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CORRELATION of PROTOCOL CLOCKS

SRNTN 58

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19 ABSTRACT (Continue on reverse if necessary and identify by block number)

This SRNTN explores the ability and need to synchronize events in an LPR network. Event synchronization is discussed in terms of synchronizing time reference and/or correlating them. The use of different timestamping schemes is discussed. The synchronizing and/or correlating of events network-wide is necessary for both network control and network monitoring activities. Several methods of correlation and/or synchronization and their precision are reviewed and an implementation suggestion is made.

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INTRODUCTION:

The ability to synchronize events in an LPR network is fundamental to
the operation of the new protocols being designed. Synchronization of
events may be accomplished by synchronizing time references or by cor-
relating them. The following is an edited rendition of Jim Stevens'
presentation to the SURAN implementors meeting held 3-5 September 1986.

DEFINITION OF TERMS:

SYNCHRONIZED   state in which clocks indicate the same time.

CORRELATED   state in which clocks indicate different times, but
                        differ by a constant, known OFFSET.

RF CLOCK   clock used by IOP to transmit/receive code-slotted
                        packets (Units = 5 microseconds).

8086 CLOCK   clock used by 8086 protocol and 8086 OS in the LPR
                        (Units = 26.0416 microseconds).

RF TIME   time from RF CLOCK, synchronized within a subnet
                        work.

UNIVERSAL RF TIME   time to which a network of several overlapping sub-
                        networks, having different RF TIMEs, has been
                        correlated.

8086 TIME   time from 8086 CLOCK used by protocol and OS within
                        a single LPR.

UNIVERSAL 8086   8086 TIME which has been correlated by an OFFSET
     TIME   within a subnetwork or network (multiple
                        subnetworks).

USE OF CORRELATED TIMESTAMP:

The LPR should use its 8086 CLOCK internally both for time tagging and for calculating time intervals.

When the LPR reports time tags externally it can report either:

1 - RF TIME
         or
2 - UNIVERSAL 8086 TIME
         or
3 - 8086 TIME and the RF TIME

Methods 1 and 2 require significant calculation and continual maintenance of the OFFSET by the LPR. Method 3 however shifts the burden of calculations and/or OFFSET maintenance to the external entity, e.g. the network monitor.

When an external entity puts a TIME into a packet intended for interpretation by an LPR it can put either :

1 - 8086 TIME
         or
2 - UNIVERSAL 8086 TIME
         or
3 - RF TIME

Method 1 requires that the external entity maintain a table of OFFSETs containing the OFFSET for each LPR in the network. This table would need to be continually updated to account for OFFSET changes in the LPRs as well as the entrance and exit of LPRs to and from the network. This method is highly impractical, requiring a high processing overhead and eliminating the use of broadcast packets.

Method 2 requires that each LPR maintain an OFFSET and perform its own correlation calculations. OFFSET maintenance would need to be performed at least every 8 minutes (explained in a later section).

Method 3 requires an LPR to calculate the difference in current RF TIME and externally specified RF TIMES and convert to local 8086 clock units for event scheduling. These conversions would be necessary only occasionally and do not involve an OFFSET calculation.

APPLICATIONS OF CORRELATED CLOCKS:

(1)   Monitoring devices (such as the network monitor) could use RF TIME or UNIVERSAL 8086 TIME to correlate the Monitoring Data Packets (MDPs) or other information it receives from the LPRs out in the net.

(2)   Monitoring devices (such as the network monitor) could use RF TIME or UNIVERSAL 8086 TIME to command an LPR to clear its cumstats at time X, take a snapshot at time Y, and report the data back to the device at time Z. This would allow a test to be run between time X and Y without any extraneous monitoring traffic being broadcast to skew the test data.

```
     |                                    |    different      |
     |                                    |   for each LPR    |
     |<--------- run test ----------->|<- to reduce net ->|
     |                                    |    congestion     |   UNIVERSAL
---|--------------------------------|-------------------|------>  8086
     X                                    Y                   Z       TIME

     LPRs clear                  LPRs take           LPRs report
     cumstats                    snapshot            snapshots
```

(3)   Network managing devices (such as a network control center) could use RF TIME or UNIVERSAL 8086 TIME to command LPRs to change network-wide parameters at time T. For example, the network could be told to change frequency at time T and all of the LPRs would change over at the same time. Thus there would not be a substantial period of time when the PRNET would be partitioned as would be if a scheme were used that did not require correlated clocks.

HOW TO CORRELATE CLOCKS:

Following are the steps required to correlate the network clocks.

(1)   Correlate or synchronize the RF CLOCKs:

If there is only one subnetwork, then synchronize RF CLOCKS as de-
scribed in David Young's SRNTN 29.

$$RF\ TIME = RF\ CLOCK$$

If there is more than one subnetwork and the subnetworks have
different RF CLOCKs, then correlate subnetwork time to a UNIVERSAL
RF TIME and synchronize RF CLOCKs within each subnetwork to the
subnetwork time.

$$UNIVERSAL\ RF\ TIME = RF\ TIME + RF\_OFFSET$$
$$= RF\ CLOCK + RF\_OFFSET$$

(2)   Find the OFFSET between the 8086 CLOCK and the RF CLOCK:

If the LPR is maintaining the OFFSET, it must do the calculation
periodically and should update the OFFSET every time it has to
perform a coarse synchronization. The LPR could determine the
OFFSET by requesting the IOP to read the RF CLOCK and then
determining the OFFSET between the returned RF TIME and the current
8086 TIME. Note that a conversion from the RF TIME units to the
8086 TIME units is first required, since the RF CLOCK is kept in 5
us ticks and the 8086 CLOCK is kept in 26.0416 us ticks.

If the external entity is maintaining the OFFSET, then it would do
the calculation every time it received a timestamp from an LPR
consisting of 8086 TIME and RF TIME.

(3)   If there is only one subnetwork:

$$UNIVERSAL\ 8086\ TIME = RF\ TIME$$
$$= RF\ CLOCK$$
$$= 8086\ CLOCK + OFFSET$$

If there are more than one subnetwork:

$$UNIVERSAL\ 8086\ TIME = UNIVERSAL\ RF\ TIME$$
$$= RF\ TIME + RF\_OFFSET$$
$$= 8086\ CLOCK + OFFSET + RF\_OFFSET$$

PRECISION OF CORRELATED CLOCKS:

The reference for the correlated time clocks is the RF CLOCK. The RF
CLOCKs within a network can be synchronized (across a neighbor link) to
within 5 microseconds using FINE synchronization. Note that the
synchronization error across a network is naturally expected to be
larger than across a single link; however, it should still be an order
of magnitude less than a millisecond.

The error in correlating the UNIVERSAL 8086 TIME will come from the
random delays introduced by performing an IOP call to read the RF CLOCK
and correlating it with the 8086 TIME. While the correlation
calculation, with different units of measure for the two clocks, will
introduce some error, the primary error component will be the
uncertainty associated with the RF TIME received back from the IOP
compared to the 8086 TIME due to interprocessor call/return delays (see
timeline below). The delay can be minimized by having the LPR OS
timestamp the IOP call with 8086 TIME at the time of the call and at the
time the IOP returns to the LPR OS for scheduling of the protocol job.
This technique would eliminate delays due to the transfer of processing
between the protocol and the LPR OS and the delays the LPR OS will
encounter when the IOP is busy, since the first timestamp would be the
time at which the IOP channel is available. Should the IOP delay the
return from the call, the delayed_by_receive indication will be set.
This sample should be discarded by the protocol and the IOP call issued
again. Having both timestamps allows saving the lowest delay
encountered/expected for a "good" IOP call (with no extra delays). The
protocol would discard any reading which included a delay greater than
(C-A)minimum + variance. Variance could be on the order of 20%. The
filtered random delay is expected to be on the order of a few
milliseconds and can be further compensated for by performing many calls
and taking an average, but the gain in precision may not be worth the
extra processing time overhead. However several calls may be desirable
after initialization to establish the lowest expected delay value.


```
                         IOP task block runs:
                          - Reads RF TIME;
                          - Returns to LPR OS
                                  |
IOP ---------------------------------|-----------------------------------> RF TIME
                                  B
                      A                     C
LPR -|-----------------|-----------------------|-------------------|-> 8086 TIME
     |                 |                       |                   |
LPR job runs:   LPR OS runs:          LPR OS runs:         LPR job runs:
-Queues time    -Calls IOP            -Stamps 8086 TIME    -Verifies sample
   request      -Stamps 8086 TIME     -Schedules LPR job   -Calculate OFFSET
```
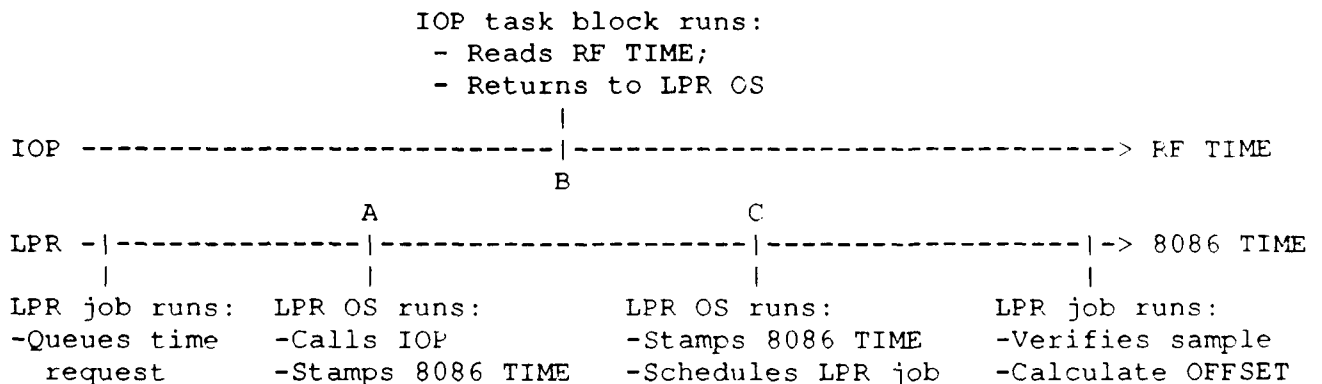
Two simple ways to calculate OFFSET between RF CLOCK and 8086 CLOCK:

(1) Ignore the task block call time or return time and treat either
     time A or C as occurring at the same instant as B.

          B - A = OFFSET   or   B - C = OFFSET

(2) Consider the task block call and return times to be about equal.

$$B - \frac{A + C}{2} = OFFSET$$

More complicated ways to calculate the OFFSET would require multiple
calculations of the OFFSET and taking the average of the different
OFFSETs.

The drift of the RF CLOCK is less than 1 part per million. The drift of
the 8086 CLOCK is less than 1 part per ten thousand. Let's assume that
we desire that the clocks be correlated to within 0.1 second, which
implies that each LPR could be off by + or - 50ms:

     * RF CLOCK

        At 1 part per million, the RF CLOCK could drift 50ms after
        50,000 seconds

             50,000 secs = 13.89 hours

     * 8086 CLOCK

        At 1 part per ten thousand, the 8086 CLOCK could drift 50ms
        second after 500 seconds

             500 secs = 8.33 mins

Thus, if the LPR is maintaining the OFFSET, it would have to correlate
the 8086 CLOCK with the RF CLOCK about once every 8 minutes, assuming
that the RF CLOCK would be correlated much more often than every 14
hours. It is desirable to maintain a much more accurate correlation than
50ms should transmission scheduling be implemented (scheduled
transmissions are synchronized by the protocol using 8086 TIME). Should
an accuracy on the order of the uncertainty of the RF TIME to 8086 TIME
correlation be desired (a few miliseconds), then the correlation should
occur about ten times as often or every minute (actually 0.83 min).

Suggested Implementation:

It is suggested that time correlation within the network be accomplished using existing features. The current thinking is that the LPR should be burdened with as little extraneous processing as possible. This goal may be reached by using the UNIVERSAL RF TIME.

RF TIME sychronization is already in place in the current code (Refer to SRNTN 29 "SURAP Network Time Synchronization"). It is accomplished using timestamps on the PROPs which occur every 7.5 seconds.

In an implementation scheme where the LPR is maintaining the OFFSET, the OFFSET calculation must be performed by every LPR in the network whenever a coarse RF TIME change is made (possibly every 7.5 seconds) AND every 8.33 minutes (to compensate for drift between the RF and 8086 CLOCKS). This extra processing burden may be reduced by sending the host the necessary data (8086 TIME and RF TIME) to calculate the OFFSETs if needed. It is suggested that the MDP (Monitoring Data Packet) header be modified to include an RF TIMESTAMP in addition to the 8086 TIMESTAMP which is already included. This single modification would present the host with all the necessary data to calculate the UNIVERSAL 8086 TIME.

This is not to imply that the individual LPR does not need the ability to correlate its individual 8086 and RF TIMEs. In the case of host-directed future events , the host should send times for future events in RF TIME and each LPR would calculate the necessary 8086 TIME and schedule the event using this calculated time.

```
8086-TIME-for-task = [8086-TIME-when-request-received  +
           ( (RF-TIME-for-task  -  RF-TIME-when-request-received) /
                    (26.0416 / 5) )]
```

In this way the LPR is not burdened with OFFSET calculations except when scheduling host-directed future events. This situation would be infrequent when compared to the frequency of LPR-to-host data transmissions.

SUMMARY:

This paper has addressed the subject of time correlation within the LPR
network. After reviewing the pros and cons of maintaining a UNIVERSAL
8086 TIME, it is suggested that the RF TIME be used instead.
Specifically:

  (1) It is suggested that time correlation within the network be
  accomplished using existing features. The current thinking is that
  the LPR should be burdened with as little extraneous processing as
  possible.

  (2) RF TIME sychronization is already in place in the
  current code (Refer to SRNTN 29 "SURAP Network Time
  Synchronization"). This virtually eliminates the need for the
  correlation of 8086 TIMEs within the network since all nodes are
  synchronized to one RF TIME .

  (3) An RF TIMESTAMP should be included in MDP packets and
  correlation calculations of UNIVERSAL 8086 TIMES should be done by
  the requesting host, in most cases. In this way the LPR is not
  burdened with OFFSET calculations except when scheduling
  host-directed future events. This situation would be infrequent
  when compared to the frequency of data transmission from LPR to
  host.

  (4) The suggested implementation scheme would require little extra
  software, thereby consuming less LPR memory and allowing for faster
  implementation.

  (5) The current testing mechanism, (PC-NETSIM) does not require
  the correlation of 8086 and RF TIMEs and the current development
  status of the LPR radio would indicate that the actual correlation
  scheme may be unnecessary. Should the actual correlation prove to
  be necessary, however, it could easily be added to the current
  scheme at a later date.