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Reference Clocks in 5G and Time Sensitive Applications

OCP GLOBAL SUMMIT

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Reference Clocks in 5G and Time Sensitive Applications

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Topics

TELCO

- The need for Synchronisation Data Centres
- Context of ORAN based 5G, TSN and other applications
- Synchronisation Architectures
- System and synchronization requirements
- Reference Clocking options

Need for Synchronisation in Data Centres

Traditional data centres are more on data processing, limited on time critical requirements.

New applications (Financial, industrial, automotive and 5G) are driving the finer granularity of time alignment in data centres.

- Timing regulations under MiFID II and Consolidated Audit Trail (CAT) demand high accuracy and proof of compliance.
- Time Sensitive Networks requires low latency and high accuracy
- High degree of time alignment is required for the efficient operation of 5G networks and network performance

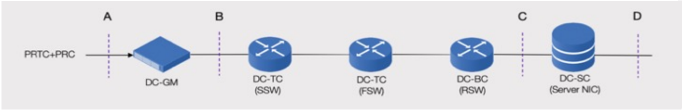
Mobile Edge Computing architecture fits well with combining data centre and 5G equipment functions

Initiatives for Synchronisation

OCP – TAP community is defining the Data Center profile for IEEE – 1588

HRM by OCP-TAP

5uS end to end



Reference Point	Limit
A	max|TE| ≤ 100 ns
B	max|TE| ≤ 250 ns
C	max|TE| ≤ 1000 ns
D	max|TE| ≤ 5000 ns

TSN applications – Industry 4.0, Automotive

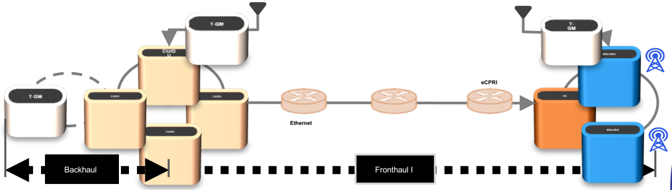
IEEE802.1-AS – 2020

1uS end to end

5G CU/DU functionality to move to data centers

3G PP requirements

130ns end to end



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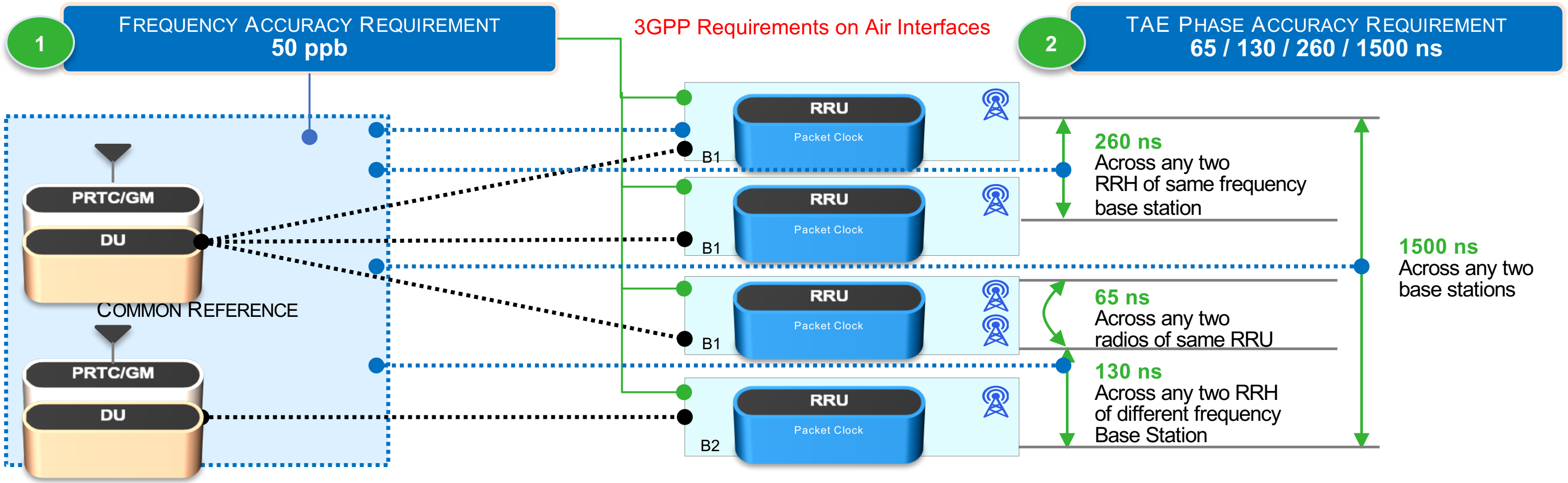
5G – The killer application on Data Centres



IEEE801.CM requirements on Front-Haul

Cat.	Applications Details	TAE proposed by IEEE801.CM		TAE (for Application)
		Case 1	Case 2	
A+	MIMO or TX diversity transmissions, at each carrier frequency	-	20ns	65ns
A	Intra-band contiguous carrier aggregation, with or without MIMO or TX diversity	60ns	70ns	130ns
B	A & Inter-band carrier aggregation, with or without MIMO or TX diversity	100ns	200ns	260ns
C	3GPP LTE TDD	1100ns	1100ns	1500ns

ITU – T requirements on Transport Networks

Parameter	T-BC - A	T-BC - B	T-BC - C	T-BC - D
Max Absolute Time Error	100	70	30	FFS
Max Absolute Time Error (Low pass filtered)				5
Constant Time Error	50	20	10	FFS
Dynamic Time Error MTIE	40	40	10	FFS
Dynamic Time Error MTIE with Temp	40	40	10	5
Dynamic Time Error TDEV	4	4	2	FFS

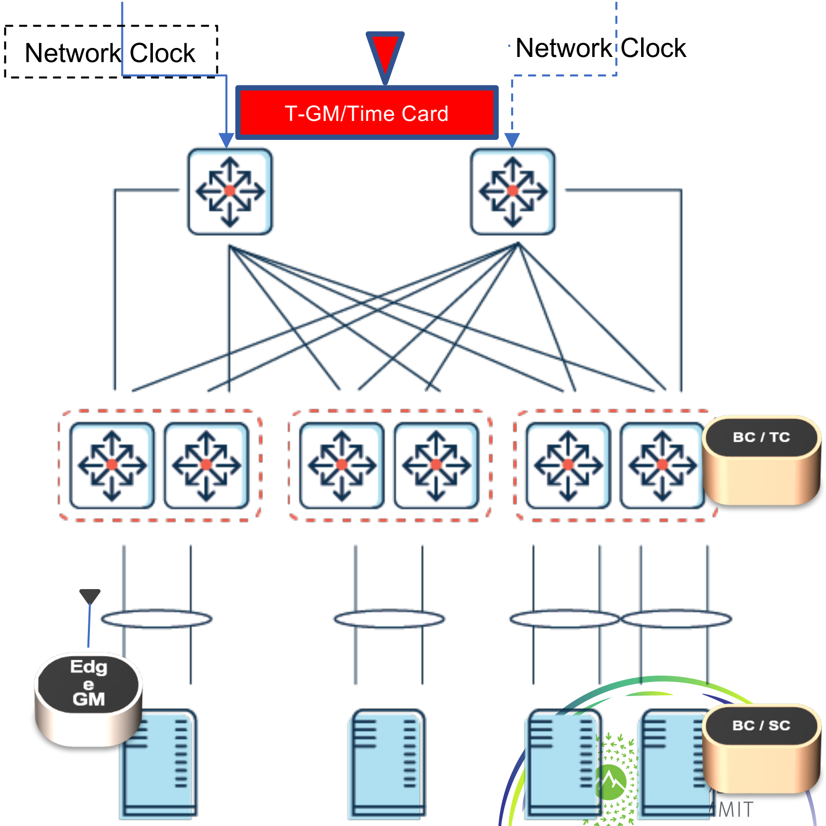
Synchronisation architecture for data centres

The potential application is ORAN with DU-Servers, Network Switches and DC Time Master cards

Time - Grand Master systems will be providing the source timing.

The Network switches - Front-haul switching /routing devices, T-BC C or D category and G.8273.4 like standards

The DU servers will have either on-board or NIC based synchronisation essentially providing a “partial timing support“ as defined by ITU-T standard G.8273.4



Synchronisation Requirements – Dynamic

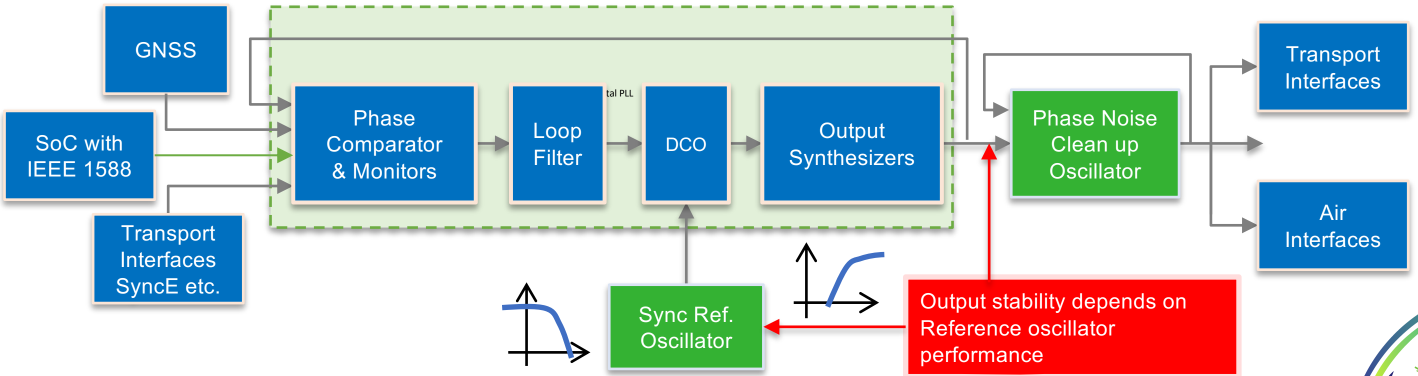
Dynamic performance requirement

- “Wander Generation” – Intrinsic low frequency noise of servo system when the input signal is perfect
- Time Alignment Error in normal operation across all environmental conditions

Servo Output performance

- Depends on the combination of the input noise from the network & reference clock noise
- As the filtering has lower bandwidth, more of the reference oscillator noise appears on the output

Generic Architecture of a Synchronisation System implementation



Reference Clock Requirements – Dynamic Error

Support for Standards

- Support for GNSS
- Class D or C of G.8273.2
- Support for G.8273.4, Assisted & Partial Timing Support

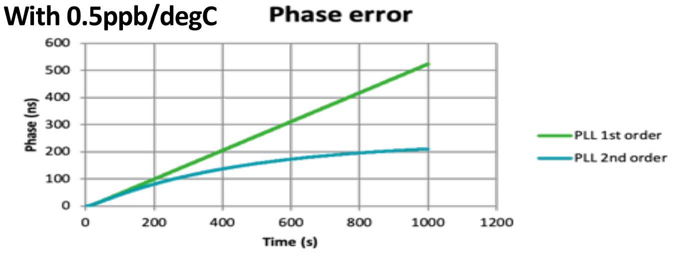
Key filtering specifications

- **1 to 30 mHz:**
  GNSS 1 PPS input requires low bandwidth filtering
- **Sub mHz:**
  Sub mHz filtering suggested for Partial timing support clocks
- **~50 mHz:**
  T-BC (G.8273.2) worst case filtering

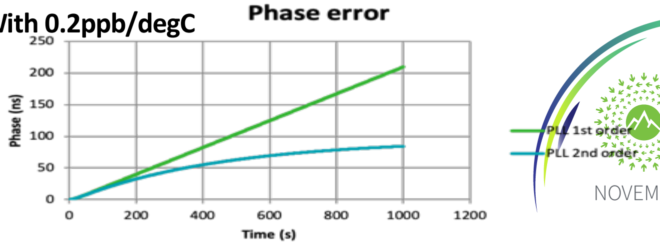
Key Reference Clock Parameter

- To achieve dynamic phase error behavior <1 ns output error, the recommended oscillator stability for across entire temperature range
- **<0.05-0.1 ppb/°C sensitivity is required**

- **With 0.5ppb/degC**



- **With 0.2ppb/degC**



Holdover for Data Centres

Holdover - the ability to hold the time and frequency within a certain limit for a certain period of time when synchronisation references are lost

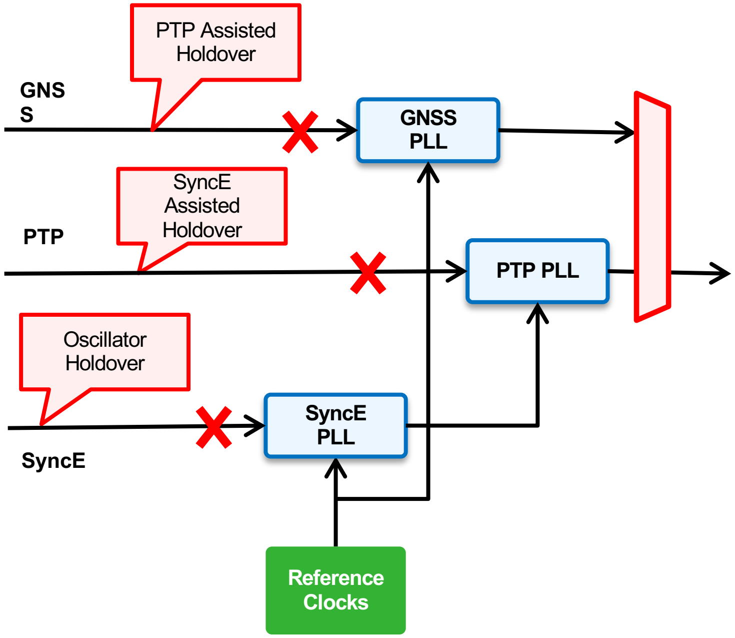
Key Drivers

- **GNSS Jamming & Spoofing**
  - The GNSS based synchronisation is very easily available everywhere, and so is the fact that the signals from GNSS can be get jammed or spoofed. The vulnerability of GNSS is a key threat
- **Synchronisation service failure**
  - The synchronisation path and the data path could be different, especially with packet layer synchronisation.

Key Drivers

- **Reference Switching Intervals**
  - For various reasons of switching the references, the systems may evaluate various reference possibilities and short holdover during such periods anticipated
- **Reference failures**
  - Scenarios of references declared as Do Not Use will need to holdover. In situations where the GNSS signal unavailability due to physical damages or environmental conditions etc.

Holdover Scenarios of a modern clock



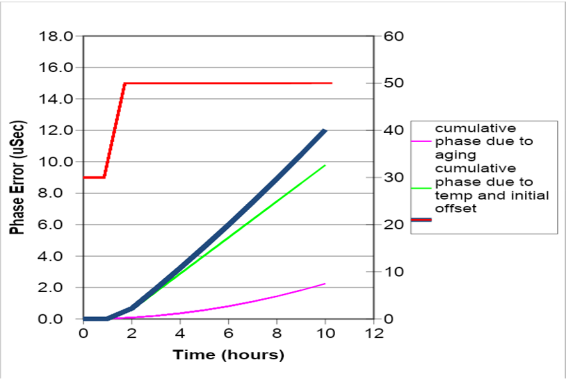
- **Clocks implement multiple reference sources**
  - ❑ Primary GNSS with Assisted PTP and supported SyncE is a common method
- **The following holdover scenarios supported**
  - ❑ Holdover based on Packet clocks or more precisely based on IEEE1588 clocks - Since the 1588 has the capability to distribute time as well, this becomes handy to hold with 1588.
  - ❑ Holdover based on Physical layer clocks, most commonly based on SyncE. The long-term frequency accuracy advantage of the clocks hold the phase error to minimal
  - ❑ Holdover based on oscillators. In traditional notion of holdover, the system relies on local oscillators when all reference to the system are lost

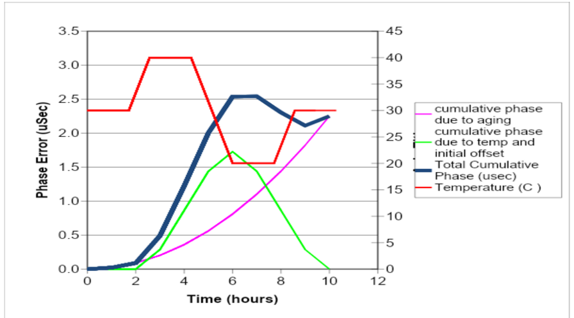
Worst Case Phase Holdover

Worst Case Phase Holdover At Time (t):

$$x(t) = x_o + (f_o + \text{average}(\Delta f_{env} + \Delta f_{OT}))*t + \tfrac{1}{2}*\text{aging} * t^2$$

x_o= Initial phase offset
fo: The initial fractional frequency offset (ppb)
Δf_{env}: sum total of the changes in frequency (ppb) due to environmental factors (including temperature, input voltage, output loading, pressure, humidity, acceleration etc.)
Δf_{RW}: Random frequency noise not associated with environmental effects or long term aging
Aging: The long term change in frequency over time (ppb/day)





- Initial phase and frequency offsets
- At long time frames, the ageing dominates
- The "average($\Delta f_{temp} + \Delta f_{OT}$)"
- Other effects -> Random Walk, Hysteresis, micro-jumps
- Estimating this term can be very challenging since it depends not only on the size of the temperature changes, but more importantly **when** they occur during the holdover period.

Reference Clock Choices

Sl No	I	TCXO	HTCXO	miniOCXO	OCXOs
1	Overall temperature stability	50-300ppb	10-50ppb	1-10ppb	0.25-1ppb
2	Ageing	10ppb/day	1ppb/day	.2ppb/day	0.01ppb/day (compensated)
3	Temperature sensitivity	5-10ppb/degC	0.2-3ppb/degC	0.2-0.5ppb/degC	<0.05ppb/degC
4	Holdover	Not recommended.	15min-1 hour	1-4 hours	4-24 hours
4	Life time stability	4.6ppm-6ppm	3ppm	1ppm	1ppm
5	Phase noise	Very Good*	Excellent*	Good	Good
5	Power & Size	30mW, 7x9, 5x3.2	300mW 7x9	400mW 9x7,14x9	750mW 25x22, 38x27
6	Start up time	100s of ms	10s	1min	3min
7	Cost & Availability	$ Volume shipping	1.5 X $ Volume shipping	3 X $	4 X $ - 20 X $

*Phase noise plots available

Summary Reference clocks for performance

- New applications and networks are demanding superior synchronisation performance
- Dynamic behaviour and holdover capabilities are important on reference selection
- Current technology enables to have wide range of varieties of reference clocking options at varying cost levels to suit the application

Call to Action

Where to buy: www.rakon.com

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Thank you!

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