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Synchronization OAM requirements

ITU-T G-series Recommendations – Supplement 68

ITU-T

ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

INTERNATIONAL TELEPHONE CONNECTIONS AND CIRCUITS	G.100–G.199
GENERAL CHARACTERISTICS COMMON TO ALL ANALOGUE CARRIER-TRANSMISSION SYSTEMS	G.200–G.299
INDIVIDUAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON METALLIC LINES	G.300–G.399
GENERAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON RADIO-RELAY OR SATELLITE LINKS AND INTERCONNECTION WITH METALLIC LINES	G.400–G.449
COORDINATION OF RADIOTELEPHONY AND LINE TELEPHONY	G.450–G.499
TRANSMISSION MEDIA AND OPTICAL SYSTEMS CHARACTERISTICS	G.600–G.699
DIGITAL TERMINAL EQUIPMENTS	G.700–G.799
DIGITAL NETWORKS	G.800–G.899
DIGITAL SECTIONS AND DIGITAL LINE SYSTEM	G.900–G.999
MULTIMEDIA QUALITY OF SERVICE AND PERFORMANCE – GENERIC AND USER-RELATED ASPECTS	G.1000–G.1999
TRANSMISSION MEDIA CHARACTERISTICS	G.6000–G.6999
DATA OVER TRANSPORT – GENERIC ASPECTS	G.7000–G.7999
PACKET OVER TRANSPORT ASPECTS	G.8000–G.8999
ACCESS NETWORKS	G.9000–G.9999

For further details, please refer to the list of ITU-T Recommendations.

Supplement 68 to ITU-T G-series Recommendations

Synchronization OAM requirements

Summary

Supplement 68 to ITU-T G-series Recommendations provides an overview of synchronization operations, administration and maintenance (OAM) and includes fault management, performance monitoring, alarms and events.

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Table of Contents

Supplement 68 to ITU-T G-series Recommendations

Synchronization OAM requirements

1 Scope

This Supplement provides an overview of synchronization operations, administration and maintenance (OAM) and includes fault management, performance monitoring, alarms and events. It describes synchronization OAM performance monitoring methods and measurements.

This Supplement describes synchronization OAM by considering the following areas separately:

- Frequency synchronization over the physical layer – Ethernet or optical transport network (OTN).
- Frequency synchronization via packets – precision time protocol (PTP).
- Time synchronization – precision time protocol (PTP) or one pulse per second (1PPS).

2 References

[ITU-T G.709] Recommendation ITU-T G.709 (2020), *Interfaces for the optical transport network*.

[ITU-T G.781] Recommendation ITU-T G.781 (2020), *Synchronization layer functions for frequency synchronization based on the physical layer*.

[ITU-T G.810] Recommendation ITU-T G.810 (1996), *Definitions and terminology for synchronization networks*.

[ITU-T G.8260] Recommendation ITU-T G.8260 (2020), *Definitions and terminology for synchronization in packet networks*.

[ITU-T G.8262] Recommendation ITU-T G.8262/Y.1362 (2018), *Timing characteristics of a synchronous equipment slave clock*.

[ITU-T G.8264] Recommendation ITU-T G.8264/Y.1364 (2017), *Distribution of timing information through packet networks*.

[ITU-T G.8271] Recommendation ITU-T G.8271/Y.1366 (2020), *Time and phase synchronization aspects of telecommunication networks*.

[ITU-T G.8275.1] Recommendation ITU-T G.8275.1/Y.1369.1 (2020), *Precision time protocol telecom profile for phase/time synchronization with full timing support from the network*.

[ITU-T G.8275.2] Recommendation ITU-T G.8275.2/Y.1369.2 (2020), *Precision time protocol telecom profile for time/phase synchronization with partial timing support from the network*.

[ITU-T GSTR-GNSS] ITU-T Technical Report, *Consideration on the Use of GNSS as a Primary Time Reference in Telecommunications*.

[IEEE 1588-2008] IEEE Standard 1588-2008, *IEEE standard for a precision clock synchronization protocol for networked measurement and control systems*.

[IEEE 1588-2019] IEEE Standard 1588-2019, *IEEE standard for a precision clock synchronization protocol for networked measurement and control systems*.

3 Definitions

3.1 Terms defined elsewhere

This Supplement uses the following terms defined elsewhere:

Definitions related to synchronization are contained in [ITU-T G.810], [ITU-T G.8260] and [ITU-T G.781].

3.2 Terms defined in this Supplement

None.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

AIS Alarm Indication Signal

BC Boundary Clock

ESMC Ethernet Synchronization Messaging Channel

GE Gigabit Ethernet

GFP-F Frame mapped Generic Framing Procedure

GM Grandmaster

GNSS Global Navigation Satellite System

GPS Global Positioning System

OAM Operations, Administration and Maintenance

OC Ordinary Clock

OSC Optical Supervisory Channel

OTN Optical Transport Network

OTUk Optical Transmission Unit of level k

PDU Protocol Data Unit

PLL Phase-Locked Loop

1PPS One Pulse Per Second

PRC Primary Reference Clock

PTP Precision Time Protocol

SSM Synchronization Status Message

TC Transparent Clock

ToD Time of Day

5 Conventions

None.

6 Synchronization OAM functional diagram

There are two layers of a synchronization network: the basic frequency synchronization network and the time synchronization network based on it. From the perspective of management and maintenance, each of the two layers of the synchronization network has its own features, and each has its own operations, administration and maintenance (OAM) function requirements. Therefore, frequency synchronization OAM and time synchronization OAM are operated separately. However, since time synchronization is based on frequency synchronization, the performance of frequency synchronization may affect the performance of time synchronization, the interactive mechanism between frequency synchronization OAM and time synchronization OAM is taken into consideration. Figure 1 shows a synchronization OAM functional diagram.

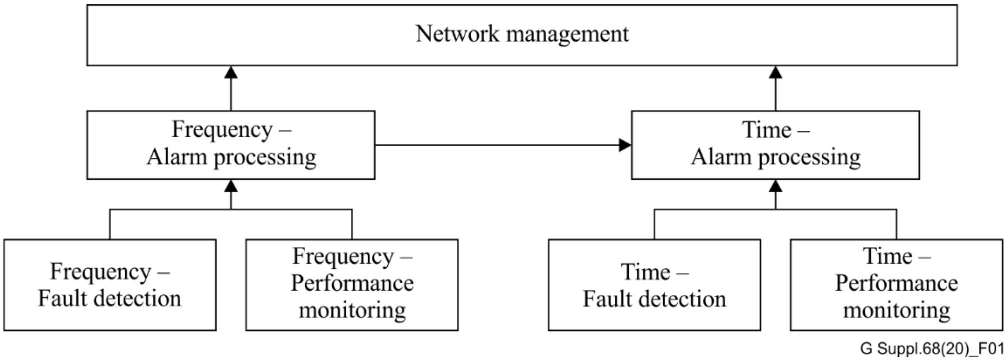

Figure 1 – Synchronization OAM functional diagram

6.1 Frequency synchronization OAM

Frequency synchronization OAM functions should include:

– Fault detection

- Input-output faults of the external clock, including: loss of external clock signal (e.g., GPS, 2 MHz, 2 Mbits), external clock alarm indication and/or suppression (AIS), loss of frame (LOF), etc. The faults should be detected and reported to the network management through the alarm processing module.
- Input-output faults of the line clock, including: loss of line clock signal such as gigabit Ethernet (GE), precision time protocol (PTP), etc., frequency signal faults of the line clock, etc. The faults should be detected and reported to the network management through the alarm processing module.
- Port failures, including: failure of the external clock port, failure of the line clock port. The clock device should support its detection and report to the network management through the alarm processing module.

– Performance monitoring

- Hardware performance, including: Crystal aging and temperature beyond the limit, Clock oscillator frequency drift, etc. The hardware performance of device should be monitored and reporting to the network management through the alarm processing module.
- Network performance, including: frequency offset, frequency source quality, etc. The network performance data is monitored and reported constantly. If a performance data is out-of-limit, a corresponding alarm is reported to the network management through the alarm processing module.

– Alarm processing

- It is used to convert the received alarms and performance data from the fault detection module and the performance monitoring module into a uniform format, and report the alarm information to the upper processing layer (i.e., Network management).
- It also needs to process the frequency sync OAM and time sync OAM interactive mechanisms, which is for further study.

6.2 Time synchronization OAM

Time synchronization OAM functions should include:

– Fault detection
  - Global navigation satellite system (GNSS), including: loss of signal, signal unavailable, loss of start, etc. The corresponding alarms should be reported to the network management through the alarm processing module.
  - PTP message, including: loss of Announce message, loss of Sync or Delay_Resp message, etc. The corresponding alarms should be reported to the network management through the alarm processing module.
  - 1PPS+ToD, including: loss of 1PPS signal or time of day (ToD) information, etc. The corresponding alarms should be reported to the network management through the alarm processing module.

– Performance monitoring
  - Hardware performance, including: Crystal aging and temperature beyond the limit, etc. The hardware performance of device should be monitored and reporting to the network management through the alarm processing module.
  - Network performance, including: time offset, PTP delay monitoring, etc. The network performance data is monitored and reported constantly. If a performance data is out-of-limit, a corresponding alarm is reported to the network management through the alarm processing module.

– Alarm processing
  - It is used to convert the received alarms and performance data from the fault detection module and the performance monitoring module into a uniform format, and report the alarm information to the upper processing layer (i.e., network management).
  - It also needs to process the frequency sync OAM and time sync OAM interactive mechanisms, which is for further study.

6.3 Frequency sync OAM and time sync OAM interactive mechanism

The frequency layer and the time layer adopt different technologies, and they are mutually independent. However because frequency synchronization is the foundation of time synchronization, the synchronous fault or degradation of frequency layer will affect the performance of time synchronization. Therefore, the fault detection and performance monitoring outcomes of the frequency layer is able to transmit to the time layer and activate the corresponding time layer alarm process.

The interactive mechanism is for further study.

7 Frequency synchronization over the physical layer

The functions are common to synchronous OTN ("SyncO") and synchronous Ethernet ("SyncE") technologies.

7.1 Fault management

7.1.1 Frequency reference source loss

If the selected frequency reference source is lost, an alarm of the frequency reference source loss is reported.

Refer to [ITU-T G.781] clause 6.3.1, function of Loss of timing inputs (dLTI).

7.1.2 Clock unlock

If the status of the system clock is "unlocked", an alarm of Clock unlock is reported. The alarm is cleared if the status of the system clock is "locked".

Refer to [ITU-T G.781] clause 6.3.1, function of Clock unlock.

7.1.3 Clock hardware failure

When there is a non-recoverable hardware failure of the local clock, for example when the local clock does not oscillate, an alarm of Clock hardware failure is reported.

NOTE – Reporting of this failure requires at least two additional clock sources to compare and to be cross examined so that the fault source can be isolated. It can be achievable within a multi-card chassis system. Details are given in Appendix I.

7.1.4 Frequency reference source SSM quality level degradation

A quality level threshold of the frequency reference source is preset.

If the synchronization status message (SSM) quality level of the selected frequency reference source is worse than the preset threshold, an alarm of the degradation is reported.

Refer to [ITU-T G.781] clause 7.1, function of SSM level degradation defect.

7.1.5 SSM message loss measurement

If no valid Ethernet synchronization messaging channel (ESMC) protocol data unit (PDU) is received during 5 seconds (refer to [ITU-T G.8264] and [ITU-T G.781]), an alarm of the ESMC message loss is reported. When the first ESMC PDU is received, the alarm is cleared.

Refer to [ITU-T G.781] clause 8.9.2, function of dLOESMC.

For OTUk interface, if no valid GFP-F(SSM) is received for 5 seconds (refer to [ITU-T G.709]), an alarm of the SSM loss is reported. When the first GFP-F(SSM) is received, the alarm is cleared.

Refer to [ITU-T G.781] clause 8.10.2, function of dLOSSM.

For OSC interface, if no valid SSM is received during vendor-specific period, an alarm of the SSM loss is reported. When the first SSM message is received, the alarm is cleared.

Refer to [ITU-T G.781] clause 8.11.2, function of dLOSSM.

7.2 Performance monitoring

7.2.1 Frequency offset monitoring of selected reference source

Frequency offset (in 15 minutes intervals) between the selected reference source and the local oscillator (prefer) or the system clock is monitored.

If the frequency offset over a preset threshold (e.g., ±4.6 ppm, refer to [ITU-T G.8262]), an alarm of the frequency offset over the limit is reported.

7.2.2 Frequency offset monitoring of reference sources in the priority list

Frequency offsets (in 15 minutes intervals) between the reference sources in the priority list and the local oscillator are monitored.

If the frequency offset over a preset threshold (e.g., ±4.6 ppm, refer to [ITU-T G.8262]), an alarm of the frequency offset over the threshold is reported.

For an equipment that is capable of monitoring the frequency offset of multiple input reference sources, if only one frequency offset associated one reference source exceeds the preset threshold, this event indicates that the fault maybe related to this reference source; if all of frequency offsets exceed the threshold, this event indicates that the fault maybe related to the local oscillator.

For an equipment that is capable of monitoring the frequency offset of multiple input reference sources, a relative frequency offset of one reference source relative to another reference source can be obtained via the difference of frequency offsets of the reference sources and the local oscillator. If the relative frequency offsets of one reference source relative to all other reference sources exceed a preset threshold, and the relative frequency offsets of any two other reference sources are less than the preset threshold, this event indicates that the fault maybe related to this reference.

The assumption in this case is that the multiple references are all traceable to a primary reference clock (PRC) source.

7.2.3 Clock pull-in, hold-in range notice

Reported when the local clock is close to its frequency adjustment limit and may soon not be able to meet pull-in or hold-in range specification.

NOTE – Reporting of this failure typically requires at least one additional clock source, such as SyncE or GNSS input, to compare against.

7.2.4 Clock power-cycle notice

Reported after a power-cycle of the equipment if the local clock may not meet some of the applicable clock specifications for some short period of time (and cleared thereafter).

7.3 Alarms and events

Table 1 lists frequency Sync alarms and events.

Table 1 – Frequency Sync alarms and events

Classification	Alarm level	Alarm description
Alarm	Critical alarm	Frequency reference source loss
		Clock unlock
		Clock hardware failure
	Major alarms	SSM message loss
		Frequency offset of current reference source is over the limit
		SSM quality level degradation of current frequency reference source
		Clock pull-in or hold-in notice
		Clock power-cycle notice
	Minor alarms	Frequency offset of reference source listed in priority list is over the limit
		Clock oscillator frequency drift notice
Event	Event	Frequency reference source switch
		Frequency synchronization status switch

8 Frequency synchronization via packets

The functions are specific for packet timing technologies – precision time protocol (PTP).

8.1 Fault management

8.1.1 Frequency reference source loss

If the selected frequency reference source is lost, an alarm of the frequency reference source loss is reported.

8.1.2 Frequency reference source clockClass quality level degradation

A quality level threshold of the frequency reference source is preset.

If the clockClass of the selected frequency reference source is worse than the preset threshold, an alarm of the degradation is reported.

8.1.3 Announce message loss measurement

If no Announce message is received in a period of time, then an alarm of Announce message loss is reported.

The period of time is related to the "portDS.announceReceiptTimeout" defined in [IEEE 1588-2008] and [IEEE 1588-2019]. The default initialization value and the configurable range is provided in the applicable profiles e.g., [ITU-T G.8275.1].

8.1.4 Sync message loss measurement

If slave port does not receive a Sync message sent by a master in a preset period of time, an alarm of Sync message loss is reported.

The range and default value of this timeout parameter are for further study.

8.1.5 PTP packet timing signal unusable

If the PTP packet timing signal is not usable for the slave to achieve the performance target, an alarm of PTP packet timing signal unusable is reported.

The criteria used to determine PTP packet timing signal unusable is for further study.

8.2 Performance monitoring

8.2.1 Frequency offset monitoring of current reference source

Frequency offset (in 15 minutes intervals) between the selected reference source and the local crystal oscillator (prefer) or system clock is monitored.

If the frequency offset over a preset threshold (e.g., ±4.6 ppm, refer to [ITU-T G.8262]), an alarm of the frequency offset over the limit is reported.

See also the performance monitoring parameters provided by Annex M of [IEEE 1588-2019].

8.2.2 Frequency offset monitoring of reference sources in the priority list

Frequency offset (in 15 minutes intervals) between reference sources in the priority list and local oscillator is monitored.

If the frequency offset over a preset threshold, an alarm of the frequency offset over the threshold is reported.

See also the performance monitoring parameters provided by Annex M of [IEEE 1588-2019].

8.2.3 Frequency offset monitoring by satellite CV

By using satellite common view (Satellite CV), frequency offset performance between the selected reference node and the selected monitored node is monitored. The reference node and the monitored node can be any node in the synchronization network with satellite receiver.

If the frequency offset over a preset threshold, an alarm of the frequency offset over the limit is reported.

The technical details of the satellite CV are referred to [ITU-T GSTR-GNSS].

8.3 Alarms and events

Table 2 lists frequency Sync (via packet) alarms and events.

Table 2 – Frequency Sync (via packet) alarms and events

Classification	Alarm level	Alarm description
Alarm	Critical alarm	Frequency reference source loss
		Clock unlock
	Major alarms	Announce message loss
		Sync message loss
		PTP packet timing signal unusable
		Frequency offset of current reference source is over the limit
		clockClass degradation of current frequency reference source
	Minor alarms	Frequency offset of reference source listed in priority list is over the limit
		Frequency offset by PTP detection is over the limit
Event	Event	Frequency reference source switch (Note)
		Frequency synchronization status switch
NOTE – "Frequency reference source switch" event can also be caused by a failure of the slave port.		

9 Time synchronization

The functions are common to different transport technologies including packet and OTN technologies.

9.1 Fault management

9.1.1 Announce message loss measurement

If no Announce message is received in a period of time, then an alarm of Announce message loss is reported.

The period of time is related to the "portDS.announceReceiptTimeout" defined in [IEEE 1588-2008] and [IEEE 1588-2019]. The default initialization value and the configurable range is provided in the applicable profiles e.g., [ITU-T G.8275.1].

9.1.2 Sync or Delay_Resp message loss

If Sync or Delay_Resp message is not received in a preset period of time, then an alarm of Sync or Delay_Resp message loss is reported.

9.1.3 PTP degradation

A quality level threshold for PTP reference source is preset.

If the clockClass of the selected PTP reference source is worse than the threshold, and the stepsRemoved of the selected PTP reference source is 0, then an alarm of PTP input degradation is reported.

9.1.4 1PPS+ToD input loss

When the time reference source is selected from 1PPS+ToD, if 1PPS signal or ToD information is lost, an alarm of 1PPS+TOD input loss is reported.

9.1.5 1PPS+ToD degradation

When the time reference source is selected from 1PPS+ToD, if the clockClass of the selected 1PPS+ToD input signal is worse than the quality level threshold (i.e., 0x00), an alarm of the degradation is reported.

The alarm is cleared if the clockClass of the selected 1PPS+ToD is equal or better than the threshold.

9.1.6 Time unlock

The state of phase-locked loop (PLL) is monitored.

When the PLL does not work properly (i.e., the system time is not locked to the time reference source), a Time unlock alarm is reported.

9.2 Performance monitoring

9.2.1 PTP time offset monitoring

PTP time offset monitoring monitors the current time offset (e.g., "offsetFromMaster" defined in [IEEE 1588-2018] and [IEEE 1588-2019]).

The reported PTP time offset data include: maximum value, minimum value and average value (default report interval is 15 minutes), which can be illustrated in a form of performance curve.

For real-time monitoring, the report period should be no longer than 5 seconds.

Performance monitoring parameters are provided by Annex M of [IEEE 1588-2019].

9.2.2 PTP delay monitoring

PTP delay is monitored. The reported data include: PTP timestamp T2-T1 one-way delay information, PTP timestamp T4-T3 one-way delay information and Mean-path-delay information, including maximum value, minimum value and average value (default report interval is 15 minutes), which can be illustrated in a form of performance curve.

Performance monitoring parameters are provided by Annex M of [IEEE 1588-2019].

9.2.3 PTP time offset accumulation monitoring

PTP time offset accumulation monitoring monitors the time offset by doing accumulation in a report interval.

The reported data include: peak-to-peak value, average value and the last accumulation value (default report interval is 15 minutes), which can be illustrated in a form of performance curve.

If the peak-to-peak value over a preset limit, then an alarm of time offset accumulation over the limit is reported.

The limit is determined by system parameters including the network architecture (e.g., the number of hops).

See also the performance monitoring parameters provided by Annex M of [IEEE 1588-2019].

For understanding the concept of this function, an example is given below based on the full timing support scenario where the offsetFromMaster can be used for this purpose.

In a report interval, there are N offset values, $1 \le n \le N$, offsetFromMaster(n) is the n^{th} offset value. Time offset accumulative sum is the sum from the initial offset value to the current offset value within the report interval,

$$SUM(n) = \sum_{i=1}^{n} offsetFromMaster(n)$$

SUM_{max} is the maximum value of the accumulative sum values, SUM_{max} = max(SUM(n));

SUM_{min} is the minimum value of the accumulative sum values, SUM_{min} = min(SUM(n));

SUM_{p2p} is the peak-to-peak value (the maximum fluctuation value) of the accumulative sum values, $SUM_{p2p} = SUM_{max} - SUM_{min}$;

SUM_{avr} is the average value of the accumulative sum values, $\text{SUMavr} = \sum_{i=1}^{N} SUM(n)/N$;

SUM_{end} is the last accumulative sum value, SUM_{end} = SUM(N).

Table 3 shows an example of PTP time offset accumulation monitoring. In this example, in a report interval of 15 minutes, there are 5 offset values (i.e., N = 5), and each offset value is:

Table 3 – Example of PTP time offset accumulation monitoring

n	1	2	3	4	5
offset(n)	−10 ns	0 ns	10 ns	10 ns	20 ns
SUM(n)	−10 ns	−10 ns	0 ns	10 ns	30 ns

Then the reported data in the PTP time offset accumulation monitoring function are:

$SUM_{p2p} = SUM_{max} - SUM_{min}$ = 30ns − (−10 ns) = 40 ns;

$SUM_{avr} = \sum_{i=1}^{N} SUM(n)/N$ = 20 ns/5 = 4 ns;

SUM_{end} = SUM(5) = 30 ns.

9.2.4 Time error measurement by reference comparison

If device can obtain global positioning system (GPS) time directly or obtain absolute time reference source from 1PPS+ToD directly, then the time difference between external reference time and PTP time can be provided, including maximum value, minimum value and average value (default report interval is 15 mins).

If the time difference over a preset limit, then an alarm of measured time error by reference comparison over the limit is reported.

9.2.5 Time error measurement based on passive port (e.g., in ring topology)

For a PTP clock, if a SLAVE port and a PASSIVE port are present simultaneously, the PTP clock can get the time error of the SLAVE port and the PASSIVE port, and compare the time difference.

If the time difference exceeds a preset limit, an alarm of measured time error based on PASSIVE port is reported.

The details are provided in Annex G of [ITU-T G.8275.1] and Appendix III of [ITU-T G.8275.2].

9.2.6 Time error monitoring by Satellite CV

By using satellite common view (Satellite CV), time error performance between the selected reference node and the selected monitored node is monitored. The reference node and the monitored node can be any node in the synchronization network with satellite receiver.

The reported time offset data, including maximum value, minimum value, peak-to-peak value, average value, etc., which can be illustrated in a form of performance curve.

If the monitored time error performance value over a preset limit, a corresponding alarm is reported.

The technical details of the satellite CV is referred to in [ITU-T GSTR-GNSS].

9.2.7 Asymmetric measurement by line-swapping

Automatically generate the compensation data for time delay asymmetric between uplink and downlink based on uplink delay, downlink delay and time difference.

In normal circumstances, the timestamp is interactive transmitted between PTP master-slave equipment through PTP message. Then, the uplink fibre and downlink fibre are swapped manually or automatically through the master-slave equipment port. After the line-swapping, the timestamp is interactive transmitted through PTP message. The equipment calculates the uplink delay, the downlink delay and the time difference, and then automatically generates the compensation for the time delay asymmetric between uplink and downlink, and records the data in the equipment.

This procedure can be used (assuming the PTP protocol is used) only between two BCs, two OCs, or a BC and an OC, with no TCs or non PTP devices in between.

For further details see Appendix IV of [ITU-T G.8271].

9.3 Alarms and events

Table 4 lists time Sync alarms and events.

Table 4 – Time Sync alarms and events

Classification	Alarm level	Alarm description
Alarm	Critical alarm	1PPS+TOD input loss
		PTP physical link failure
		Time unlock
	Major alarms	TOD input degradation
		PTP input degradation
		Announce message loss
		Sync or Delay_Resp message loss
	Minor alarms	Time offset accumulation is over the limit
		Measured time error by reference comparison is over the limit
		Measured time error based on passive port is over the limit
		Measured time error based on PTP message is over the limit
Event	Event	Slave port switch
		GM clock switch
		Time synchronization status switch

Appendix I

Oscillator and frequency monitoring within a multi-card chassis system

A multi-card chassis system typically consists of two control-timing cards and several line cards. The two control-timing cards are for redundancy purpose. Figure I.1 shows an example of the clock flow between the primary control-timing card and line cards.

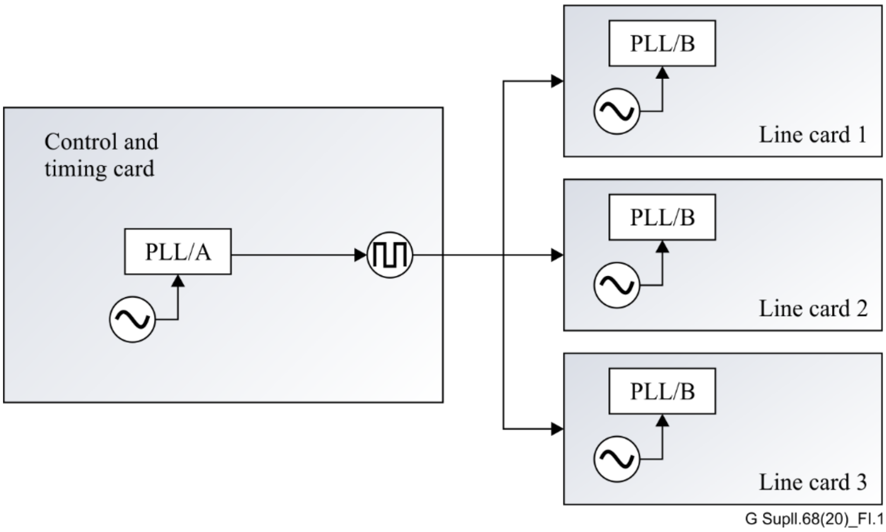

Figure I.1 – Clock flow and detection within chassis system

In this example, when the system only has one line card (such as line card 1), if line card 1 detects that there is a PLL loss of lock or out of frequency alarm, then the failure point could not be isolated because it could be a result of a timing component failure either on the timing card or on the line card 1.

With the addition of line card 2 and line card 3, the point of fault can be isolated by analysing the reporting failure from each line card.

- If only one single line card detects the failure, then this event indicates that the fault maybe related to this line card.
- If all line cards detect the failure, then this event indicates that the fault maybe related to the control timing card.

NOTE – For the out of frequency failure detection, if the oscillator in the line card has less accuracy compared to the one in the timing card, then the out of frequency failure will not be detected if the drift of the clock in the timing card is less than the pull-in range of the PLL in the line card.

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