National Information & Communications Technology Authority

NETWORK SYNCHRONISATION GUIDELINE

Issue: August, 2023
Document Reference No.
Engineering & Resource Planning
NICTA Headquarters
Frangipani Street
Hohola, Port Moresby.

Contents

1. Introduction

The introduction of digital circuit-switching has driven the need for network synchronization in the late 70s and early 80s. Since then, telecommunication providers have set up synchronization networks to synchronize their switching and transmission equipment. Network synchronization has since gained increased importance in digital telecommunication as new network systems and services were introduced overtime.

Synchronization of telecommunication networks is very important for inter-network operability and effective transfer of relevant time used information between networks and processing information by each network.

NICTA is obliged to ensure that requirements on network synchronization are complied with by telecommunications networks in Papua New Guinea (PNG).

2. Scope

This technical document provides guidance on the practical approach to telecommunication networks, whether new or existing, on the design, planning, implementing, operational and maintaining the Synchronization Network in an efficient manner. It is based on best practices and world telecommunications standards and principles as set out in various ETSI and ITU-T Standards and Recommendations.

3. Objective

The objective of this document is;

- to ensure that the synchronization network for all incumbent and new telecommunications network and service providers in PNG is implemented and complies with internationally recognized standards and best practices,
- to ensure that telecommunication networks in PNG are synchronized for optimum performance and high availability,
- to ensure that all telecommunication network and service providers are equipped with necessary network synchronization plan and guidelines in PNG.

4. Definitions and Abbreviations

Bilateral - A synchronization link where the corrective action to maintain locking is active at both ends of the link.

Clock - A device which provides a reference timing signal.

ETSI – European Telecommunications Standards Institute is a European Standards Organisation (ESO) for Telecommunication, Broadcasting and other electronic networks and services.

GPS - Global Positioning System

Holdover Mode - An operating condition of a clock which has lost its controlling input and is using stored data, acquired while in locked operation, to control its output. The stored data are used to control phase and frequency variations, allowing the locked condition to be reproduced within specifications. Holdover begins when the clock output no longer reflects the influence of a connected external reference, or transition from it. Holdover terminates when the output of the clock reverts to locked mode condition.

ITU-T – A sector of the International Telecommunications Union (ITU) that develops and updates standards, known as Recommendations for the telecommunication and ICT industry.

Jitter - Short term variations of the significant instants of a digital signal from their reference positions in time.

Local node - A synchronous network node which interfaces directly with customer equipment.

Master Clock - A clock providing a reference timing signal to other clocks, behaving as slave clocks.

NE - Network Element

Network Synchronization - A generic concept that depicts the way of distributing a common time and/or frequency to all elements in a network.

Node Clock - Clock distributing synchronization reference timing signals within a node

PDH - Plesiochronous Digital Hierarchy

Plesiochronous mode - A mode where the essential characteristic of time scales or signals such that their corresponding significant instants occur at nominally the same rate, any variation in rate being constrained within specified limits.

PRC - Primary Reference Clock

Pseudo-synchronous mode - A mode where all clocks have long term frequency accuracy compliant with a primary reference clock as specified in EN 300 462-6-1 [5] under normal operating conditions. Not all clocks in the network will have timing traceable to the same PRC.

Primary Reference Clock (PRC) - A reference clock that provides a reference timing signal compliant with EN 300 462-6-1 [5], in order to synchronize all or a large part of a network.

SASE - Stand Alone Synchronization Equipment

SDH - Synchronous Digital Hierarchy

SEC - Synchronous Equipment Clock

Slip - The repetition or deletion of a block of bits in a synchronous or plesiochronous bit stream due to a discrepancy in the read and write rates at a buffer.

SSM - Synchronization Status Message

STM-N - Synchronous Transport Module N

Synchronization Chain - An active interconnection of synchronization nodes and links.

Synchronization area – geographical area in which all synchronous NEs are synchronized the one master PRC in the that area.

Synchronization network: - A network to provide reference timing signals. In general, the structure of a synchronization network comprises synchronization nodes connected by synchronization links.

Synchronous network - Where all clocks have the same long-term accuracy under normal operating conditions.

Synchronization Supply Unit (SSU) - A logical function for reference timing signal selection, processing and distribution, having the frequency characteristics given in ETSI EN 300 462-4-1 [3].

Slave Clock - A clock which is locked to a reference timing signal.

NOTE 1: When a slave clock loses all its reference timing signals and goes holdover, it can be considered as being a master clock under these conditions.

NOTE 2: In locked mode, the slave clock is synchronized to a reference timing signal. The output frequency of the clock is the same as the frequency of the reference timing signal over the long term, and the phase difference between the input and the output is bounded.

Time - Is used to specify an instant (time of the day) or as a measure of time interval.

Wander – The long-term variations of the significant instance of a digital signal from their ideal position in time (where long term implies that these variations are of frequencies less than 10 Hz).

5. The Synchronization Network

Synchronization aligns time and frequency scales of equipment clocks in a network to remain constrained to specific limits so the equipment operates at the correct time and in the correct order. Networks Synchronization deals with the distribution of synchronization reference signal over a network of clocks spread over a wider area. A synchronization network is the facility that implements network synchronization. The basic elements of a synchronization network are the nodes (autonomous and slave clocks) and the links connecting them.

5.1 The Need for Synchronization

Synchronization is required to meet availability and performance requirements for digital telecommunications networks.
The synchronization network distributes reference timing signals of required quality to network elements (NE)s that perform routing, switching and multiplexing to function synchronously and within stringent specifications and limits. Poor network synchronization gives rise to higher counts of jitter and wander. The end result being the degradation of network performance, throughput and availability, resulting in bad quality of service and unsatisfactory consumer experience and reduction in revenue generation for the network operator.
Network providers must provide high quality synchronization in order to meet network performance and reliability. Good timing in a network is essential if continuous error-free performance is desired and to meet the Quality of Service (QoS) demanded by the network end users. Telecommunications network links, switching nodes and transmissions interfaces, all entities must be synchronized.

5.2 Synchronization Network Components

The following elements are found in the synchronization network:

- A *master clock*, which is called the Primary Reference Clock (PRC). This is the clock that provides the highest quality clock signal. It may be free running, e.g. A cesium atomic clock, or slaved to other free running clock of a high accuracy by terrestrial or satellite radio e.g. A *coordinated universal time* (UTC) signal transmitted via the GPS system.
- High-quality *slave clocks*, which are called the *Synchronization Supply Units (SSU.)* These clocks take their reference from the PRC and, once filtered and regenerated, distribute it to all the NEs of their node. They may serve as temporary references for parts of the network when the connection to the PRC is lost in failure situations. SSU may be integrated with a network element or be a standalone equipment referred to as Stand-Alone Synchronization Equipment (SASE).
- *NE clocks,* which is the synchronous equipment clock (SEC). These clocks take their reference from an SSU. Basically, they are the ones using the clock, although they may also send it to other NEs. It is the internal clock of all the NEs (multiplexer, ADM, etc.).

The above clocks comply with the required performance margins defined by the corresponding ITU-T recommendations as summarized in Table 5.2.

Clock Type	Accuracy	Holdover	ITU-T Rec.
PRC	1×10^{-11}	-	G.811
SSU-T	5×10^{-10}	10×10^{-10} /day	G.812
SSU-L	5×10^{-8}	3×10^{-7} /day	G.812
SEC	4.6×10^{-6}	5×10^{-7} /day	G.813

Table 5.2 Synchronization Clocks Accuracy

- *Links*, which are responsible for transporting the clock signal. They may be dedicated for synchronization only, or alternatively form a part of a transport network; apparently, the clock signal is extracted from data flow.

5.3 Synchronization Strategy

Several strategies for synchronizing nodes do exist, among which, the Hierarchical Master-Slave (HMS) method is recommended by international standards. It is the most widely adopted to synchronize modern digital telecommunications networks, due to the excellent timing performance and reliability that can be achieved at limited cost.

The HMS standard architectures are organized into two or more hierarchical levels and allow for several protection mechanisms against link and clocks failures. All clocks must be synchronized with reference to a higher level. The highest level being the autonomous master clock. Figure 5.3 shows a typical HMS synchronization strategy.

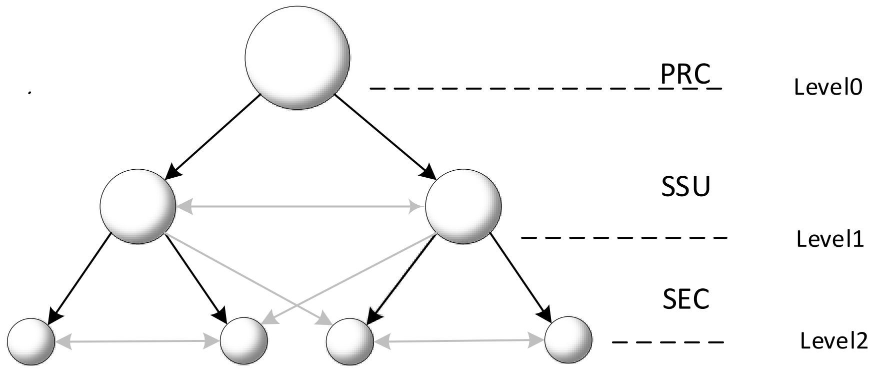

Figure 5.3 Hierarchical Master-Slave Synchronization

5.4 Synchronization Network Architecture

The architecture of the synchronization network of network operators must be in accordance with the ITU-T Recommendation G.803 and ETSI EN 300 462-2-1 Part 2-1: Synchronization network architecture based on SDH networks. The aspects of the distribution of reference signal within a synchronization network focuses on the need for all network element (NE) clocks to be traceable to a Primary Reference Clock (PRC) and to maintain a good short-term stability performance in order to comply with the generic slip rate objectives in ITU-T Recommendation G.822.
The transfer of synchronization reference signals is via dedicated 2048 kbit/s signals over PDH transport networks or the STM-N signal in SDH networks.

5.5 Synchronization Network Reference Chain

The synchronization reference signal in HMS architecture is distributed from the PRC down to all others nodes via a chain of cascaded slave clocks. Long chains of timing distribution should be avoided as quality of timing deteriorates as the number of synchronization links increases.
The synchronization network reference chain as defined by ITU is shown in Figure 5.5 below.

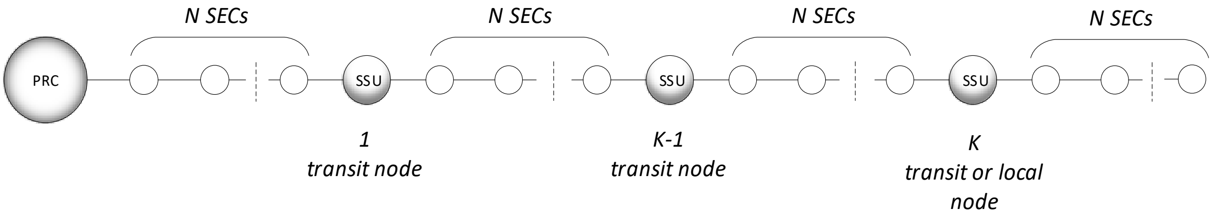

Figure 5.5: Synchronization Network Reference Chain adapted from ITU-T Rec G.803

The longest chain should not exceed K SSUs with up to N SECs interconnecting any two SSUs. Based on theoretical calculations, there should not be more than 10 SSUs in the chain, and the number of SECs between two subsequent SSUs should not be more than 20. This implies that the maximum number of G.813 clocks in the synchronization chain is 60, and the maximum number of G.812 clocks is 10.
It should be noted that the values of K and N have been derived from theoretical calculations and practical measurements are required for their verification. However, in practical synchronization design, the number of network elements must be minimized for reliability reasons. Synchronization should be protected. There should be more than one source of the timing signal for each network element.

6. Synchronization Network Planning

It must be the ultimate goal of the network operator to design and construct a synchronization network that reliably distributes synchronization to all synchronous NEs. This consists of selecting the synchronisation distribution architecture, the qualities of clocks along with facilities to be used.

Practical issues of planning the synchronization network must be in accordance with ITU-T and ETSI Recommendations and Standards and international best practices.

The planning of synchronization in multi operator networks must be fully independent of each other with the exception of one operator providing another operator with synchronization signals.

The synchronization plan should be centred on meeting a balance between initial investment and reliability.

A synchronization network plan should contain details of the network synchronization engineering process. It may also contain initial test and evaluation results, logs, etc. It should be as simple as possible to understand, implement and maintain. The synchronization plan should be maintained by constant updating whenever any synchronization related activities are carried out by the network provider/operator within the synchronization areas.

7. Guideline for Network Synchronization

It is imperative that the applicable international recommendations and standards be followed when designing a synchronization network. ETSI EG 201 793 provides an excellent guide for the planning,

implementing and maintaining of synchronization network.
The HMS architecture is recommended by international standards and must be adapted when planning synchronization networks. It is preferable that the reference source is located near the geographical centre of a synchronisation network. A secondary PRC for backup is also recommended.
Synchronisation signals are generally distributed from the top down in accordance with the switching network hierarchy. If a primary synchronization path normally used for top-down synchronisation fails, if possible, a secondary path should be available. It may originate from the same network node as the normal path but via a different transmission route or else from a different node
The transfer of synchronization between the networks of separate operators must be configured in one direction only. It must not be fed backwards at any point.
Timing loops within a synchronised network must be avoided. These occur when a clock receives a reference frequency which may be traced back to itself. Network operators should ensure that clock loops do not occur under fault conditions when secondary clock sources may be selected.

8. Implementation of Synchronization Network

The aspects of the synchronization network architecture and distribution of synchronization over a digital transport network is covered in detail in the ITU-T Recommendation G.803.
A digital transport network shall be synchronized with the primary reference clock (PRC) system by means of a synchronization network. It is preferable that the reference source is located near the geographical centre of the synchronization area the operator domain.

The synchronization network structure shall comply with the relevant internationally accepted standards and its performance shall meet the requirements set out by the ITU-T and ETSI recommendations and standards.
The hierarchical master-slave (HMS) shall be the accepted architecture to be used in the distribution of synchronization reference signal.
Either the synchronous or the pseudo synchronous modes may be used between multiple networks. In pseudo-synchronous mode, not all clocks in the network will be traceable to the same PRC.
However, each PRC must comply with ITU-T Recommendation G.811 and therefore pointer adjustments will occur at the synchronization boundary network element. This is the normal mode of operation for the international and inter-operator network.
The synchronization connections between the network nodes must be secured. The primary and secondary synchronization connections shall be chosen in such a way that the synchronization will not form a loop in any situation.
Use of high-quality clocks with good hold-over performances complemented by duplication of synchronisation trails is inevitable to minimise slips that can degrade performance of the end-to-end services.
A synchronisation network management system must be setup to support reconfiguration of the overall network level in instances of failure.

9. Operational and Performance Requirement for Synchronization Network

9.1 Synchronization

All networks must be synchronised from a reference source traceable to a Primary Reference Clock (PRC). The synchronization technique is single-ended in which the slave clocks select a synchronization trail as their reference and switch to an alternative if the original trail fails.
To ensure reliability in the operation of the synchronization network, all node clocks and NE clocks shall gather timing from at least two synchronisation trails and that timing loops are avoided. The reference trails must be of a higher or similar quality than the clock itself at that point in time.

Two methods shall be employed to achieve PRC traceability.

- One method would be for the operator of the network to provide a PRC, in which case the network would operate plesiochronously with other networks.
- The second method would be for the network to accept PRC-traceable timing from an interconnected network.

The method of synchronization shall be negotiated between any two networks operators. The details shall be clearly indicated in any bilateral agreement drawn up between operators of the network concerned.

9.2 Primary Reference Clock (PRC)

All telecommunication transport networks shall be synchronized to the PRC by means of a synchronization network.
The PRC system with which the networks are synchronized shall meet the timing requirements specified in ITU-T Recommendation G.811.
The synchronization network operator may run two (or more) PRC's at different locations in their network in order to achieve a very high availability of PRC reference signals to the network. In case of a fault of the currently active PRC the standby PRC will take over the role of the failed PRC.
The frequency accuracy of the PRC shall not be less than $1x\ 10^{-11}$.

9.3 Slave clocks

The specifications for timing characteristics of slave clocks should be in accordance with the requirements that are contained in ITU-T Recommendation G.812.

9.4 Control of Jitter and Wander within synchronization networks

The specifications for jitter and wander within synchronization networks should be in accordance with the ITU-T Recommendation G.823 and ETSI standard EN 300 462-3-1.

9.5 Slip Performance

Controlled slip rates should meet the objectives presented in ITU-T Recommendation G.822.

It shall be a goal for the network to be as slip – free as possible, consistent with reasonable economic constraint and keeping in mind the end – user application of the various channels in the network.

10. Maintenance of Synchronization Network

The owner of the PRC system and the other operators shall agree to the principles which are to be applied in the maintenance of the system and in the sharing of the cost caused by it.
Synchronization Network Maintenance should be done in order to keep the performance within ITU-T Recommendation G.822 limits. ITU-T Recommendation M.2130 serves as the basis for maintaining synchronization networks.

11. Synchronization Network Management

It is very important to manage all types of synchronization faults efficiently to avoid possible negative impact on services. The reporting of synchronization faults allows the operator to avoid some service affecting events entirely or, when services are impacted, reduce restoration time.

A management system is required to provide visibility of the Synchronization Network to the operator. It may be a management system that is used specifically for synchronization purposes or is integrated in a general network management system. It is an important component that will ensure the working state of the synchronization network and all its different components is actively monitored. The Synchronization Network Management System must be able to cover a range of requirements from configuration of equipment, network topology, fault detection, troubleshooting. This allows for the network operator to minimize cost for operating the network by remotely initiating required tasks where possible or by physically accessing the specific nodes that required onsite maintenance.

Since the Synchronization network management system will allow for remote actions to be carried out on synchronization equipment and network topology, careful consideration must be taken when changes are done to the network or any equipment configuration to avoid any degradation of synchronization distribution such as timing loops.

It is also important that access to synchronization network management system is secured with different access levels enabled, from the mere reading of event logs to network and equipment configuration.

12 GSMA 5G TDD SYNCHRONISATION RECOMMENDATIONS

12.1 NICTA agrees with the following GSMA TDD Synchronisation recommendations (Source[1]):

i. Recommendation No 1: The default parameters for national TDD synchronisation should be defined before awarding the spectrum.
ii. Recommendation No 2: A migration roadmap of all LTE and WiMAX legacy systems in the relevant bands should be defined.
iii. Recommendation No 3: All networks should use the same frame structure at a national level.
iv. Recommendation No 4: Networks should be synchronised at an international level whenever possible.
v. Recommendation No 5: To manage cross-border coordination, use a common frame structure or consider alternatives to find localised solutions.
vi. Recommendation No 6: Consider using the following options to identify practical solutions to coexistence of networks using different synchronisation frame structures.
vii. Recommendation No 7: Operators should be permitted to agree on localised arrangements including different synchronisation frame structures.
viii. Recommendation No 8: Public mobile operators should be permitted to update the agreed national TDD synchronisation parameters.
ix. Recommendation No 9: All networks should use the same UTC clock reference with a common starting point.
x. Recommendation No 10: All networks should use the same Special slot "S" format at a national level.

13 NETWORK SYNCHRONISATION FRAMEWORK

13.1 LTE TDD Frame Structure

In TDD, the transmission is divided into *time domain* which means at one moment of time either downlink subframe is transmitted or the uplink.

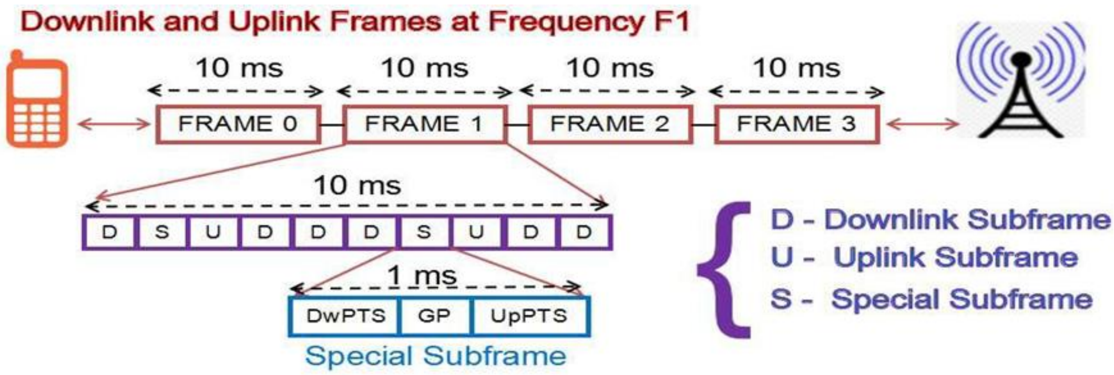

Figure 2: LTE TDD Frame Structure

Each radio frame of length 10ms consists of 10 subframes of length 1ms each, and that subframe can be either downlink "D", uplink "U" or special subframe "S". The sequence of these subframes has been defined by 3GPP with the name TDD Frame Configurations. There are fixed patterns of these configurations and network operator has to choose out of these defined patters. There are total of 7 LTE TDD configurations as shown below:

Configuration	3GPP release	Downlink to uplink switch point periodicity (ms)	Subframe number										Number of subframes / frame		
			0	1	2	3	4	5	6	7	8	9	D [DL]	U [UL]	S [SSF]
0	8	5	D	S	U	U	U	D	S	U	U	U	2	6	2
1	8	5	D	S	U	U	D	D	S	U	U	D	4	4	2
2	8	5	D	S	U	D	D	D	S	U	D	D	6	2	2
3	8	10	D	S	U	U	U	D	D	D	D	D	6	3	1
4	8	10	D	S	U	U	D	D	D	D	D	D	7	2	1
5	8	10	D	S	U	D	D	D	D	D	D	D	8	1	1
6	8	5	D	S	U	U	U	D	S	U	U	D	3	5	2

Table 2 - 7 LTE TDD Configurations

And there comes a Special subframe which comes when there is transition from downlink subframe to uplink subframe. It has three parts – DwPTS (Downlink Pilot Time

Slot), GP (Guard Period) and UpPTS (Uplink Pilot Time Slot) and all of these have configurable lengths, which depends upon Special subframe configuration.

13.1.1 DwPTS is considered as a "normal" DL subframe and carries reference signals and control information as well as data for those cases when sufficient duration is configured. It also carries PSS.

13.1.2 GP is used to control the switching between the UL and DL transmission. Switching between transmission directions has a small hardware delay for both UE and eNodeB and needs to be compensated by GP. GP has t0 be large enough to cover the propagation delay of DL interferes. Its length determines the maximum supportable cell size.

13.1.3 UpPTS is primarily intended for sounding reference signals (SRS) transmission from UE. Mainly used for RACH transmission. Special subframe configuration as

Configuration	3GPP release	Number of OFDM symbols / subframe		
		Dw	GP	Up
0	8	3	10	1
1	8	9	4	1
2	8	10	3	1
3	8	11	2	1
4	8	12	1	1
5	8	3	9	2
6	8	9	3	2
7	8	10	2	2
8	8	11	1	2
9	11	6	6	2

shown below:

Table 3: Special Subframe Configurations

Selecting a synchronization option for LTE-TDD requires:

i. Selection of a timing reference (beginning of the frame);
ii. Selection of a frame structure;
iii. Selection of special sub-frame configuration.

13.2 Compatibility of 5G-NR Frame with LTE-TDD Frame Structure

With the synchronized operation of 5G-NR and LTE-TDD, noting that every LTE-TDD frame configuration has at least one compatible 5G-NR equivalent configuration, the 5G-NR TDD pattern should be based on the following sequence of DL, UL and special slots: "DDDSUUDDDD". Two example variants19 may be considered:

i. **Variant 1 (When Incumbents are not present in the band):** LTE-TDD and 5G-NR have an aligned frame start, e.g., "DDDSUUDDDD";
ii. **Variant 2 (When Incumbents are present in the band):** non-zero frame start offset between LTE-TDD and 5G-NR, e.g., "DDDDDDDSUU".

These variants, with 30 kHz subcarrier spacing (SCS) can be aligned to LTE- TDD "DSUDD" frame structure with 15 kHz SCS (LTE-TDD frame configuration #2).

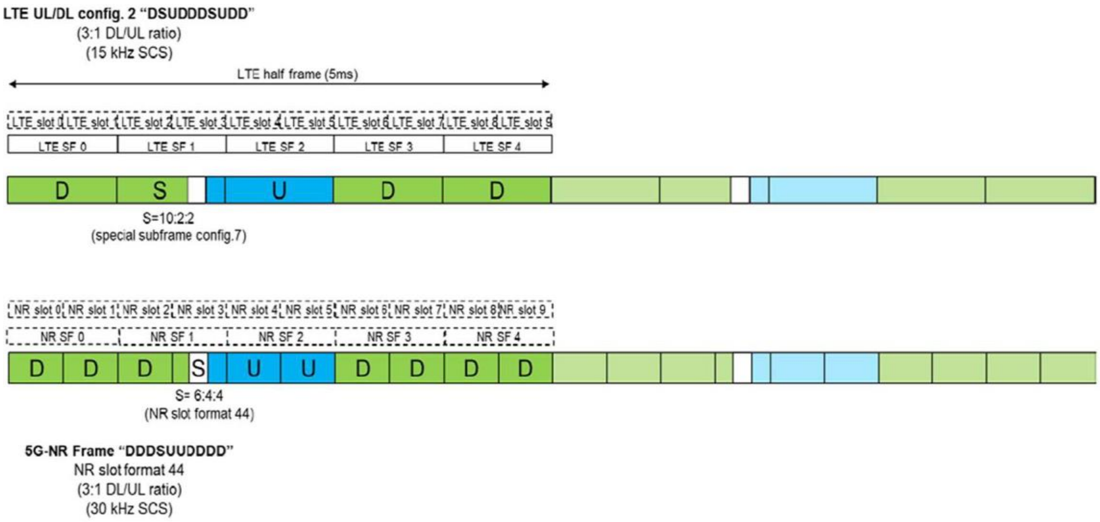

Figure 3: Variant 1 - Synchronised operation of 5G-NR ("DDDSUUDDDD" frame) and LTE-TDD ("DSUDD" frame)

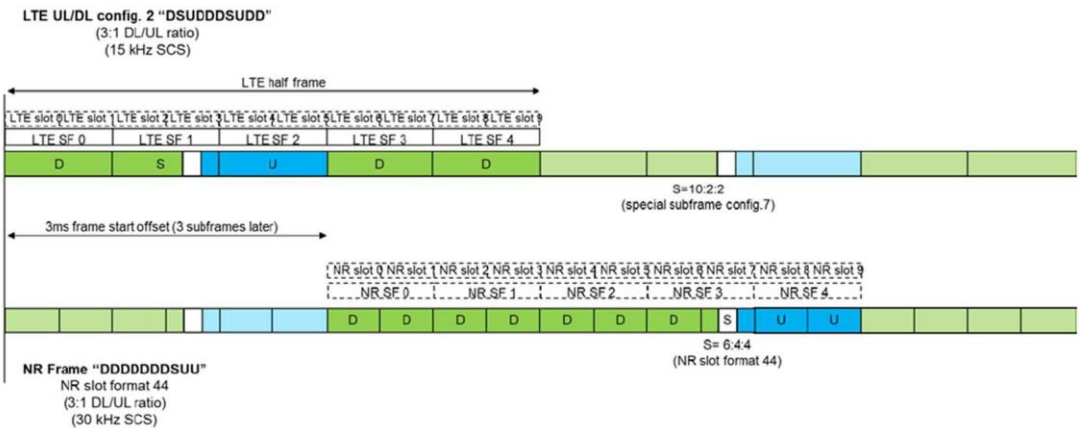

Figure 4: Variant 2 - Synchronised operation of 5G-NR ("DDDDDDDSUU" frame) and LTE-TDD ("DSUDD" frame)

It is to be noted that there should also be a compatible structure for the symbols within the LTE-TDD "S" sub-frame. For the studies considered, the "DDDDDDDSUU" frame configuration is used to represent the performance that 5G-NR would have in case of synchronised operation with a neighbour LTE-TDD network in the same band and in the same area using LTE-TDD frame configuration #2. Note that similar results apply in case the non-shifted variant, i.e., "DDDSUUDDDD", is used.

Selecting a synchronisation / semi-synchronisation option for 5G-NR requests:

i. Selection of a timing reference (beginning of the frame);
ii. Selection of normal or extended prefix;
iii. Selection of a subcarrier spacing configuration;
iv. Selection of a slot configuration.

13.3 Common Clock Reference

A common accurate reference clock must be agreed, including accuracy/performance constraints. Operators may share clock infrastructure or set up clock solution within their own network. Available proper reference clock sources include, but not limited to the National Institute of Metrology and GPS. The clock system is required to be periodically monitored, and administrations and operators should take actions in order to ensure that the clock quality is met and there is no synchronization error.

The phase synchronization requirements are as shown below:

Technology	Phase accuracy relatively to the reference clock
LTE	±1.5μs for cell radius ≤ 3km
	±5μs for cell radius > 3km
NR	±1.5μs

Table 4: Phase Synchronization Requirement

Moreover, the holdover period has to be defined based on quality of the oscillator (internal clock generator) for the system to operate properly when the primary reference time clock (PRTC) is lost. If there is no PRTC for the duration longer than the holdover period, the system must be shut off to prevent interference to other systems. Some equipment currently available in the market has holdover period of 2 – 4 hours.

13.4 TDD Frame Structure

The frame structure, including frame length, with specific DL/UL ratio shall be carefully determined taking into account of traffic. The selection of frame structure will contribute to network performance.

Technology	sub-carrier spacing (kHz)	DL/UL ratio
LTE	15	4:1
NR	30	8:2

Table 5: Example of Frame Structures

For example, the more frequent DL/UL and UL/DL switching allows shorter latency and improve spectral efficiency. In order to avoid simultaneous UL/DL transmissions while assure network efficiency, each operator must determine an appropriate frame structure for their own network and agree on a compatible frame structure among operators. It is feasible for cross technology synchronization LTE – NR if the frame structures are aligned. An example of LTE and NR equivalent configurations is as shown in Table 5:

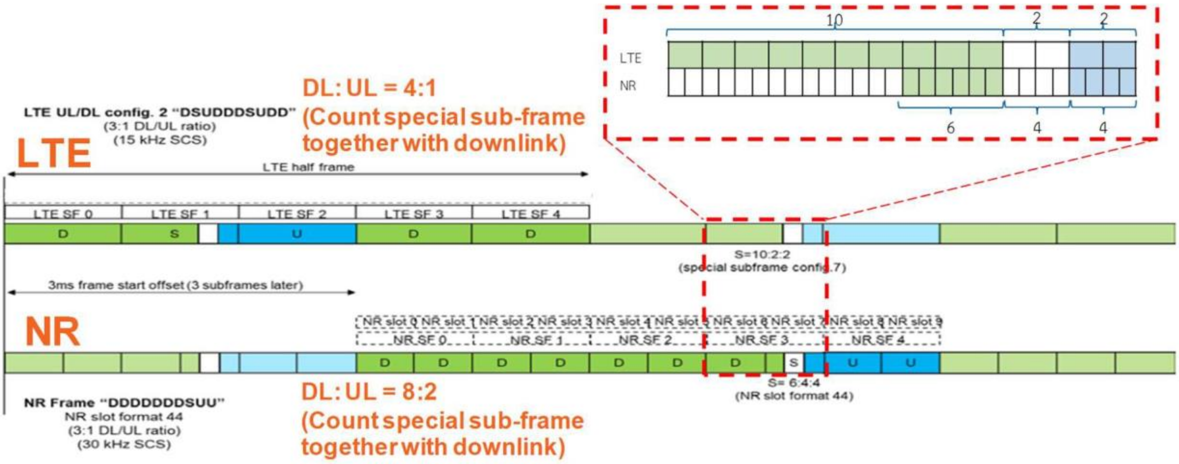

Figure 5: Example of LTE and NR Frame Structure Configurations *(Source: ECC Report 296)*

Notes on special subframe: The special subframe can be configured as symbols ratio for downlink: guard: uplink. For example, in the figure above, the symbol ratio of special subframe of LTE network is 10:2:2 and that of NR network is 6:4:4.

14 TDD NETWORK SYNCHRONISATION RECOMMENDATION

14.1 NICTA proposes a mandatory Network Synchronization for TDD Spectrum Arrangements as per GSMA Recommendations. The Network Synchronization shall apply to all operators of TDD spectrum. The details of the recommended Network Synchronization are as follows;

i. Recommended Phase Clock Synchronization

For primary reference time clock (PRTC), Global Positioning System (GPS) or other Global Navigation Satellite System (GNSS) should be used. (In case of other GNSS, the clock signal should be converted into timescale of GPS.) If GPS/GNSS cannot be used (e.g. for indoor sites), Precision Time Protocol (PTP) for transmission of clock signal in the network (according to standard IEEE 1588 version 2) should be used with error within ±1.5 microseconds relative to GPS.

If a site cannot receive clock signal for synchronization either by GPS/GNSS or PTP, site should maintain clock signal using internal clock generator with error within ±1.5 microseconds relative to GPS until it can receive clock signal for synchronization again. The minimum period of time that sites can maintain clock signal using internal clock generator (holdover period) should be at least 2 hours.

If a site cannot receive clock signal for synchronization and cannot maintain clock signal using internal clock generator, as a last resort, site should be shut off until it can receive clock signal for synchronization again.

ii. **Clock reference**: GPS for outdoor and PTP for indoor or small cell.
   - GNSS/GPS cannot be used for the indoor setting or ultra- dense urban area, so using PTP instead is necessary. External outdoor GPS can feed clock signal to indoor sites but there are limitations.
   - The obstruction of small-cells may have issue for both indoor and even outdoor (e.g., obstruction from trees).

iii. **Holdover Period**: Typically, 2-4 hours, though some equipment have longer holdover period.

iv. **Frame Structures**

Technology	sub-carrier spacing (kHz)	DL*/UL ratio
LTE	15	4:1
NR	30	8:2

Table 6: Frame Structure

Note: *Downlink includes Special Subframe during the transition from Downlink to Uplink*

It is noted that the frame structure above is based on assumption that LTE will continue to be used in the foreseeable future.

An operator may use frame structure different from specified above, provided that agreements with NICTA and other operators in the same frequency band are reached.

- Currently using Configuration No.2 for LTE.
- However, there is no strong opinion for future arrangement of frame structures (LTE – NR and NR –NR) at this time.
- The frame structure should be flexible for revision to support possible changes in downlink/uplink traffic. Traffic pattern may change in the future, e.g., more uplink traffic for 5G applications that are not mobile broadband.

15 Document Administration

15.1 Document Approval

This document has been approved by NICTA Board, as the technical guideline for synchronization of telecommunication networks in Papua New Guinea.

15.2 Document Amendment

NICTA shall, from time to time, alter, update or modify these technical performance requirements to suit current technologies and meeting international and/or national requirements.

15.3 Document Enforcement

This document is in force and effective from the date the NICTA Board approves it and is subject to the appropriate provisions of the NICT Act 2009 (as amended).

15.4 Document Publication and/or Distribution

This document once approved by the NICTA Board shall be published on the NICTA website https://www.nicta.gov.pg for general public information. The document shall also be distributed to relevant authorities for reference and compliance.

16 References

ETSI EN 300 462-1-1 - *Transmission and Multiplexing (TM); Generic requirements for synchronization networks; Part 1-1: Definitions and terminology for synchronization networks, V1.1.1 (1998-05).*

ETSI EN 300 462-2-1 - *Transmission and Multiplexing (TM); Generic requirements for synchronization networks; Part 2-1: Synchronization network architecture, V1.2.1 (2002-06).*

ETSI EN 300 462-3-1 - *Transmission and Multiplexing (TM); Generic requirements for synchronization networks; Part 3-1: The control of jitter and wander within synchronization networks, V1.1.1 (1998-05).*

ETSI EN 300 462-4-1 - *Transmission and Multiplexing (TM); Generic requirements for synchronization networks; Part 4-1: Timing characteristics of slave clocks suitable for synchronization supply to Synchronous Digital Hierarchy (SDH) and Plesiochronous Digital Hierarchy (PDH) equipment, V1.1.1 (1998-05).*

ETSI EN 300 462-5-1 - *Transmission and Multiplexing (TM); Generic requirements for synchronization networks; Part 5-1: Timing characteristics of slave clocks suitable for operation in Synchronous Digital Hierarchy (SDH) equipment, V1.1.2 (1998-05).*

ETSI EN 300 462-6-1 - *Transmission and Multiplexing (TM); Generic requirements for synchronization networks; Part 6-1: Timing characteristics of primary reference clocks, V1.1.1 (1998-05).*

ETSI EN 300 462-7-1 - *Transmission and Multiplexing (TM); Generic requirements for synchronization networks; Part 7-1: Timing characteristics of slave clocks suitable for synchronization supply to equipment in local node applications, V1.1.2 (2001-06).*

ETSI EG 201 793 - *Transmission and Multiplexing (TM); Synchronization network engineering V1.1.1 (2000-10).*

ITU-T Rec. G.803 - *Architecture of transport networks based on the synchronous digital hierarchy (SDH), Geneva, (03/2000)*
ITU-T Rec. G.810 - *Definitions and Terminology for Synchronization Networks, Geneva, (08/96).*
ITU-T Rec. G.811 - *Timing characteristics of primary reference clocks, Geneva, (09/97).*
ITU-T Rec. G.812 - *Timing requirements of slave clocks suitable for use as node clocks in synchronization networks, Geneva, (06/04.)*
ITU-T Rec. G.813 - *Timing characteristics of SDH equipment slave clocks (SEC), Geneva, (03/03.)*
ITU-T Rec. G.822 - *Controlled slip rate objectives on an international digital connection, Geneva, (11/88).*

ITU-T Rec. G.823 - *The control of jitter and wander within digital networks which are based on the 2048 kbit/s hierarchy, Geneva, (03/00).*
ITU-T Rec. M.2130 - *Operational procedures for the maintenance of the transport network, Geneva, (02/00.)*
ITU-T Rec. M.3010 - *Principles for a telecommunications management network, Geneva, (02/00).*