perform speech conferencing using the SATNET stream facility had revealed problems in the SATNET interface code in our gateway. This code has been substantially modified during this quarter, and further testing in cooperation with them is ongoing.

We also assisted UCL staff this quarter, in testing Network Independent FTP.

A gateway for the Fort Bragg station, which will be ARPANET host 46 (octal), has been assembled in anticipation of its deployment there.

As described in section 3.1.2, previous tests of network performance have been contaminated by traffic to the station-resident gateway congesting the station PR. A station using an exported gateway to test network performance under more realistic conditions was released. Results from testing with the exported gateway configuration are expected from SRI next quarter.

5. HARDWARE

During this quarter, Packet Radio unit 1 failed and was repaired by Collins personnel during an on-site visit. Also, with telephone direction from Collins, we disabled auto-restart in both PRs. This had been interfering with debugging efforts.

We returned some borrowed PR RF hardware to SRI, replacing it with new equipment. This equipment, coaxial cable and attenuators, is used to connect the two PRs at BBN. From SRI we received a 5-port DMA 1822 LSI-11 minigateway/port expander. The mounting, installation And checkout of this unit is proceeding.

In trying to prepare the disk of station software for Collins (see section 3.2), we twice encountered failures of the "limits" card in the station disk drive. These prevented us from formatting the disk cartridge. Each failure was repaired by DEC, finally permitting disk delivery of software to Collins.