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TELNET under Single-Connection TCP Specification

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February 2, 1976

Technical Note #76

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1 Introduction

One of the goals of the evolving Packet Radio Network (PRNET) is to provide for network access through portable packet radio terminals. These terminals will implement packet radio software on a DEC LSI-11, INTEL 8080, or similar microprocessor. Owing to the unnecessary complexity and generality of the Transmission Control Protocol [1] used by the PRNET, a single connection subset (TCP0) has been designed specifically for portable PRNET terminal application [2].

Given a user TCP0, it is necessary to provide a means of interfacing a user at the portable interactive terminal to the TCP0 and thereby to the net to which he is attached. This interface should provide for establishment and control of network connections, and interactive data flow between the net and the user, as well as specification by the user of various echoing and command intercept options. In the Arpanet, these functions are provided by the TELNET protocol [3]. This paper provides an implementation specification for a TELNET to run under TCP0 without operating system support on a microprocessor. Design objectives were therefore small size, simplicity, and a structure appropriate for character at a time data streams at or slower than 120 cps. It is assumed that the reader is familiar with the TCP0 user interface [2], the TELNET protocol [3], and the Arpanet TIP user interface [4].

2 The User TELNET

All interactive traffic flow between the terminal and the network is mediated by the TELNET, which also performs user command interpretation and execution, presenting a subset of the standard Arpanet TIP user interface. Commands include:

- 1) "`eo <NET>,<TCP>,<SOCKET>`": opens the full duplex connection specified by the supplied foreign net, tcp and socket numbers, and the implied local socket.
- 2) "`ec`": closes the network connection.
- 3) "`et c`": sets transmit character at a time mode.
- 4) "`et l`": sets transmit line at a time mode.
- 5) "`ee l`": sets local echo mode.
- 6) "`ee r`": sets remote echo mode.
- 7) "`el <character code>`": sets a new command intercept character.

The TELNET consists of a single, non-reentrant, non-preemptable process, composed of a set of service routines and a single cyclic wait (polling) routine, from which the service procedures are dispatched on event completion. (Note that execution of the wait causes a context switch to the next in a circular queue of processes: TELNET, TCP0 SEND, TCP0 RECEIVE). Events include:

- 1) Change in connection or command handling status (e.g., connection opened, or bad command syntax).
- 2) Reception of new data over the network connection.
- 3) Reception of a new character from the terminal.
- 4) TCP0 send completion.
- 5) Terminal output completion.

An event scoreboard composed of logical flags is used to signal these events and control dispatch of the appropriate service routines. The flags corresponding to 1 through 5 above are:

1) STATUS flags: these control dispatch of the procedure COMPOSEMESSAGE. They include OPEN (connection opened), ERROR (connection error), CLOSED (connection closed), HOSTNR (host not responding), CANT (command cannot be serviced), and BAD (bad command syntax). Any of these but BAD can be set to TRUE by TCP0.

2) NEWDATA: dispatches either PROCESSDATA or PROCESSTELNETCMD, dependent upon whether the current input is a TELNET escape sequence. This flag is set to TRUE by TCP0 when new data awaits delivery to the user process.

3) TTYINPUT: dispatches either PROCESSCHAR or PROCESSCOMMAND dependent upon whether the current input is a user command intercept sequence. It is set to TRUE by the TTY input interrupt service routine.

4) SENDREADY: dispatches AWAKENSEND. This flag is set to TRUE by TCP0 when new data can be accepted for sending to the net.

5) PRINTERIDLE: dispatches AWAKENPRINTER. It is set to TRUE by the TTY output interrupt service routine.

Note that other conditions can inhibit the dispatch of any of the above service routines. In general, test conditions in the wait routine permit a routine call only if the routine can run to completion

at that time, without the need for an intermediate event wait. For example, `PROCESSDATA` will not be called while there is no buffer space for the new character, even though `NEWDATA` signals data reception. For the one volatile event, `TTYINPUT`, a special flag, `RINGBELL`, is set should neither service routine be immediately dispatchable. This causes the terminal output driver to warn the user with a `CONTROL-G` (bell) that input is being rejected.

3 Data Structures

The data structures used by the TELNET are eight buffers:

`TELNETMSGBUF(j)`: two linear buffers ($j=0$ or 1) in which TELNET option negotiation messages destined for the net are placed for double buffered output. Associated with these buffers is a flag, `TELNETCMDREADY`, which indicates that the current buffer (`TELNETMSGBUF(j)`) contains an unsent TELNET command. This flag inhibits dispatch of `PROCESSTELNETCMD` and execution of the user command "E" (echo mode) until its value is `FALSE`.

`SENDBUF(i)`: two linear buffers ($i=0$ or 1) in which the output stream of user data to the net is queued for double buffered output. Associated with these buffers is three variables: a). `XMITMODE` (= "C" or "L")--indicates whether character- or line-at-a-time transmission is in effect, b). `CHARSTOSEND`--a flag that indicates to the procedure `AWAKENSEND` when it is time to `SEND` the contents of `SENDBUF(i)` to the net, c). `BYTECOUNT`--this counter is passed to the `TCP0` in a `SEND` call and specifies the number of octets to be sent. Service routine dispatch for the `TTYINPUT` event is inhibited while `SENDBUF(i)` is full.

`MESSAGEBUF`: a linear buffer used for construction of user status messages destined for the terminal. Dispatch of `COMPOSEMESSAGE` is inhibited while this buffer is non-empty.

`ECHOBUF`: a circular queue containing the stream of characters to be locally echoed. All characters of a command intercept sequence are automatically enqueued here. Associated with this buffer is a variable `ECHOMODE` (= "R" for remote, "L" for local) which indicates whether locally generated characters are to be echoed.

`RECEIVEBUF`: a circular queue in which characters received over the network connection are placed. Dispatch of `NEWDATA`

event service procedures is inhibited while RECEIVEBUF is full.

COMMANDBUF: a linear queue for assembly of user commands. If it is overflowed, the user is informed with a "BAD" status message.

Note that there are two output streams to the network (TELNETMSGBUF[j] and SENDBUF[i]) and three output streams to the terminal (MESSAGEBUF, ECHOBUF, RECEIVEBUF). This scheme greatly simplifies buffer management and the overall control structure, as well as permitting a priority structure to be assigned to different characters, depending upon source (the streams are listed above from highest to lowest priority); characters of higher priority are processed for output before those lower in the hierarchy.

Also an important part of the control/data structure are two counting variables:

TELNETCOUNT: indicates how many bytes of a TELNET escape sequence have been received over the network connection (the start of such a sequence is signalled by an "IAC" in the TELNET input stream). On NEWDATA event it is used to select between PROCESSDATA (if=0) and PROCESSTELNETCMD (if>0).

COMMANDCOUNT: indicates how many bytes of a command intercept sequence have been received from the terminal (the start of such a sequence is signalled by an INTERCEPTCHAR in the terminal input stream). On TTYINPUT event, it is used to select between PROCESSCHAR (if=0) and PROCESSCOMMAND (if>0).

4 Service Routines

There are four categories of TELNET service procedures:

1) Net input handlers: PROCESSDATA, PROCESSTELNETCMD.

2) Terminal input handlers: PROCESSCHAR, PROCESSCOMMAND, PARSE, ASCII TO BINARY.

3) Net output handlers: AWAKENSEND, TELNETREPLY, SENDCHAR.

4) Terminal output handlers: TTYINPUTINTERRUPTSERVICE, TTYOUTPUTINTERRUPTSERVICE, COMPOSEMESSAGE, AWAKENPRINTER, TYPENEXT, TYPE.

Each list of routines is in top level to lower level order.

COMPOSEMESSAGE is called from the event wait loop when MESSAGEBUF is free and a STATUS flag has been set. For each set flag, status text is placed in MESSAGEBUF. All status flags are then reset to FALSE.

PROCESSDATA is called from the wait loop if a terminal-bound character arrives and RECEIVEBUF has space. The character is fetched from the TCP0 via a RECEIVE call, and then enqueued in RECEIVEBUF, unless it is "IAC", in which case TELNETCOUNT is incremented.

PROCESSTELNETCMD is called from the wait loop when a TELNET command byte arrives. It has two entry points, one chosen by the value of TELNETCOUNT. The first handles reception of the second byte of the escape sequence. If this byte is "IAC", then it is enqueued in RECEIVEBUF and TELNETCOUNT reset to zero, else it is saved in the variable COMMAND and TELNETCOUNT incremented. The second entry point handles reception of the third byte (stored into OPTION) and acts on the TELNET command received by sending out an appropriate TELNET reply, plus possibly setting a new ECHOMODE value.

TELNETREPLY is called from PROCESSTELNETCMD, and passed either "DONT" or "WONT". It assembles a TELNET reply in TELNETMSGBUF[j], using this parameter and OPTION, and sets TELNETCMDREADY to TRUE.

PROCESSCHAR is called from the wait loop when a new net-destined character arrives from the terminal and there is buffer room for it. If the new character is the command intercept character, INTERCEPTCHAR, then conditions are initialized for command collection, otherwise the character is prepared for transport to the net by a call on SENDCHAR.

PROCESSCOMMAND is called from the wait loop when a user command byte arrives from the terminal. The character is enqueued in ECHOBUF and COMMANDBUF. If a carriage return, PARSE is called.

SENDCHAR is called from PROCESSCHAR and PROCESSCOMMAND. The character, passed in the global variable CHAR, is enqueued in SENDBUF[i], and if local echo is set, it is also enqueued in ECHCBUF. If the character is special (e.g., a control character, carriage return, or escape), if the transmission mode is character at a time, or if SENDBUF[i] is full, CHARSTOSEND is set to TRUE, signalling that a SEND should be issued.

PARSE is called when COMMANDBUF contains a complete command. Syntax is checked; if not good, BAD is set to TRUE. Otherwise, the appropriate action is taken (e.g., issuing an OPEN, CLOSE, setting a new intercept character, etc.).

ASCIITOBINARY is called from PARSE, and converts an ASCII string in radix-10 to binary, of length in bits specified by a parameter. This

routine uses a global index into COMMANDBUF, STRINGORIGIN, to find the left end of the string. A global flag, BADSTRING, is set to TRUE if bad string syntax. STRINGORIGIN is returned pointing to the character past the string delimiter (CR or COMMA if good syntax).

AWAKENSEND is dispatched from the event wait loop on signal from the TCP0 via SENDREADY. If there is a TELNET reply ready, it is sent via a SEND call. Otherwise, if CHARSTOSEND, then SENDBUF[i] is output via a SEND. In either case, buffer switching is performed after the SEND.

TTYINPUTINTERRUPTSERVICE and TTYOUTPUTINTERRUPTSERVICE are called via device interrupt. They set to TRUE the TTYINPUT and PRINTERIDLE flags respectively.

AWAKENPRINTER is called from the event wait loop when PRINTERIDLE. From highest to lowest priority it will do one of:

- 1) TYPE a CONTROL-0 if RINGBELL is TRUE, and set RINGBELL to FALSE.

- 2) TYPE the next character of a carriage return expansion (if CRCOUNT>0). A variable, NULLSNEEDED, controls the number of null characters generated in the expansion.

- 3) TYPE the next space of a tab expansion (if TABCOUNT>0).

- 4) TYPENEXT the contents of MESSAGEBUF, if non-empty.

- 5) TYPENEXT the contents of ECHOBUF, and set TABCOUNT or CRCOUNT to the appropriate value if the character is a tab or carriage return.

- 6) TYPENEXT the contents of RECEIVEBUF.

TYPENEXT is passed a buffer, from which it dequeues the next character and then TYPEs it. A variable COLCOUNT is also maintained. This is used in setting TABCOUNT for tab expansion.

TYPE is passed a character which it sends to the terminal for printing. PRINTERIDLE is set to FALSE.

5 Pseudo-Algol Implementation Guide

```

begin
TELNETINIT:
  (initialize all buffers);
  TELNETCOUNT←COMMANDCOUNT+3;
  TABCOUNT←CRCOUNT+3;
  BYTECOUNT←COLCOUNT+3;
  i←j←0;
  NULLSNEEDED←(whatever is appropriate for the device);
  ECHOMODE←REQUESTEDMODE←"R";
  XMITMODE←"C";
  INTERCEPTCHAR←"e";
  (all flags but PRINTERIDLE set to FALSE);
  PRINTERIDLE←TRUE;
  (whatever other minor housekeeping details);

WAITLOOP:
  (wait for signal);

  if (OPEN|ERROR|CLOSED|CAN'T|BAD|BUSY|N?) and (MESSAGEBUF empty) then
    COMPOSEMESSAGE;

  if NEWDATA and (RECEIVEBUF not full) then
    if (TELNETCOUNT=0) then
      begin
        NEWDATA←FALSE;
        PROCESSDATA;
      end

    else if (not TELNETCMDREADY) then
      begin
        NEWDATA←FALSE;
        PROCESSTELENETCMD;
      end;

  if TTYINPUT then
    begin
      if (SENDBUF(i) full) or (ECHOBUF full) then RINGBELL←TRUE else
        if COMMANDCOUNT=0 then PROCESSCHAR else PROCESSCOMMAND;
      TTYINPUT←FALSE;
    end;

  if SENDREADY then AWAKENSEND;

```

```

if PRINTERIDLE then AWAKENPRINTER;

go to WAITLOOP;

PROCEDURE COMPOSEMESSAGE;

begin
  if BAD then (place "BAD<CRLF><NULL STRING>" in MESSAGEBUF);
  if CANT then (place "CANT<CRLF><NULL STRING>" in MESSAGEBUF);
  if OPEN then (place "OPEN<CRLF><NULL STRING>" in MESSAGEBUF);
  if ERROR then (place "CONNECTION ERROR . . . etc);
  if HOSTNR then (place "HOST NOT RESPONDING . . . etc);
  if CLOSED then (place "CLOSED . . . etc);
  BAD←CANT←OPEN←ERROR←HOSTNR←CLOSED←FALSE;
end;

PROCEDURE PROCESSDATA;

begin
  RECEIVE (CHAR,1,BYTESXFERRED);
  if CHAR=IAC then TELNETCOUNT←1 else (enqueue CHAR in RECEIVEBUF);
end;

PROCEDURE PROCESSTELNETCMD;

case TELNETCOUNT of

  -1:
  begin
    RECEIVE (COMMAND,1,BYTESXFERRED);

    if COMMAND not equal (WILL|WONT|DO|DONT) then
      begin
        TELNETCOUNT←0;
        if COMMAND=IAC then (place "IAC" in RECEIVEBUF);
      end
    else TELNETCOUNT←2;

  end;

  -2:
  begin
    TELNETCOUNT←0;
    RECEIVE (OPTION,1,BYTESXFERRED);

    case COMMAND of

      -WILL:
      if (OPTION=ECHO) and (REQUESTEDMODE="R") then
        ECHOMODE←"R"
      else TELNETREPLY(DONT);
    end;
  end;
end;

```

```
-DO:
  TELNETREPLY(WONT);

-WONT:
  if (OPTION=ECHO) then
    if REQUESTEDMODE="R" then CANT-TRUE else
      ECHOMODE="L";

-DONT:
  TELNETREPLY(WONT);

end;

PROCEDURE TELNETREPLY(CMD);

  begin
    (place "<IAC><CMD><OPTION>" into TELNETMSGBUF(j));
    TELNETCMDREADY-TRUE;
  end;

PROCEDURE PROCESSCHAR;

  begin
    (fetch tty character to CHAR);

    if CHAR=INTERCEPTCHAR then
      begin
        COMMANDCOUNT+1;
        (initialize COMMANDBUF);
        (enqueue CHAR in ECHOBUF);
      end
    else SENDCHAR;

  end;

PROCEDURE SENDCHAR;

  begin
    if (ECHOMODE="L") then (enqueue CHAR in ECHOBUF);
    (enqueue CHAR in SENDBUF(i));
    BYTECOUNT+BYTECOUNT+1;
    if (CHAR a special character) or (XMITMODE="C") or (SENDBUF(i) full)
      then CHARSTOSEND-TRUE;
  end;

PROCEDURE PROCESSCOMMAND;

  begin
    (fetch tty character to CHAR);
    (fold CHAR to upper case);

    if COMMANDCOUNT=1 and CHAR=INTERCEPTCHAR then
```

```

begin
  COMMANDCOUNT+3;
  SENDCHAR;
end

else begin
  (enqueue CHAR in ECHOBUF);

  if (COMMANDBUF not full) then
    begin
      (enqueue CHAR in COMMANDBUF);
      COMMANDCOUNT+COMMANDCOUNT+1;
      if CHAR=CR then PARSE;
    end

    else begin
      BAD+TRUE;
      COMMANDCOUNT+0;
    end;

  end;

end;

end;

PROCEDURE PARSE;

  if COMMANDBUF(2) not equal (SPACE|CR) then BAD+TRUE else

    begin
      case COMMANDBUF(1) of

        =C:
          if COMMANDBUF(2)=CR then CLOSE else BAD+TRUE;

        =0:
          begin
            BADSTRING+FALSE;
            STRINGORIGIN+3;
            NET+ASCII TO BINARY(8);
            TCP+ASCII TO BINARY(16);
            SOCKET+ASCII TO BINARY(24);

            if BADSTRING or COMMANDBUF(STRINGORIGIN-1) not = CR then
              BAD+TRUE

            else begin
              OPEN(NET, TCP, SOCKET, RETURN CODE);
              if RETURN CODE not equal 0 then CANT+TRUE;
            end;

          end;

        end;

      end;
    end;

```

```

=I:
begin
BADSTRING←FALSE;
STRINGORIGIN←3;
TEMP←ASCIITOBINARY(7);

if BADSTRING or COMMANDBUF (STRINGORIGIN-1) not =CR then
  BAD←TRUE
else INTERCEPTCHAR←TEMP;

end;

=T:
if COMMANDBUF(4)=CR and COMMANDBUF(3)="C"|"L" then
  XMITMODE←COMMANDBUF(3)
else BAD←TRUE;

=E:
begin
if COMMANDBUF(4)=CR and COMMANDBUF(3)="L"|"R" then
  if ECHOMODE not equal COMMANDBUF(3) then
    if TELNETCMDREADY then BAD←TRUE else

      begin
        REQUESTEDMODE←COMMANDBUF(3)
        if REQUESTEDMODE="L" then
          (set <IAC><DONT><ECHO>
           in TELNETMSGBUF(j))
        else (set <IAC><DO><ECHO>
              in TELNETMSGBUF(j));
        TELNETCMDREADY←TRUE;
      end

else BAD←TRUE;
end;

=(anything else):
BAD←TRUE;

COMMANDCOUNT←0;
end;

```

```

BINARY PROCEDURE ASCIITOBINARY(LENGTH);

```

```

begin
(convert string from left to right starting at
STRINGORIGIN in COMMANDBUF to binary, and stop when a
delimiter is found or "LENGTH" bits is overflowed);

if (LENGTH is overflowed) or (delimiter not equal (cr|",")) then
  BADSTRING←TRUE;

```

```
(leave STRINGORIGIN pointing to character after delimiter);  
end;
```

```
PROCEDURE AWAKENSEND;
```

```
  if TELNETCMDREADY then  
    begin  
      TELNETCMDREADY←SENDREADY←FALSE;  
      SEND(TELNETMSGBUF[j],3);  
      j←(j+1) mod 2;  
    end
```

```
  else if CHARSTOSEND then
```

```
    begin  
      CHARSTOSEND←SENDREADY←FALSE;  
      SEND(SENDBUF[i],BYTECOUNT);  
      BYTECOUNT←0;  
      i←(i+1) mod 2;  
    end;
```

```
PROCEDURE AWAKENPRINTER;
```

```
  if RINGBELL then
```

```
    begin  
      RINGBELL←FALSE;  
      TYPE(CONTROLG);  
    end
```

```
  else if CRCOUNT>0 then
```

```
    begin  
      CRCOUNT←CRCOUNT+1;  
      if CRCOUNT=2 then TYPE(LF) else  
        begin  
          TYPE(NULL);  
          if CRCOUNT=NULLSNEEDED+2 then CRCOUNT←0;  
        end  
    end
```

```
  else if TABCOUNT>0 then
```

```
    begin  
      TYPE(SPACE);  
      TABCOUNT←TABCOUNT-1;  
    end
```

```
  else if (MESSAGEBUF not empty) then TYPENEXT(MESSAGEBUF)
```

```
  else if (ECHOBUF not empty) then
```

```
begin
  if (next character is TAB) then TABCOUNT←(8-COLCOUNT) else
    if (next character is a CR) then CRCOUNT←1;
  TYPENEXT(ECHOBUF);
end

else if (RECEIVEBUF not empty) then TYPENEXT(RECEIVEBUF);

PROCEDURE TYPENEXT(BUFFER);

begin
  (dequeue next character from BUFFER into CHAR);
  if (CHAR is printable) then COLCOUNT←(COLCOUNT+1) MOD 8 else
    if CHAR=CR then COLCOUNT←0;
  TYPE(CHAR);
end;

PROCEDURE TYPE(CHARACTER);

begin
  PRINTERIDLE←FALSE;
  (send CHARACTER to tty);
end;

PROCEDURE TTYINPUTINTERRUPTSERVICE;

begin
  (service the device);
  NEWDATA←TRUE;
end;

PROCEDURE TTYOUTPUTINTERRUPTSERVICE;

begin
  (service the device);
  PRINTERIDLE←TRUE;
end;

end.
```


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