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SPECTRACOM PROTOTYPE
NETWORK SYNCHRONIZATION PLAN

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SECTION 1: CONNECTING THE SPECTRACOM MASTER CLOCK TO THE PRIMARY SERVER

This prototype plan may be used as a model for writing a specific plan for your network. Sections may be modified, added, or eliminated as required to mold the plan to the needs of your organization.

SECTION 2: SCOPE OF THIS PLAN

The purpose of this Plan is to maximize the quality and reliability of the network, to the extent that they are affected by timing. The Plan does this by the establishment of a Synchronization Network which distributes and controls the timing throughout the network. It provides insurance against timing impairments that degrade communication quality and reliability.

This Plan establishes slip performance objectives that meet industry standards set forth in EIA/TIA-594 Private Digital Network Synchronization (Ref 1). It contains a map of the synchronization network, which is configured as an overlay on the existing communication network. It also provides engineering rules to be followed that insure meeting the slip performance objectives. Lastly, it describes the responsibilities of the Synchronization Coordinator for synchronization network maintenance, record keeping, coordination, administration, and training.

SECTION 3: NETWORK GOALS

Synchronization goals are set to further the overall network reliability performance goals as determined by the network owners. Both sets of goals should be clearly stated in writing. Some examples of network reliability performance goals are:

- 99.5% error-free seconds (see Ref 1, par 4.3.1.1)
- No down time
- Faults shall be self-healing
- Down time for each in-service circuit not to exceed 5 minutes in any
- Calendar month
- Total down time not to exceed 20 circuit-minutes in any calendar month

3.1 The Need For Synchronization

Network performance and reliability is a function of synchronization quality. Good timing in a network is essential if continuous error-free performance is desired. (The terms *timing* and *synchronization* are used interchangeably in this document.) Having good timing means maintaining at the receiving end of a communication link the exact same clock frequency as that at the transmitter. Because of the complexity of most network topologies, this means having precisely the same clock frequency at every point in the network. If clock frequencies are slightly different, data buffers (elastic stores) will overflow or underflow, resulting in frame slips, bit errors, and possible downstream misframes.

If high quality timing is maintained, troubleshooting other types of network problems is much simpler. Good timing will not rectify all network impairments, but it will greatly simplify the process of locating them. Finding a system problem is much easier when there are not two or more sets of problems to deal with simultaneously.

3.2 Frame Slips

In a DS1 transmission system, the receiving buffer temporarily stores up to two complete frames of data, each containing 193 bits. The buffer accommodates any phase misalignment of the incoming bit streams with the internal bit streams at the receiving end. This misalignment is caused by jitter and wander introduced in the transport, and by clock frequencies that are not exactly equal to each other.

If the transmitter sends at a bit rate higher than the receiving system clock, the receiver buffer will eventually overflow, causing one frame to be discarded in order to re-center the data in the buffer. If the received bit stream is at a lower bit rate, the buffer will underflow, causing a frame to be repeated. Either occurrence is called a frame slip, and results in bit errors. If the frame slip causes other downstream network elements to go through a re-sync (reframing) process, continuous bit errors can occur for up to 50 milliseconds (259 frames). This cascading effect can continually frustrate network managers, as its cause is difficult to locate.

SLIP RATES DUE TO CLOCK INSTABILITIES

Clock Stability	**Possible Slip Rate With Reference**	
	Impaired	***Normal***
Stratum 2	No slips for 5 days	Negligible
Stratum 3	255 slips first day,	One slip/day then 132 slips/hour
Stratum 4	922 slips per hour	100 slips/day

Frame slips have an effect on the quality of each type of service:

PERFORMANCE IMPACT OF ONE FRAME SLIP

Type of Service	Potential Impact
Encrypted Text	Encryption key must be resent. Possible reboot of computer system.
Digital Data	Deletion or repetition of data. Possible misframe.
Facsimile	Deletion of 4-8 scan lines. Drop call.
Video	Freeze frame for several seconds. Loud pop on audio.
Voice Band Data	Transmission errors for .01 to 2 sec. Drop call.
Voice	Possible click.

3.3 Timing Impairments That Cause Frame Slips

1. Timing reference sources of slightly unequal frequency.
2. Equipment failure resulting in an out-of-lock network element from which timing is derived.
3. Timing loops where two ends of a link each extract timing from the other, with no master timing reference. This is an unstable condition which will ultimately result in loss of synchronization.
4. Large jitter bursts caused by intermittent problems along the transport path.
5. Network rearrangements that temporarily interrupt a data stream or change its path length.
6. Diurnal temperature variations along the transport path. Wire lines are more subject to this effect than fiber.
7. SONET pointer adjustments occurring in the transmission path

The effect of most of these impairments can be minimized by the use of a station clock (called a BITS clock by the phone companies) at each key node in a network. The station clock provides timing for an entire node or office, and its "holdover" feature maintains timing integrity for the node when impairments occur on incoming timing lines. The station clock can be either a "master" clock, such as a cesium oscillator or a GPS or GPS disciplined oscillator, or it can be a "slave" clock that locks to an incoming DS1 data stream of good stability. In either case, the station clock's output is distributed to all the network elements (MUX, switch, DACS, PBX, SONET ADM, etc.) in the node that can be externally timed.

SECTION 4: SLIP PERFORMANCE OBJECTIVES

It shall be a goal for this network to be as slip-free as possible, consistent with reasonable economic constraints and keeping in mind the end-user applications of the various channels in the network. For example, voice-only circuits need not be completely slip-free, but data, facsimile, and video circuits should be slip-free.

The wander of any transmitted signal in the network shall not exceed 28 unit intervals (28 UI) over any 24-hour observation time, and shall not exceed 23 UI over any 1-hour observation period, per paragraph 5.3.1 of Reference 1. This equates to a slip rate of less than one slip per week under worst-case conditions where the daily wander is always in the same direction.

Clock wander is measured over the given observation time as maximum time interval error, or MTIE, per Figure 1 of Reference 1. Measurements shall be made relative to a PRS.

This limitation on nodal clock wander allows for several intermediate (transit) nodes between any master clock reference and the last clock in a chain if the master clock wander is negligible compared to the slave nodes that form the clock chain. It also assumes that the intermediate nodes and the end office will sometimes wander in the same direction at the same time, making the wander of the nodes cumulative (additive).

SECTION 5: SYNC NETWORK TOPOLOGY

5.1 Description

The Synchronization Network (sync network) is configured as an overlay on the existing communications network. Master clocks are located at key nodes. Timing is passed to slave nodes via traffic-bearing channels. The Engineering Rules shown in Section 6 were followed in laying out the sync network. *These Engineering Rules must also be followed when making any network changes.*

5.2 Sync Network Map

In the map shown in Figure 1, the master nodes are designated M1 through M5. These are the nodes that contain the master clocks to which the rest of the network is slaved. This means that each of the slave nodes, designated S1 through S21, must receive its timing from another node. All slave timing must originate at a master node, but may pass through other slave nodes in its path.

All of the master nodes in this network contain a Spectracom GPS Uninterruptible Timing Supply (UTS). These are the primary references at all five nodes. Nodes M1, M2, and S13 use DS1's from the local exchange carrier as backup (secondary) master references. Nodes M3, M4 and M5 receive their backup timing from M2 via other slave nodes.

In the network map, solid lines represent a primary timing reference path, and dashed lines represent backup timing paths. The arrowheads show the direction of timing flow. Keep in mind that *traffic* flows in both directions along all of the paths shown. This diagram shows only the *timing* flow. To assure a robust timing network, the following rules were applied when this network was laid out:

As many nodes as possible must receive timing from two sources: a primary and a backup source. All network elements *within* a node are timed from the same source. If the primary source fails and backup timing must be used, all elements in the node must then use backup timing.

All master nodes will use GPS as their primary timing reference. Backup timing will come from the exchange carrier if there is a direct connection available; if not, backup timing will originate at another master that uses an exchange carrier as its backup.

Backup timing must arrive via a different node than that supplying the primary timing. For this reason, end offices (e.g. S1, S3, S4, etc.) cannot receive backup timing since there is only one path to each of them. (Actually, a second T1 could carry backup timing to an end office, but it would probably be subject to the same path failures as the primary timing.)

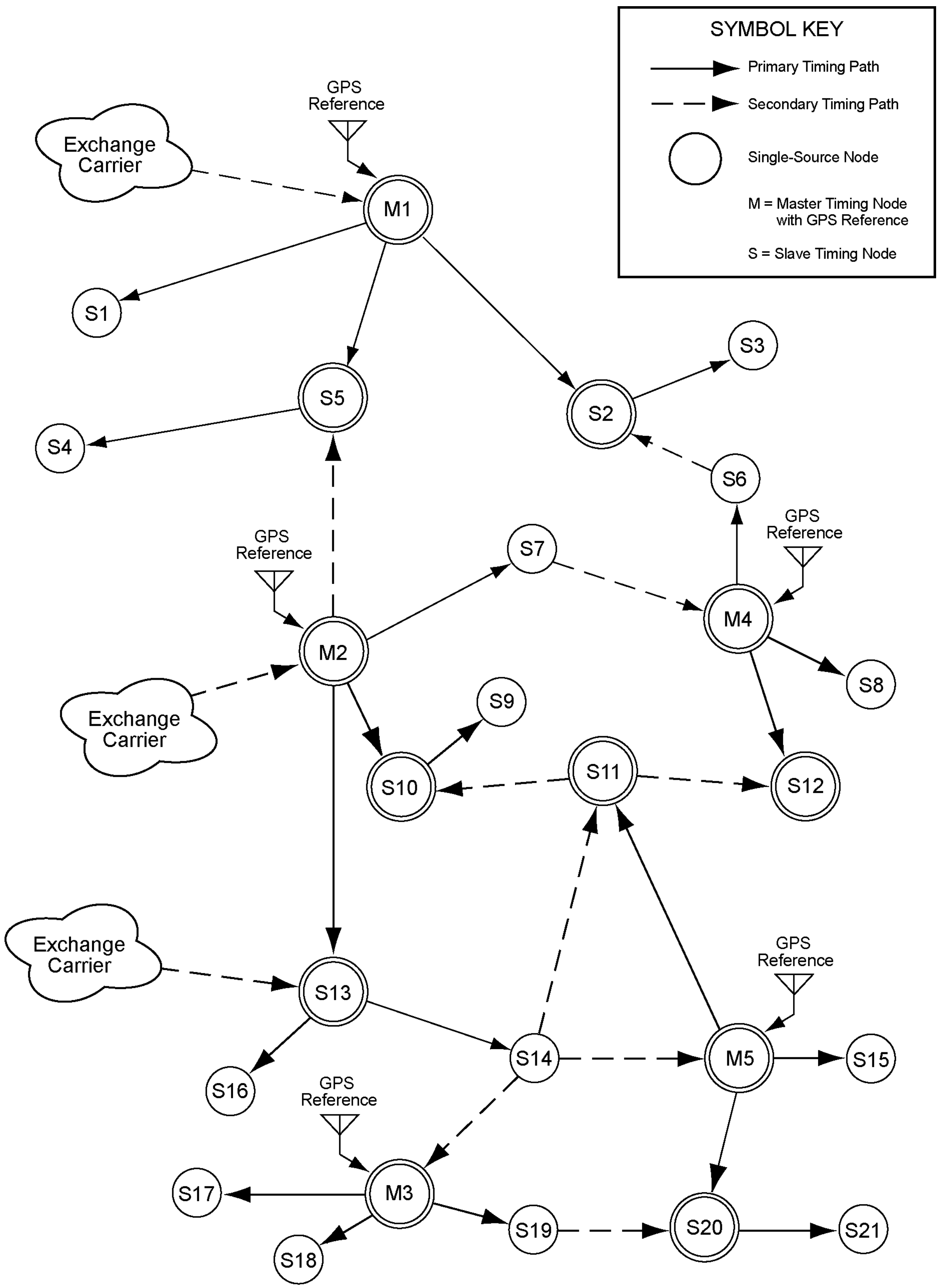
Primary timing will not pass through more than two slave nodes en route from its master to any destination node.

Backup timing will not pass through more than two slave nodes en route from its master to any destination node.

No timing loops are allowed. Further, any combination of failures or cable cuts shall not cause the formation of a timing loop as nodes switch from primary to backup timing. To meet this rule, two subsidiary rules are followed:

a. Only one arrow may connect any pair of nodes.
b. Following the direction of the arrows, no "round trips" are possible, beginning with any node and ending at that same node.

When any map changes are made, the sync coordinator should check the results by determining the effect of two or more simultaneous nodal or path failures to insure that as many as possible of the remaining nodes still receive acceptable timing.


SYMBOL KEY
Primary Timing Path
Secondary Timing Path
Single-Source Node
M = Master Timing Node with GPS Reference
S = Slave Timing Node
GPS Reference
Exchange Carrier
M1
S1
S5
S4
S2
S3
S6
GPS Reference
S7
M4
S8
GPS Reference
M2
Exchange Carrier
S9
S10
S11
S12
GPS Reference
Exchange Carrier
S13
S14
M5
S15
S16
GPS Reference
M3
S17
S18
S19
S20
S21

SECTION 6: ENGINEERING RULES FOR THE SYNCHRONIZATION NETWORK

6.1 Avoidance of Timing Loops

Timing loops must never be allowed to occur in the network. The sync network maps and documentation shall include analysis to insure that timing loops do not occur.

6.1.1 Any combination of failures or cable cuts shall not cause the formation of a timing loop as nodes switch from primary to backup timing.

6.2 Clock Transmission Paths

6.2.1 Series cascading of more than four clocks in the synchronization network must be avoided to minimize wander.

6.2.2 SONET tributaries must not be used for timing transmission paths due to the phase jumps introduced by "pointer adjustments." If SONET circuits must be used for timing transmission, the "derived" DS1 outputs from the optical line rate should be used, but only if the quality of the timing source is known to be sufficient.

6.3 Backup Clock Feeds

6.3.1 All transit nodes shall have two sources of timing wherever possible. Switching between primary to secondary (backup) clock references shall be automatic at each node.

6.3.2 Backup sources shall arrive at the node by a different route and from a different node than primary sources.

6.3.3 When it is impossible to provide backup timing at some nodes, it is frequently possible to choose which one will receive the backup from among any one of two or more nodes. These choices should be made to benefit the maximum number of nodes. That is, nodes that provide timing to the most other nodes should have priority in getting backup timing.

6.3.3 All nodes that do not receive backup timing from another node should have an internal free-running clock that can be designated as a "backup master" for the node, in the event of failure of primary timing.

6.4 Hierarchical Clock Distribution

6.4.1 At least three clocks in the network shall be Primary Reference Sources consisting of either GPS station clocks or stratum 2 or better feeds from an interexchange or local exchange carrier.

6.4.2 All clocks in the network shall be traceable to a Primary Reference Source.

6.4.3 Clock distribution through the network must adhere to the hierarchical rules associated with stratum level. That is, all slave clocks in the network shall use a reference of equal or higher stratum. (See Appendix B of Ref 1)

6.5 Station Clocks

6.5.1 All nodes shall have a designated Station Clock from which timing will be distributed to all other network elements in the node. Intra-nodal timing loops must be avoided.

6.5.1.1 If the Station Clock is internal to a unit of transmission equipment, all of the network elements in the node and all of the downstream network elements must be able to lock to it when it goes into holdover or free-run.

6.5.1.2 If the Station Clock is external to any transmission equipment, it will be Stratum 3 or better. (Stratum 2 is required if there are any downstream Stratum 2 clocks that must lock to it.)

6.5.1.3 The Station Clock shall be capable of using as its references either GPS or DS1 traffic feeds from other nodes or from other networks. If GPS is the primary reference at a node, the backup reference shall be a DS1 traffic feed from another node or another network. If DS1 traffic provides the primary reference at a node, where possible the backup reference shall be either GPS or a second DS1 feed from another node or another network.

6.5.2 All network elements that receive timing from a Station Clock should have a backup timing source that is either internal or, if received from another network element, is fed into a secondary timing input port.

6.6 Clock Stability Constraints at Network Interfaces

At all interfaces with carriers and other networks, the timing passed across the interface shall be specified and agreed to by both networks.

6.6.1 If the carrier or other network does not specify and control these interface stratum levels, then timing received from them may be used only for point-to-point circuits. Such timing shall not be propagated through the network.

6.6.2 If the carrier or other network specifies only that their timing is "stratum 1 traceable," then timing received from them shall be allowed to propagate through the network only as backup timing. This constraint is necessary to insure that any stratum 2 or stratum 3 clocks in the network do not ever need to lock to the carrier or other network clock of lower stratum level that might be in holdover or free running.

6.6.3 Any timing feed from a carrier or another network should be isolated from the network by a stratum 2 or stratum 3 clock at the point of entry if possible.

SECTION 7: RESPONSIBILITIES OF THE SYNCHRONIZATION COORDINATOR

7.1 Sync Plan

Implement and maintain this plan. Update it as the network evolves and as synchronization needs change.

7.2 Records

Keep records required for good sync administration.

7.2.1 Clock stratum levels at all nodes.

7.2.2 Clock data for each node: Brand, serial number, configuration, option settings, alarm utilization, periodic testing and calibration.

7.2.3 Sync routing diagrams & maps. Include a listing of facilities used to carry primary and secondary references.

7.2.4 Details of all timing entering the network from external networks or sources. This includes stratum level, source, transport path, and name and phone number of the person in the other network to contact if questions or problems arise.

7.2.5 Log book to record actions taken, changes in the sync network, problems occurring and how they were solved, etc.

7.3 Procedures

Rearrangement notification & coordination procedures shall be written and disseminated to all network OAM&P personnel to insure that these activities do not adversely affect network synchronization.

7.4 Training

The responsibilities of each person or organization that can impact synchronization must be communicated throughout the organization. An understanding of the importance of timing, and how timing can be adversely affected is essential to the maintenance of a reliable network.

7.5 Planning

Produce an annual sync network review report, budget, and action plan for the next year.

APPENDIX A: REFERENCES

1. EIA/TIA-594 Private Digital Network Synchronization

2. ANSI T1.101 Synchronization Interface Standard for Digital Networks

APPENDIX B: NETWORK NODE SYNCHRONIZATION RECORD

Node:____

Primary Timing Source: ____

Backup Timing Source: ____

Network Element Receiving Timing: ____

____

____

- Primary Port____
  - ❑ DS1 Framed All 1's
  - ❑ DS1 Traffic
  - ❑ 64 kb/sec RS-485
  - ❑ 1544 kb/sec RS-422
- Backup Port____
  - ❑ DS1 Framed All 1's
  - ❑ DS1 Traffic
  - ❑ 64 kb/sec RS-485
  - ❑ 1544 kb/sec RS-422