Synchronization Architectures & Reference Clock Requirements in Data Centres

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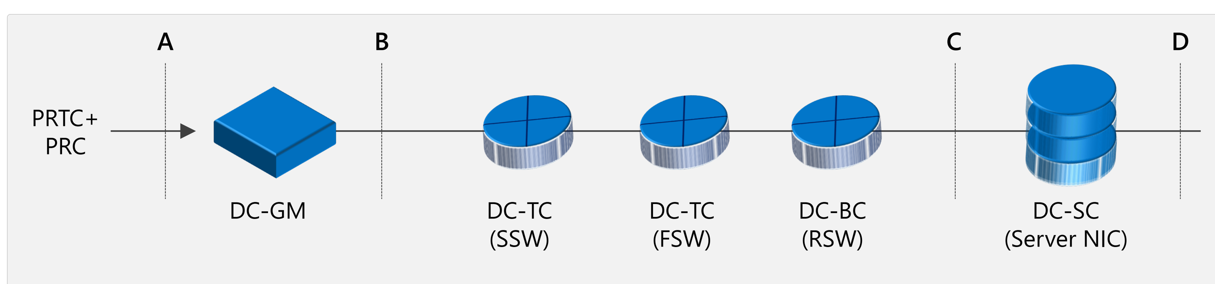
Motivation: 5G envisions an open network infrastructure ecosystem. The baseband processing function is virtualised and being moved into telecom cloud data centres. Mobile Edge Computing is realised from cloud data centres and they are becoming part of the Radio Access Network. Synchronization of the data centres is becoming critical.

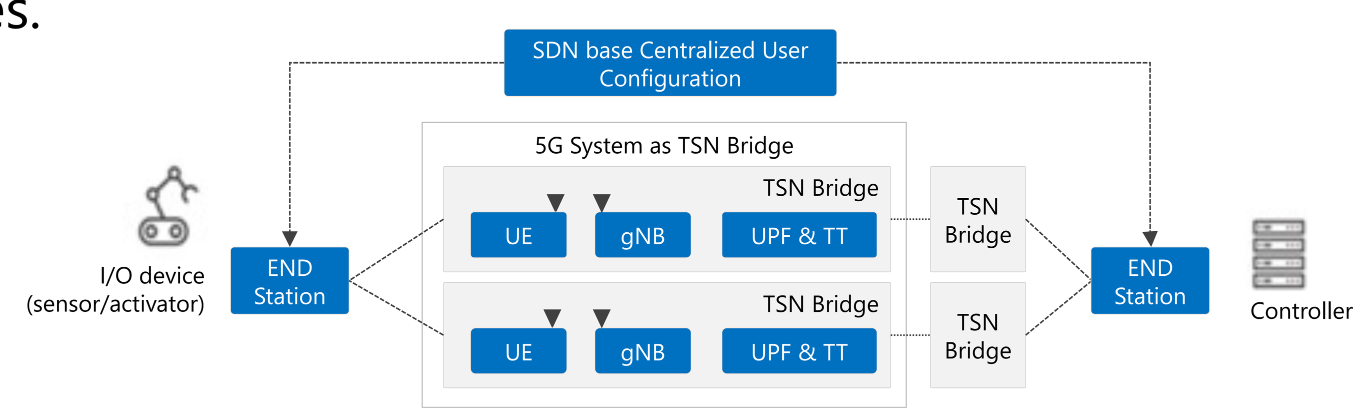
Activities around Data Centre Synchronization: A number of Standards bodies are developing standards that would influence the architecture of synchronization in the data centres.

OCP-TAP: The Open Compute Project-Time Appliances Project is building a DC -Profile for PTP (IEEE 1588 Precision Timing Protocol), stipulating a reference model of Synchronization and target accuracies.



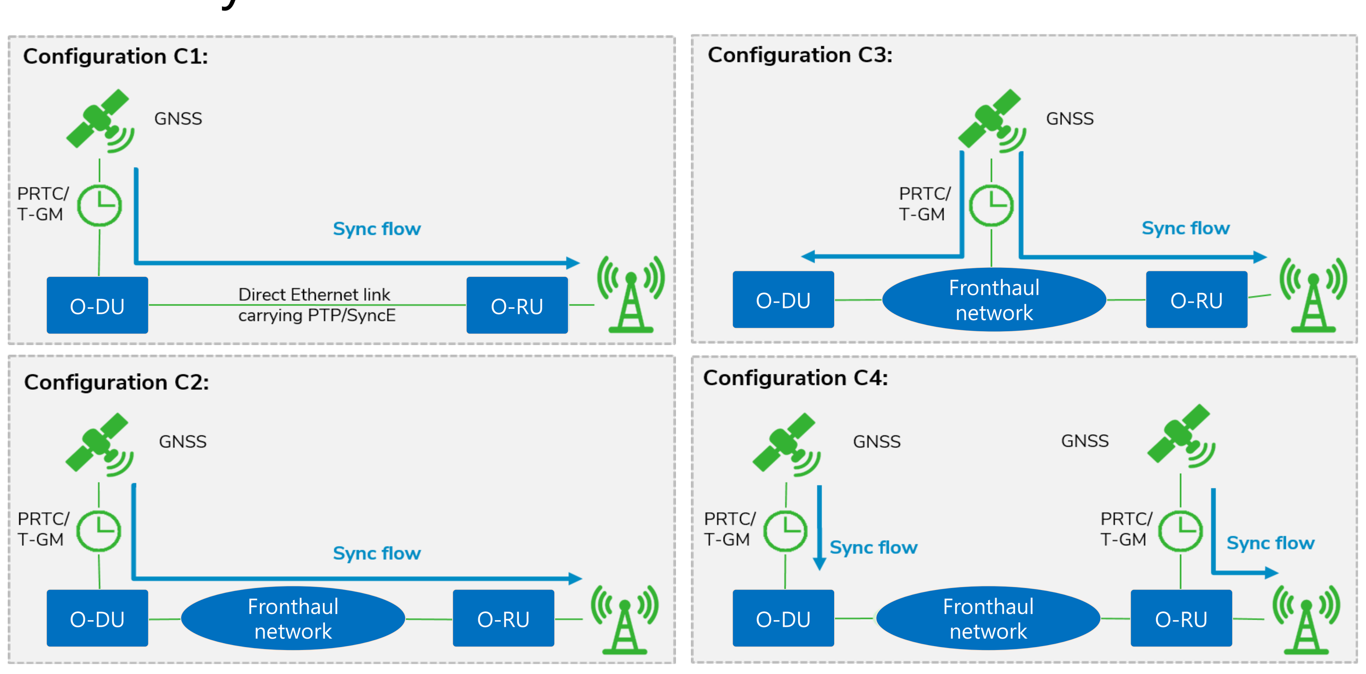
Reference point	Limit
A	Max [TE] ≤ 100 ns
B	Max [TE] ≤ 250 ns
C	Max [TE] ≤ 1000 ns
D	Max [TE] ≤ 5000 ns

IEEE802.1AS-2020: IEEE802.1AS-2020 standard defines the requirements of Timing Synchronization for TSN (Time Sensitive Networks). 5G can be regarded as a TSN bridge in the overall TSN network architecture and provides communication and synchronization services for various use cases.



UE – User Equipment gNB – 5G nodeB UPF – plane Function TT – TSN Translator

O-RAN Alliance: The O-RAN Alliance defines standards for the deployment of synchronization on 5G networks.



IEEE802.1CM: Based on the time-sensitive network standards, the various components for Time Alignment errors are defined.

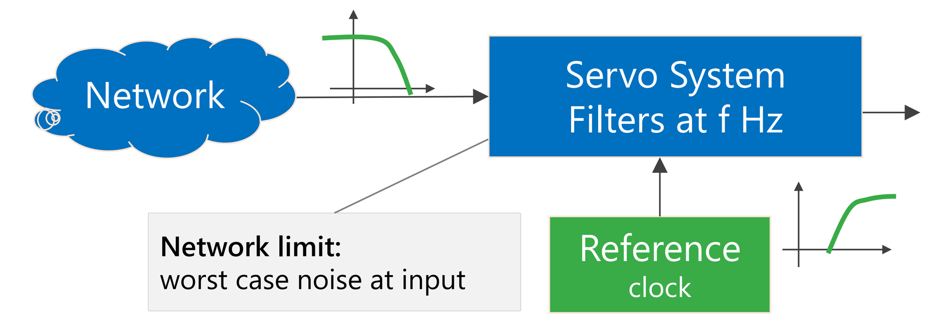
Category	Applications Details	TAE proposed by EEE801.CM	TAE (for END Application)
		Case 1	
A+	MIMO or TX diversity transmissions, at each carrier frequency	-	65 ns
A	Intra-band contiguous carrier aggregation, with or without MIMO or TX diversity	60 ns	130 ns
B	A & Inter-band carrier aggregation, with or without MIMO or TX diversity	100 ns	260 ns
C	3GPP LTE TDD	1100 ns	1500 ns

ITU-T SG15 Q13: ITU-T defines standards for transport networks. The performance in ns of the various classes of transport equipment clocks is listed below.

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

Reference Clock requirements: Synchronization information from traceable primary reference clock steers local clock references to generate equipment clocks as below. The stability of the local reference depends on the target performance, amount of filtering and holdover required. Dynamic performance and holdover are key considerations.

Dynamic Error: is a combination of filtered network noise and high pass reference clock noise at the filtering frequency.



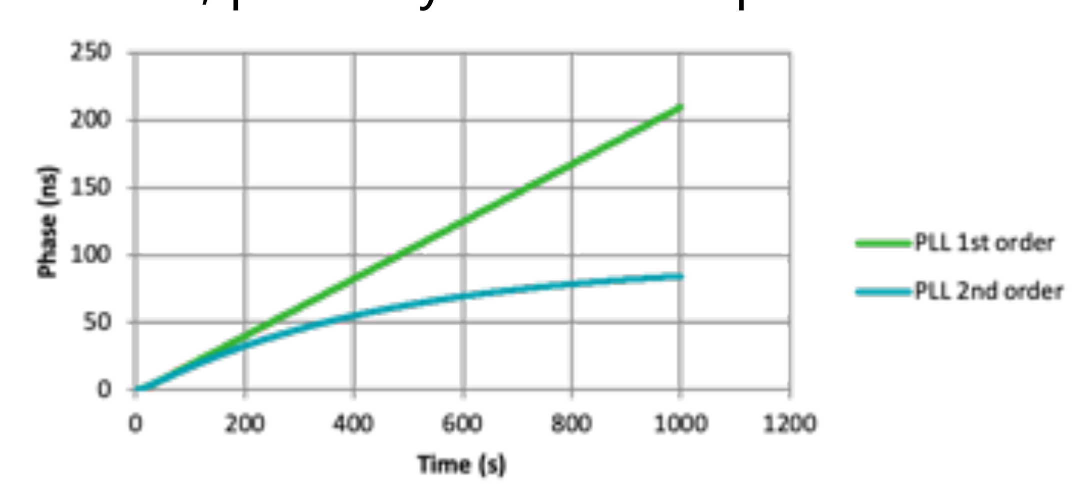
Clocks use low bandwidth in the following application scenarios:

a. **GNSS Support:** GNSS clocks use 1PPS. 1PPS input into a servo system uses very low bandwidth in the range of 10 – 30 mHz

b. **5G RRU:** To generate ±50 ppb accuracy at the air interface from a G.8262 network noise require low bandwidth filtering in the range of 10 – 50 mHz)

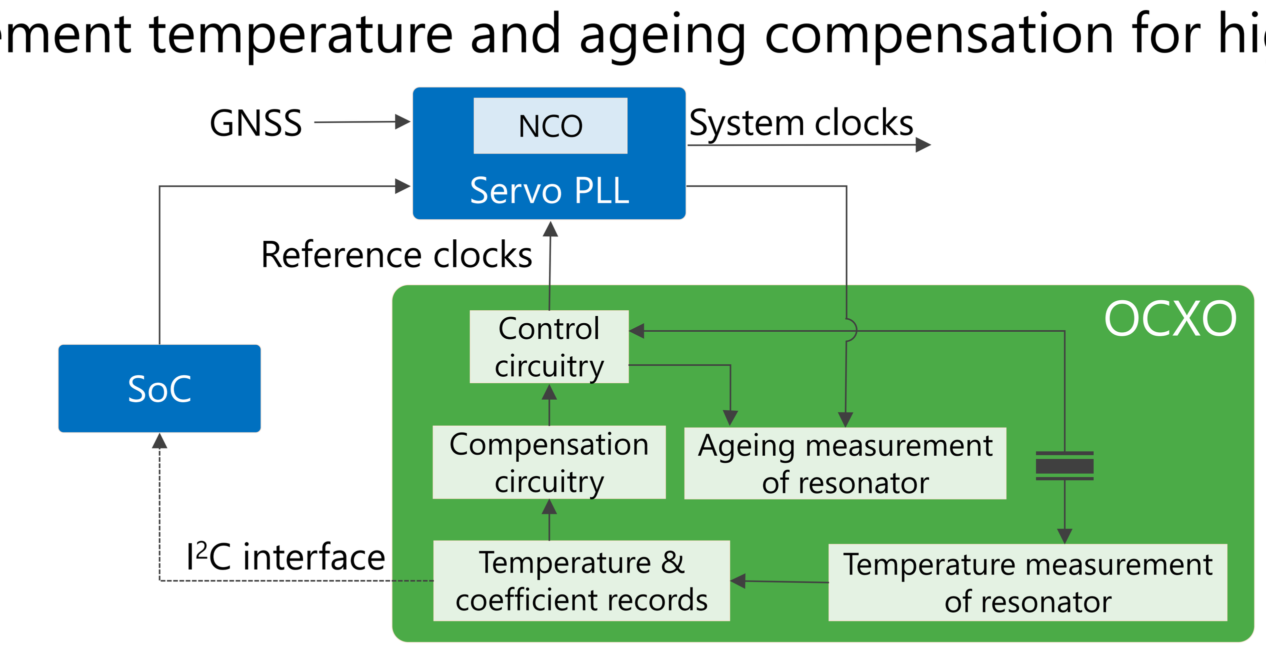
c. **APTS clocks:** Assisted and partial timing clocks require very low bandwidth and can usually be below the mHz range.

The intrinsic noise for low bandwidth clocks are from the impairments of the reference clocks, primarily due to temperature changes.



A reference clock with 0.1 – 0.5 ppb/°C temperature sensitivity is desired for ~10 ns of ns phase error.

Holdover is the ability of the system to maintain synchronisation primary source of synchronisation is lost. New generation clocks implement temperature and ageing compensation for high stability.



Such implementations are able to achieve holdover performances of 1.5 µs across 24 hours.