Horsebridge Network Systems Limited

Network Synchronisation Overview

What is Network Synchronisation?

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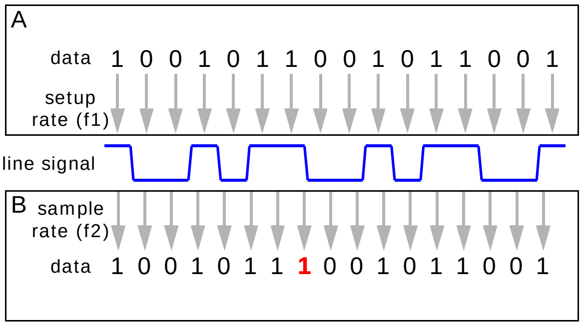
At its most basic, network synchronisation is simply the means by which all digital equipment in a communication network operates at the same average rate.

Why is Synchronisation Important?

Consider a very simple network comprising of just two elements, imaginatively named A & B.

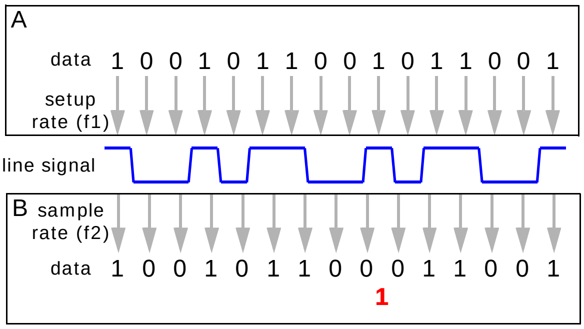
Element A clocks digital levels into the transmission line at a clock frequency of f1. However, Element B is sampling the signals on the transmission line at clock frequency f2 - which is greater than f1.

Figure 1. f1 < f2



As the sample frequency is too high erroneous bits become added to the data stream at element B. Conversely if clock frequency f1 is greater than f2...

Figure 2. f1 > f2



As the sample frequency is too low data is lost from the data stream recovered at element B.

With today's SDH and SONET structured transmission technology operating at Giga-bits per second, synchronising the insertion and recovery rates is extremely important. Synchronisation must exist at three levels; bit, time slot, and frame.

Bit Synchronisation

We have just looked at a very simplistic example of bit synchronisation, where the transmit and receive ends of a transmission line must operate at the same clock rate, so bits are not misread or lost. Bit synchronisation is achieved by the receiving element attempting to align its sampling frequency with the frequency of the incoming data. This can be compromised by short term events such as transmission line jitter and ones density. These issues are addressed by placing requirements on the alignment mechanism and the transport system.

Time Slot Synchronisation

Time slot synchronisation aligns the transmitter and receiver so that time slots within the structured transmission signal, can be identified for recovery. Time slot alignment is possible by using fixed frame formats to define their position. The main synchronisation issues at the time slot level are reframe time and framing loss detection.

Frame synchronisation

Frame synchronisation aligns the transmitter and receiver so that the beginning of a frame, within the structured transmission signal, can be identified for recovery.

What are Slips?

A slip is the name given to the recovery buffer underflow or overflow events caused by the poor synchronisation of the transmit and receive clocks of two network elements. As we have seen a slip results in corruption of the data being transmitted.

What are the effects of Slips?

The effect of a slip is dependant upon the type of data being corrupted:

Uncompressed Digitized Voice

The human ear is not usually sensitive enough to detect the loss of a few bits of digitized uncompressed voice and typically only about 5% of slips will be noticed as audible clicks.

Compressed Voice

The decompression mechanism compounds the data corruption and a slip will result in an audible click.

As the complexity of the data being transmitted increases so does the effect on the service.

Facsimile

A slip during a facsimile transmission could result in the loss of several lines of text or image.

Modem Connection

At best a slip will cause several seconds of drop out. At worst a slip will cause the connection to drop altogether.

Compressed Video

The effect of a slip on compressed video is to potentially wipe out several lines of screen. A burst of slips can cause frame freeze for several seconds.

Encrypted Data

The corruption of encrypted data due to a slip, results in the failure of the decryption routine. This in turn results in a retransmission request, amounting to a much larger volume of data than the corruption itself being re-sent - increasing decryption time and wasting network bandwidth.

Slip Rate

The rate at which slips will occur between two network elements can be easily calculated from the following equation:

Slips per day = fd x Fr x 86400

Where:

fd = Frequency difference between A and B [Hz]

Fr = Frame Rate (transmitted frames per second)

Consider a basic E1 signal with a frame rate of 8000 frames per second (frame duration of 125µS).

TABLE 1.

fd [Hz]	*Slip Rate*
0	No Slips
$1x10^{-11}$	1 slip every 4.6 months
$1x10^{-10}$	1 slip every 14.5 days
$1x10^{-9}$	1 slip every 1.45 days
$1x10^{-8}$	6.9 slips per day
$1x10^{-7}$	69 slips per day
$1x10^{-6}$	691 slips per day
$1x10^{-5}$	288 slips per hour

If you expect your customers to pay for quality communication services, the suppression of slips is key. Therefore,
network synchronisation = quality of service.

How do I get my Network Synchronised?

There are two interrelated issues to be resolved to satisfy this question; what sort of Primary Reference should I use? How should I distribute and regenerate synchronisation in my network? We will look at the first issue.

Choosing a Primary Reference

All network elements should have access to a synchronisation reference derived from a very stable frequency source, referred to as the Primary Reference, such as the OSA 6500 or OSA 5585.

The Primary Reference is the anchor for all synchronisation. The ITU have laid down a standard for Primary Reference Clocks (G.811), which states that the maximum frequency offset or error from Co-ordinated Universal Time (UTC) for a Primary Reference Clock (PRC) should be no more than $1x10^{-11}$.

Therefore the maximum frequency offset between any two PRCs can be no more than $2x10^{-11}$ and consequently the maximum slip rate between two PRC synchronised elements will be no more than one slip every 72 days for E1 based traffic.

There are a number of methods of deriving a Primary Reference:

- Central master clock.
- Fully distributed master clocks.
- Partially distributed master clocks.
- Fully distributed clock references from a co-operating network.
- Partially distributed clock references from a co-operating network.

Central Master Clock

A centralized master clock synchronisation network usually has a single PRC located at the logical center of the network. Synchronisation is distributed to each traffic element, usually through the traffic network. For SDH or SONET only the aggregate signals should be used to transport synchronisation, for pure PDH, tributary signals should be used.

Fully Distributed Master Clocks

A distributed master clock synchronisation network has a number of active pseudo-synchronous master clocks. The network structure is composed of a number of small autonomous sub-networks or islands. This approach has the benefit of simpler distribution planning and shorter distribution paths.

Although technically feasible, it would not be economically viable to deploy cesium based master clocks in such an arrangement. However, the Global Positioning System (GPS) provides a suitable synchronisation source when harnessed by the OSA 5548b or OSA 5581c.

Partially Distributed Master Clocks

A partially distributed master clock synchronisation network has a limited number of active pseudo-synchronous master clocks. The network structure is composed of a number of autonomous sub-networks or islands. This approach has an economic benefit over fully distributed master clocks but requires more complex distribution planning and longer distribution paths.

Fully Distributed Clock References from Co-operating Network

If a co-operating, adjacent network has master clock synchronisation, which is easily accessible at multiple points, then it is possible to use these references to synchronise the entire network. The synchronisation network structure is composed of a number of small autonomous sub-networks or islands. In this case as both networks are slaved to the same master clock then theoretically the slip rate at the network boundaries should be zero.

In practice there are a number of issues associated with this strategy; can the quality and availability of synchronisation be guaranteed? Is there a cost implication of utilizing synchronisation as a service?

Partially Distributed Clock References from Co-operating Network

If a co-operating, adjacent network has master clock synchronisation, which is accessible at limited points, then it is possible to use these references to synchronise the entire network.

The synchronisation network structure is composed of a number of large autonomous sub-networks or islands. This approach has the same issues as that of a fully distributed clock references from

co-operating network with he addition of more complex distribution planning and longer distribution paths.

The decision as to which method to choose is usually based upon a number of factors including; network size or potential, political and commercial considerations. The form of Primary Reference also dictates how synchronisation will be distributed throughout the network.

How should I Distribute Synchronisation?

Now that we have a master clock solution, distribution of synchronisation must be addressed. There are a number of issues which must be considered in planning our synchronisation distribution.

Wander

Wander is a phase variation of synchronisation and traffic signals from their ideal position, where the variation is greater than 10Hz in frequency.

Diurnal Wander is a phase variation caused by the heating and cooling effects of a transmission medium throughout the course of a day. A transmission line, be it; optical fiber, copper pair, coaxial cable or microwave (air) is composed of a physical medium. The propagation speed and slight differences in length due to heating and cooling cause the phase of the emerging signal to move.

The wander generated by optical fiber is approximately: 80pS/Km/°C

The wander generated by copper cable is approximately: 725pS/Km/°C

High amplitude wander is also generated by SDH or SONET tributaries as a result of pointer activity.

Wander is impossible to filter out in a synchronisation network so it must be minimized by network planning, for example; the avoidance of very long over-ground cables, subject to wide temperature variations, and SDH or SONET tributaries for synchronisation transport.

Jitter

Jitter is a phase variation of synchronisation and traffic signals from their ideal position, where the variation is less than 10Hz in frequency.

In order to derive a synchronisation signal suitable for clocking out going tributaries a network element must convert the gapped clock presented on its line interface to a regular clock. The gaps in the gapped clock will have been produced dynamically and therefore cannot be predetermined by the desynchroniser and a phase locked loop (PLL) is required to smooth out the clock gaps. Unfortunately this process is not perfect and a certain amount of phase variation is introduced to the clock known as justification jitter.

Wander and Jitter are two important issues to be resolved when distributing synchronisation. Wander cannot be filtered and should be minimized by design. Jitter accumulates as synchronisation is recovered and rebuilt at each network element but this can be filtered using a narrow band synchronisation filter elements commonly called; Stand Alone Synchronisation Elements (SASE), Source Synchronisation Units (SSU) or Building Integrated Timing Systems (BITS), three names for the same device.

SASEs, SSUs and BITS

SASEs actually provide three main functions:

- Under normal conditions they provide a jitter filtering capability.
- Under fault conditions they are able to automatically select alternative synchronisation sources.
- Under severe fault conditions, where all input references are lost, the SASE is able to enter Holdover mode and use its own stable on-board oscillators to provide synchronisation within specification for a short time, normally days.

Horsebridge provide two SASEs in the form of the OSA 5548b and the OSA 5581c. The ITU have compiled several standards with regard to the performance and distribution of SASEs.

ITU-T G.803 defines how SASEs should be distributed in order to fulfill their role as jitter filters. A SASE must regenerate synchronisation derived from a primary reference after a maximum chain of twenty traffic elements. No more than ten SASEs should filter synchronisation in a single synchronisation chain and no chain should be more than sixty traffic elements in length.

Network Synchronisation Planning

The correct planning and implementation of network synchronisation is crucial. Not only should your network be planned and implemented to provide synchronisation to all network elements within specification under normal conditions but should also be resilient to common failures.

Each network element; traffic or SASE, is capable of deriving synchronisation from a number of sources. The selection of sources must be dynamic and virtually instantaneous if synchronisation is to be maintained, therefore alternative selection must be pre-planned and implied by the prioritization of sources. Planning the steady-state and fault recovery actions of the synchronisation network can be incredibly tedious and time consuming given the complexity of the network and the number of possible automatic actions, unless you are using an effective planning and simulation tool such as Sync Architect.

Conclusion

The effective provisioning and distribution of network synchronisation is vitally important to the quality of services you provide over your network.

Horsebridge provide a complete range of synchronisation equipment all backed by a host of services ranging from network design through installation, commissioning life-cycle support and role based training.

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