Inter-Office Memorandum

To	Communication Protocols	Date	July 3, 1978
From	Ed Taft	Location	Palo Alto
Subject	Synchronous Line Transport Protocol	Organization	PARC/CSL

XEROX

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Low-speed synchronous lines used to transport Pups are controlled by means of the Synchr
Line Transport Protocol (sometimes referred to as the SLA protocol because synchronous li
first interfaced to Novas using a Synchronous Line Adapter). In addition to Pup encapsu
protocol entails some network-specific, non-Pup communication that enables hosts to main
dynamic information about line status and sub-network connectivity.

The Synchronous Line Transport Protocol is used by Nova and Alto Gateways. We presently
consider it to be a private'' protocol among Gateways, and it is subject to change at

All numbers are decimal unless suffixed with B', in which case they are octal.

Packet Framing

All packets (whether or not they are Pups) are transmitted as transparent BiSync data fr
are using only a subset of the full BiSync line control protocol, namely the part dealin
transparent transmission of data frames.

Frame Format

A frame consists of the following sequence of 8-bit bytes:

SYN SYN ... SYN DLE STX ... transparent data ... DLE ETX CRC1 CRC2

The frame begins with at least two SYN bytes, which the receiver searches for in order t
byte synchronization. The sequence DLE STX signals the start of the data portion of the

Within the data portion, all bytes are treated as literal data except DLE, which is an es
A literal data byte whose code corresponds to DLE is transmitted by doubling it, i.e., by
DLE. If the sequence DLE SYN appears, both bytes are ignored. Some synchronous interfaces automatically transmit DLE SYN when a transmit data-late condition occurs.

The end of the transparent data is indicated by the sequence DLE ETX. Following this are
containing the 16-bit CRC (Cyclical Redundancy Check), transmitted low-order byte first.
algorithm is given below. The CRC is computed over the transparent data bytes and the ET
the sequence DLE DLE appears, only one of the DLEs contributes to the CRC. When DLE SYN
appears, neither byte is included.

Byte synchronization is not necessarily maintained from one frame to the next, so after

the receiver should restart its bit-at-a-time search for a SYN byte. The data transmitt
frames is not specified, but it should not be a pattern that could be mistaken for SYN o
zeroes or all-ones are good choices for inter-frame data.

All bytes are transmitted low-order bit first. When the transparent data is treated as
the order of bytes in each word is high-order, then low-order.

Character Codes

We use the ASCII codes for the special characters. These are:

SYN	026B
DLE	020B
STX	002B
ETX	203B

CRC Algorithm

The CRC algorithm used is the industry-standard CRC-16. The CRC is a 16-bit number which
remainder from dividing the data bit stream by the polynomial $x^{16}+x^{15}+x^{2}+x^{0}$. Hardware
implementations of CRC-16 are available in the form of integrated circuits such as the F

The manner in which the CRC is generated and checked is as follows. The transmitter ini
CRC to zero. Then, for every bit in the data stream, it updates the CRC using a simple x
technique. At the end of the data, the transmitter appends the CRC, low-order bit first

The receiver computes the CRC in a similar manner except that the 16 bits of CRC at the e
data are *included* in the CRC computation. The CRC algorithm has the property that if no er
have occurred, the result of applying the algorithm to the data *and* the received CRC will

The CRC may be computed in software or microcode by any of several methods. One that is
understand works a single bit at a time, but this is relatively expensive since it must
times for every data byte. The following BCPL procedure, given a partial CRC and a new d
(right-justified), returns the updated CRC:

```
let UpdateCRC(crc, data) = valof
    [
    for i = 1 to 8 do
        [
        let xorFeedback = (crc xor data) & 1
        crc = crc rshift 1
        data = data rshift 1
        if xorFeedback ne 0 then crc = crc xor 120001B
        ]
    resultis crc
    ]
```

The idea is to right-shift the partial CRC and the data byte by one bit and to compare t
are shifted out. If they are the same, the CRC is not modified further; if they are di
(shifted) CRC is XORed with the constant 120001B.

A faster technique updates the CRC a full byte at a time, using a 256-word table, CRCTAB, initialized as follows:

```
for i = 0 to 255 do
    [
    let crc = 0
    let val = i
    for power = 0 to 7 do
        test (val & 1) eq 0
            ifso val = val rshift 1
            ifnot
                [
                crc = crc xor (120001B rshift (7 - power))
                val = (val rshift 1) xor 120001B
                ]
    CRCTAB ! i = crc
    ]
```

The procedure for updating the CRC is then simply:

```
let UpdateCRC(crc, data) =
    (crc rshift 8) xor CRCTAB ! ((crc xor data) & 377B)
```

Packet Formats

Two types of packets are presently transported over synchronous lines: *encapsulated Pups* and *network routing tables*. Refer to Figure 1. The two types are distinguished by the first word packet. An encapsulated Pup is type 512 and a routing table is type 513. 16 bits are reserved for the Type word because we contemplate subdividing it to include other information such as that required for sub-network fragmentation of large packets.

Note that what is shown in the figure is the *transparent data* only; all packets are carried frames as described in the preceding section. This should be assumed for the remainder document.

Pup Encapsulation

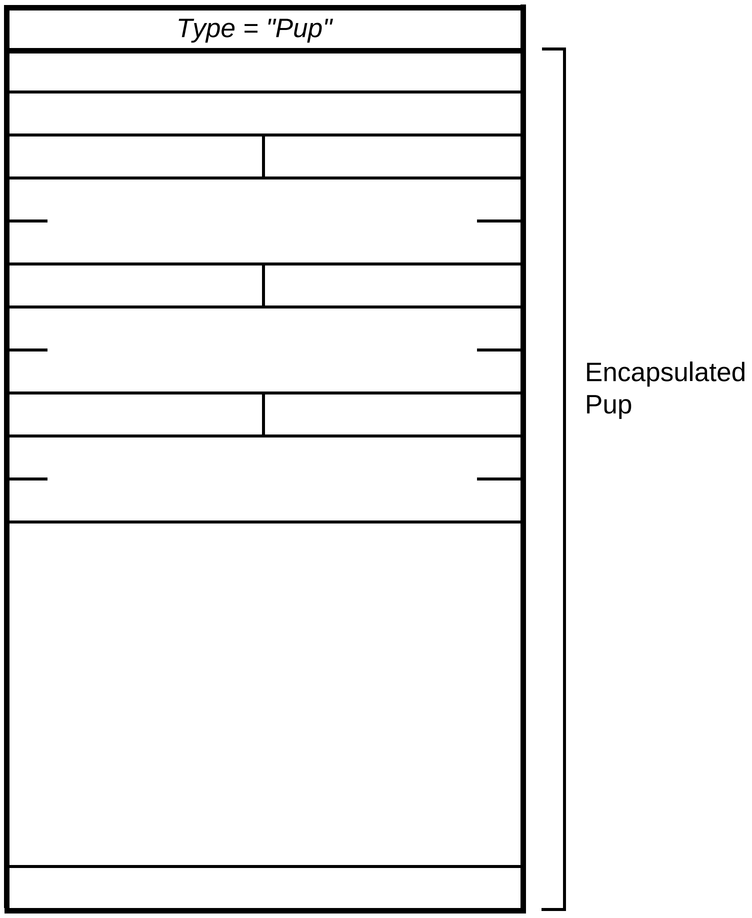
A Pup is encapsulated simply by prefixing the appropriate Type word. Note that the pack *not* carry immediate source and destination host numbers, though the immediate destination derived and used by the sub-network routing algorithm to determine on which outgoing lin transmit the packet. A consequence of the packet's not carrying the immediate destination host number is that the Pup must undergo inter-network Pup routing at every sub-network node through which it passes. This in turn implies that all sub-network nodes must be Pup Gateways.

Sub-Network Routing Table

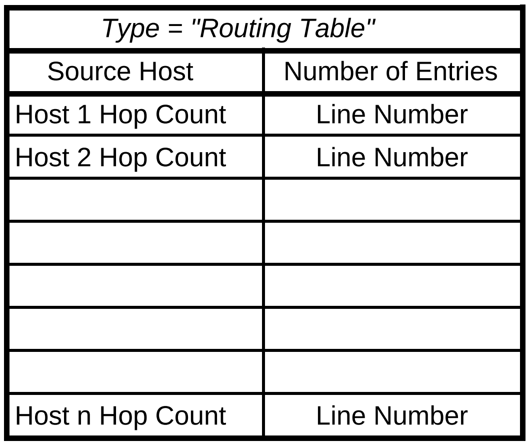
A Routing Table is a *non-Pup* packet carrying sub-network routing information. This shoul confused with a Gateway Information Pup, which is network-independent and carries inter- routing information.

The packet consists of an identifying Type word, the sub-network host number of the pack sender, the number of routing entries, and the routing entries themselves. The first ro refers to sub-network host 1, the second to host 2, etc. This arrangement implies that there can't be very many hosts in the sub-network, and the host number space must be fairly dense.

Each routing table entry contains a hop count and a line number. The hop count is the e minimum number of point-to-point lines between the host generating the routing table and to which the routing table entry refers. The entry corresponding to the sending host it



Pup Encapsulation



Type = "Routing Table"	
Source Host	Number of Entries
Host 1 Hop Count	Line Number
Host 2 Hop Count	Line Number
Host n Hop Count	Line Number

Sub-Network Routing Table

Figure 1.
Synchronous Line Transmission Protocol Packet Formats

contain a hop count of zero. Entries corresponding to hosts that are believed to be ina
contain a hop count of 255.

The line number identifies the line over which the sending host believes it can achieve
path claimed by the hop count. This information is useless to a host receiving the routing table. It is included so that the body of a Routing Table packet may be generated simply by copying the internal representation of the sender's routing table.

Sub-Network Organization and Algorithms

A collection of hosts interconnected by synchronous lines is treated as a single network
Pup inter-network. This network is assigned a unique network number, and the hosts are
unique host numbers within that network. To avoid any confusion between the Pup inter-n
and a specific network composed of nodes interconnected by synchronous lines, we refer t
latter as the *sub-network*.

Each host in the sub-network maintains a local routing table containing an entry for eve
host. Each entry contains a hop count and a line number, as described in the preceding
Additionally, for each synchronous line connected to the host there is a *line state* with val
up, and *looped back*, and a timer used to time out dead lines.

Every 5 seconds, the host sends a Routing Table packet on every line.

Upon receiving a routing table from some line *l*, the host updates its local state as fol

> The timer for line *l* is reset.
>
> The local routing table is enumerated. For each entry whose line number field is
> the hop count is set to 255. The effect of this is to purge obsolete information about line *l*, since new information is about to be incorporated.
>
> If the *Source Host* is equal to the local host number, the line state for line *l* is se
> *back* and no further processing is performed on the Routing Table packet.
>
> The line state for line *l* is set to *up*.
>
> The local routing table and the entries in the packet are enumerated in parallel.
> host, if the hop count in the local routing table is greater than the correspondin
> in the packet, the local routing table entry's hop count is replaced by the packet
> plus one and the line number is replaced by *l*. If the resulting hop count is great
> constant *MaxHops* (presently 15), it is replaced by 255 (thereby marking the host
> inaccessible).

If no routing tables are received over some line *l* during a period of 20 seconds, the lin
changed to *down*. Then all entries in the local routing table are enumerated. For each
line number field is equal to *l*, the hop count is set to 255.

Outgoing Pups are routed to lines by computing the *immediate destination host* (an operation
performed at the Pup inter-network level) and simply using it as an index into the local
table. If the routing table entry's hop count is 255, the host is inaccessible and the
discarded.

This is an extremely simplified version of the routing algorithm used in the Arpanet. Its major defects are that (a) it uses an imperfect metric (hop count) for making routing decisions, (b) it is unable to make effective use of multiple paths to a given destination, and (c) it does not extend well to large sub-networks.