NOKIA

Nokia X-Haul

Nokia Wavence

Product Description

NOKIA

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1. Introduction

The Nokia Wavence microwave product family introduces innovative high-capacity Ultra-Broadband Transceivers (UBT) to support operators in their transition towards 5G networks.

As 5G already brought (and even more in the near future) new requirements on transport networks, Wavence allows mobile service providers to provide the microwave transport network suitable to answers to 5G needs: High-Throughput and Low Latency Transceivers, advance carrier aggregation techniques, automation trough SDN are just few examples on how Wavence portfolio and related feature set can help operators for the transport part of their 5G networks.

The Wavence microwave product family introduces new state-of-the-art Ultra-Broadband Transceivers (UBT) to better address the new market's needs: the UBT-Twin, a "dual carrier in a box" configuration supporting multiple frequencies in the same radio, the UBT-Single and UBT-Compact, two powerful Single Carrier transceivers, and the UBT-m 80GHz, a compact E-band radio. They support backhaul and front haul evolutions with multi-gigabit capacities and low latency transport.

The Wavence UBT drastically reduces the number of parts and is ready to support multiple frequencies in the same radio, thus enabling the use of multiband antennas and simplifying installation and maintenance. It also provides 10G high-speed connectivity and programmability through SDN to support the evolution towards telco cloud.

UBT-m 80GHz is the Wavence solution for the E-Band radio designed for extremely high capacity application, up to 20G. E-band portfolio includes a high-power version (UBT-m X) and an ultra-compact version with embedded antenna suitable for urban applications (UBT-m URBAN).

Zero footprint

All UBT radios can address both Full-Outdoor and Split-mount architecture using the same hardware components. Nokia promotes and provides the concepts of Universal ODU, based on which mobile operators can adopt a single product for any in-field application.

Wavence offers in addition also the possibility to adopt also in this configuration carrier aggregation.

20G capacity over the air

Nokia Wavence UBT natively delivers multi-gigabit capacities and can support 1 or 10G interfaces. With its dual-carrier design, the UBT-T delivers up to 2.5 Gbps in one box, with two carriers in the same or different bands, for highly reliable links. Deployed as a single box or in cross polarization configuration, the highly compact UBT-m 80GHz delivers 10 and 20 Gbps respectively, the best "bit per liter" performance on the market.

UBT-Twin or UBT-Single and UBT-m 80GHz can also be combined for microwave and millimeter-wave carrier aggregation, providing up to 20 Gbps capacity on long, reliable links, making this configuration well suited for high capacity macro and metro cell backhaul.

5G-ready low latency

With a latency down to 100µs and 10µs respectively, the UBT-Twin/Single/Compact and UBT-m 80GHz are suitable for all backhaul and Ethernet front haul architectures.

High output power

As output power really matters in microwave, Wavence portfolio has been built offering several transceivers with high power option:

- UBT-m X is the E band option offering best in class output power
- UBT-S /T at low frequency (6-11 GHz) are coming with two different options, standard power and high power. With a high output power, Wavence UBTs can achieve longer hops with smaller antennas. UBT-C at low frequency (6,7,8 GHz) is proposed in High Power version.

Long haul split mount solution

To complete the product and to offer an effective solution for long links multichannel Wavence introduces

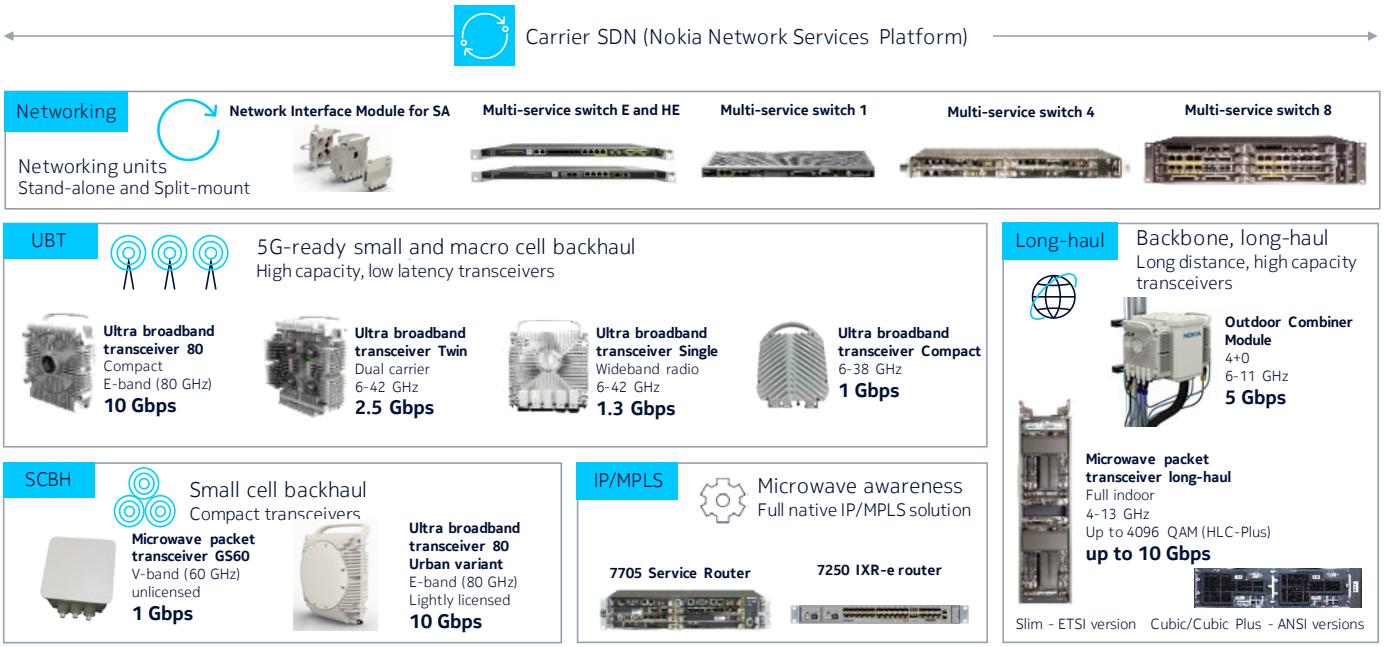
- OCM (outdoor combiner module) available in conjunction with UBT-T for 6-11 GHz frequencies with possibility to group on a single antenna up to 8 carriers with excellent system gain. The solution is very compact and modular.
- Space diversity configurations in conjunction with carrier aggregation to counteract selective fading

2. System architecture

2.1 Nokia Wavence platform

The Nokia Wavence is a very comprehensive and flexible platform applicable to all radio configurations, keeping the same hardware variants in all cases.

Figure 1 – Wavence platform



The Nokia Wavence is composed of two main building blocks:

- MSS: Indoor unit including all user interfaces, switching capability, carrier aggregation functionalities and radio protection.
- UBT (or MPT): Ultra Broadband Transceiver part including radio and modem. This unit can work connected to MSS or in a stand-alone mode, requiring only a software configuration. MPT–HL is the solution for long haul indoor trucking systems.

The Nokia Wavence can support the following configurations:

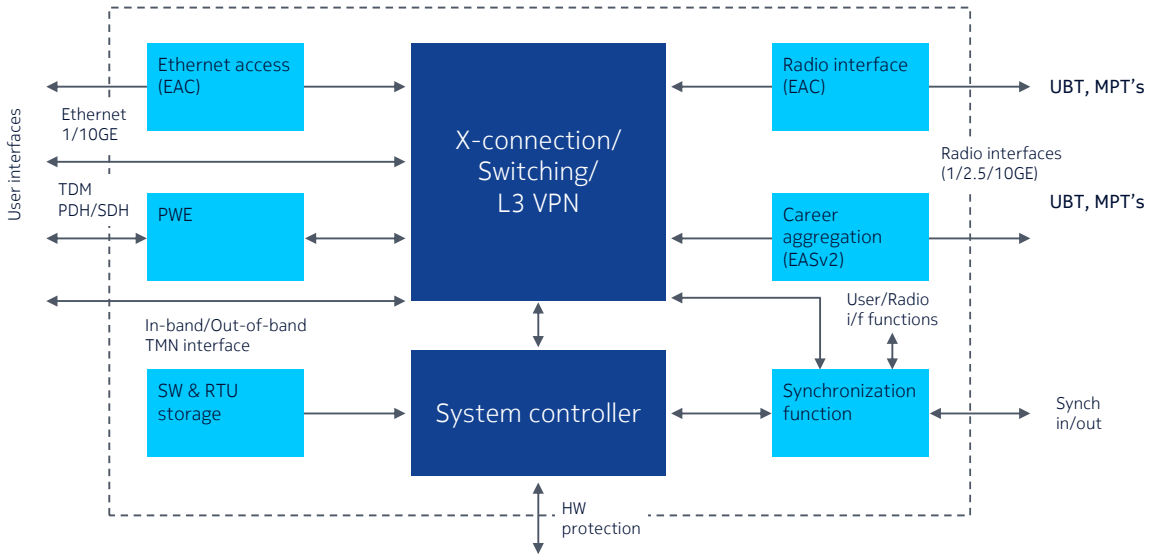
- Split mount Indoor/Outdoor (IDU/ODU): The functions are split into IDU and ODU units (MSS and UBT respectively) in the following configurations:
  - Terminal configuration
  - Repeater configuration
  - Node configuration
- Standalone (UBT): All the functions are in the outside unit next to the antenna; different configurations are supported:
  - UBT-T/s/m in 1+0

- UBT-m in 2 x (1+0) XPIC
- UBT-T in 2+0 (XPIC)
- Carrier aggregation with 2 UBT (UBT-m, T/S)

2.1.1 MSS architecture

The Wavence high level MSS architecture is sketched in the figure below.

Figure 2 MSS 4/8 architecture



The IDU can manage multiple peripherals of different types (eg: radio interfaces, local access Ethernet, TDM) and to connect each of them to a core. Up to six peripherals are supported with the MSS-8 and up to two with MSS-4.

With a 100 Gbit/s no blocking switching matrix and with a 10G back panel, MSS provides full 10G capabilities. Ethernet Access Cards (EAC, EAC10G) can be used to interface UBT up to 10G connectivity.

The number and the type of peripherals can be configured according to the customer needs.

For MSS-4/8 here below the list of modules:

- CorEvo 10G and 1G: controller, switching function and Ethernet access
- EAC 10G and EAC: radio and ethernet user interface
- EASv2: radio and ethernet user interface performing carrier aggregation
- PDH and SDH user interface.

MSS family is completed by a series of indoor unit not based on plug in but with optimized interfaces:

- MSS-E: with several 1 / 2.5 Gbps and PDH traffic interfaces
- MSS-HE with several 1/ 2.5/10 Gbps and PDH traffic interfaces

MSS-E/HE can be used in conjunction with any UBT radio

2.1.2 UBT architecture

The UBT can be connected to a dedicated plug-in (EAC card or EASv2), directly to the corEvo card or to the MSS-E/HE is using optical or electrical GE cables according to the specific UBT.

Additionally the UBT may be deployed in Stand Alone mode without any MSS connection.

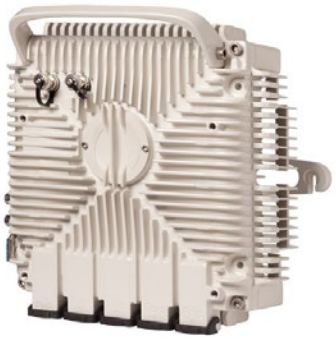
UBTs are available in 4 different variants:

- UBT- Twin (SM or SA)
- UBT – Single (SM or SA)
- UBT- m (80 GHz) (SM or SA)
- UBT-Compact (SM only)

2.1.2.1 UBT-T

The UBT-Twin is a “dual carrier in a box” configuration supporting traditional multiple microwave frequencies, up to 42 GHz.

Figure 3 UBT Twin



The UBT-Twin provides multi-gigabit capacity and low latency transport with best-in-class transmitted power.

The Nokia Wavence UBT-T implements a flexible product design, with a hardware split between the active wideband radio part and the Antenna Interface Module (AIM), a passive component interfacing the antenna.

The active part (dual transceiver) is a true wide band radio. It is not sub-band dependent, meaning that a UBT-T at a given frequency can support all sub-bands and all shifters specified for that frequency.

UBT–T is able to operate also in 2 different frequency range or with different channel spacing.

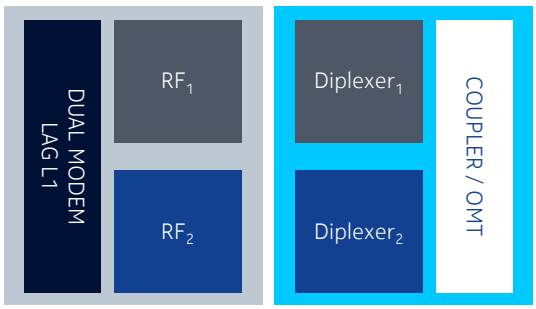
The solution with dual frequency (i.e. 11 and 32 GHz) is completed by a dedicated antenna.

The passive part (Antenna Interface Module) provides an interface between the antenna and the wideband active radio part. It is frequency dependent and embeds the diplexers, coupler or OMT, hence defining the exact frequency configuration.

Thanks to this innovative design, the UBT can support channels belonging to different sub-bands on the same box. This offers high flexibility in deployment options; the configuration specificities being managed inside the AIM.

Being purely passive, it doesn't require any replacement in field as it cannot be subject to faults.

Figure 4 UBT-T Architecture block diagram

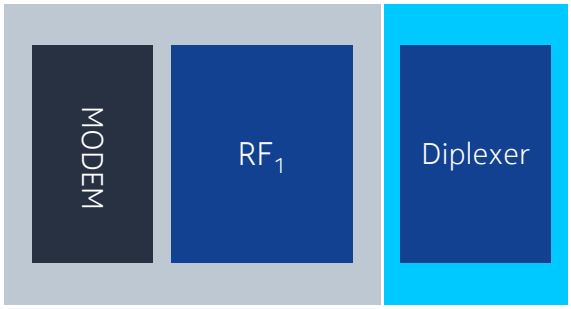


At low frequency (6-11 GHz) two different UBT-T version are available in the catalogue: standard power and high power. The AIM module is common for the two versions (standard power/high power).

2.1.2.2 UBT-S

The UBT-Single (or UBT-S) is the single carrier radio variant for traditional microwave frequencies, up to 42 GHz. UBT-S is sharing the same architecture as UBT-T having the active part in a separate unit vs the passive one.

Figure 5 UBT Single and architecture block diagram



UBT-m 80GHz is the E-Band radio system of the Wavence family, designed to reach extremely high capacity of 20 Gbps with XPIC. UBT-m can operate in split mount connected to MSS or on full outdoor configurations. Three variants are available:

- UBT-m, with 10G interfaces, XPIC support and up to 2 GHz
- UBT-m X, with 10G interfaces, XPIC support and up to 2 GHz and higher PTx
- UBT-m URBAN, with embedded 38 dBi antenna

Figure 6 UBT-m 80 GHz

UBT-m

UBT-mX

UBT-m URBAN

2.1.2.4 UBT-C

UBT-C is the compact version supporting traditional microwave frequencies and specifically studied for tail and enterprise applications. The passive part (diplexer) is integrated.

Figure 7 UBT-C and block diagram

2.1.3 MPT (for full indoor applications)

Wavence platform covers the need for urban, rural and backbone scope. The family is covering full indoor installation (4 GHz to 13 GHz), with dedicated transceivers and systems managed by the same SW

- MPT-HLS for ETSI market
- MPT-HLC for ANSI market
- MPT-HLC Plus for ANSI market with excellent performances in term of system gain and high modulation.

3. Main features

3.1 10G interfaces

The Nokia Wavence does offer full non-blocking 10 Gb/sec capabilities. This is achieved using a CorEvo-10G card pluggable in MSS-8/4, which provides 2 x 10 Gb/s SFP+ interfaces and embeds a 100Gb/s traffic switching matrix or using Ethernet Access card (EAC-10G) providing one additional 10G port per cards

Overall MSS-8 10G shelf can offer a total of 6x10 G ports (2 embedded in the corEvo and 1x4 EAC-10G cards) for a total user traffic of 60 Gbit/sec, while MSS4-10G can offer a total of 4x10G ports (2 embedded in the corEvo and 1x2 EAC-10G cards) for a total user traffic of 40 Gbit/sec.

UBT-S, UBT-T and UBT-m support 1x10G port each (additionally to 1 G ports), offering in this way for full outdoor application standard connection to routers or 4.5G/5G base stations.

MSS-HE offers 10 Gbps user and radio interface in a 0,5 U indoor unit and embeds a 60 GB/s switching traffic matrix. MSS-HE hosts 1 x Optical interfaces (SFP+) supporting 1Gb/2.5Gb/10Gb Ethernet in addition to several 1 xGbps interfaces.

3.2 Multiservice Ring Protection (ITU-T G.8032v2)

Multiservice Ring Protection is based on ITU-T G.8032 Ethernet Ring Protection Switching (ERPS), and provides sub-50 ms protection and recovery switching traffic in a ring topology, protecting all types of traffic: Ethernet, TDM E1/DS1, channelized SDH and transparent SDH (planned in a future release).

Each Ethernet Ring Node is connected to adjacent Ethernet Ring Nodes participating in the same Ethernet Ring, using two independent links. A ring link is bounded by two adjacent Ethernet Ring Nodes, and a port for a ring link is called a ring port. The minimum number of Ethernet Ring Nodes in an Ethernet Ring is two.

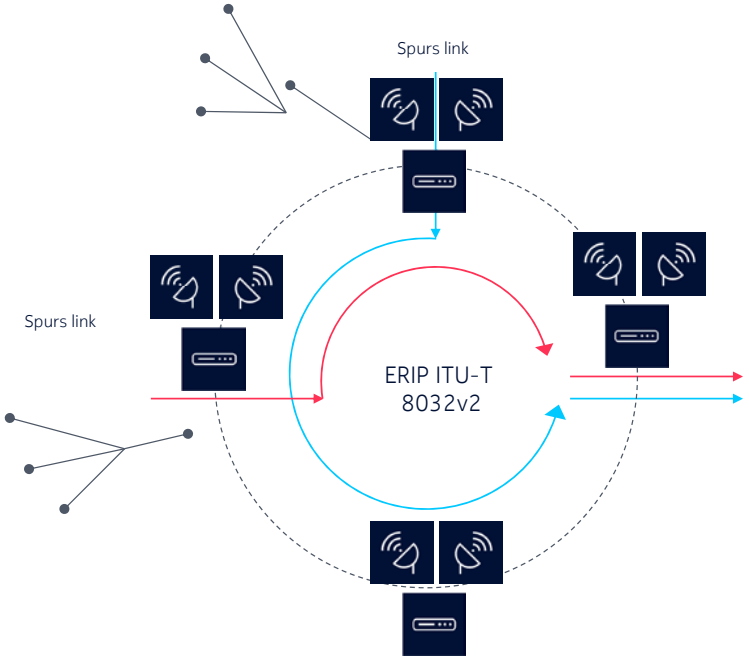
The fundamentals of this ring protection switching architecture are:

- The principle of loop avoidance.
- The utilization of learning, forwarding, and Filtering Database (FDB) mechanisms defined in the Ethernet flow forwarding function (ETH_FF).

Loop avoidance in an Ethernet Ring is achieved by guaranteeing that, at any time, traffic may flow on all but one of the ring links. This link is called the Ring Protection Link (RPL), and under normal conditions this ring link is blocked, that is, not used for service traffic. One designated Ethernet Ring Node, the RPL Owner Node, is responsible for blocking traffic at one end of the RPL. Under an Ethernet ring failure condition, the RPL Owner Node is responsible for unblocking its end of the RPL (unless the RPL has failed), allowing the RPL to be used for traffic. The other Ethernet Ring Node adjacent to the RPL, the RPL Neighbor Node, may also participate in blocking or unblocking its end of the RPL.

An Ethernet Ring failure results in protection switching of the traffic. This is achieved under the control of the ETH_FF functions on all Ethernet Ring Nodes. An automatic protection switching (APS) protocol is used to coordinate the protection actions over the ring.

The ring is implemented by east- and west-facing radio directions. Traffic can follow on both ring directions: clockwise and counter-clockwise.



Protection is triggered by physical criteria (no protocol intervention). Protection is based on R-APS messages sent on both sides of the ring by the nodes detecting the failure. Traffic is redirected by each node of the ring locally, ensuring parallel processing to speed up protection time.

- The ITU-T G.8032v2 algorithm operates on the VLAN, regardless of the type of traffic transported: TDM (TDM2TDM and TDM2ETH) and Eth (multiple CoS and services) traffic types can be protected
- Traffic flows (any type/priority) can be allocated on both ring directions to exploit the maximum ring bandwidth in normal conditions for best-effort traffic and to limit packet delay when traffic enters from different points of the ring.
- ITU-T G.8032v2 is supported on all MSS-1/MSS-4/MSS-8 units.
- Synchronization is managed through SSM messages.
- Carrier aggregation configuration can be supported inside the ring, with optional error-free adaptive modulation configured. A carrier aggregation link with N channels is declared “faulty” when all the N channels of the link are operationally down.
- The Wavence does support ITU-T G.8032v2 in mixed configuration as well, meaning that some links can be microwave and some links can use fiber.
- With the CorEvo-10G card, the Wavence offers 10G ring capability.
  - In a complete fiber ring using the 2 x 10 Gb/s interfaces, the total capacity carried is up to 10 Gb/s.
  - In a microwave application
    - the maximum capacity carried is 2.5 Gb/s with MPT
    - In case of UBT-m connected to EAC card the maximum capacity can reach 10Gbps

3.3 Ethernet features

The Wavence provides several service interfaces and it is also able to provide a wide assortment of service interfaces by configuring appropriate service interface boards.

The LAN interface supports jumbo frames up to 9280 bytes.

3.3.1 Level-2 addressing

The address management function is performed in the switch through the address table (Level 2 Table) that can manage up to 65,536 entries in the switch. New entries are automatically learned when a packet is received on the port.

The aging process periodically removes dynamically learned addresses from the “address resolution table.” The default aging time is 300 seconds. Aging time can be configured.

3.3.2 IEEE 802.3x flow control

In case of incoming Ethernet traffic leading to exhaustion of buffers on input queues, PAUSE frames are transmitted from the switch to a remote peer to slow down the traffic (if the peer supports flow control).

In the other direction, when the switch receives a pause frame on a specific port from peer equipment, the switch stops the packet transmission on that port until it receives a pause frame with resume transmission command.

Fully effective flow control (no packets lost inside the network) requires that all devices in the end-to-end path support flow control.

The flow control function is supported only when the capability is full duplex.

The flow control setting on the switch ports linked to user Ethernet ports must be consistent with the setting on the user ports.

3.3.3 VLAN management

- Supported services: Ethernet services (EVCs)
  - E-Line (point-to-point)
  - E-LAN (multipoint)
- Support for VLAN: The Wavence supports up to 4096 VLANs.
- IEEE 802.1Q: This standard allows of partition of the switch ports into virtual private domains.
- The 802.1Q VLAN tagging feature can be enabled including the stripping or adding of the tag and VLAN lookups in addition to MAC lookups (this feature can be useful for re-routing TMN traffic to the controller).
- The IEEE 802.1Q VLAN tagging feature can be enabled or disabled (be transparent for the VLAN). It can be useful to logically break a physical LAN into a few smaller logical LANs and to prevent data flow between the sub-LANs, dropping non-VLAN frames.
- IEEE 802.1ad: Stacked VLAN (Q-in-Q)
  The switch supports double tagging according to IEEE 802.1ad, in particular:
  - Adding a service VLAN on the ingress traffic, per-port or per-service VLAN
  - pbits value of service VLAN is a) user configurable and b) the same value as the customer VLAN

The EtherTypes supported are:

  - EtherType 0x8100
  - EtherType 0x9100
  - EtherType 0x88A8

- Port based rate limiting: It is possible, on a per-port basis, to define an ingress/egress port rate limit. Per-port ingress rate control is used to meter and limit the rate of data stream input. If the ingress rate exceeds the limit configured, the switch can either transmit flow control or drop the frame. If the egress rate control is enabled, the traffic exceeding the configured threshold is dropped. Granularity is 64 kb/s.
- Per flow policer: This is the ingress rate limiter per VLAN, dropping the traffic exceeding a given committed information rate (CIR) value.
- Per CoS policer: This is the ingress rate limiter per CoS, dropping the traffic exceeding a given CIR value. The rate limiter is applied to a tagged Ethernet flow classified according to the value of VLAN ID and PCP fields of the VLAN tag. One VLAN ID value and one PCP value identifies the flow.
- Broadcast storm control: This is the ingress rate limiter on broadcast traffic.
- Multicast storm control: This is the ingress rate limiter on broadcast frames.
- Destination Lookup Failure (DLF) storm control: DLF refers to frames having a unicast destination MAC address, which is not present in any port MAC lookup table. These packets are typically flooded to all switch ports. The storm control limits the broadcast of such frames.
- MAC address control list: Only packets with SA inside a given list are transmitted toward the radio.
- IEEE 802.1AX: Link Aggregation: Link Aggregation allows two or more Ethernet links to be aggregated together to form a Link Aggregation Group (LAG), consisting of N parallel instances of full duplex point-to-point links operating at the same data rate. Link aggregation can be used for two main purposes:
  - Traffic Aggregation, using L2 hashing algorithm and spreading the traffic over multiple interfaces
  - Link Protection, achieved mainly with static LAG, where one link of the group is active and the other(s) is in stand-by condition
- Frame distribution: Frame distribution over Ethernet interfaces inside the LAG is based on Ethernet switch hashing function. Two options can be selected for the hashing function:
  - L2 Hash (DMAC, SMAC, VLANID, Ethertype)
  - L3 Hash (IPdst, IPsrc, TCP/UDP dst port, TCP/UDP src port)
- IEEE 802.1AX Link Aggregation with LACP is supported by ports belonging to corEvo card or by ports belonging to EAC cards (same card or different EAC card). 802.1AX is often used to achieve interface protection: in this case two ports of Wavence IDU are connected to another device 802.1AX-capable. If two Ethernet ports belonging to two different EAC cards are used (with 802.1AX and LACP) are used, equipment protection is achieved too.

3.3.4 Quality of service

- UBT QoS management is supported by:
  - Scheduler queues: 12 queues
  - Scheduling: Strict priority, WFQ, combination of Strict priority and WFQ
  - Frames discard: Tail drop
  - Buffer sizes: 60 MB per queue, 8 x 60 MB = 480 MB total
- MSS buffer size:
  - CorEvo: 16 Mbit total
  - EASv2: 8 Mbit total
  - MSS-E and -HE: 16Mbit total

The frame buffer size is a function of the frame size.

- Priority classification

The priority for traffic class (TC) queue mapping is based on whether the port is trusted/tagged or not. The following options are supported:

  - DSCP value in IP header
  - TC field bits in MPLS header
  - Reuse priority bits in C-tag (Q-tag, VLAN) or S-tag

3.3.5 IEEE 802.3ag/ITU-T Y.1731 - Ethernet Service OAM

Ethernet Service OAM (IEEE 802.3ag/ITU-T Y.1731) provides network end-to-end Ethernet L2 OAM capabilities. The supported Connectivity Fault Management (CFM) functions are:

- Continuity Check (CC) – CC is a proactive OAM used to detect loss of continuity between pairs of maintenance end points (MEPs). Optionally Port status TLV and Interface status TLV can be used to supervise the status of the transmitting MEPs interface or switch port.
- Remote Defect Indication (RDI) – Proactive OAM function used by a MEP to communicate to its peer MEPs that a defect condition has been encountered
- Loopback (LB) – Unicast; on-demand OAM function used to verify connectivity of a MEP with its peer MEP (or a maintenance intermediate point [MIP]). A MEP can optionally use Data TLV; for example, to verify connectivity for jumbo frames.
- Link Trace (LT) - On-demand function used for fault localization

3.3.6 IEEE 802.3ah – Ethernet Link OAM

Ethernet link layer OAM, based on the IEEE 802.3ah specification, enables service providers to monitor and troubleshoot a single Ethernet link. The following features are supported

- Discovery: Identifies devices in the network and their OAM capabilities. It uses periodic OAM Protocol Data Units (PDUs) to advertise OAM mode, configuration and capabilities; to advertise PDU configuration and platform identity.
- Remote loopback: Puts the remote link partner into loopback mode so that every frame received is transmitted back on the same port. This is used to ensure the quality of links during installation or troubleshooting.

3.3.7 Y.1731 Bandwidth Notification Messages

Wavence installed in split mount and standalone supports Y. 1731 bandwidth notification messages.

Reference standard is I**TU-T G.8013/Y.1731: OAM functions and mechanisms for Ethernet based networks.**

In particular, Clause 7.13 deals with Ethernet bandwidth notification (ETH-BN)

- The current microwave bandwidth can be signaled to a router, using the ITU-T G.8013/Y.1731 bandwidth notification message (BNM) protocol. Frames with ETH-BN information carry the current and nominal bandwidth of the microwave link. On receiving frames with ETH-BN information, the router can use bandwidth information to adjust service policies, e.g. to reduce the rate of traffic being directed towards the degraded link.

3.4 Carrier aggregation

Modern methods combine two or more radio channels to create a higher capacity virtual link have several names, including channel bonding, radio link aggregation (LAG) and carrier aggregation. Although all methods use multiple channels to scale microwave capacity, implementations and efficiency levels can differ.

Carrier aggregation refers to the capability to aggregate multiple carriers in same frequency band or in different frequency bands over the same link.

Wavence family is supporting carrier aggregation

- In same frequency band (intra band carrier aggregation)
- In different microwave band (microwave + microwave)
- Combining a microwave with millimeter frequencies

In fact combining multiple frequencies bands over the same link Wavence could provide several benefits, on top of plain throughput increase, leading to an efficient use of the available spectrum. Two different working modes are available in Wavence platform for different requirements.

- **Mode 1: Carrier aggregation on homogeneous nodes.**
  This functionality is mainly applicable to links that are meant to combine homogeneous radios or channel spacing, being the primary application new links. It is applicable also to upgrade of throughput for installed microwave links.
- **Mode 2: High capacity link upgrade**
  This operating mode is applicable mainly to upgrade existing links when an E band or a UBT-T high capacity link is added increasing in strong way throughput, maximizing the re-usage of the installed base.

In case of mode 1 the traffic is distributed packet by packet while in case of mode 2 the load balancing is performed at flow level.

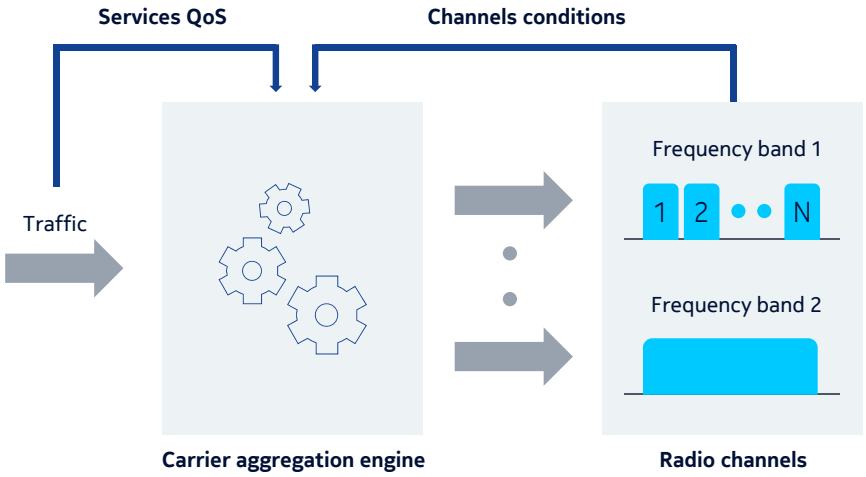
Please check roadmap for availability of different options.

Carrier aggregation mode 1 is designed to work with features such as:

- High-order adaptive modulation
- Carrying legacy TDM services as packet traffic together with IP traffic

The engine performing the packet distribution is based on an algorithm that guarantees maximum availability for the high priority traffic. The engine is receiving real time communications from the different channels with respect to available capacity (vs propagation conditions), such as hitless switch is guaranteed when fading occurs.

Figure 9 Carrier aggregation diagram

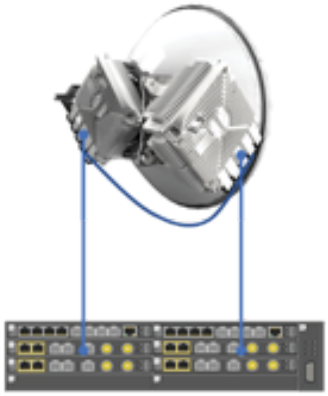


Wavence carrier aggregation is offering a very high efficiency and the total throughput for a group of 2 (or more) radios is equal to the sum of single radio throughput. The overhead introduced is totally negligible.

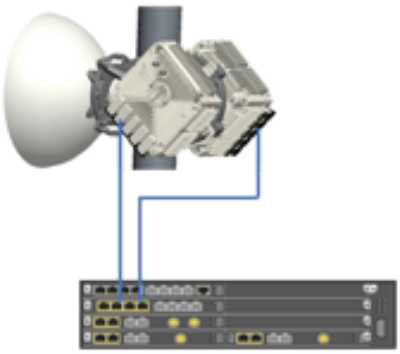
The mechanism implemented is also offering the possibility to mix in the same link MPT and UBT radios.

For all use cases maximum capacity for carrier aggregation is derived from hardware capabilities: with EASv2 card it is up to 2.5Gbps, while with EAC and UBT or with UBT full outdoor radio maximum throughput is 10Gbps.

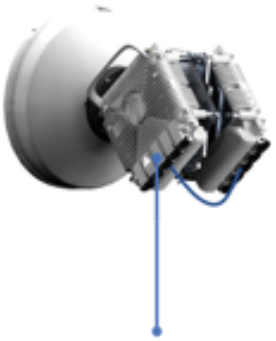
Figure 10 carrier aggregation examples



CA 10G 3+0 UBT-m + UBT-T
in split mount, connection to MSS8/EAC
with dual band antenna



CA 2, 5G 4+0 UBT-T
in split mount, connection
to MSS8/EASv2

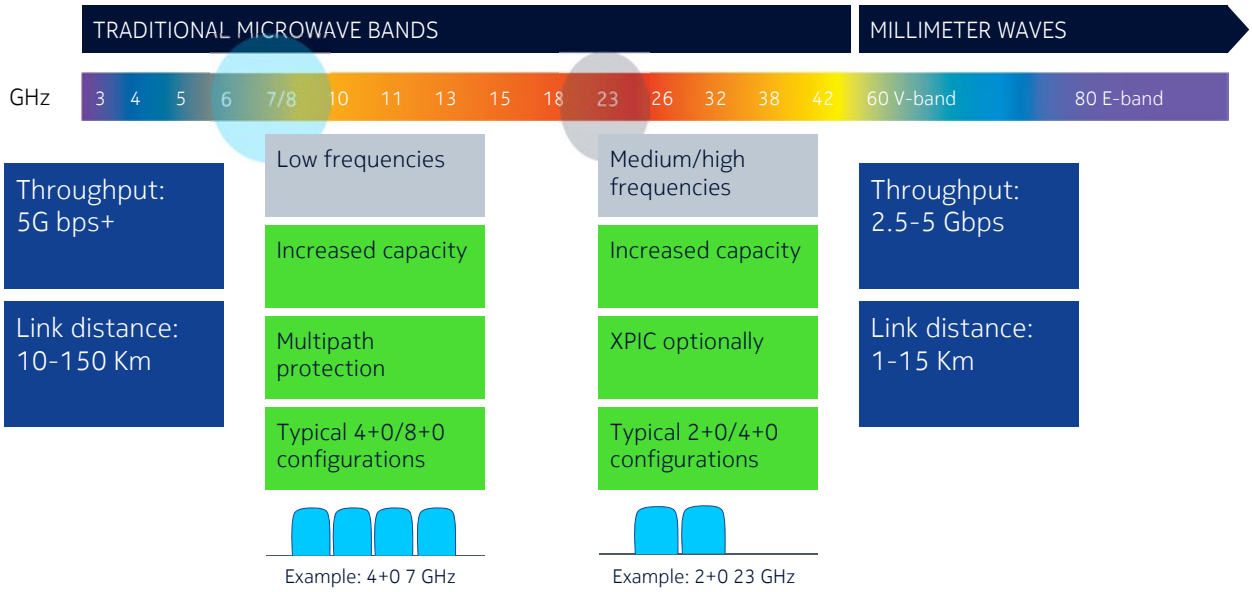


CA 10G, UBT-m 2+0
in standalone

Carrier aggregation intra band

1) Aggregation of two or more uWave carriers belonging to same frequency band.

Figure 11 Carrier aggregation intra band



This case refers to aggregation to two or more channels (up to 8) belonging to same frequency band. This case is applicable to UBT-T or UBT-S and MPTs.

The carriers can have the same channel spacing or different one.

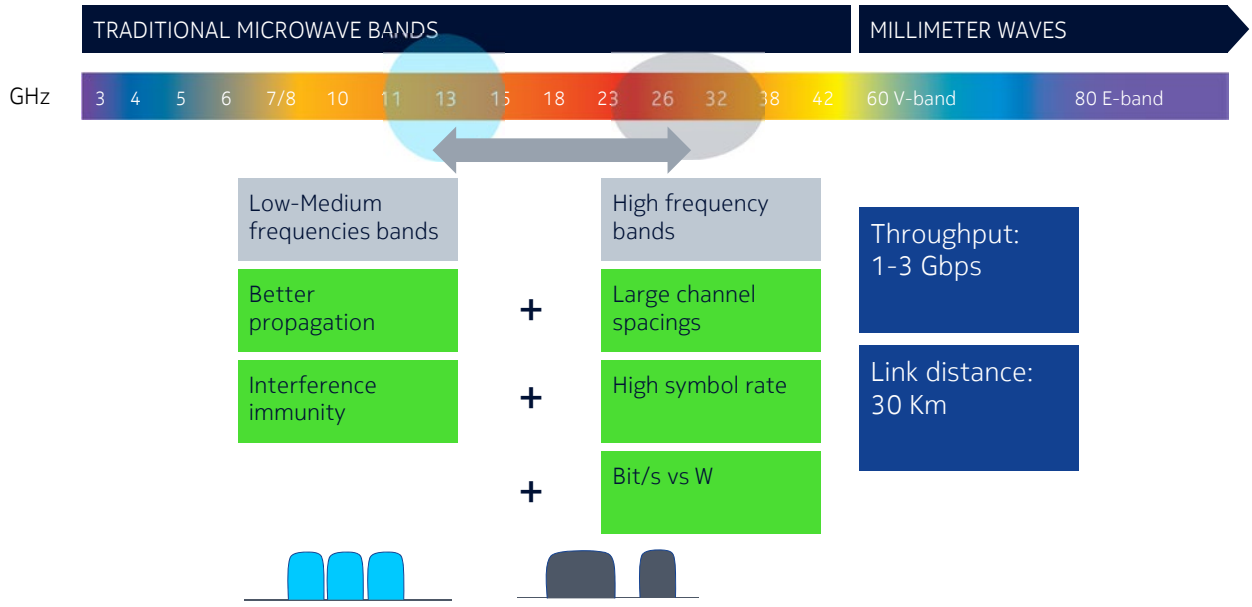
The main application is to increase the capacity carried by the radio link.

In case of long links where low frequency are mainly applicable the carrier aggregation is also a very efficient way to counteract propagation phenomena. For this specific case and N+1 protection scheme replacement please check the dedicated chapter.

3.4.1 Carrier aggregation microwave + microwave

Aggregation of two or more uWave carriers (any band from 6 to 42GHz).

Figure 12 Carrier Aggregation microwave + microwave



Such use case refers to the aggregation between two or more uWave equipment (UBT-S or UBT-T).

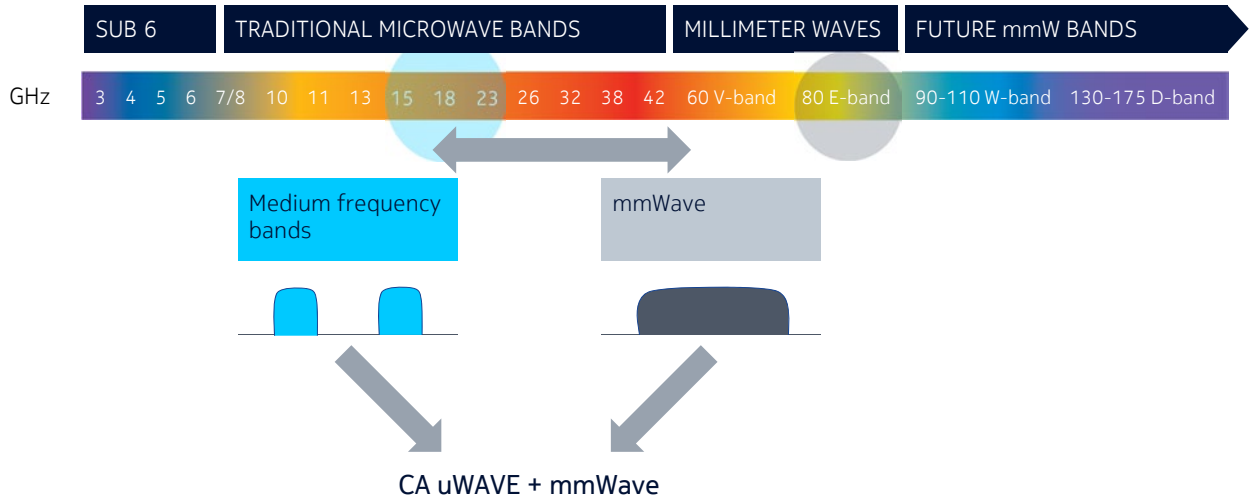
The main objective is to increase total capacity exploiting available spectrum. In many cases in fact the required bandwidth cannot be found in a single band due to spectrum congestion.

An interesting aggregation is the one involving low/medium frequency bands, providing capacity increase with a link length in rural environment (e.g. 20km), combining over the same link frequencies such as 13 and 23 GHz. Specific sub-cases of this option are UBT-T supporting wide band RF capability: UBT-T at 7-8 GHz, 10.5-11 GHz, 13-15 GHz, 24-26 GHz and 28-32 GHz offers the capability to select whatever channels in the supported frequency range, including to have one channel (as pure example) working at 13 GHz and one cannel working at 15 GHz.

3.4.2 Carrier aggregation microwave and millimetre frequency

1) Aggregation of one/two microwave carriers and one E-band carrier

Figure 13 Carrier aggregation microwave + millimeter wave



Such use case refers to the aggregation between microwave equipment (UBT-S or UBT-T) and UBT-m 80GHz.

The main objectives are to boost the throughput and to increase the link coverage in order to reuse Eband in suburban areas (e.g. 7-10 km).

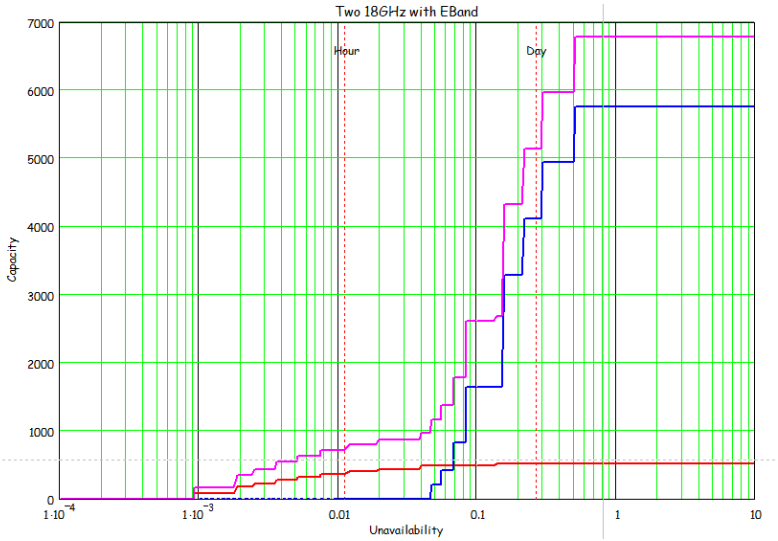
The most interesting frequency bands to be aggregated with E-band are in the range 13 to 23 GHz. In fact, in such case the microwave frequency would provide high availability for high priority traffic (some hundreds Mbps), while mmWave would provide additional traffic (multi-Gbps) with lower but decent availability.

Carrier aggregation between two frequency bands can always use two different antennas (one per each band attached to the related UBT). For some combinations dual-band antennas will be introduced in order to optimize the installation. Such options include:

- 18/80 GHz (2ft)
- 15/80 (2 ft)
- 23/80 GHz (2ft)

Here is an example of network design (capacity in Mbps vs unavailability in %) performed by aggregating one UBT-T at 18GHz and one UBT-m 80GHz with 1 GHz channel spacing for a 7.5 km link:

Figure 14 Network design example for carrier aggregation



Traditional frequency can grant 200 Mbps at more than 99.99%, while Eband can boost throughput (more than 5 Gbps) with just 1-day yearly unavailability.

In Standalone, Carrier Aggregation 10G is supported with 2 UBT:

- UBT-m + UBT-m (2+0)
- UBT-m + UBT-T (3+0)
- UBT-m + UBT-S (2+0)
- UBT-T + UBT-T (4+0)
- UBT-S + UBT-S (2+0)

3.4.3 Carrier aggregation intra band for long haul application

Unlike traditional N+1 technique to scale microwave link capacity, carrier aggregation systems do not require spare protection channels to protect link capacity. Instead, carrier aggregation systems use the concept of spare capacity across a bundle of active channels.

Carrier aggregation algorithm distributes traffic load evenly based on algorithms that do not leave channels underutilized or impact services, even in the event of a channel failure: it does not require each channel in a bundle to have the same capacity as the most demanding service.

Wavence multichannel carrier aggregation has a unique algorithm that outperforms native TDM or hybrid technology provided by Nokia microwave competitors in long haul. These legacy technologies supported by competitors statically allocate radio capacity per service type (TDM/SDH or Ethernet) leading to poor capacity repartition per services and possible waste of throughput. In fact, radio time-slot division implies a fixed distribution of capacity to multiple services.

When adaptive modulation is used, a channel does not have to be in an “on” or an “off” state; it can be in a partially working state, although at a reduced capacity. In the rare case where the capacity available in the multichannel bundle is lower than requested, high-priority committed traffic is preserved and only best-effort traffic is discarded.

From a network design standpoint, the probability of delivering the committed traffic is very high. That is because the degradation on one channel can be compensated with the excess capacity available on other channels in the bundle. In Nokia implementation, the adaptive modulation changes and the reallocation of traffic from one channel to the other is completely hitless on high-priority traffic.

Traditional N+1 link protection mechanism do not support the spare capacity concept when scaling and protecting microwave links. If channel capacity drops, all traffic is moved to a dedicated protection channel, stranding any remaining capacity on the degraded channel.

3.5 Synchronization

Synchronization distribution is very often needed in transmission networks. The specific customer need depends on the final application - for example, in the case of mobile backhauling networks, “frequency” or “frequency and phase/ToD” synch distribution might be required depending on the RAN technology, such as 5G, LTE, 3G, 2G, etc. Multiple interfaces and multiple flavors of synch signals must be taken into account in a transmission network.

The Wavence family supports the following:

- Synchronous Ethernet (SyncE), a mechanism to transfer frequency over the Ethernet physical layer as specified by ITU-T G.8261. As SyncE uses the physical layer, it is immune to traffic load and packet delay variation. SSM according to G.8264 are supported.
- 1588 T-TC (Telecom Transparent Clock).
  T-TC is supporting the synch distribution via IEEE 1588. The basic principle behind “T-TC on path support” on a transport node is that local delay experienced by each 1588 packet is evaluated and then stored into the “correction field” of the 1588 packet. Consequently, 1588 slaves after this node can use “correction field” information to compensate for the variable delays introduced by the intermediate nodes.

  Wavence implementation is compliant with ITU-T profiles and performance targets (high accuracy ClassB in ITU-T G.8273.3).
- 1588 T-BC (Telecom Boundary Clock).
  T-BC is supporting the synch distribution via IEEE 1588. “T-BC on path support” on a transport node improves the E2E quality of the synch distribution, increases the scalability of the 1588 solution and allows for quality monitoring on intermediate nodes. 1588 BC takes into account the delay within the slave clock function and relays a new reference clock with the master function. BC provides a reliable phase synchronization normally needed with 5G.

  Wavence implementation is compliant with ITU-T profiles and performance targets (high accuracy ClassB in ITU-T G.8273.2).

  1588 T-TC and BC are supported also in case of UBT-T/s and UBT-m in split mount in carrier aggregation.

  1588 T-TC is supported also for UBT in full outdoor configurations.

3.6 Layer 3 Virtual Private Networks (L3 VPN)

Wavence supports Layer 3 Virtual Private Network (L3VPN) services. Nokia products refer to this type of services as Virtual Private Routed Network (VPRN).

These services can be activated and managed through Nokia NSP (Network Services Platform).

The equipment implements a standard IP/MPLS forwarding plane.

Both IPv4 and IPv6 VPN addressing schemes are supported. The IP/MPLS underlay infrastructure is IPv4-based.

L3 services can coexist (in the same node and in the same interface) with L2 and TDM flows. This is a clear benefit for smooth migrations from existing network deployments to new ones requiring routing capabilities.

Linear and tree network topologies can be implemented via the usage of a static IP/MPLS infrastructure provisioning via static routes and static LSPs. Using NSP, the path placement operations can be automated to reduce the amount of manual operations that this deployment would involve.

Whenever more enhanced scenario shall be supported (e.g., ring and meshed topologies), Wavence provides control plane capabilities for topology discovery and tunnel creation to populate the network infrastructure. With this feature set, the following functionalities are supported:

- Automatic propagation of IP/MPLS information to network nodes or IGP listeners used for IGP topology discovery – IGP is based on OSPFv2 (i.e., IPv4-based Data Plane) and Segment Routing (SR) extension for label distribution
- Support of redundant topologies (e.g., ring, partial/full-mesh) through the SPF (Shortest Path First) calculation
- Automatic traffic restoration in case of link/node failures

Supported redundant topologies include, but are not limited to, ring networks. Exploiting the path computation capabilities, any topology can be supported: each node is capable to identify the best path among the multiple ones (even more than two). It's possible to combine as an example, as alternate East/West direction:

- Fiber with any radio (e.g., MPT/UBT, 1+0, 1+1, 2+0, 2+2 and LAG)
- Radio with radios (with the above variability)
- Fiber with fiber

From a different perspective, other combination like a 2xN+0 direction (comprising two links in parallel) can be combined with a third one.

The redundant topology support is composed of two different functionalities working together: the dynamic routing through OSPFv2 and Segment Routing for both label distribution (OSPF Segment Routing extensions) and protection mechanisms.

VPRN service creation requires the management of the entire IP/MPLS data plane stack including IP data plane, MPLS LSP and L3 VPN services. In the following sections, each of those layers will be explained.

3.6.1 IP Data Plane

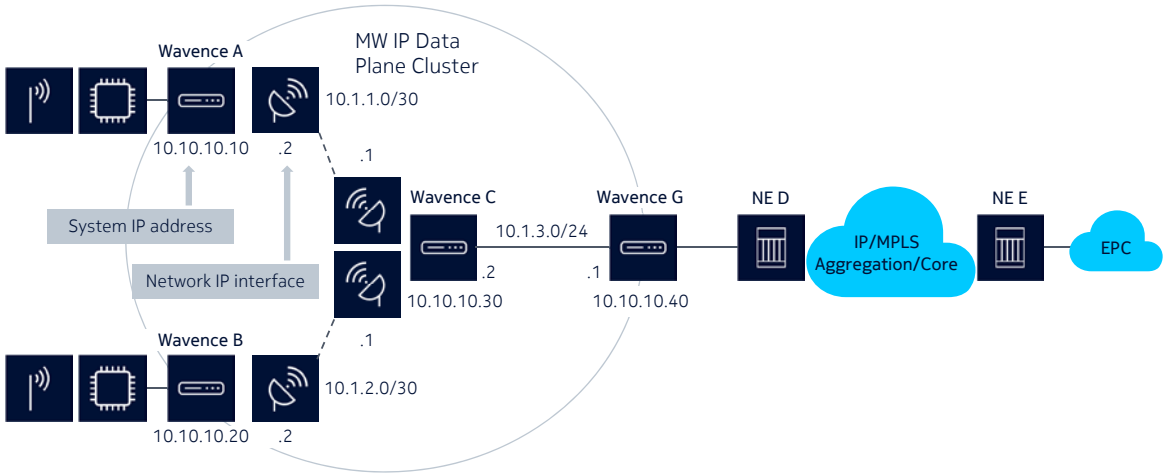
IP data plane enables Wavence routing capabilities.

A system IP interface is associated to the system (with an associated /32 IP address). This IP address is used globally into the network to identify a specific node.

Additionally, network IP interfaces are created on radio or user interfaces the relevant IP information.

Network IP interfaces can be associated to any MSS-4/8 Core-Evo based platform interface: Core, EAC and EASv2 boards 1+0/1+1 Radio interfaces (both MPT and UBT), L1 LAG interfaces (both Intra and Cross board), Carrier Aggregation, Ethernet LAGs and User Ethernet ports.

An IP data plane VLAN separates IP Data Plane traffic from other services.



The IP data plane can be provisioned in two manners: via static routes or running IGP – OSPF so that all the necessary routing information are available in the node.

OSPFv2 is supported for the distribution of the IPv4 IP data plane information like system IP, network IP interfaces and to identify the next hop to be used to reach them.

An OSPF instance can be created in the node to manage the protocol mechanisms and configurations. OSPF interfaces can be created and associated to existing network interfaces.

Router ID, by default, is inherited from the node system IP; it can be provisioned by the user with a different value.

Wavence supports the Area Border Router (ABR) function.

Stub areas are supported as well through the user association of this attribute to a given area.

Additionally, ASBR functions can be configured to manage static route redistribution into the OSPF domain.

Route preference for OSPF routes are supported. A different route preference can be associated to static routes as well in order to arbitrate between static and dynamic deployed information.

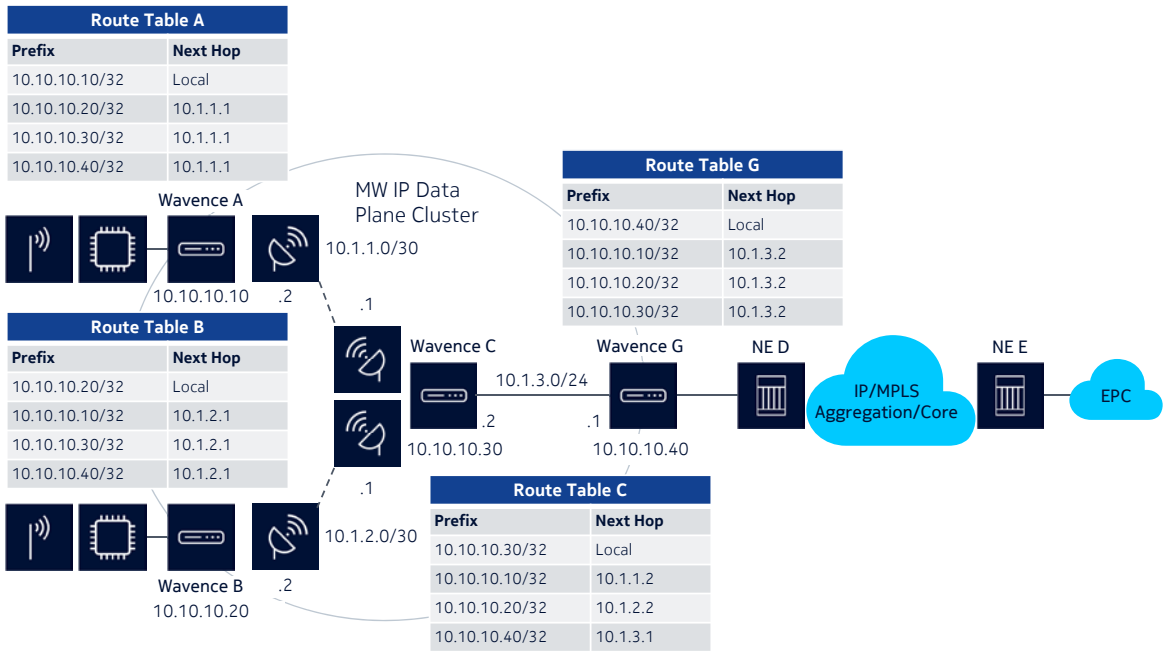
Whenever a network interface has a lower layer redundancy mechanism configured (e.g., 2+0, 1+1, LAG L1), OSPF interface's consequent action is evaluated after the lower layer processes' ones are accomplished. In any failure condition, the lower layer algorithm has a higher priority and consequent actions at OSPF level are triggered whenever those protection mechanisms failed to recover.

Each interface supports either point-to-point or broadcast interface type. This attribute is user configurable and it is point-to-point by default. The system supports the Designated Router (DR) and Backup DR (BDR) election. In case of point-to-point type, this algorithm is disabled to speed-up in interface and adjacency bring up.

Metrics are supported and are user configurable.

To avoid or minimize any traffic impact during core protection switchover, Wavence implements graceful restart according to RFC 3623.

IP troubleshooting tools (ping and traceroute) are available to verify the IP data plane connectivity. A comprehensive set of additional debug interfaces can be used to assess the control and forwarding plane status.



3.6.2 MPLS

MPLS layer is provisioned statically by NSP providing label forwarding information necessary to connect PE nodes.

MPLS configuration is based on Segment Routing.

A Segment Routing Global Block (SRGB) is defined in every node. It represents the MPLS label range each network element is allowed to use. SRGB is a local property of the node (i.e., there could be a different range in each node) and shall be used consistently in the label signaling operations so that adjacent nodes send the traffic to the next-hop according to its own SRGB.

The system shall support two type of SID label range mode: a global mode and a per-instance mode. In the global mode, the entire SRGB label range is used; per-instance mode requires the configuration of the label range subset associated to Segment Routing LSPs.

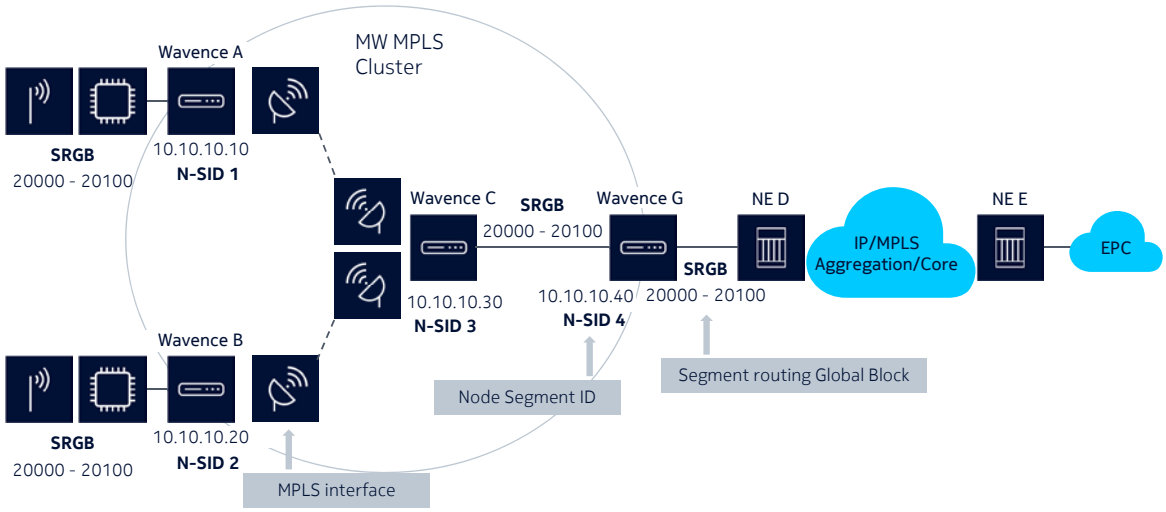
A Node SID (Segment ID) is associated to each node. It has a global significance and shall be unique. Node SID is used as an index in the SRGB to identify the MPLS label to be used for label switching operations.

MPLS interfaces are in charge of managing MPLS traffic in the ingress/egress directions.

As similar as the IP data plane provision, the MPLS layer management options are twofold.

A static approach via the provisioning of Static LSP (Label Switched Path) and label map tables and a dynamic one using OSFP and Segment Routing signaling.

In case of static approach, at the PE node (Ingress LER), the system allows the configuration of an LSP to reach the desired remote PE node.

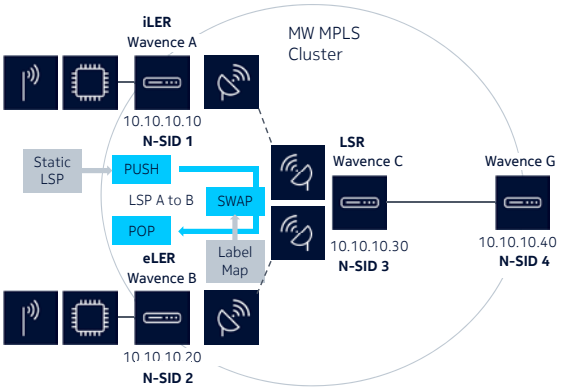


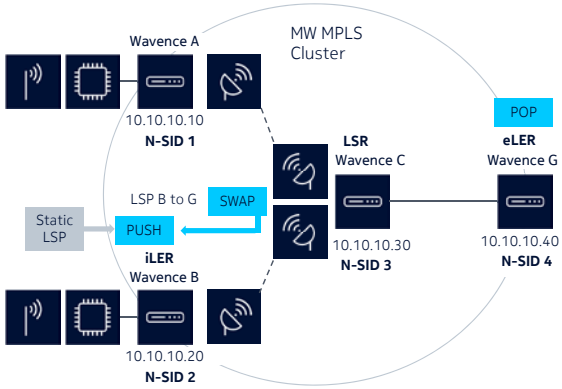
At the LSR/Egress LER, the system allows the configuration of a Label Map to instruct the node on the way it has to manage traffic at the ingress MPLS interface (e.g., based on ingress label, swap operation and forward to an egress MPLS interface; pop operation for LSP termination).

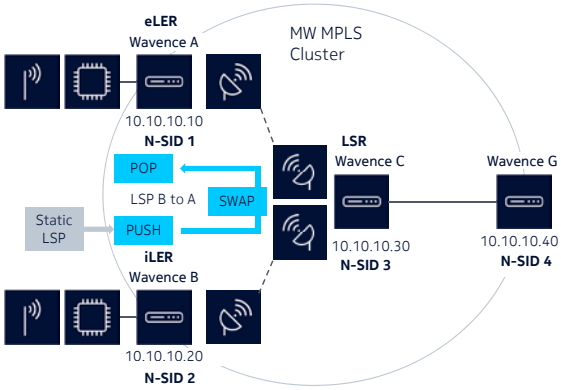
Through the support of IGP protocols extensions to negotiate and signal Segment Routing/MPLS information all along the topology, the dynamic deployment scenario can automatically populate the MPLS layer forwarding plane.

MPLS labels to be used in the forwarding plane are calculated according to local and remote (i.e., other nodes') Node SID and SRGB.

Among all the possible paths connecting two NEs, the system selects the one according to the IGP SPF (Shortest Path First) algorithm. SR LSPs are created automatically into the network to connect the entire MW topology in a full-meshed manner.





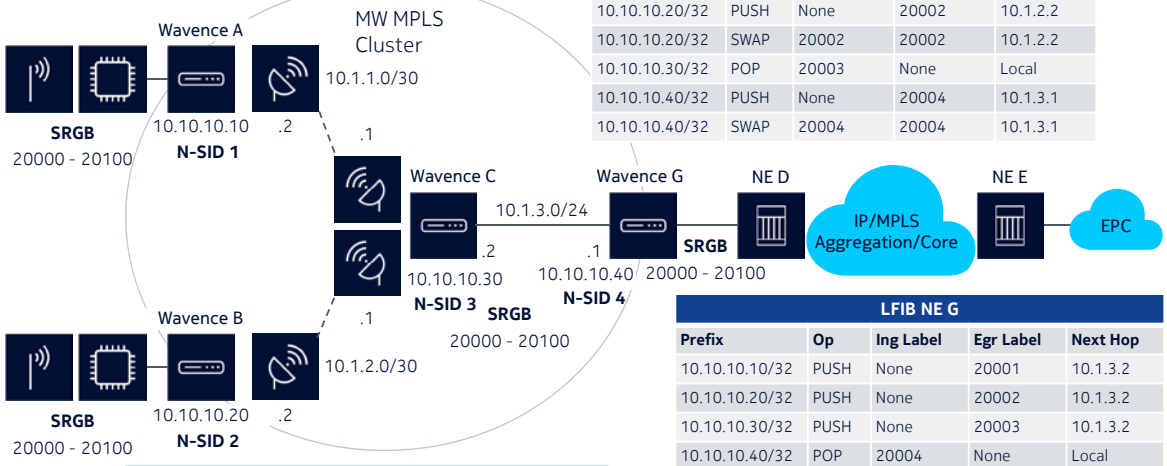


LFIB Wavence A

Prefix	Op	Ing Label	Egr Label	Next Hop
10.10.10.10/32	POP	20001	None	Local
10.10.10.20/32	PUSH	None	20002	10.1.1.1
10.10.10.30/32	PUSH	None	20003	10.1.1.1
10.10.10.40/32	PUSH	None	20004	10.1.1.1

LFIB Wavence D

Prefix	Op	Ing Label	Egr Label	Next Hop
10.10.10.10/32	PUSH	None	20001	10.1.1.2
10.10.10.10/32	SWAP	20001	20001	10.1.1.2
10.10.10.20/32	PUSH	None	20002	10.1.2.2
10.10.10.20/32	SWAP	20002	20002	10.1.2.2
10.10.10.30/32	POP	20003	None	Local
10.10.10.40/32	PUSH	None	20004	10.1.3.1
10.10.10.40/32	SWAP	20004	20004	10.1.3.1



LFIB NE G

Prefix	Op	Ing Label	Egr Label	Next Hop
10.10.10.10/32	PUSH	None	20001	10.1.3.2
10.10.10.20/32	PUSH	None	20002	10.1.3.2
10.10.10.30/32	PUSH	None	20003	10.1.3.2
10.10.10.40/32	POP	20004	None	Local

LFIB Wavence B

Prefix	Op	Ing Label	Egr Label	Next Hop
10.10.10.10/32	PUSH	None	20001	10.1.2.1
10.10.10.20/32	POP	20002	None	Local
10.10.10.30/32	PUSH	None	20003	10.1.2.1
10.10.10.40/32	PUSH	None	20004	10.1.2.1

3.6.3 VPRN services

PE (Provider Edge) nodes deal with L3 customer traffic at the boundary of the provider network. They instantiate VRPN instances and the associated VRF (Virtual Routing and Forwarding) function to route customer traffic towards the destination (i.e., egress local interface or remote PE node). The connection among PE node is provided by the MPLS transport layer described in the previous section.

Multiple VPRNs can be created in a node.

Additionally, one or more SAP (Service Access Point) is associated to the VPRN. SAP is the logical access interface for customer's IP traffic, and it is associated to a port/C-VLAN pair to classify the customer traffic and associate it to the related VPRN service (NOTE: customer traffic is supposed to be C-VLAN tagged).

SAP can be associated to:

- user ports
- Ethernet LAGs
- radio interfaces

Multiple SAPs can share the same physical port. Traffic mapping is performed thanks to a C-VLAN classification. SAP sharing the same physical port can belong either to the same VPRN or to different ones.

VPRN interfaces are created in the system acting as IP interfaces in the customer network address space. VRPN interfaces are provisioned with their IP interfaces information and they are associated to existing SAPs.

VPRN interfaces associated to different VPRN can use the same addressing so that IP addresses can be reused on different services. If VPRN interfaces belong to the same VPRN, IP address overlapping is prevented.

The VRF table of each VRPN instance is configured statically through the provisioning of Static Routes.

The system supports default static routes.

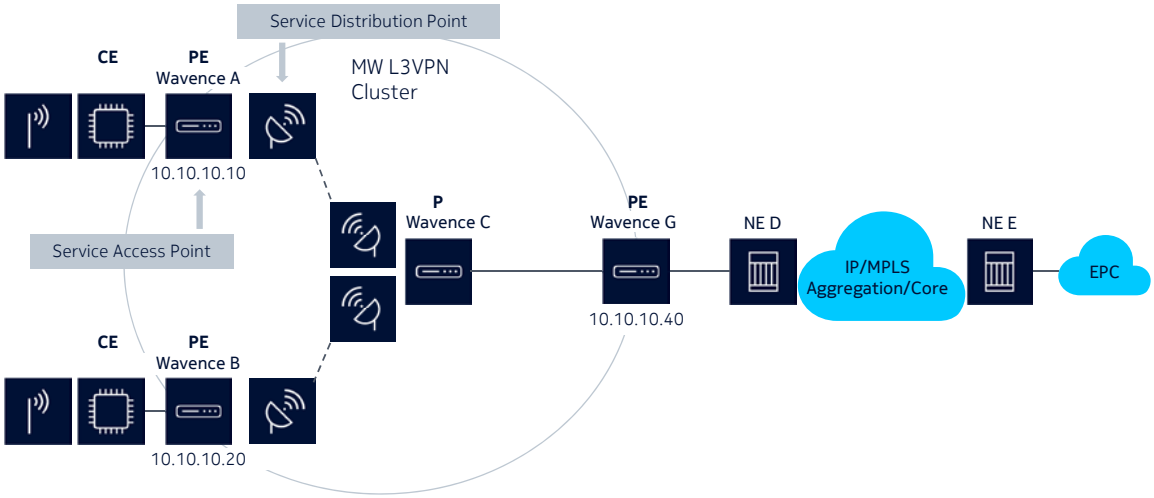
The system supports static routes configuration using blackhole next-hop, allowing the traffic discard of any traffic matching with the provisioned prefix. This capability can be used either as an ACL mechanism or to tailor the PE end-point reachability creating full meshed or hub & spoke topologies.

A VC (Virtual Circuit) Label is provisioned as well, so that an MPLS Service Label is pushed in the MPLS label stack and the traffic, at the remote PE, can be associated to the proper VRF function.

These parameters can be automatically provisioned by NSP, on behalf of control plane signaling protocols (i.e., MP-BGP).

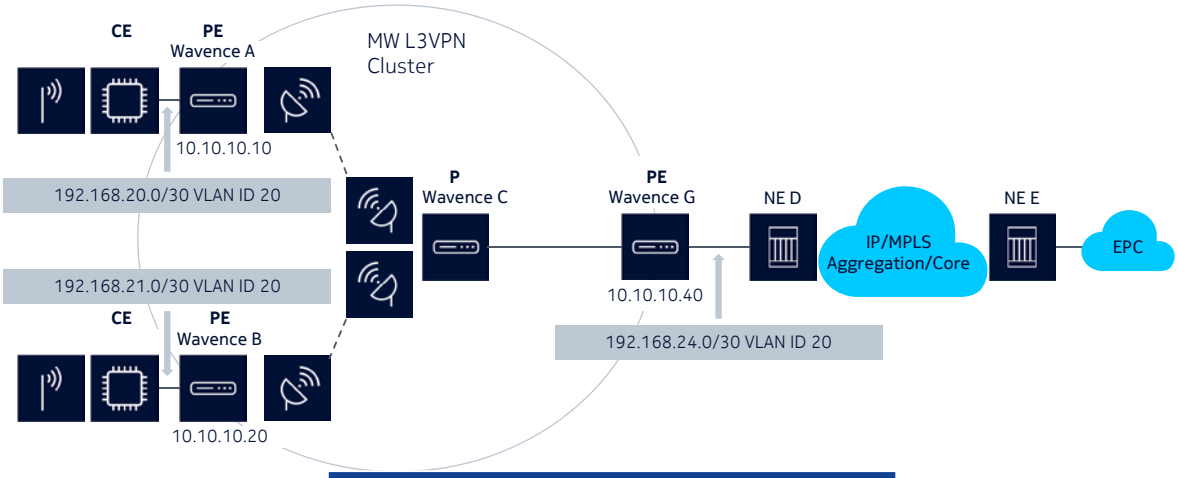
An SDP (Service Distribution Point) is a logical representation of the transport tunnel that shall be used to deliver the service data to the egress PE. The transport tunnel to be associated to the SDP is the Static LSP or Segment Routing LSP towards the remote PE. SDP uses the system IP address to identify the remote PE. This association is done automatically creating the SDP with that specific LSP type

The SDP provide the binding between the service labels and the transport tunnel. To make a VPRN service to use an SDP for distribution, the service shall be joined to the SDP using SDP binding i.e. Spoke SDP.



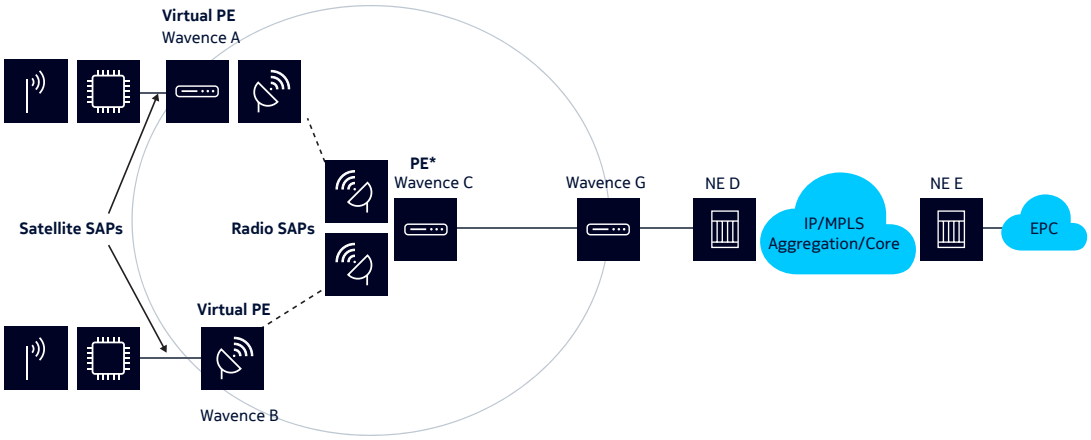
Wavence A		
VPRN 200 Route Table (VRF)		
Prefix	**Next Hop**	**VC Label**
192.168.20.0/30	Local	None
192.168.21.0/30	10.10.10.20	2000
192.168.24.0/30	10.10.10.40	2000

Wavence G		
VPRN 200 Route Table		
Prefix	**Next Hop**	**VC Label**
192.168.24.0/30	Local	None
192.168.20.0/30	10.10.10.10	2000
192.168.21.0/30	10.10.10.20	2000



Wavence B		
VPRN 200 Route Table		
Prefix	**Next Hop**	**VC Label**
192.168.21.0/30	Local	None
192.168.20.0/30	10.10.10.10	2000
192.168.24.0/30	10.10.10.40	2000

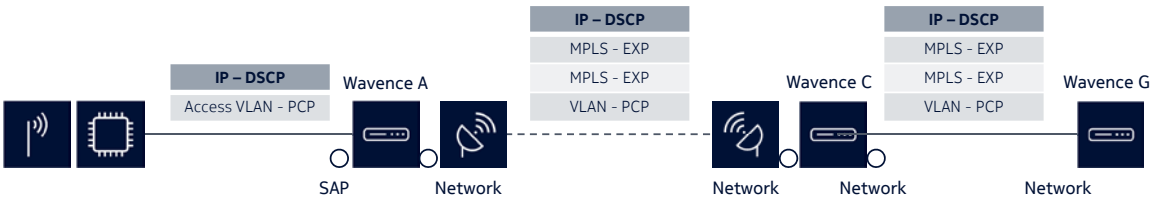
SAPs can be deployed on radio interfaces and the VPRN service can be extended to hybrid scenarios combining L2 and L3 transport technologies. The L3 service end-points are extended towards customer premises via the usage of service extension capabilities (e.g., physical link or VLAN services). Radio and Ethernet SAP can be combined on the same node to provide the best flexibility in any deployment scenario.



IP troubleshooting tools (ping and traceroutes) are supported and can be generated either by CE or PE equipment to test the connectivity with other CE/PE/customer nodes/nodes external to the MW L3VPN cluster.

The management of QoS is performed by four main functions:

- Classification of ingress traffic at SAP Ingress and Network Ingress to assign a forwarding class (FC);
- Mapping FC to egress queue at SAP Egress and Network Egress;
- Marking egress traffic at Network Egress interface;
- Scheduling the traffic out of the egress queues.



SAP ingress policy classification supports both PCP and DSCP.

Remarking of customer DSCP field is not supported.

Marking of EXP bits is done at the first Network Egress interface. EXP bits of both MPLS LSP Label and Service Label are marked with the same value. Remarking of EXP bits at any other Network Egress interface is not supported.

Since VLAN Tag is always removed at ingress and added as egress (for both SAP and Network interfaces), marking of PCP bits is always performed at SAP Egress or Network Egress interface.

The management of QoS at both ingress and egress side is made by means of QoS Policies.

3.6.5 NSP management

The Carrier SDN service fulfilment functionalities are provided by the means of two important components of the Nokia Network Services Platform (NSP) solution: NSD (Network Services Director) and NFM-P (Network Function Manager for Packet). NSP is conceived as a platform allowing the customer to choose the modules required for their needs.

NFM-P represents the state-of-the-art in terms of NMS capabilities being able to create a complete network topology and resource view and operate the network through configuration, maintenance and monitoring capabilities. In this specific Carrier SDN application, NFM-P acts as a topology manager and mediation function allowing NSD to deploy services.

Different models applied depending on the level of control plane enabled in the network:

- NFM-P either runs path computation algorithms to identify the shortest path to a specific destination and distribute routing and MPLS information as a consequence of that
- Or, in case of OSFP and Segment Routing scenarios, it's used to discover the network signaled topology and information to be used for the later service provisioning and assurance

NSD provides the service automation capabilities via its Service Fulfillment application. The service provisioning process is easily abstracted with an intuitive resource visualization and a configuration process that minimizes the amount of information that the user has to provide. The application has an important role in the configuration of multi-domain scenario streamlining the end-to-end deployment thanks to its network topology and resource awareness.

Following capabilities are provided by NSP:

- Node and physical topology discovery
- Configuration of the IP data plane and Segment Routing infrastructure (automation of Node SID assignment and SRGB default ranges are required)
- Discovery of the IGP topology and static/SR LSPs and consequent visualization of those entities through GUI – consistently with the end-to-end Nokia user experience
- Creation of L3 VPN services (both IPv4 and IPv6) and service end-points
- Service binding to either static or SR LSP
- QoS policies management
- Launch troubleshooting tests
- Management of operative states, alarm and statistics. These capabilities are exposed through the assurance NSP web applications (e.g., Fault Management, Analytics, Service Supervision, ...)
- Expose supported functionalities through GUI and NBI

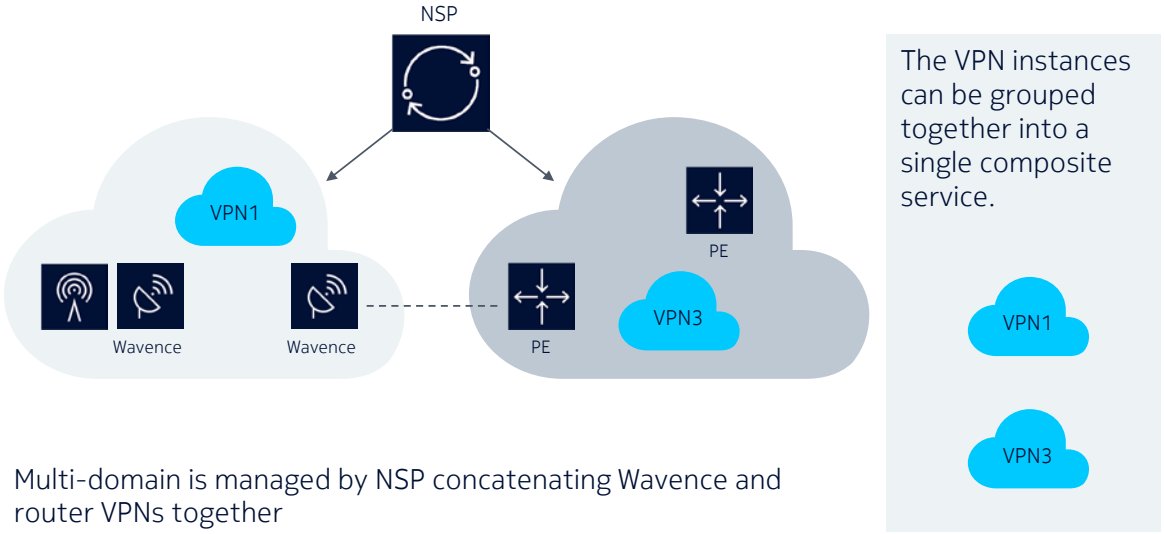
Both Meshed and Hub&Spoke (H&S) service topologies can be provisioned through NSD.

3.6.5.1 Multi-domain

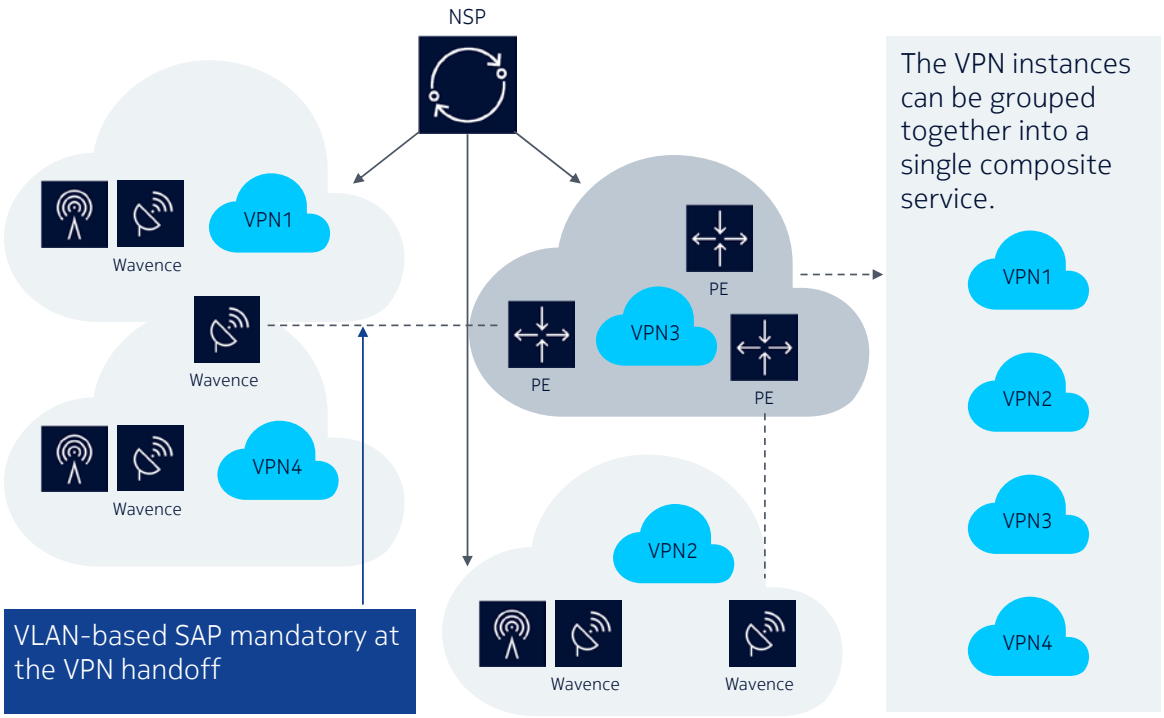
L3 VPN can be deployed in a single-domain scenario where the feature scope is limited to a Wavence-only topology and the service access points belong to Wavence nodes.

Service management can be extended to a multi-domain scenario where one or more Wavence clusters are connected to an aggregation IP/MPLS domain.

Multi-domain scenarios are managed according to Inter-AS VPN Option A. Route redistribution among domains is performed through static route provisioning.

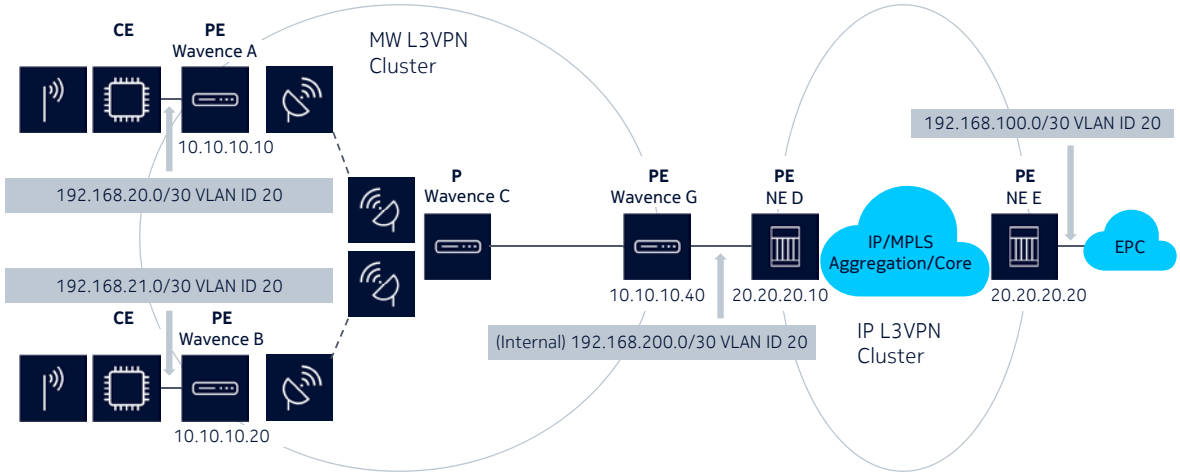


Multi-domain is managed by NSP concatenating Wavence and router VPNs together



Service fulfilment operations allow the creation of an end-to-end service selecting end-points from Wavence and IP/MPLS access interfaces.

End-to-End Service provisioning



Wavence A

VPRN 200 Route Table (VRF)

Prefix	Next Hop	VC Label
192.168.20.0/30	Local	None
192.168.21.0/30	10.10.10.20	2000
192.168.200.0/30	10.10.10.40	2000
192.168.100.0/30	10.10.10.40	2000

NE E

VPRN 100 Route Table

Prefix	Next Hop	VC Label
192.168.100.0/30	Local	None
192.168.20.0/30	20.20.20.10	5000
192.168.21.0/30	20.20.20.10	5000
192.168.200.0/30	20.20.20.10	5000

Wavence G

VPRN 200 Route Table

Prefix	Next Hop	VC Label
192.168.200.0/30	Local	None
192.168.20.0/30	10.10.10.10	2000
192.168.21.0/30	10.10.10.20	2000
192.168.100.0/30	192.168.200.2	None

Wavence D

VPRN 100 Route Table

Prefix	Next Hop	VC Label
192.168.200.0/30	Local	None
192.168.20.0/30	192.168.200.2	None
192.168.21.0/30	192.168.200.2	None
192.168.100.0/30	20.20.20.20	5000

In case of H&S service topologies, NSD deploy default static routes to route the traffic to the hub site in the IP/MPLS domain and prevents traffic routing among spoke sites.

3.7 SDN, Analytics and Network Automation

Next generation networks require an advanced service management with a strong flexibility to support new services and optimize costs.

NSP (Network Services Platform) is the Nokia solution for carrier-grade SDN deployment introducing service automation and network optimization capabilities all over the Nokia transport portfolio.

Combining NSP service management with Wavence portfolio, user can easily deploy the desired services requiring performance targets (e.g., throughput, reliability, latency). NSP and Wavence joint interworking takes care of the optimized service configuration exploiting the network resource available in real-time. As an example, UBT-m links can be used to allocate low-latency services while other services can be moved to traditional bands.

Network topologies are evolving as well going towards ring or meshed deployments. Due to the several degrees of freedom (topologies offering different paths to the same destination, different physical resources, dynamic service demands) a centralized SDN controller like NSP helps the user in the service creation offering the network abstraction. NSP can be also integrated in a hierarchical architecture for multi-domain scenarios and interworking with orchestrators.

3.7.1 NETCONF protocol support

NETCONF protocol is supported according to RFC 6241.

The transport protocol is SSH as it is described in RFC 6242 (NETCONF over SSH).

NETCONF Call Home defined by RFC 8071 is supported as well. Call home is generally useful for both the initial deployment and ongoing management of networking elements. The network element may proactively “call home” after being powered on for the first time in order to register itself with its management system.

3.7.1.1 Radio management

The management of radio configuration is made available through the support of TR-532 Microwave Model (version 1.1)

TR-512 Core Information Model is supported to allow the proper representation of the network element and radio interfaces at system level.

System supports all MPT and UBT radio types connected to any MSS interface.

Supported configurations are:

- Radio parameters
- 1+1
- Carrier aggregation

A set of proprietary extensions are embedded in the model to manage Wavence capability not represented natively in the standard ONF model

Alarm notifications and monitoring capabilities are provided as defined by TR-532 model.

3.7.1.2 Equipment inventory

The system exposes through NETCONF the equipment information for inventory purpose.

Equipment is represented through TR-512 Core Information Model.

Equipment information are:

- MSS type (MSS-4, MSS-8)
- MSS peripherals (boards, ports, SFPs)
- Radio peripherals (MPTs, UBTs)

Equipment provisioning operations is performed through WebCT and properly notified to NETCONF.

3.7.1.3 Fault management

Alarm notification specified by supported ONF model is managed.

Additionally, to have a consistent fault management capability through NETCONF, it's supported notifications of all Wavence alarms. Since many of these alarms are not represented in the ONF models, alarm notifications shall be communicated through the signalling of the impacted resource and alarm description.

4. Hardware components

4.1 UBT-T and UBT-S

4.1.1 UBT-T

The Wavence UBT-T (T stands for Twin) implements a modular design, with hardware split between the active wideband radio part and the Antenna Interface Module (AIM), a passive component interfacing the antenna. Thanks to this design, the UBT-T can support channels belonging to different sub-bands on the same box. This offers high flexibility in deployment options, the configuration specificities being managed inside the AIM, thus simplifying the installation, maintenance and spare part management.

Figure 15 UBT Twin: exploded view

UBT-T can cover the following radio configurations with one ODU:

1. 1+0
2. 2+0 Copolar / Alternate Polar/XPIC

The UBT-T can address both Full-Outdoor and Split-mount architecture using the same hardware.

4.1.2 UBT-S

The Wavence UBT-S (S stands for Single) implements an innovative product design, equivalent to the one implemented in UBT-T, with hardware split between the active wideband radio part and the Antenna Interface Module (AIM), a passive component interfacing the antenna. This simplifies maintenance and spare part management.

Figure 16 UBT-S exploded view

UBT-Single can cover the following radio configurations:

3. 1+0
4. 2+0 Copolar / Alternate Polar/XPIC (with 2 ODUs)

The UBT-Single can address both Full-Outdoor and Split-mount architecture using the same hardware.

4.1.3 UBT-S/UBT-T summary

UBT-T	UBT-S
• Full IP packet radio system • Ethernet port 1G / 2.5G / 10G • WideBand RF • High PTx and excellent System Gain • Two carriers radio platform • Radio/Modem capacity up to 2.5 Gbps • Each carrier running from 7 to 120 MHz • Each carrier running independently in FCM / ACM from 4QAM up to 4096 QAM • Embedded XPIC • Embedded Carrier Aggregation • Minimized latency • SynchE and 1588 TC/BC capable • PoE capable or separate DC power • DC + PoE redundancy • SDN support • Dual frequency in one box UBT-T (11+32GHz)	• Full IP packet radio system • Ethernet port 1G / 2.5G / 10G • WideBand RF • High PTx and excellent System Gain • Radio/Modem capacity up to 1.2 Gbps • Channel Spacing from 7 to 120 MHz • Modulations from 4QAM up to 4096 QAM • XPIC support • Minimized latency • SynchE and 1588 TC/BC capable • PoE capable or separate DC power • DC + PoE redundancy • SDN support

4.1.4 Radio capabilities

The UBT-T and UBT-S provide excellent radio capabilities in all bands. Please refer to technical summary for details.

In 6/7/8 and 11 GHz, in addition to the standard power version, a UBT-T and UBT-S HP (High Power) variant is proposed to be used for long haul links

UBT-T and UBT-S support modulations from QPSK up to 4096QAM

In case of UBT-T XPIC is supported between 2 carriers on same transceiver. XPIC is embedded inside the UBT-T and does not require any external cable. In case of UBT-S XPIC is performed between two different transceivers with a dedicated cable.

The 2 carriers in UBT-T can even have different channel spacing.

UBT-T dual frequency is supported: 11 and 32 GHz are supported in one ODU.

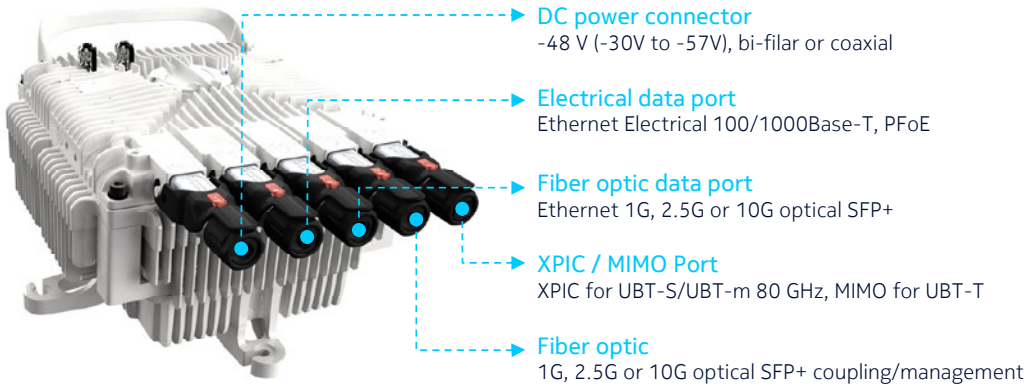
4.1.5 Interfaces

UBT-T and UBT -S provide the following interfaces:

- DC port: the same connector can host bi-filar or coaxial cable
- 100/1000 Base T RJ45 (up to 1 Gbps), PFoE capable
- Optical port (SFP 1 / 2.5Gbps or SFP+ 10 Gbps) for data
- Optical port (SFP 1 / 2.5Gbps or SFP+ 10 Gbps) for coupling with another UBT or management
- XPIC / MIMO port (used in UBT-S for XPIC in this release)

100/1000 Base T RJ45 is used as default management port or as user port.

Figure 17 UBT-T interfaces



For all ports, Outdoor Connector Transceiver Inside System (OCTIS) connectors are used, allowing easy manipulation.

Figure 18 OCTIS connector (Outdoor Connector Transceiver Inside System)

In Split-mount configuration, several speeds are supported, from 1 G to 10G, including a 2.5 Gbps interface which provides operators with an optimized cost for many configurations.

4.1.6 Frequencies support

Frequency	Part Numbers	Frequency range (MHz)
6 GHz	1	5726-7125
6 GHz HP	1	5726-7125
7 GHz	1	7107-8497
8 GHz		
7 GHz HP	1	7107-8497
8 GHz HP		
10 GHz	1	10000-11705
11 GHz		
10 GHz HP	1	10000-11705
11 GHz HP		
13 GHz	1	12700 - 15400
15 GHz		
18 GHz	1	17699 - 19701
23 GHz	1	21198 - 23639
24 GHz	1	24050 - 26980
26 GHz		
28 GHz	1	27500-33383
32 GHz		
38 GHz	1	37050 - 40000
42 GHz	1	40550 - 43500

4.2 UBT-C

The UBT-C is a 1G Compact version. It targets simple configurations.

The UBT-C is integrated in the Nokia Network Services Platform for common management and fully compatible with the Nokia Microwave Service Switches (MSS) and the rest of the Nokia microwave portfolio.

The UBT-C can address both Full-Outdoor and Split-mount architecture using the same hardware.

4.2.1 Overview

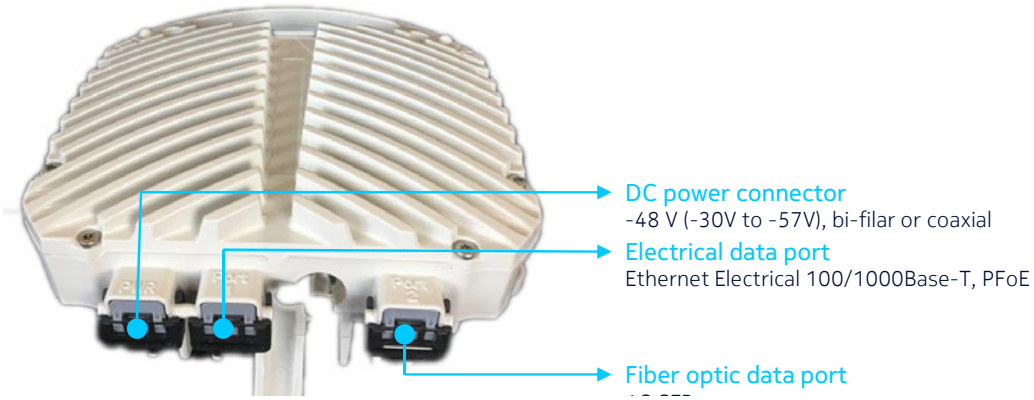
- Full IP packet radio system
- High PTx and excellent System Gain
- Capacity up to 1 Gbps
- Channel Spacing from 7 to 112 MHz
- Modulations from 4QAM up to 4096 QAM
- Minimized latency
- SynchE and 1588 TC capable
- PFoE capable or separate DC power
- DC + PoE redundancy
- Compact mechanical shape: 265 x 265 x128 mm
- Power consumption 44W

4.2.2 Interfaces

UBT-C provides the following interfaces:

- DC port: the same connector can host bi-filar or coaxial cable
- Electrical port 100/1000 Base T RJ45 (up to 1 Gbps), PFoE capable
- Optical port (SFP 1 Gbps) (not used in this Release)

Figure 19 UBT-C interfaces



For all ports, Outdoor Connector Transceiver Inside System (OCTIS) connectors are used (same as UBT-S/T), allowing easy manipulation.

4.2.3 Frequencies support

- 6GHz Duplex spacing : 252 MHz, 340MHz
- 7GHz Duplex spacing :150 MHz, 154MHz, 161 MHz,
- 8GHz Duplex spacing : 119/126 MHz, 294/305/311 MHz
- 13 GHz Duplex spacing : 266MHz
- 18GHz Duplex spacing : 1008MHz, 1560MHz
- 15 GHz Duplex spacing : 420MHz, 490MHz
- 23 GHz Duplex spacing : 1008MHz, 1232MHz
- 38 GHz Duplex spacing : 1260MHz

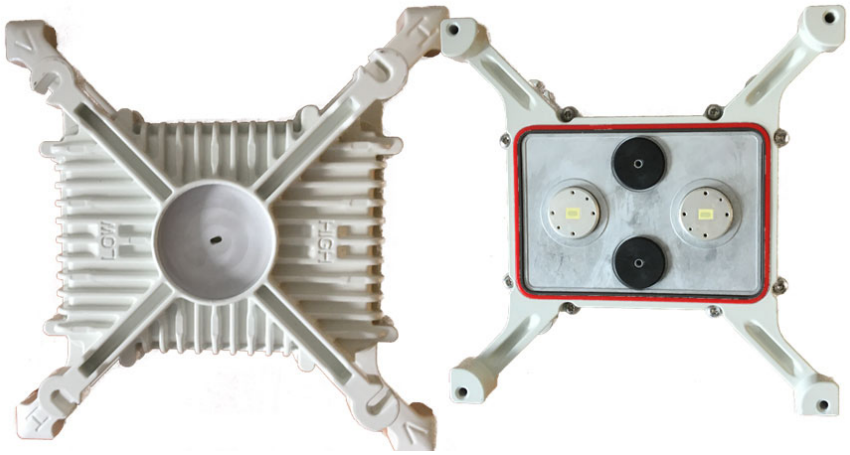
4.3 Antenna interface Module

All UBT-S and UBT-T need an AIM to be installed on an antenna.

Figure 20 Antenna interface module

The AIM-S contains one diplexer. The same AIM is used on both ends of a link. The HW piece is simply rotated to transform the ODU from Low (transmit frequency f1, receive frequency f1') to High (transmit frequency f1', receive frequency f1).

Figure 21 AIM-S

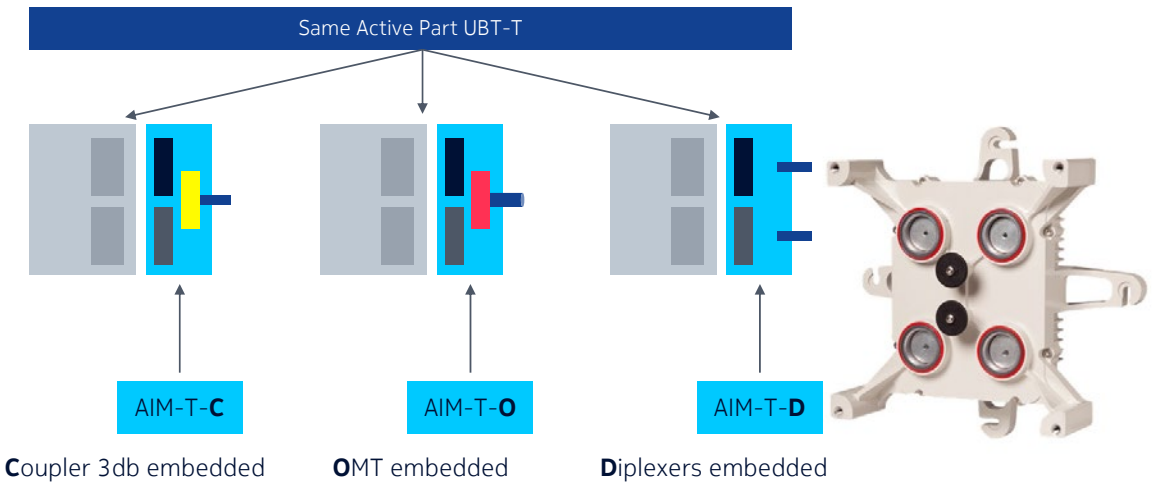


AIM-S (towards antenna) | AIM-S (internal face towards UBT)

There are 3 flavours of AIM-T:

- AIM-T-C : contains 2 diplexers + 1 Coupler (3dB)
  - Main target configuration 2+0 Copol in one box
- AIM-T-O : contains 2 diplexers + 1 OMT
  - Main target configuration 2+0 Alternate Polar (including XPIC) in one box
- AIM-T-D: contains 2 diplexers
  - Main target configurations 2+0 with not integrated antennas and 4+0 XPIC with OMT-C.

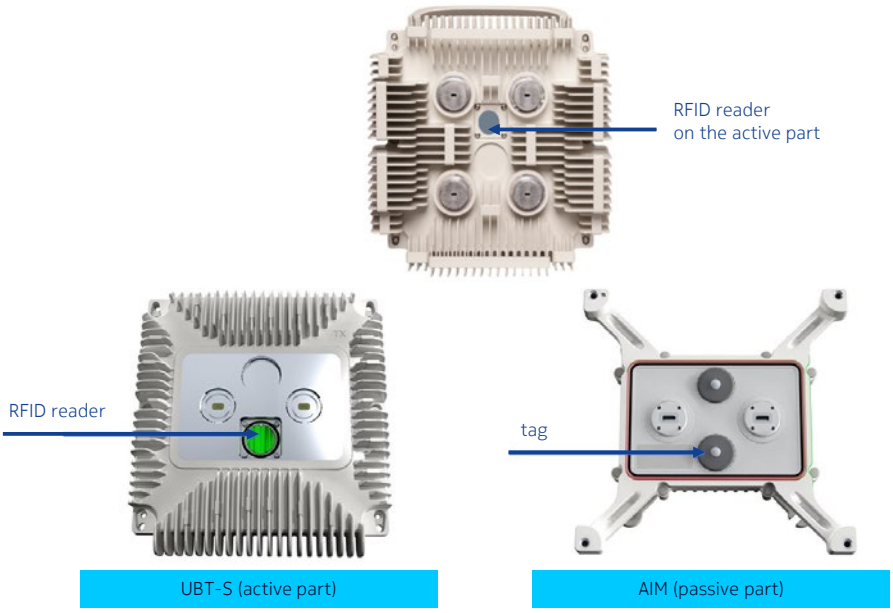
Figure 22 Different AIM-T type



A mechanism has been implemented to automatically retrieve the radio capabilities of the AIM (and consequently of the ODU).

This mechanism is based on RFID: the AIM supports a RFID tag which contains the capability of the AIM. At UBT switch-on, the reader (in the active part) illuminates the tag and retrieves the information. Consequently, it is no longer necessary to manually select the shifters from a long list.

Figure 23 RFID reader



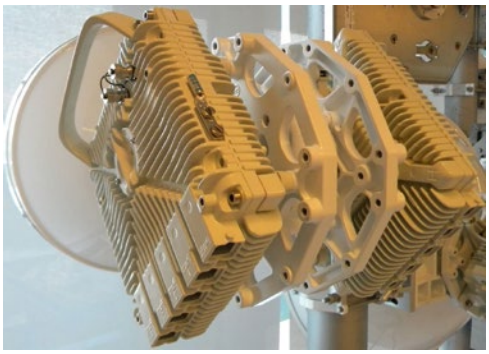
4.3.1 External couplers

Figure 24 External couplers

A coupler is used to connect two UBT-T with AIM-T-C or two UBT-S, to an integrated antenna (single polarization). It allows a 4+0 or 2+0 configuration respectively. Two versions are available: an equal-split 3 dB/3 dB coupler recommended for the above configuration, and an unequal-split coupler with nominal 1 dB/10 dB insertion losses on main/standby paths.

4.3.2 External Ortho-Mode Transducer

Figure 25 OMT

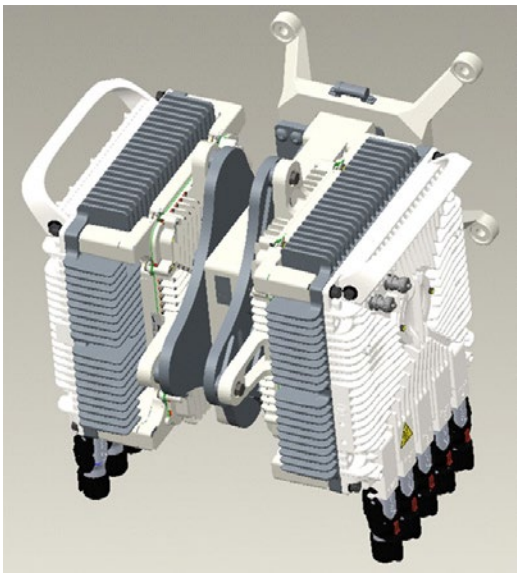


External OMT are available all bands from 6 to 42GHz. They can be used both with UBT-S (2+0, with or without XPIC) and UBT-T with AIM-T-C (4+0 without XPIC).

These OMT are available bundled with antennas (RFS or Tongyu) but also as stand-alone for upgrades of RFS antennas.

4.3.3 OMT-C

Figure 26 OMT-C



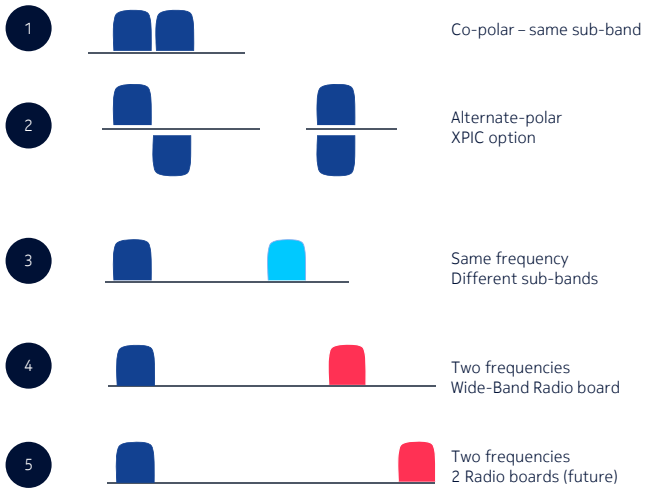
OMT-C combines in one device a first level with two balanced couplers and a second level with an OMT. It is available in all bands from 6 to 42GHz.

Attached to an integrated antenna Dual Pol (the same used with AIM-T-O), it allows mounting two UBT-T with AIM-T-D to achieve a 4+0 configuration on two polarizations. XPIC can be performed inside each UBT-T (frequency reuse). OMT-C are delivered separately and ate compatible both with RFS and Tongyu antennas.

4.3.4 Configurations supported with one UBT-T

The figure here below is summarizing main radio configurations that can be realized with a single transceiver UBT-T.

Figure 27 UBT-T Addressable Configuration



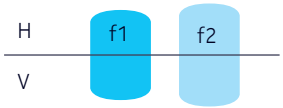
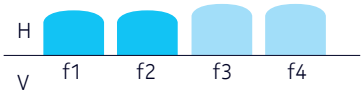
Configuration 3) requires different diplexers - this configuration is possible thanks to the flexibility of the AIM.

Configuration 4) benefits from the wideband capability of the radio boards, allowing, for example, simultaneous usage of 13 and 15 GHz in one box.

Configuration 5) is composed of 2 radio boards at different frequencies, currently proposed at 11 + 32 GHz.

4.3.5 Configurations supported with two UBT-T

- 4+0 Co-polar, using AIM-T-C and a 3 dB external coupler (see Couplers chapter).
- 4+0 Alternate polar, using OMT-C. This configuration allows frequency re-use (XPIC).
- 2+2 HSB
- 2+2 HSB SD

Configuration	Frequencies	Implementation
4+0 AP configuration with 2xUBT-T with OMT-C		
4+0 XPIC configuration with 2xUBT-T with OMT-C		
4+0 Copolar configuration with 2xUBT-T with coupler		

4.4 OCM

Outdoor combiner module is the Nokia external branching box to be used in conjunction with UBT-T to realize high capacity long haul links. Configurations supported from 4 to 16 channels in modular mode.

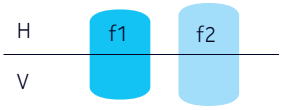
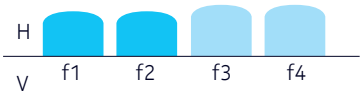
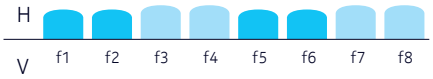
Frequencies supported are from 6 to 11 GHz.

OCM is very compact and light solution allowing to be easily installed on pole mounting.

Main advantages for Nokia Wavence OCM solution are:

- Solution applicable in split mount and in full outdoor offering a real long haul full outdoor with zero footprint and without need of external cabinet.
- Very low insertion losses and high system gain
- Same HW for UBT-T as for configurations up to 2 channels.
- Possibility to mix 6L and 6U or 7 and 8 GHz in same antenna and in same OCM
- Support for adjacent channels and XPIC
- Support for space diversity configuration
- Exploiting same efficient carrier aggregation available in UBT family

4.4.1 Configurations supported with OCM+ UBT-T

Configuration	Frequencies	Implementation
4+0 AP configuration with 2xUBT-T with OCM		
4+0 XPIC configuration with 2xUBT-T with OCM		
4+0 Copolar configuration with 2xUBT-T with OCM		
8+0 Copolar configuration with 4xUBT-T with 2 OCM		

In case of need of space diversity, the same configurations as above are supported doubling the UBT-T and OCM in 1+1 SD .

4.5 UBT-m 80GHz

UBT-m (m stands for millimetre) is a UBT in E-Band, capable of 10 Gbps.

UBT-m is proposed in 3 flavors:

- UBT-m for Standard Power
- UBT-mX (X standing for eXtended reach) with increased transmit power
- UBT-mU (U standing for Urban) with an embedded flat antenna

UBT-m 80GHz can be deployed either in Split Mount configuration, connected to indoor unit MSS, or in Full Outdoor configuration (connected to a switch/router or directly to a base station).

In all cases, advanced QoS and L2 features (i.e. VLAN port management, .1q/.1ad services, OAM, egress shaping, flow control) are supported.

NOKIA

4.5.1 Overview

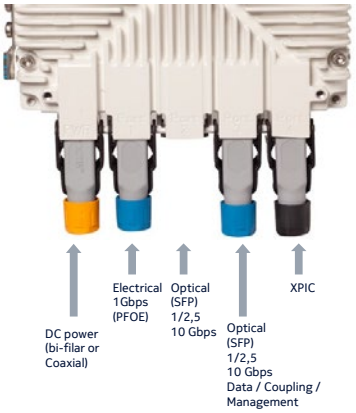
- Full IP packet radio system
- Ethernet ports 1G / 2.5G / 10G
- Radio/Modem capacity up to 7.5 Gbps and 10 Gbps in XPIC
- Channel size at 62.5 / 125 / 250 / 500 / 750 / 1000 / 1250 / 1500 MHz / 2000 MHz
- Mode of operation: FCM or ACM from BPSK up to 512 QAM
- Adaptive Baud Rate (ABR)
- XPIC capable
- Embedded LAG L1 capability, enabling Carrier Aggregation up to 10 Gbps (mmWave + whatever frequency band or 2 mmWave)
- Extreme low latency
- Packet compression
- Enhanced quality of service algorithms with 12 queues, able to optimize different Ethernet CoS transport (and legacy TDM, if any).
- Radio Encryption
- SyncE and 1588 TC/BC capable
- PoE capable or separate DC power
- DC + PoE redundancy
- SDN support
- Compact mechanical shape (240mm x 220mm x 80 mm)
- Embedded antenna option: UBT-mU includes a 38dBi flat antenna in a very slim form factor (240mm x 220mm x 88 mm)
- Excellent system gain: UBT-m is proposed in 2 power options, UBT-m and UBT-mX, for eXtended Reach
- Same product for Split Mount and Full Outdoor

4.5.2 Interfaces

UBT-m 80GHz provides the following interfaces:

- DC port: the same connector can host bi-filar or coaxial cable
- Electrical port (up to 1 Gbps), PFoE capable
- Optical port (SFP 1 / 2.5 Gbps or 10 Gbps) for data
- Optical port (SFP 1 / 2.5 Gbps or SFP+ 10 Gbps) for coupling with another UBT or management
- XPIC port

Figure 28 UBT-m user interfaces



For all ports, OCTIS connectors are used, allowing easy manipulation.

UBT provides a 10 Gbps interface, able to handle global air throughput. This simplifies the integration of full-outdoor radio with a third party indoor system (e.g. switches/routers), which today must resort to a multiple cables/ports solution because of protocol interoperability (e.g. IEEE 802.3ad Link Aggregation).

In Split-mount configuration, several speeds are supported, including a 2.5 Gbps interface which provides operators with an optimized cost for many configurations.

4.5.3 Main radio capabilities

UBT-m 80GHz is able to support standard and most common E band channel spacings (250-500 MHz), but also narrow channel spacing (62.5-125 MHz) as well as larger ones (up to 2 GHz).

Hitless adaptive modulation from BPSK to 512 QAM allows a wide range of modes associated to different link attenuation conditions.

Adaptive baud rate (1/2, 1/4) is also supported on top of standard channels to improve robustness to propagation effects, thus switching to lower channel sizes with a higher system gain when attenuation increases on the link. Such improvement is not negligible, as it corresponds to around 8-10dB vs 4QAM modulation scheme, providing higher availability for a small part of the traffic.

Excellent system gain and ultra-low latency (down to 10us) are two main characteristics of the solution.

Frequency reuse with XPIC is also supported, giving the possibility to double capacity in a compact enclosure using a single frequency channel. XPIC function is supported up to 2GHz channel spacing and requires a dedicated interconnection between the two involved units (H and V polarization).

4.5.4 Configurations

Main supported configurations by UBT-m 80GHz (split mount/Full Outdoor) are:

- 1+0

In such a configuration, maximum throughput is 10 G, achieved in 1.5 or 2 GHz channel spacing.

In standard channel (500 MHz) 3Gbps throughput can be provided.

- 1+1 HSB

For HW protection

- 2+0 with XPIC

Through aggregation of two E-band ODUs it is possible to double the throughput up to 10 Gbps. The aggregation is performed through LAG L1 functionality.

In order to optimize the spectral efficiency, it is necessary to reuse the same channel with XPIC functionality at the receiver side.

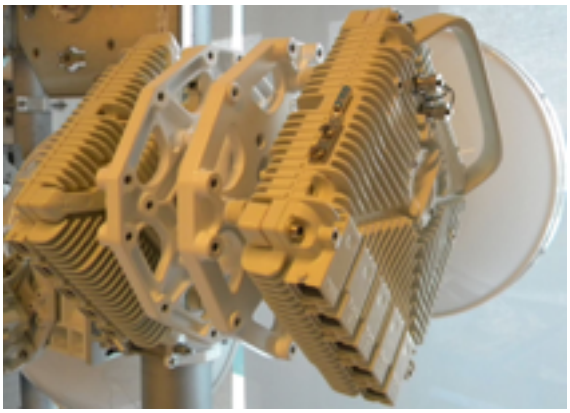
XPIC is supported up to 2GHz channel spacing.

- Carrier aggregation

Carrier aggregation is supported between traditional (UBT-Tor UBT-S) and E-Band (UBT-m 80GHz), reaching 10 Gbps capacity over the air (see dedicated chapter). Configuration available also in full outdoor configuration (zero footprint).

4.5.5 External Ortho-Mode Transducer

Figure 29 OMT E-Band



Using one Ortho-Mode Transducer (OMT) and two UBT-m, it is possible to have a double polarization configuration with an integrated antenna. The channel frequencies can be different (in a same band) or identical (XPIC). The OMT can be rotated for proper alignment of the two facing DP antennas. This OMT is available only bundled with antennas 1ft or 2ft.

4.6 Antennas

4.6.1 Integrated antennas

Figure 30 Integrated antenna

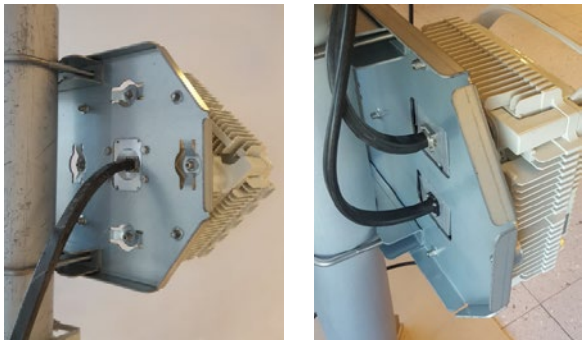
These antennas are attached to a pole using a mount which is included, and MW equipment is attached directly on their back plate.

- One version including an ODU interface with rectangular waveguide, for use in single polarization with AIM-T-C, UBT-S, UBT-C, external coupler and UBT-m.
- One version including an ODU interface with circular waveguide, for use in dual polarization with AIM-T-O or OMT-C.
- One version including an external OMT (see External Ortho-mode Transducer chapter for more details) for use in dual polarization..

They are available in Class 3 and some in Class 4 too.

4.6.2 Not-integrated antennas

Figure 31 Not integrated antenna connection



With these antennas, UBT is mounted on a plate (attached to a pole) and connected to the antenna with a flextwist.

- One type of plate for AIM-T-C and UBT-S, requiring a nose between ODU and flextwist.
- One type of plate for AIM-T-D, not requiring noses between ODU and the two flextwists.

4.6.3 Dual Band antennas

Dual Band antennas (DBA) support the connection of an Eband Radio on one port and another radio at traditional frequency on the other port.

The following combinations are currently supported:

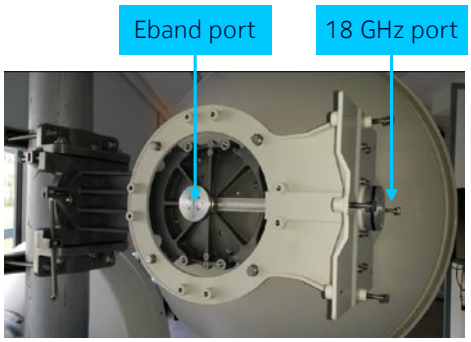
- Single pol /Dual pol 2ft 15/80 GHz
- Single pol /Dual pol 2ft 18/80 GHz
- Single pol/ Dual pol 2ft 23/80 GHz

DBA are compliant to ETSI Class 3 and FCC Class A

There are two antenna ports: one at 80 GHz (center) and one for the traditional frequency (side). Consequently, the following combinations are supported:

- 80 GHz port: UBT-m
- Traditional band port:
  - UBT-S
  - UBT-T with AIM-T-C
  - UBT-T with AIM-T-O

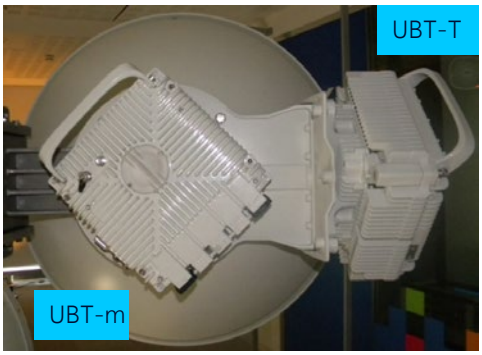
Figure 32 Dual band antenna



Nokia dual Band Antennas are intrinsically Dual Pol. In fact:

- Polarization can be set as V or H on each of the two ports independently (using UBT-m for Eband and UBT-T with AIM-T-C or UBT-S for the microwave band)
- Dual polarization is possible on the traditional band port, using an UBT-T with AIM-T-O (XPIC is supported)

Figure 33 Dual band antenna with UBT mounted



4.7 MSS

4.7.1 MSS shelves

The MSS shelves implement the functionalities of grooming, routing, switching and protection, exploiting a packet-oriented technology.

The MSS is available in four different versions, described in the following Sections.

Shelf acronym	Description
MSS-8 	MSS-8 slots are allocated as follows: • Slot 1 is dedicated to the CorEvo Main Board. • Slot 2 is dedicated to the CorEvo Spare Board; Slots 3-8 are universal and can be used for transport and/or radio plug-ins. MSS-8 is a 2RU shelf supporting up to: 2 CorEvo, 6 peripheral plugins and 24 radios. MSS-8 supports a double battery input.
MSS-4 	MSS-4 is a 1RU shelf that can support up to: 2 CorEvo, 2 peripheral plugins and 12 radios. MSS-4 slots are allocated as follows: • Slot 1 is dedicated to the CorEvo Main Board. • Slot 2 is dedicated to the CorEvo Spare Board; • Slots 3-4 are universal and can be used for transport and/or radio plug-ins.
MSS-1 	MSS-1 is a compact system. The MSS-1 is a fanless 0.5RU indoor shelf supporting up to six radios. The MSS-1 is a compact system, offering Ethernet and E1/DS1 connectivity. Main MSS-1 interfaces are: • 6 x GE ports: 2 x RJ45 PoE + 2 x RJ45 + 2 x SFP • 16 x E1/DS1 – SCSI connector • 1 port for housekeeping • 1port for local Management • 1 QMA connector for dedicated UBT powering Main radio configurations are: 1+0, 1+1, 2+0 LAG L1, up to 6x(1+0), radio repeater, ring.

Shelf acronym	Description
MSS-E 	MSS-E is a compact system, offering Ethernet and PDH connectivity. It is a fanless 0.5RU indoor shelf supporting up to four radios; main MSS-E interfaces are: • Eth ports: 2xSFP 1/2.5G + 3 x RJ45 1G • 16 x E1/DS1 – SCSI connector • 1port for local Management Features and configurations supported in W20: • Eth ports 1,2,4,5 support User Eth and/or connection to UBT-m/-T/-S/-C. All radios in 1+0, UBT-T also in 2+0. • Eth port 3 supports User Ethernet connections (station 'internal' environment) • E1 TDM2TDM Node Timing • 1588 Transparent Clock (TC) HW readiness for further features: 1588 Boundary Clock (BC), 1+1 UBT protected, 8032 ring, DS1, E1 differential
MSS-HE 	MSS-HE is a compact system, offering Ethernet and PDH connectivity. It is a fanless 0.5RU indoor shelf supporting up to eight radios; main MSS-HE interfaces are: • Eth ports: 2xSFP 1/2.5G + 2xSFP+ 1/2.5/10G + 2xCombo 1G (SFP/RJ45) + 2xRJ45 1G • 16 x E1/DS1 – SCSI connector • 1port for local Management • 2 x QMA connectors for UBT powering Features and configurations supported in W20: • Eth ports 1-8 support User Eth and/or connection to UBT-m/-T/-S/-C. All radios in 1+0, UBT-T also in 2+0. • E1 TDM2TDM Node Timing • 1588 Transparent Clock (TC) • Combo ports config is fixed: 5=electr, 6=optical HW readiness for further features: 1588 Boundary Clock (BC), 1+1 UBT protected, 8032 ring, DS1, E1 differential

4.7.2 MSS-4/8 plug in

Board acronym	Description
CorEvo-10G 	The CorEvo-10G board provides node management and cross-connection between MSS plugins and radio or Ethernet ports up to 10 Gb/s. The CorEvo-10G board embeds a microSD Card, which stores the terminal software configuration and the node license. CorEvo-10 G can be inserted in MSS-4/8. The front panel interfaces provide: • 4 x RJ-45 10/100/1000Base-T ports • 2 x SFP+ 1/2.5/10 Gbps ports • 2 x SFP electrical/optical GE ports (1/2.5 Gbit/s) • 1 x RJ-45 10/100 for TMN • Reset button and status/activity LEDs CorEvo-10G provides hardware support for 10 Gbps user interfaces, 10Gbps ring, IEEE 1588 on-path support, enhanced Ethernet features and L3 MPLS forwarding capabilities for L3 VPN support The CorEvo board can be protected through a CorEvo “Spare” to provide Control platform redundancy and protection of aggregated data using an external switch.
CorEvo-1G 	The CorEvo-1G board provides same functionalities as CorEvo-10 G except 10 G interfaces. CorEvo-1 G can be inserted in MSS-4/8. The front panel interfaces provide: • 4 x RJ-45 10/100/1000Base-T ports • 4 x SFP electrical/optical GE ports (1/2.5 Gbit/s) • 1 x RJ-45 10/100 for TMN • Reset button and status/activity LEDs CorEvo-1G provides hardware support for IEEE 1588 on-path support, enhanced Ethernet features and L3 MPLS forwarding capabilities for L3 VPN support. The CorEvo board can be protected through a CorEvo “Spare” to provide Control platform redundancy and protection of aggregated data using an external switch.
PDH Access board E1/DS1 	The PDH Access board provides E1 and DS1 line interface options. It has two main functions: • Termination or reconstruction of the E1/DS1 signal with the original PDH Timing (G.823/824) • Encapsulation/extraction of those PDH data flows into/from standard Ethernet packets that are MEF-8 compliant • The front panel interfaces include: • 32 x E1/DS1 • One LED indicator for Status To achieve EPS line protection, two boards will be plugged inside the sub-rack and an additional protection panel will perform a Y-connection for both Tx and Rx PDH signals

Board acronym	Description
Ethernet Access Card 	The Ethernet Access Cards can be used as an interface to connect MPT/UBTs and/or additional user ports. The main EAC physical characteristics are: • 2 x 10/100/1000Base-T ports for UBT connection and/or user traffic. These ports can also power the UBT through the same CAT5 cable; • 2 x SFP 1/2.5 Gbs for UBT connection and/or user traffic; • 1 x QMA Connector for UBT power feeding The main EAC functions are: • Radio interface towards the UBT/MPT • Additional user ports for the MSS • Power supply interface towards the UBT/MPT • Lightning and surge protection for both electrical GE and power interfaces that are connected to the MPT/UBT • Clock distribution function • Communication with CorEvo controller for provisioning and status report • Ports can be mixed for MPT/UBT connection and/or user port connection
EAC-10G (Ethernet Access Card 10G) 	The Ethernet Access Card 10 G can be used as an interface to connect MPT/ UBTs and/or additional user ports. The main EAC-10G physical characteristics are: • 2 x 10/100/1000Base-T ports for UBT connection and/or user traffic. These ports can also power the UBT through the same CAT5 cable; • 2 x SFP 1/2.5 Gbs for UBT connection and/or user traffic; • 1 x SFP+ Optical 10 GE for optical data connectivity to/from the UBT or from/to user traffic. • 2 x QMA for UBT power feeding The main EAC-10G functions are: • Radio interface towards the UBT and MPT • Additional user ports for the MSS • Power supply interface towards the UBT • Lightning and surge protection for both electrical GE and power interfaces that are connected to the UBT • Clock distribution function • Communication with CorEvo controller for provisioning and status report • Ports can be mixed for UBT connection and/or user port connection • on EAC-10G card the usage of the ports [1xSFP+] and [(2xRJ45) +(2xSFP)] is mutually exclusive

Board acronym	Description
EASv2 card 	The EASv2 card can be used as an interface to connect MPT/ UBTs and/or additional user ports. The EASv2 card provides four PfoE-capable 10/100/1000BaseT Ethernet interfaces and four Ethernet SFP interfaces. EASv2 is supporting Ethernet access and several radio configurations: • 1+0 • 1+1 cross-EAS • Carrier aggregation N+0 cross-EAS and intra-EAS • Carrier aggregation N+N cross-EAS Other features: • Electrical ports with/without PoE • Synchronous Ethernet on user ports (SynchE SFP, SynchE RJ-45) • SSM
SDH access card 	The board manages the specificities of the related external interface and implements the adaptation function between the external interface and the boundary internal interface. Up to 2 x STM-1/OC-3 are transparently transported through a single radio link. The card supports 1 x STM-1 in channelized mode or up to 2 x STM-1 interfaces in transparent transport mode (two optical interfaces or one electrical interface). The front panel interfaces include: • 2 x SFP (optical LC connector or electrical 1.0/2.3 connector) • One LED indicator for status For EPS line protection, two boards are plugged inside the sub-rack. Optional splitter Y-cables are provided for both Tx and Rx SDH signals.
SDH mux/demux access card 	The STM-1 mux/demux behaves like a terminal multiplexer, terminating or originating the SDH frame. It multiplexes up to 63 x E1 into a STM-1 electrical/optical line connection. Standard VC4 mapping of lower-order E1 traffic streams to/from STM-1 is applied, which means that a VC4 directly maps up to 63 x VC12 into an STM-1 signal (in turn each VC12 contains 1xE1). A typical application is direct connection to SDH add-drop multiplexers (ADMs). The board is available (ETSI only) The front panel interfaces include: • 2 x SFP (optical LC connector or electrical 1.0/2.3 connector) • One LED indicator for status

4.7.3 SFP

In this chapter the specific SFP developed for Wavence portfolio are described

SFP name	Where to plug	Description
SFP Synch IN/OUT 	CorEvo and MSS-1 standard SFP ports.	The MSS can deliver or receive frequency synchronization to/from an external device such as a BTS via a dedicated SFP. Electrical format can be 2.048 MHz G.703 or 5/10 MHz sine wave via two 1.0/2.3 coaxial connectors.
SFP ToD 	CorEvo card	'SFP ToD' provide a 1588 ToD/1PPS synch output. Connector and pinout: RJ45, as per G.703 Clause 17.1.
SFP EoSDH 	CorEvo card and MSS-1 (max 2 SFP per card)	EoSDH SFP (ETSI only) supports the following basic features: • Delivers GE traffic over a single STM-1 link • Supports standard GFP encapsulation according to ITU-T G.7041/Y.1303: GE frames are mapped into VC-4 • Physical interface is 1 x STM-1 optical in an SFP cage with an LC connector EPS protection is available in case the CorEvo card is protected - the secondary SFP is hosted by the stand-by CorEvo and an optical splitter is provided to connect the two SFPs.
SFP E3/DS3 		E3/DS3 interface is available through an SFP module to be plugged into one port of core card. Line Imped.: 75 Ohm, unbalanced Line code: HDB3, AMI

4.7.4 Fans Module

Fans module name	Where to plug	Description
Fan alarm Evo 	MSS-8	The 'Fan Alarm Evo' card must be plugged into the MSS-8 shelf in conjunction with CorEvo. It hosts 6 long-life axial fans, which are controlled and performance-monitored by the controller. A Sub-D 15 poles connector provides 8 housekeeping IN and 3 housekeeping OUT signals. Six leds provide equipment alarms and battery/fan module status.
Fan1U 10G 	MSS-4	The 'Fan1U 10G' card must be plugged into the 'MSS-4 10G' shelf in conjunction with CorEvo.

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5. System configurations

UBT-T, UBT-S and UBT-m 80GHz can work in standalone mode or in split mount mode connected to one of the following networking units:

- MSS-8 and MSS-4
- MSS-1
- MSS-E/HE

In the attached table details are reported:

MSS board	Interfaces	UBT-T	UBT-S	UBT-m
corEvo 10 G	1/ 2,5/10 Gb/sec	• 1+0 (2 channels) • CA mode 2 • CA mode 1	• 1+0 • CA mode 2 • CA mode 1	• 1+0 • CA mode 2 • CA mode 1
corEvo 1 G	1/ 2,5 Gb/sec	• 1+0 (2 channels) • CA mode 2 • CA mode 1	• 1+0 • CA mode 2 • CA mode 1	• 1+0 • CA mode 2 • CA mode 1
EAC	1/ 2,5 Gb/sec	• 1+0 (2 channels) • 1+1 HSB (2+2) (cross board) • 1+1 SD (2+2) • CA mode 1	• 1+0 • 1+1 HSB (cross board) • 1+1 SD • CA mode 1	• 1+0 • 1+1 HSB (cross board) • CA mode 1
EAC 10 G	1/ 2,5/10 Gb/sec	• 1+0 (2 channels) • 1+1 HSB (2+2) (cross board) • 1+1 SD (2+2) • CA mode 1	• 1+0 • 1+1 HSB (cross board) • 1+1 SD • CA mode 1	• 1+0 • 1+1 HSB (cross board) • CA mode 1
EASv2	1 Gb/sec Optical Electrical	• 1+0 (2 channels) • CA mode 1 (intra and cross board) • CA mode 2 • CA mode 1 + SD	• 1+0 • CA mode 1 (intra and cross board) • CA mode 2	• 1+0 • CA mode 1 (intra and cross board) • CA mode 2
MSS-1	1 Gb/sec Optical Electrical	• 1+0 (2channels) • 1+1 HSB (2+2) • CA mode 1 intra	• 1+0 • 1+1 HSB	• 1+0 • 1+1 HSB
MSS-E	1 / 2,5 Gb/sec Optical Electrical	• 1+0 (2channels) • CA mode 1 intra UBT • CA mode 1 with UBT SA	• 1+0 • CA mode 1 with UBT SA	• 1+0 • CA mode 1 with UBT SA
MSS-HE	1/ 2,5/10 Gb/sec Optical Electrical	• 1+0 (2channels) • CA mode 1 intra UBT • CA mode 1 with UBT SA	• 1+0 • CA mode 1 with UBT SA	• 1+0 • CA mode 1 with UBT SA

UBT-C is supported in 1+0 configuration, connected to MSS-1, CorEvo or EAC (1Gb/sec) or MSS-E/-HE.

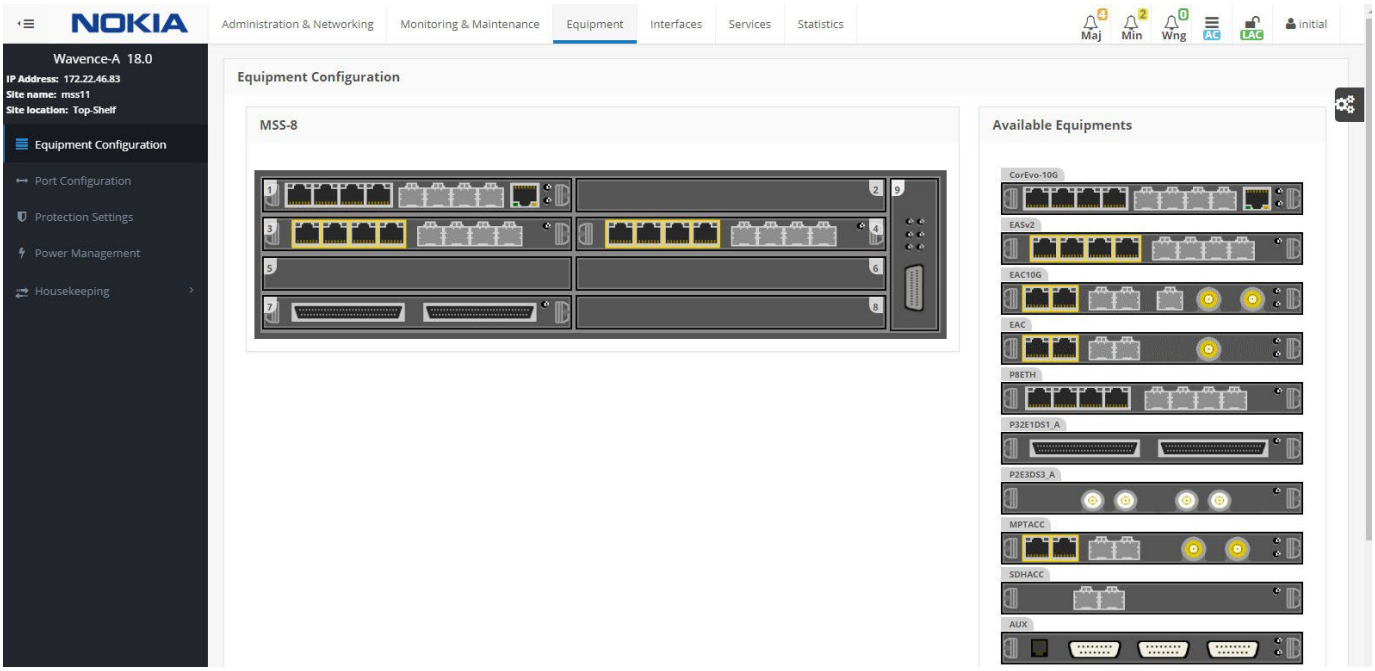
6. Wavence configuration and maintenance

The Wavence platform provides a web enabled user interface with the following functionality:

- Zero installation on user PC: Web interface is loaded on NE
- Cross-platform: no dependency from OS, device, browser
- No third-party software installation is required outside the use of standard web browser.
- No version compatibility between GUI and embedded software
- Performance improvements vs. Java based clients
- Connection to the WebCT is via secure HTTPS protocol
- Simplified procedures for daily operation
- General info on NE, Alarm synthesis and Connected User are always visible on top.
- Navigation is always performed starting from the Domains on the top bar, and then selecting the specific feature from the domain menu on the left.

The Domains are broken up into the following categories

- Administration & Networking
- Monitoring & Maintenance
- Equipment
- Interfaces
- Services
- Statistics



7. Directives, standards and recommendations

Product family compliance with international standards and decisions is reported in the tables below.

For a specific mapping with respect to the different Wavence sub-units, please refer to the Wavence User Manual.

7.1 ITU-R and ITU-T recommendations

Table 11-1. ITU-R

Reference	
ITU-R F.383	Radio-frequency channel arrangements for high-capacity fixed wireless systems operating in the lower 6 GHz (5925 to 6425 MHz) band
ITU-R F.384	Radio-frequency channel arrangements for medium- and high capacity digital fixed wireless systems operating in the upper 6 GHz (6425 to 7125 MHz) band
ITU-R F.385	Radio-frequency channel arrangements for fixed wireless systems operating in the 7 GHz (7110 to 7900 MHz) band
ITU-R F.386:	Radio-frequency channel arrangements for fixed wireless systems operating in the 8 GHz (7725 to 8500 MHz) band
ITU-R F.387	Radio-frequency channel arrangements for fixed wireless systems operating in the 11 GHz band
ITU-R F.497	Radio-frequency channel arrangements for fixed wireless systems operating in the 13 GHz (12.75 to 13.25 GHz) frequency band
ITU-R F.636	Radio-frequency channel arrangements for fixed wireless systems operating in the 14.4 to 15.35 GHz band
ITU-R F.595	Radio-frequency channel arrangements for fixed wireless systems operating in the 17.7 to 19.7 GHz frequency band
ITU-R F.637	Radio-frequency channel arrangements for fixed wireless systems operating in the 21.2 to 23.6 GHz band
ITU-R F.746	Radio-frequency arrangements for fixed service systems
ITU-R F.748	Radio-frequency arrangements for systems of the fixed service operating in the 25, 26 and 28 GHz bands
ITU-R F.749	Radio-frequency arrangements for systems of the fixed service operating in sub-bands in the 36 to 40.5 GHz band
ITU-R F.2006	Radio-frequency channel arrangements for fixed wireless systems operating in the 71 to 76 and 81 to 86 GHz bands
ITU-R F.592	Vocabulary of terms for the fixed service
ITU-R F.1101	Characteristics of digital fixed wireless systems below about 17 GHz
ITU-R F.1102	Characteristics of fixed wireless systems operating in frequency bands above about 17 GHz
ITU-R F.1191-1-2	Necessary and occupied bandwidths and unwanted emissions of digital fixed service systems
ITU-R F.1330	Performance limits for bringing into service the parts of international PDH and SDH paths
ITU-R F.1668	Error performance objectives for real digital fixed wireless links used in 27 500-km hypothetical reference paths and connections
ITU-R F.1703	Availability objectives for real digital fixed wireless links used in 27 500-km hypothetical reference paths and connections

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Table 11-2. ITU-T

Reference	Recommendation
ITU-T G.664	Optical safety procedures and requirements for optical transport systems
ITU-T G.702	Digital hierarchy bit rates
ITU-T G.703	Physical/electrical characteristics of hierarchical digital interfaces
ITU-T G.704	Synchronous frame structures used at 1544, 2048 kb/s hierarchical levels
ITU-T G.706	Frame alignment and cyclic redundancy check (CRC) procedures relating to basic frame structures defined in Recommendation G.704
ITU-T G.707	Network node interface for the synchronous digital hierarchy (SDH)
ITU-T G.775	Loss of Signal (LOS), Alarm Indication Signal (AIS) and Remote Defect Indication (RDI) defect detection and clearance criteria for PDH signals
ITU-T G.781	Structure of Recommendations on equipment for the SDH
ITU-T G.784	Management aspects of synchronous digital hierarchy (SDH) transport network elements
ITU-T G.803	Architecture of transport networks based on the synchronous digital hierarchy
ITU-T G.805	Generic functional architecture for transport networks
ITU-T G.806	Characteristics of transport equipment - Description methodology and generic functionality
ITU-T G.808-1	Generic protection switching
ITU-T G.810	Definitions and terminology for synchronization networks
ITU-T G.811	Timing requirements at the outputs of primary reference clocks suitable for plesiochronous operation of international digital links
ITU-T G.812	Timing requirements at the outputs of slave clocks suitable for plesiochronous operation of international digital links
ITU-T G.813	Timing characteristics of SDH equipment slave clocks (SEC)
ITU-T G.821	Error performance of an international digital connection operating at a bit rate below the primary rate and forming part of an Integrated Services Digital Network
ITU-T G.822	Controlled slip rate objectives on an international digital connection
ITU-T G.823	The controls of jitter and wander within digital networks that are based on the 2048 kb/s hierarchy
ITU-T G.825	The control of jitter and wander within digital networks which are based on SDH
ITU-T G.826	End-to-end error performance parameters and objectives for international, constant bit rate digital paths and connections
ITU-T G.828	Error performance parameters and objectives for international, constant bit rate synchronous digital paths
ITU-T G.829	Error performance events for SDH multiplex and regenerator sections
ITU-T G.831	Management capabilities of transport networks based on the Synchronous Digital Hierarchy (SDH)
ITU-T G.957	Optical interfaces for equipment and systems relating to the synchronous digital hierarchy
ITU-T G.7043	Virtual concatenation of PDH signals
ITU-T G.7710	Common equipment management function requirements
ITU-T G.8010	Architecture of Ethernet layer networks
ITU-T G.8011	Ethernet over Transport - Ethernet services framework
ITU-T G.8011.1	Ethernet private line service
ITU-T G.8011.2	Ethernet virtual private line service
ITU-T G.8012	Ethernet UNI and Ethernet over transport NNI
ITU-T G.8021	Characteristics of Ethernet transport network equipment functional blocks
ITU-T G.8032	Ethernet ring protection switching
ITU-T G.8261	Timing and synchronization aspects in packet networks
ITU-T G.8262	Timing characteristics of a synchronous Ethernet equipment slave clock
ITU-T G.8264	Distribution of timing through packet networks

Reference	Recommendation
ITU-T G.8271	Time and phase synchronization aspects of packet networks
ITU-T G.8271.1	Network limits for time synchronization in packet networks
ITU-T G.8273.2	Timing characteristics of telecom boundary clocks and telecom time slave clocks
ITU-T G.8273.3	Timing characteristics of telecom transparent clocks
ITU-T G.8275	Architecture and requirements for packet-based time and phase distribution
ITU-T G.8275.1	Precision time protocol telecom profile for phase/time synchronization with full timing support from the network
ITU-T Y.1291	An architectural framework for support of QoS in packet networks
ITU-T Y.1541	Network performance objectives for IP-based services

10.2 ETSI

Table 11-3. ETSI

Reference	Recommendation
ETSI EN 302 217	Parts 1,2,3,4 - Fixed Radio Systems; Characteristics and requirements for the use of equipment and antennas in system point-to-point
ETSI TR 101 506	Fixed Radio Systems; Basic definitions, terminology and applicability of the essential requirements given in Article 3.2 Directive 1999/05/EC on the fixed radio systems
ETSI TR 101 036	Fixed Radio Systems; Basic definitions for standards relating to digital fixed radio systems (DFRS)
ETSI TR 102 243	Fixed Radio Systems; Representative values for the transmitter power and antenna gain for the analysis of inter-and intra-compatibility and sharing
ETSI EG 201 399	Electromagnetic compatibility and ERM; Guidelines for the preparation of harmonized standards for application under the R & TTE Directive
ETSI EN 300 019	Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment. Part 1-2-3
ETSI EN 301 126-1	Fixed Radio Systems; Conformance testing; Part 1: Point-to-point equipment - Definitions, general requirements and test procedures
ETSI EN 301 126-3-1	Fixed Radio Systems; Conformance testing; Part 3-1: Point-to-point antennas - Definitions, general requirements and test procedures

10.3 EU directive

Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity (R&TTE Directive).

Table 11-4. ERC/REC

Reference	Recommendation
ERC/REC 14-03 E	Harmonized radio frequency channel arrangements and block allocations designed for low and medium capacity in the band 3400 to 3600 MHz
ERC/REC 12-08 E	Harmonized radio frequency channel arrangements and block allocations for low, medium and high capacity systems in the band 3600 to 4200 MHz
ERC/REC 14-01 E	Radio frequency channel arrangements for high capacity analogue and digital radio-relay systems operating in the band 5925 to 6425 MHz
ERC/REC 14-02 E	Radio frequency channel arrangements for high, medium and low capacity digital fixed service systems operating in the band 6425 to 7125 MHz
ECC/REC/(02)06	Channel arrangements for digital fixed service systems operating in the frequency range 7125-8500 MHz
ERC/REC 12-05 E	Harmonized radio frequency channel arrangements for digital terrestrial fixed systems operating in the band 10.0 - 10.68 GHz
ERC/REC 12-06 E	Preferred channel arrangements for fixed service systems operating in the frequency band 10.7 - 11.7 GHz
ERC/REC 12-02 E	Harmonized radio frequency channel arrangements for analogue and digital terrestrial fixed systems operating in the band 12.75 GHz to 13.25 GHz
ERC/REC 12-07 E	Harmonized radio frequency channel arrangements for digital terrestrial fixed systems operating in the bands 14.5 - 14.62 GHz paired with 15:23 - 15:35 GHz
ERC/REC 12-03 E	Harmonized radio frequency channel arrangement for digital terrestrial fixed systems operating in the band 17.7 GHz to 19.7 GHz
T/R 13-02 E	Preferential channel arrangements for fixed service systems in the frequency range 22.0 - 29.5 GHz
REC T/R 12-01	Preferential channel arrangements for fixed service systems operating in the frequency band 37 - 39.5 GHz
ECC/REC/(09)01	Use of the 57-64 GHz frequency band for point-to-point fixed wireless systems
ECC/REC/(05)02	Use of the 64-66 GHz frequency band for fixed service
ECC/REC/(05)07	Radio frequency channel arrangements for fixed service systems in the bands 71-76 GHz and 81-86 GHz
ECC REP 124	Coexistence between fixed service operating in 71-76 / 81-86 GHz and the passive services

10.4 ECC

Table 11-5. IEC Standards

Reference	Recommendation
IEC 60153	Hollow metallic waveguide
IEC 60154 Parts1-7	Flanges for waveguides. Part 1-7
IEC 60529	Degrees of protection provided by enclosures (IP code).
IEC 60657	Non-ionizing radiation hazards in the frequency range 10 MHz to 300 000 MHz
IEC 60950-1	Information technology equipment – Safety Part 1: General requirements
IEC 61000-4	Electromagnetic compatibility (EMC) - Part 4: Testing and measurement techniques
IEC 721-3	1,2,3,4 Classes - Classification of environmental conditions including classes: 1K4, 1Z2, 1Z3, 1Z5, 1B2, 1C2, 1S3, 1M2 2K4, 2B2, 2C2, 2M2 3K5, 3Z2, 3Z4, 3B2, 3C2(3C1), 3S2, 3M2 4K2, 4Z5, 4Z7, 4B1, 4C2(4C3), 4S2, 4M5
IEC EN 55022	Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement
IEC EN 60825-1 and -2	Safety of laser products
IEC EN 62311	Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz – 300 GHz)
IEC EN 60215	Safety requirements for radio transmitting equipment

Table 11-6. IEEE standards

Reference	Recommendation
802.1ad	Virtual Bridge LAN - Am.4: Provider Bridge
802.1ag	Virtual Bridged LAN - Am.5: Connectivity Fault Management
802.1AX	Local and metropolitan area networks – Link Aggregation
802.1D	MAC Bridges (rollup of 802.1D-1998, 802.1t, 802.1w, P802.1y, and 802.11c)
802.1p	Traffic Class Expediting and Dynamic Multicast Filtering
802.1Q	Local and Metropolitan Area Networks - Virtual Bridged Local Area Networks
802.3	
802.3u	100BASE-TX, 100BASE-T4, 100BASE-FX Fast Ethernet at 100 Mbit/s (12.5 MBps) w/auto negotiation – Media Access Control Parameters, physical layer, medium attachment units and repeater for 100 Mbps operation
802.3x	Full Duplex and flow control. A mechanism for pause-based flow control is also added. Standards for Local and Metropolitan Area Networks: Specification for 802.3 Full Duplex Operation
802.3z	1000BASE-X Gbit/s Ethernet over Fiber-Optic at 1 Gbit/s (125 MBps)
802.3ac	Frame Extensions for Virtual Bridged Local Area Network (VLAN) Tagging on 802.3 Network
802.3ah	Ethernet in the First Mile (OAM), Media Access Control Parameters, Physical layers, and Management Parameters for Subscriber Access Networks
802.3as	Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications (Frame format extensions)

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Table 11-7. IETF standards

Reference	Recommendation
IETF RFC 0768	UDP: User Datagram Protocol
IETF RFC 0791	IP: Internet Protocol
IETF RFC 0793	TCP: Transmission Control Protocol
IETF RFC 0826	Ethernet address resolution protocol
IETF RFC 1305	Network Time Protocol (Version 3) Specification, Implementation and Analysis
IETF RFC 2212	Specification of guaranteed quality of service
IETF RFC 2474	Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers
IETF RFC 2475	“An Architecture for Differentiated Services”, December 1998
IETF RFC 2544	Benchmarking Methodology for Network Interconnect Devices
IETF RFC 2597	Assured forwarding PHB group
IETF RFC 2616	HTTP: Hyper Text Transfer Protocol
IETF RFC 2819	Remote Network Monitoring Management Information Base
IETF RFC 3032	MPLS Label Stack Encoding
IETF RFC 3246	An expedited forwarding PHB (Per-hop behavior)
IETF RFC 3916	Requirements for pseudo-wire emulation edge-to-edge (PWE3)

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Document code: SR2002041256EN (February) CID207171