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SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Digital sections and digital line system – Optical line systems for local and access networks

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40-Gigabit-capable passive optical networks (NG-PON2): Definitions, abbreviations and acronyms

Recommendation ITU-T G.989

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Recommendation ITU-T G.989

40-Gigabit-capable passive optical networks (NG-PON2): Definitions, abbreviations and acronyms

Summary

Recommendation ITU-T G.989 contains the common definitions, acronyms, abbreviations and conventions of the ITU-T G.989-series of Recommendations.

History

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FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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40-Gigabit-capable passive optical networks (NG-PON2): Definitions, abbreviations and acronyms

1 Scope

This Recommendation contains the common definitions, acronyms, abbreviations and conventions of the ITU-T G.989-series of Recommendations.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T J.185] Recommendation ITU-T J.185 (2012), *Transmission equipment for transferring multi-channel television signals over optical access networks by frequency modulation conversion*.

[ITU-T J.186] Recommendation ITU-T J.186 (2008), *Transmission equipment for multi-channel television signals over optical access networks by sub-carrier multiplexing (SCM)*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 access network (AN) [b-ITU-T G.902]: An implementation comprising those entities (such as cable plant, transmission facilities, etc.) which provide the required transport bearer capabilities for the provision of telecommunications services between a service node interface (SNI) and each of the associated user-network interfaces (UNIs).

3.1.2 Ethernet LAN service (E-LAN) [b-MEF 6.1]: An Ethernet service type that is based on a Multipoint-to-Multipoint Ethernet virtual connection.

3.1.3 Ethernet line service (E-Line) [b-MEF 6.1]: An Ethernet service type that is based on a Point-to-Point Ethernet virtual connection.

3.1.4 Ethernet tree service (E-Tree) [b-MEF 6.1]: An Ethernet service type that is based on a Rooted-Multipoint Ethernet virtual connection.

3.1.5 Ethernet virtual connection (EVC) [b-MEF 6.1]: An association of UNIs to which the exchange of service frames is limited.

3.1.6 jitter (timing jitter) [b-ITU-T G.810]: The short-term variations of the significant instances of a digital signal from their ideal positions in time (where "short-term" implies that these variations are of a frequency greater than or equal to 10 Hz).

3.1.7 service node (SN) [b-ITU-T G.902]: A network element that provides access to various switched and/or permanent telecommunication services.

3.1.8 service node interface (SNI) [b-ITU-T G.902]: An interface which provides customer access to a service node.

3.1.9 user-network interface (UNI) [b-ITU-T I.112]: The interface between the terminal equipment and a network termination at which interface the access protocols apply.

3.1.10 1:1 VLAN [b-BBF TR-101]: A VLAN forwarding paradigm involving a one-to-one mapping between user port and VLAN. The uniqueness of the mapping is maintained in the Access Node and across the Aggregation Network.

3.1.11 N:1 VLAN [b-BBF TR-101]: A VLAN forwarding paradigm involving many-to-one mapping between user ports and VLAN. The user ports may be located in the same or different Access Nodes.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 Optical access architecture terms

3.2.1.1 channel group: A set of channel pairs carried over a common fibre.

3.2.1.2 channel pair: A set of one downstream wavelength channel and one upstream wavelength channel that provides connectivity between an OLT and one or more ONUs.

3.2.1.3 channel partition: Any of the operator-specified non-overlapping subsets of TWDM or PtP WDM channels in an NG-PON2 system.

3.2.1.4 channel partition index: An identity of an operator-specified TWDM or PtP WDM channel subset in an NG-PON2 system.

3.2.1.5 channel termination (CT): See OLT PtP WDM channel termination, OLT TWDM channel termination.

3.2.1.6 coexistence element: A bidirectional functional element used to connect PON systems defined in different Recommendation series to the same ODN.

3.2.1.7 domain: A collection of all NG-PON2 network elements under a common and unique operational administration.

3.2.1.8 gigabit-capable passive optical network (G-PON): A PON system supporting transmission rates in excess of 1.0 Gbit/s in at least one direction, and which implements the suite of protocols specified in the ITU-T G.984-series of Recommendations.

3.2.1.9 next generation PON (NG-PON): In the context of ITU-T standards development activity, a generic term referencing the PON system evolution beyond G-PON. The concept of NG-PON currently includes NG-PON1, where the ODN is maintained from B-PON and G-PON, and NG-PON2, where a redefinition of the ODN is allowed from that defined in B-PON and G-PON.

3.2.1.10 NG-PON1: A PON system with a nominal aggregate capacity of 10 Gbit/s in the downstream direction. The NG-PON1 system is represented by XG-PON.

3.2.1.11 NG-PON2: A PON system with a nominal aggregate capacity of 40 Gbit/s in the downstream direction and 10 Gbit/s in the upstream direction, and implementing the suite of protocols specified in the ITU-T G.989-series of Recommendations. An NG-PON2 system is composed of a set of TWDM channels and/or a set of PtP WDM channels.

3.2.1.12 OLT PtP WDM channel termination: A logical function that resides at the OLT network element and terminates a single PtP WDM channel in a PtP WDM system.

3.2.1.13 OLT TWDM channel termination: A logical function that resides at the OLT network element and that terminates a single TWDM channel in a TWDM system.

3.2.1.14 optical access network (OAN): A part of an access network whose network elements are interconnected by optical communication channels. Note that an OAN may or may not extend all the way to the UNI, so that the user-side interface of the OAN does not necessarily coincide with the UNIs of the AN.

3.2.1.15 optical distribution network (ODN): A point-to-multipoint optical fibre infrastructure. A simple ODN is entirely passive and is represented by a single-rooted point-to-multipoint tree of optical fibres with splitters, combiners, filters and possibly other passive optical components. A composite ODN consists of two or more passive segments interconnected by active devices, each of the segments being either an optical trunk line segment or an optical distribution segment. A passive optical distribution segment is a simple ODN itself. Two ODNs with distinct roots can share a common subtree.

3.2.1.16 optical distribution segment (ODS): A simple ODN, that is, a point-to-multipoint optical fibre infrastructure that is entirely passive and is represented by a single-rooted tree of optical fibres with splitters, combiners, filters and possibly other passive optical components.

3.2.1.17 optical line termination (OLT): A network element in an ODN-based optical access network that terminates the root of at least one ODN and provides an OAN SNI.

3.2.1.18 optical network terminal (ONT): An ONU supporting a single subscriber.

3.2.1.19 optical network unit (ONU): A network element in an ODN-based optical access network that terminates a leaf of the ODN and provides an OAN UNI.

3.2.1.20 optical trunk line (OTL): A passive point-to-point segment of a composite ODN.

3.2.1.21 parenting: A passive optical network protection configuration where ONUs are connected to two CTs hosted in different OLT chassis. Typically, the OLT chassis in dual parenting are geographically remote from each other.

3.2.1.22 passive optical network (PON) system: A combination of network elements in an ODN-based optical access network that includes an OLT and one or more ONUs and implements a particular coordinated suite of physical medium dependent layer, transmission convergence layer and management protocols.

3.2.1.23 PtP WDM channel: In an NG-PON2 system, PtP WDM channel refers to the pair of one downstream wavelength channel and one upstream wavelength channel providing point-to-point connectivity.

3.2.1.24 PtP WDM PON: A multiple wavelength PON system that enables point-to-point connectivity using a dedicated wavelength channel per ONU for the downstream direction and a dedicated wavelength channel per ONU for the upstream direction.

3.2.1.25 RF video overlay: A method for video transmission in the downstream direction in a wavelength band between 1550 nm and 1560 nm according to [ITU-T J.185] and [ITU-T J.186].

3.2.1.26 TWDM channel: In an NG-PON2 system, TWDM channel refers to the pair of one downstream wavelength channel and one upstream wavelength channel providing point-to-multipoint connectivity by using, respectively, time division multiplexing and multiple access mechanisms.

3.2.1.27 TWDM PON: A multiple wavelength PON system in which each wavelength channel may be shared among multiple ONUs by employing time division multiplexing and multiple access mechanisms.

3.2.1.28 wavelength channel: A unidirectional (downstream or upstream) optical communications channel characterized by a single unique central frequency or a set of unique central frequencies mapped to one WM tributary port.

3.2.1.29 wavelength multiplexer (WM): A bidirectional functional element used to multiplex / demultiplex between NG-PON2 wavelength channel pairs and channel groups.

3.2.1.30 10-gigabit-capable passive optical network (XG-PON): A PON system supporting nominal transmission rates on the order of 10 Gbit/s in at least one direction, and implementing the suite of protocols specified in the ITU-T G.987-series of Recommendations. XG-PON is the realization of NG-PON1.

3.2.1.31 XG-PON1: A variant of an XG-PON system that operates at a nominal line rate of 10 Gbit/s downstream and 2.5 Gbit/s upstream.

3.2.1.32 XG-PON2: A variant of an XG-PON system that operates at a nominal line rate of 10 Gbit/s downstream and upstream.

3.2.2 Optical parameters, optical power, losses and penalties[1]

3.2.2.1 attenuation: See optical path loss.

3.2.2.2 channel spacing: The absolute difference between the nominal central frequencies of two adjacent wavelength channels in a given reference grid.

3.2.2.3 consecutive identical digit (CID) immunity: The longest continuous sequence of identical bits, that can be present in a digital signal without causing degradation so that the system specifications are no longer met.

3.2.2.4 differential fibre distance: The absolute difference between the fibre distances of any two given paths between the R/S and S/R-CG reference points in the same ODN.

3.2.2.5 differential optical path loss: The absolute difference between the optical losses, expressed in decibel units, of any two given paths between the R/S and S/R-CG reference points in the same ODN.

3.2.2.6 dispersion: A physical phenomenon comprising the dependence of the phase or group velocity of a light wave in the medium, on its propagation characteristics such as optical frequency (wavelength) or polarization mode.

3.2.2.7 dynamic range: An optical receiver characteristic that is equal to the ratio of the receiver overload to the receiver sensitivity.

3.2.2.8 extinction ratio (ER): With respect to a digital On-Off keying signal generated by an optical transmitter, the ratio of the average optical power level at the centre of the binary digit corresponding to the high intensity of light to the average optical power level at the centre of a binary digit corresponding to the low intensity of light.

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[1] For the definition of the NG-PON2 architectural reference points mentioned within this clause, please see clause 5.2. For the relationship between optical power and loss parameters, see clause 5.3. For the definition of the burst-mode transmitter enabled/disabled periods and the associated transient times, see clause 5.13.

For the burst-mode signal, averaging is performed over the time periods when the transmitter is enabled, but excluding the associated transient times (see clause 5.13). For the continuous mode signal, averaging is performed over the entire signal string.

3.2.2.9 fibre distance: The overall length of fibre (and, if applicable, equivalent fibre runs representing delay-inducing components) between the R/S and S/R-CG reference points.

3.2.2.10 in-band crosstalk tolerance: The minimum value of signal-to-crosstalk ratio at the S/R-CG (upstream direction) or R/S (downstream direction) reference point that maintains the receiver compliance with the sensitivity requirements. The crosstalk is assumed to be polarized and aligned with the signal polarization.

3.2.2.11 line code: In the NG-PON2 context, a code which transforms a binary digital signal into an amplitude- and time-discrete waveform for transmission over a physical channel.

3.2.2.12 mask of transmitter eye diagram: A general method of transmitter pulse shape characterization that allows the combined specification of rise time, fall time, pulse overshoot/undershoot, ringing and jitter to ensure satisfactory operation with a compliant receiver. Transmitter mask compliance is required at the appropriate reference point (S/R-CG for downstream, R/S for upstream).

3.2.2.13 mean launch optical power: An optical transmitter characteristic expressing the average optical power of an optical signal transmitted into the fibre and carrying a given digital sequence, referring to the optical power of an individual wavelength channel at the appropriate reference point (S/R-CG for downstream direction, R/S for upstream direction). When specified as a range, the minimum mean launch optical power provides the power level that the transmitter should guarantee at all times, and the maximum mean launch optical power provides the power level that the transmitter should never exceed. When applied to burst-mode transmission, the term pertains to the time interval during which the transmitter is enabled, and excludes possible starting and ending transient behaviour.

3.2.2.14 nominal central frequency: The specified frequency of a wavelength channel.

3.2.2.15 nominal line rate: The total number of bits that can be physically transferred per unit of time over a communication link. Nominal line rate accounts for useful data as well as for all possible protocol overheads and necessarily exceeds the effective data rate on any given protocol level.

3.2.2.16 ODN fibre distance class: A categorization of an ODN based on the predefined values of minimum and maximum fibre distance between the S/R-CG and any of R/S reference points.

3.2.2.17 ODN optical path loss class (ODN Class): A categorization of an ODN based on the predefined values of minimum and maximum optical path loss over all possible paths between the S/R-CG and any of the R/S reference points and over all possible operating wavelengths of a specific PON system.

3.2.2.18 operating wavelength band: The spectral interval defined by its boundaries λ_{min} and λ_{max} which includes all possible central operating wavelengths for a particular application.

3.2.2.19 optical path loss: The reduction in the optical power of light having traversed the ODN expressed as a ratio in decibel units. This loss may be caused by the fibre, connectors, splices, splitters, wavelength couplers, attenuators and other passive optical components.

3.2.2.20 optical path penalty (OPP): The apparent degradation of receiver sensitivity due to impairments from fibre transmission and an apparent increase in ODN loss due to Raman depletion. The optical path penalty accounts for the effects of reflections, intersymbol interference, mode partition noise, fibre dispersion, and fibre non-linearities.

3.2.2.21 optical power spectral density when not enabled (WNE-PSD): The optical power spectral density per transmitter, at any wavelength inside or outside the operating wavelength band, measured when the transmitter is not enabled and the allocated transient time has elapsed, at the appropriate reference point (S/R-CG for downstream direction, R/S for upstream direction). Measurements are averaged over time and are expressed as the total integrated power within a sliding spectral window of known width.

3.2.2.22 optical return loss (ORL): The total reflection at the source reference point of the optical signal propagation path, measured as a ratio of the transmitted optical power to the reflected optical power.

3.2.2.23 overload: A receiver parameter equal to the maximum average received optical power that produces the specified BER reference level, referring to the optical power of an individual wavelength channel at the appropriate reference point (S/R-CG for upstream direction, R/S for downstream direction) measured with the worst case signal, but without the optical path impairments.

3.2.2.24 per channel out-of-band optical power spectral density (OOB-PSD): The optical PSD outside the operating wavelength band measured at the appropriate reference point (S/R-CG for downstream direction, R/S for upstream direction). Measurements are averaged over the time periods when the transmitter is enabled, or when the transmitter is not enabled but the allocated transient time has not yet elapsed, and these are expressed as the total integrated power within a sliding spectral window of known width.

3.2.2.25 per channel out-of-channel optical power spectral density (OOC-PSD): For a transmitter in a stationary wavelength channel state, the optical PSD outside the spectral interval corresponding to the operating wavelength channel, measured at the appropriate reference point (S/R-CG for downstream direction, R/S for upstream direction). Measurements are averaged over the time periods when the transmitter is enabled, or when the transmitter is not enabled but the allocated transient time has not yet elapsed, and these are expressed as the total integrated power within a sliding spectral window of known width.

3.2.2.26 reflectance: The reflection from any single discrete reflection point in the optical signal propagation path, which is defined to be the ratio of the reflected optical power present at a point, to the optical power incident to that point.

3.2.2.27 sensitivity: A receiver parameter equal to the minimum average received optical power that produces the specified BER reference level, referring to the optical power of an individual wavelength channel at the appropriate reference point (S/R-CG for upstream direction, R/S for downstream direction) measured with the worst case signal, but without the optical path impairments.

3.2.2.28 side mode suppression ratio (SMSR): The ratio of the power of the largest peak of the transmitter spectrum to that of the second largest peak. The second largest peak may be next to the main peak, or far removed from it. Within this definition, spectral peaks that are separated from the largest peak by the clock frequency are not considered to be side modes.

3.2.2.29 spectral excursion: For a transmitter in a stationary wavelength channel state, the absolute difference between the nominal central frequency of the channel and the –15 dB points of the transmitter spectrum furthest from the nominal central frequency measured at the transmitter output at the appropriate reference point (S/R-CG for downstream direction, R/S for upstream direction).

3.2.2.30 spectral width: The full width of the largest spectral peak, measured 15 dB down from the maximum amplitude of the peak.

3.2.2.31 stationary wavelength channel state: An optical transmitter or receiver is said to be *in a stationary wavelength channel state,* if 1) it is fixed wavelength, or 2) it is wavelength-tunable and its transient processes associated with the execution of a wavelength channel tuning control command have completed.

3.2.2.32 tolerance to reflected optical power: A transmitter parameter that characterizes the maximum admissible ratio of the average reflected optical transmit power incident at the transmitter to the average optical transmit power.

3.2.2.33 transmitter calibration: An optical transmitter is *calibrated with accuracy* δ, if given a target transmission frequency f_0 within its tuning range, it is capable of transmitting with the spectral excursion not exceeding δ (in other words, its transmission spectrum between the −15 dB cutoff points lays entirely within the spectral interval ($f_0 - \delta$, $f_0 + \delta$)).

3.2.2.34 transmitter power wavelength dependency: For a tunable transmitter under wavelength control, the variation of the mean launch optical power when tuning within MSE.

3.2.2.35 transmitter disable transient time: For a burst-mode transmitter, the allocated transient time on de-assertion of the TxEnable signal, measured in bit periods with respect to the transmitter nominal line rate.

3.2.2.36 transmitter enable transient time: For a burst-mode transmitter, the allocated transient time on assertion of the TxEnable signal, measured in bit periods with respect to the transmitter nominal line rate.

3.2.2.37 tuning granularity: The smallest step by which a tunable device is able to adjust the operating frequency/wavelength within the tuning range of the device. This Recommendation specifies the tuning granularity by its maximum allowable value.

3.2.2.38 tuning range: The spectral interval either in frequency (f_{min}, f_{max}) or wavelength (λ_{min}, λ_{max}) over which the operating frequency/wavelength of a tunable device can be adjusted by means of tuning control.

3.2.2.39 tuning time: The elapsed time from the moment the tunable device leaves the source wavelength channel to the moment the tunable device reaches the target wavelength channel.

3.2.2.40 tuning window: The difference between the highest and lowest operating frequencies/wavelengths of a tunable device, attainable by means of tuning control.

3.2.2.41 wavelength channel spacing: See channel spacing.

3.2.3 Transmission convergence layer terms

3.2.3.1 activation: A set of distributed procedures executed by the OLT and the ONUs that allows an inactive ONU to join or resume operations on the PON. The activation process includes three phases: parameter learning, serial number acquisition, and ranging.

3.2.3.2 activation cycle: An interval of continuous ONU operation between two consecutive re-entries of the ONU state machine into the initial state.

3.2.3.3 attenuation level: A controlled attenuation applied to the output of an ONU transmitter to shift its mean launch optical power range down.

3.2.3.4 bandwidth allocation: An upstream transmission opportunity granted by the OLT for a specified time interval to a specified traffic-bearing entity within an ONU.

3.2.3.5 calibration record: A data structure which establishes an association between the wavelength channels and the corresponding values of the tuning control parameters.

3.2.3.6 calibration record status: A linear array which contains a calibration record accuracy indication for every available wavelength channel.

3.2.3.7 dynamic bandwidth assignment (**DBA)**: A process by which the OLT distributes upstream PON capacity between the traffic-bearing entities within ONUs, based on dynamic indication of their traffic activity and their configured traffic contracts.

3.2.3.8 effective key length: The number of randomly generated bits of a cryptographic key. The effective key length may be less than the nominal key length of a particular cryptosystem, if a part of the key is replaced by a well-known bit pattern.

3.2.3.9 embedded OAM: An operation and management channel between the OLT and the ONUs that utilizes the structured overhead fields of the downstream XGTC frame and upstream XGTC burst and supports time-sensitive functions.

3.2.3.10 equalization delay (EqD): The requisite delay assigned by the OLT to an individual ONU in order to ensure that the ONU's transmissions are precisely aligned on a common OLT-based upstream frame reference. The ONU's equalization delay is assigned as a result of ranging and is subject to in-service updates in the course of burst arrival phase monitoring.

3.2.3.11 loose calibration: An accuracy characterization of an ONU's calibration record with respect to a given upstream wavelength channel which allows the ONU to avoid interference with the any other upstream wavelength channels.

3.2.3.12 loose calibration bound: An upper limit for the permitted transmitter spectral excursion of ONUs, connected to an NG-PON2 system, to be considered as loosely calibrated. This is determined by the physical properties of any particular implementation of an NG-PON2 system.

3.2.3.13 one-step tuning time: The time it takes an ONU to tune its transmitter over the spectral distance equal to its tuning granularity value.

3.2.3.14 ONU management and control interface (OMCI): An operation and management channel between the OLT and an ONU that is message-based and employs an extendable management information base.

3.2.3.15 physical layer OAM (PLOAM): An operation and management channel between the OLT and the ONUs that is close to real time and is based on a fixed set of messages.

3.2.3.16 power levelling: A mechanism that allows an ONU to change its mean launch optical power.

3.2.3.17 profile: A collection of parameters describing a particular object. Within the context of the NG-PON2 TC layer, profile can pertain to a NG-PON2 system as a whole, a TWDM or PtP channel, or an upstream burst in TWDM PON system.

3.2.3.18 quiet window: A time interval during which the OLT suppresses all bandwidth allocations to in-service ONUs in order to avoid collisions between their upstream transmissions and the transmissions from ONUs whose burst arrival time is uncertain. The OLT opens a quiet window to allow new ONUs to join the PON and to perform ranging of specific ONUs.

3.2.3.19 ranging: A procedure of measuring the round-trip delay between the OLT and any of its subtending ONUs with the objective to determine and assign the appropriate equalization delay, which is necessary to align the ONU’s upstream transmissions on a common OLT CT based upstream frame reference. Ranging is performed during ONU activation and may be performed while the ONU is in service.

3.2.3.20 ranging grant: An allocation structure that is addressed to the default Alloc-ID of the ONU and has the PLOAMu flag set. A ranging grant does not specify a data allocation and has the GrantSize of zero.

3.2.3.21 requisite delay: A general term denoting the total extra delay the OLT may require an ONU to apply to the upstream transmission beyond the ONU's regular response time. The purpose of requisite delay is to compensate for variation of propagation and processing delays of individual ONUs, and to avoid or reduce the probability of collisions between upstream transmissions.

3.2.3.22 root frequency: The nominal central frequency representing a cyclic set of frequencies that forms an upstream wavelength channel.

3.2.3.23 round-trip delay: A sum of round-trip propagation delay, ONU response time, and any ONU requisite delay.

3.2.3.24 round-trip propagation delay: The total amount of time it takes an optical signal to travel from the OLT transmitter to the ONU receiver and from the ONU transmitter to the OLT receiver.

3.2.3.25 round-trip time: **T**he time interval, as observed by the OLT CT, between the start of a downstream PHY frame carrying a certain bandwidth map and the start of an upstream PHY burst specified by that bandwidth map.

3.2.3.26 serial number grant: A type of allocation structure, addressed to a broadcast Alloc-ID and having the PLOAMu flag set, that invites the ONUs in Serial Number state to transmit a Serial_Number_ONU PLOAM message either in band or via AMCC. A serial number grant does not specify a data allocation.

3.2.3.27 service adapter: A functional entity responsible for encapsulating/de-encapsulating of the SDUs belonging to the specific service type to/from the XGEM frames.

3.2.3.28 status reporting DBA (SR-DBA): A method of dynamic bandwidth assignment that infers the dynamic activity status of the traffic-bearing entities within ONUs based on explicit buffer occupancy reports communicated over the embedded OAM channel.

3.2.3.29 sufficient calibration: An accuracy characterization of an ONU's calibration record with respect to a given upstream wavelength channel which allows the ONU to guarantee transmission within the specified maximum spectral excursion (MSE) interval of that channel.

3.2.3.30 time quantum: A line-rate-invariant unit of time which is equal to 32 bit periods at the line rate of 2.48832 Gbit/s.

3.2.3.31 traffic-monitoring DBA (TM-DBA): A method of dynamic bandwidth assignment that infers the dynamic activity status of the traffic-bearing entities within ONUs based on observation of idle XGEM frame transmissions during upstream bursts.

3.2.3.32 transmission container (**T-CONT)**: A traffic-bearing object within an ONU that represents a group of logical connections, is managed via the ONU management and control channel (OMCC), and, through its TC layer Alloc-ID, is treated as a single entity for the purpose of upstream bandwidth assignment on the PON.

3.2.3.33 tunability: In the NG-PON2 context, a property of an ONU to change its wavelength.

3.2.3.34 TWDM PON transmission convergence (TWDM TC) layer: A protocol layer of the TWDM PON protocol suite that is positioned between the physical medium dependent (PMD) layer and the TWDM PON clients. The TWDM TC layer is composed of the TWDM TC service adaptation sublayer, the TWDM TC framing sublayer, and the TWDM TC PHY adaptation sublayer.

3.2.3.35 TWDM TC framing sublayer: A sublayer of the TWDM PON transmission convergence layer that supports the functions of frame/burst encapsulation and delineation, embedded OAM processing, and Alloc-ID filtering.

3.2.3.36 TWDM TC PHY adaptation sublayer: A sublayer of the TWDM PON transmission convergence layer that supports the functions of physical synchronization and delineation, forward error correction (FEC), and scrambling.

3.2.3.37 TWDM TC service adaptation sublayer: A sublayer of the TWDM PON transmission convergence layer that supports the functions of SDU (user data and OMCI traffic) fragmentation and reassembly, XGEM encapsulation, XGEM frame delineation, and XGEM Port-ID filtering.

3.2.3.38 uncalibrated ONU: An ONU is said to be *uncalibrated* with respect to a given upstream wavelength channel if its calibration record accuracy does not satisfy the criterion for loose calibration.

3.2.3.39 XGEM port: An abstraction in the TWDM TC service adaptation sublayer representing a logical connection associated with a specific client packet flow.

3.2.3.40 10-gigabit-capable PON encapsulation method (XGEM): A data frame transport scheme used in XG-PON and XG-PON-based systems that is connection-oriented and that supports fragmentation of user data frames into variable sized transmission fragments.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ACK	Acknowledgment
AES	Advanced Encryption Standard
Alloc-ID	Allocation Identifier
ALRF	Attenuation Level Request Failure
AMCC	Auxiliary Management and Control Channel
AN	Access Network
ANI	Access Node Interface
AO	Allocation Overhead
APC	Angled Physical Contact
ASCII	American Standard Code for Information Interchange
AVC	Attribute Value Change
AWG	Arrayed Waveguide Grating
BBU	Baseband Unit
BCH	Bose-Chaudhuri-Hocquenghem (code)
BE	Best Effort (service category)
BER	Bit Error Ratio
BIP	Bit-Interleaved Parity
BITS	Building Integrated Timing Source

BN	Branching Node
B-PON	Broadband Passive Optical Network (ITU-T G.983-series)
BufOcc	Buffer Occupancy
BWmap	Bandwidth Map
CAWG	Cyclic Arrayed Waveguide Grating
CD	Chromatic Dispersion
CE	Coexistence Element
CEx	Coexistence Element Type x (x = 1, 2, etc.)
CG	Channel Group
CID	Consecutive Identical Digits
Clob	Count of the loss of burst events
CMAC	Cipher-based Message Authentication Code
CP	Channel Pair
CPE	Customer Premises Equipment
CPI	Channel Partition Index
CPRI	Common Public Radio Interface
CRC	Cyclic Redundancy Check
CS	Channel Spacing
CT	Channel Termination
CTP	Connection Termination Point
CTR	Counter (block cipher mode)
DA	Destination Address
DBA	Dynamic Bandwidth Assignment
DBRu	Dynamic Bandwidth Report, upstream
DF	Disable Failure
DG	Dying Gasp
DOTX	Drift of Transmitter Wavelength
DOW	Drift Of Window
DS	DownStream (transmission direction)
DWLCH	Downstream WaveLength CHannel
ECB	Electronic Code Book (block cipher mode)
EDC	Electronic Dispersion Compensation
EDFA	Erbium-Doped Fibre Amplifier
EMS	Element Management System
EWMA	Exponentially Weighted Moving Average

eNode B	evolved Node B
EqD	Equalization Delay
ER	Extinction Ratio
EVC	Ethernet Virtual Connection
FCS	Frame Check Sequence
FEC	Forward Error Correction
FFS	For Further Study
FS	Framing Sublayer
FSR	Free Spectral Range
FTTx	Fibre To The x (B – building, business; H – home; C – cabinet, curb)
FWI	Forced Wake-up Indication
G-PON	Gigabit-capable Passive Optical Network (ITU-T G.984-series)
HEC	Hybrid Error Correction
HLend	Header Length, downstream
ICTP	Inter-Channel-Termination Protocol
ID	Identifier
IFC	Intra-Frame Counter
IK	Integrity Key
ILODS	Intermittent Loss Of Downstream Synchronization (ONU state)
Ind	Indication (format field)
KEK	Key Encryption Key
LCB	Loose Calibration Bound
LF	Last Fragment (format flag)
LOB	Loss Of Burst
LODS	Loss Of Downstream Synchronization
LOF	Loss Of Frame
LOMC	Loss Of Management Channel
LOOC	Loss Of OMCI Channel
LOPC	Loss Of PLOAM Channel
LOS	Loss Of Signal
LSB	Least Significant Bit
LSI	Local Sleep Indication
LTE	Long Term Evolution
LWI	Local Wake-up Indication
MAC	Media Access Control

MDU	Management Data Unit
MDU/SFU	Multi-Dwelling Unit/Single-Family Unit
MEF	Metro Ethernet Forum
MIB	Management Information Base
MIC	Message Integrity Check
MPLS	Multi-Protocol Label Switching
MSB	Most Significant Bit
MSE	Maximum Spectral Excursion
MSK	Master Session Key
MTE	Maximum Tuning Error
NA	Non-Assured (service category)
NACK	Negative Acknowledgment
NG-PON1	Next Generation Passive Optical Network 1 (ITU-T G.987-series)
NG-PON2	Next Generation Passive Optical Network 2 (ITU-T G.989-series)
NRZ	Non-Return to Zero
OAM	Operation, Administration and Maintenance
OAN	Optical Access Network
OC	Operation Control
OCS	Operation Control Structure
ODF	Optical Distribution Frame
ODN	Optical Distribution Network
ODN-ID	Optical Distribution Network Identifier
ODS	Optical Distribution Segment
OLT	Optical Line Terminal
OMCC	ONU Management and Control Channel
OMCI	ONU Management and Control Interface
OMCI_IK	OMCI Integrity Key
ONU	Optical Network Unit
ONU-ID	Optical Network Unit Identifier
OOB	Out-Of-Band
OOB-PSD	Out-Of-Band Power Spectral Density
OOC	Out-Of-Channel
OOC-PSD	Out-Of-Channel Power Spectral Density
OPL	Optical Path Loss
OPP	Optical Path Penalty

ORL	Optical Return Loss
OSNR	Optical Signal-to-Noise Ratio
OSS	Operations Support System
OTDR	Optical Time Domain Reflectometer
OTL	Optical Trunk Line
PDU	Protocol Data Unit
PHY	Physical interface
PIT	PON-ID Type
PL	Power Levelling
PLI	Payload Length Indication
PLOAM	Physical Layer Operation, Administration and Maintenance
PLOAMd	PLOAM downstream
PLOAMu	PLOAM upstream
PLOAM_IK	PLOAM Integrity Key
PM	Performance Monitoring
PMD	Physical Medium Dependent
PON	Passive Optical Network
PSBd	Physical Synchronization Block downstream
PSBu	Physical Synchronization Block upstream
PSD	Power Spectral Density
PSK	Pre-shared Secret Key
PSync	Physical Synchronization sequence
PtP	Point-to-Point
PtP WDM	Point-to-Point Wavelength Division Multiplexing
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
RE	Reach Extender
RF	Radio Frequency
RNG	Ranging
RRT	Round-trip Response Time
RRU	Remote Radio Unit
RS	Reed-Solomon (code)
RSSI	Received Signal Strength Indication
R/S	Receive/Send reference point at the interface of the ONU to the ODN
R'/S'	Reach extender interface to optical trunk line

RTD	Round Trip Delay
RTT	Round Trip Time
Rx	Receiver
SA	Sleep Allow (PLOAM message type)
SA	Source Address
SDU	Service Data Unit
SeqNo	Sequence Number
SFC	Superframe Counter
SFD	Start Frame Delimiter
SK	Session Key
SLM	Single Longitudinal Mode (laser type)
SMA	Secure Mutual Association
SMF	Single Mode Fibre
SMSR	Side Mode Suppression Ratio
SN	Serial Number
SN	Service Node
SNI	Service Node Interface
SOA	Semiconductor Optical Amplifier
S/R	Send/Receive reference point at the OLT side
S/R-CP	S/R for Channel Pair
S/R-CG	S/R for Channel Group
S'/R'	Reach extender interface to optical distribution network
SR	Status Reporting (DBA method)
SR	Sleep Request (PLOAM message type)
SUF	Start-Up Failure
TBD	To Be Defined
T-CONT	Transmission Container
TC	Transmission Convergence
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
TIW	Transmission Interference Warning
TM	Traffic Monitoring (DBA method)
ToD	Time of Day
TOL	Transmit Optical Level
TOx	Timeout (x = Z, 1, 2, 3, 4, 5)

TuCtrl	Tuning Control (PLOAM message type)
TuResp	Tuning Response (PLOAM message type)
Tx	Transmitter
TWDM	Time and Wavelength Division Multiplexing
UI	Unit Interval
UNI	User-Network Interface
UPC	Ultra Physical Contact
US	Upstream (transmission direction)
UWLCH	Upstream Wavelength Channel
VOA	Variable Optical Attenuator
VSSN	Vendor-Specific Serial Number
WBF	Wavelength Blocking Filter
WDM	Wavelength Division Multiplexing
WLCP	Wavelength Channel Protection
WM	Wavelength Multiplexer
WNE-PSD	When Not Enabled Power Spectral Density
WR	Wavelength-Routed (PtP WDM PON architecture class)
WS	Wavelength-Selected (PtP WDM PON architecture class)
XG-PON	10-Gigabit Passive Optical Network (ITU-T G.987-series)
XGEM	10-Gigabit-capable PON Encapsulation Method
XML	Extensible Markup Language
XOR	Exclusive OR
X/S	Crosstalk-to-Signal ratio

5 Conventions

5.1 Optical access concepts

This Recommendation reuses the optical access network terminology and definitions system adopted by [b-ITU-T G.987]. An example of an access network architecture satisfying the definition system is shown in Figure 5-1.

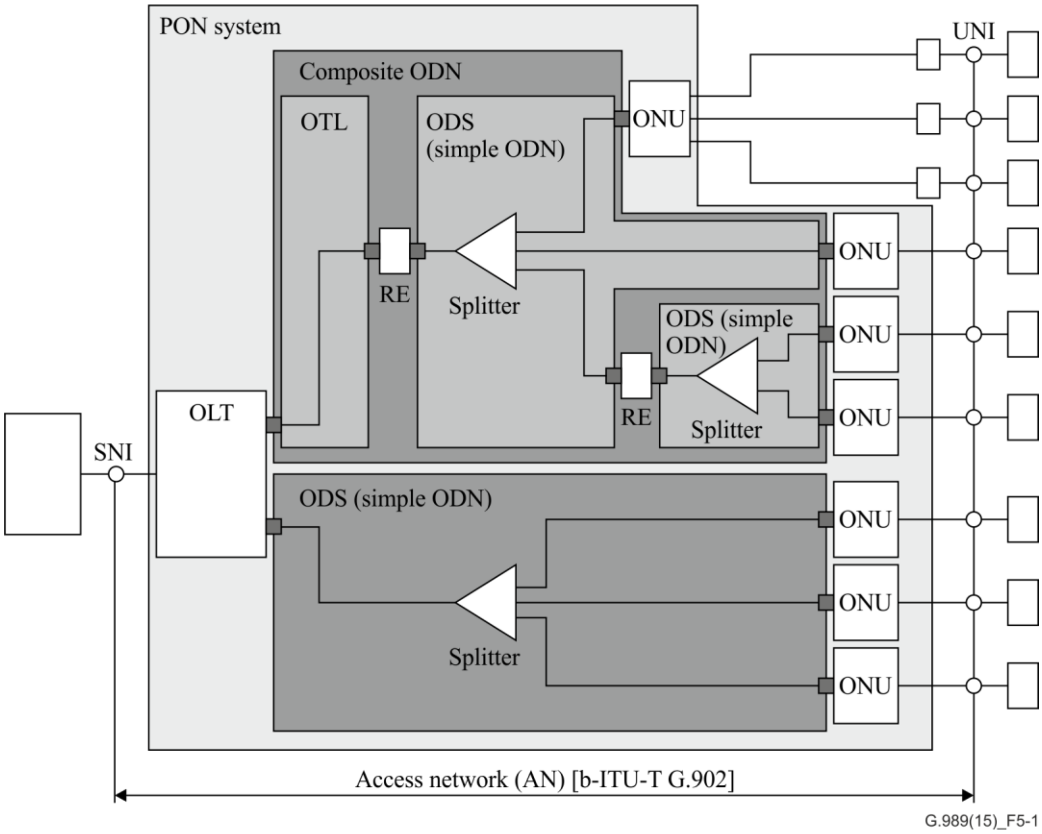

Figure 5-1 – Reference access network architecture

5.2 Multi-wavelength PON system reference points

In a multiple wavelength passive optical network (PON) system, such as next generation passive optical network 2 (NG-PON2), the optical line terminal (OLT) is conceptually composed of multiple OLT channel terminations (CTs) connected via a wavelength multiplexer (WM). The associated reference logical architecture and its reference points are presented in Figure 5-2.

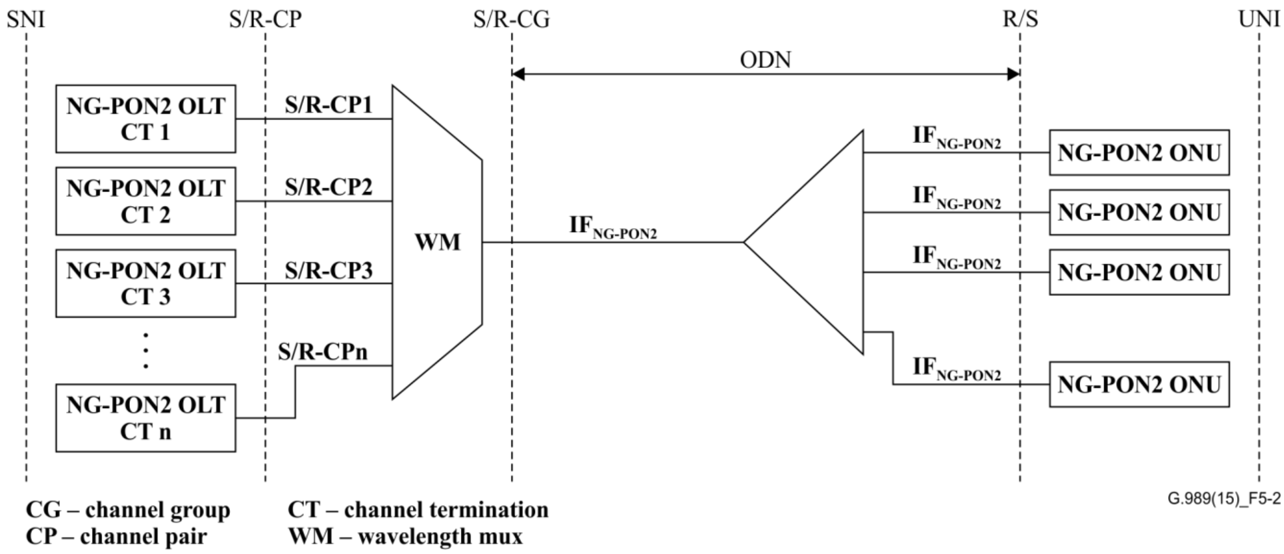

Figure 5-2 – NG-PON2 reference logical architecture

5.3 Optical power and loss parameters

The relationships between optical power and loss parameters are captured in Figure 5-3.

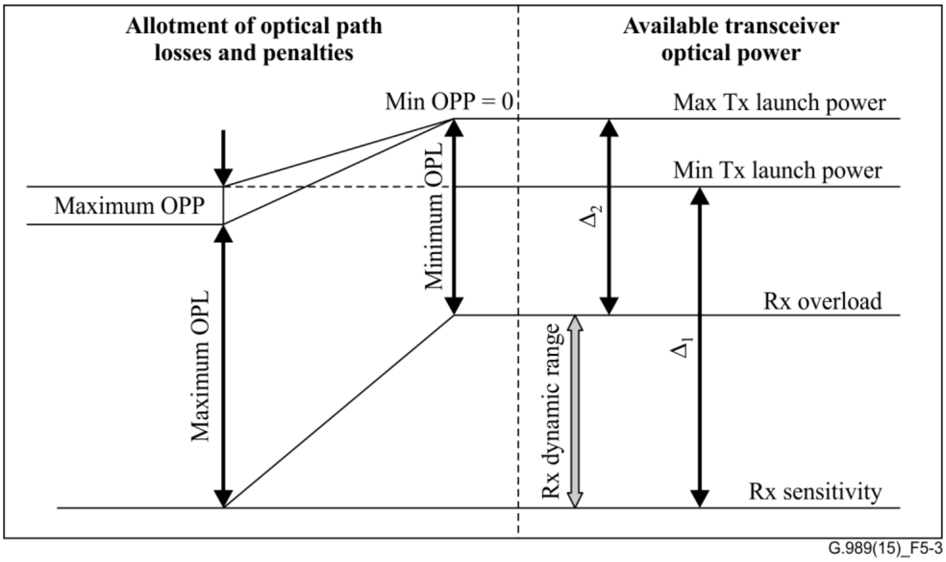

Figure 5-3 – Relationship between the optical power and loss parameters

Given an optical distribution network (ODN) characterized by the maximum and minimum optical path loss and the maximum optical path penalty, the optical links are balanced if and only if the following two constraints are met (assuming logarithmic representation of the parameters):

1. The difference between the minimum transmitter mean channel launch power and the receiver sensitivity is greater than or equal to the sum of the maximum optical path loss and the maximum optical path penalty.
2. The difference between maximum transmitter mean channel launch power and the receiver overload does not exceed the minimum optical path loss.

5.4 Dynamic range, sensitivity and overload

The concept of the dynamic range definition is illustrated in Figure 5-4. The receiver sensitivity and overload are generally understood respectively, as the minimum and maximum average received optical power at which the bit error ratio (BER) at the receiver output remains at the specified reference level. The observed values of receiver sensitivity and overload may vary as the operating temperature and signal quality change, and the system ages. The signal quality characteristics that affect receiver sensitivity and overload may include: the transmitter extinction ratio, parameters of the eye diagram, in-band crosstalk. In the present Recommendation series, receiver sensitivity and receiver overload are formally specified by their respective worst-case values, i.e., maximum sensitivity and minimum overload over the range of operating temperature and signal quality parameters, and under the end-of-life conditions.

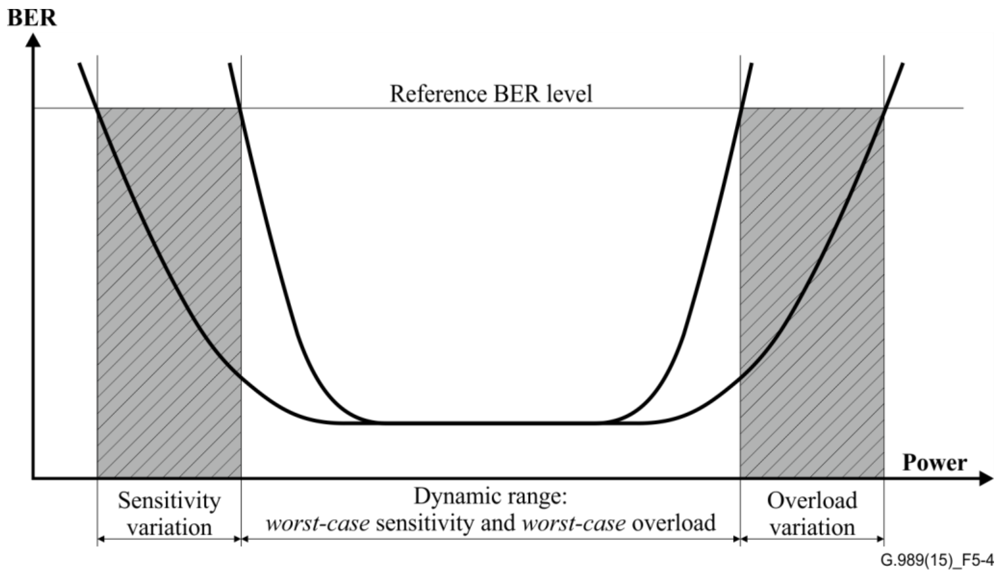

Figure 5-4 – Rx output BER as a function of received optical power and the definition of dynamic range

5.5 Sensitivity and overload in the presence of FEC

To simplify time and wavelength division multiplexing (TWDM) PON optical component verification, this Recommendation, as [b-ITU-T G.987.2] prior to it, specifies the sensitivity and overload at the reference BER level, which corresponds to the Rx output and the forward error correction (FEC) decoder input. It is assumed that the FEC algorithms specified, respectively, for continuous mode downstream and burst-mode upstream transmission are sufficiently strong to achieve the BER level of 10^{-12} or better at the FEC decoder output. See [b-ITU-T G-Sup.39] for further discussion.

5.6 Reach and distance

Like the ITU-T G.987-series of Recommendations before it, the ITU-T G.989-series addresses the linear extent parameters of NG-PON2 using the single concept of fibre distance. An optical network unit (ONU) is characterized by its fibre distance, and for each pair of ONUs on the same OLT PON interface, the differential fibre distance is the difference between the two individual fibre distances. Each specific physical medium dependent (PMD) layer parameter set contains a provision to support a specific maximum fibre distance. The NG-PON2 transmission convergence (TC) layer specification contains a provision to support specific ranges of maximum fibre distance and maximum differential fibre distance. These ranges can be configurable for a given system. It can be expected that for each NG-PON2 deployment, the configured TC layer maximum fibre distance will match the maximum fibre distance supported by the selected PMD layer parameter set. Fibre distance concepts are illustrated in Figure 5-5.

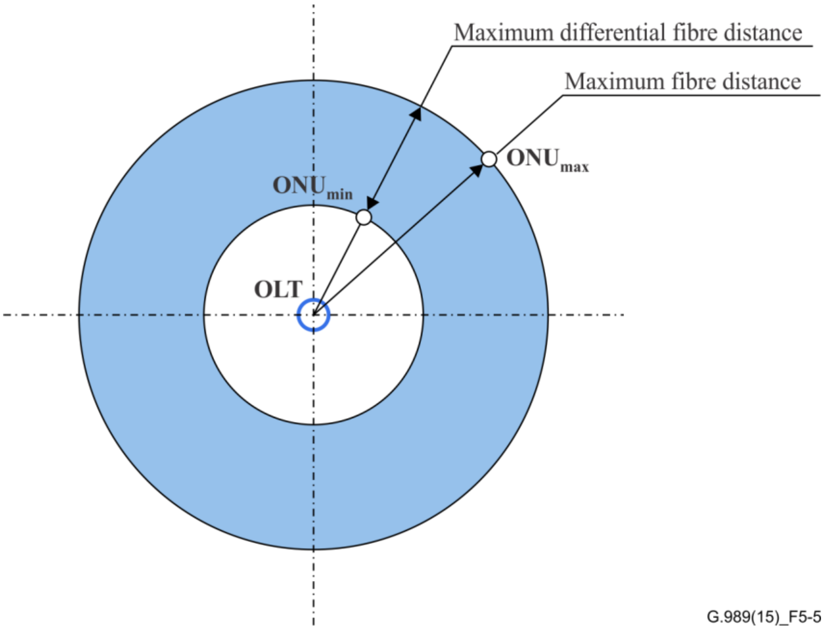

Figure 5-5 – Fibre distance concepts

5.7 Use of the term PON

Historically, the term PON was introduced to describe a point-to-multipoint fibre infrastructure composed exclusively of passive optical components. This strict-sense usage was soon naturally extended to include a fibre-in-the-loop communication system employing such an infrastructure and using time division multiplexing (TDM) to share the available digital bandwidth among many subscribers (TDM-PON). As new types of PON-based systems were introduced, leveraging various TDM transport mechanisms (B-PON, G-PON, EPON) or alternative multi-access methods (WDM-PON), it became common to use the word PON with appropriate qualification in reference to the specific architectural variations. While the term remained overloaded, referring in different contexts to a network, a system, architecture or technology, all the referenced entities shared a common attribute of containing, using or relying upon a fibre infrastructure with no active (electronic) components between the central office interface and the user equipment interface. More recently, the introduction of active reach extenders within the optical distribution network as defined in [b-ITU-T G.984.6] created a paradoxical situation when an infrastructural component of a G-PON system may not be entirely passive, that is, nominally, no longer a PON. Thus, it became apparent that the excessive overloading of what was once meant to be a precise term may adversely impact the clarity of a technical presentation.

This current series of Recommendations deliberately restricts the usage of the term PON to the contexts where it denotes a system, that is, a combination of network elements including at least one OLT and multiple ONUs interconnected by an ODN that implements a particular coordinated suite of physical medium dependent layer, transmission convergence layer and management protocols. It also strives to provide a consistent, unambiguous and extensible definition system that allows supporting efficient communication on the subject.

5.8 Use of the term ODN

In the ITU-T G.983 B-PON and ITU-T G.984 G-PON series of Recommendations (prior to [b-ITU-T G.984.6]), the term optical distribution network refers to a passive point-to-multipoint distribution means extending from the user-facing interface of the OLT to the network-facing interfaces of the ONUs. The introduction of active reach extenders and the concept of dual-homing call for a revision of the term's scope and usage, as the fibre-based distribution network extending between the OLT and ONU interfaces may be neither point-to-multipoint nor strictly passive.

This current series of Recommendations follows the ITU-T G.987-series, endorsing a generalized usage of the term ODN to denote a point-to-multipoint fibre infrastructure, which is not required to be entirely passive. In the contexts where the internal structure of the ODN is not a concern, it is the ODN that interconnects the OLT and the ONUs to form a PON system. In the contexts where the internal structure of the ODN is relevant, two types of ODNs can be distinguished. A *simple* ODN is entirely passive and is represented by a single-rooted point-to-multipoint tree of optical fibres with splitters, combiners, filters, and possibly other passive optical components. A *composite* ODN consists of two or more *segments* interconnected by active devices, each of the segments being either an optical trunk line segment or an optical distribution segment. A passive optical distribution segment in is a simple ODN itself. The definition allows two ODNs with distinct roots to share a common subtree, thus supporting the notions of dual-homing and protection within the definition system.

5.9 Use of the terms ONU and ONT

Throughout the ITU-T G.989-series of Recommendations, as in the earlier ITU-T G.987-series, the network element interfacing the end-user access facilities and the ODN is referred to as an ONU, or an optical network unit, irrespective of the number and type of user interfaces or the depth of fibre deployment. Historically, the term ONT, or optical network terminal/termination, has been used either interchangeably with ONU or with the particular semantics of "an ONU that is used for fibre to the home (FTTH) and includes the user port function" (see [b-ITU-T G.983.1]), or "a single-subscriber ONU" (see [b-ITU-T G.984.1] and other documents of the ITU-T G.984-series). This Recommendation follows the latter approach in defining ONT. Note, however, that while this definition captures one established trade interpretation of the term, the concept itself is not used as a part of the ITU-T G.989 reference access architecture.

Outside of the scope of the ITU-T G.987-series and ITU-T G.989-series of Recommendations, alternative interpretations may apply, and therefore the reader is advised to clarify the exact meaning of the term in each specific context. In particular, in some external contexts, the term ONT may be used generically to refer to any device terminating a leaf of the ODN.

5.10 Use of the terms T-CONT and Alloc-ID

A transmission container (T-CONT) is an ONU management and control interface (OMCI) managed entity representing a group of logical connections that appear as a single entity for the purpose of upstream bandwidth assignment in a PON system.

For a given ONU, the number of supported T-CONTs is fixed. The ONU autonomously creates all the supported T-CONT instances during ONU activation or upon OMCI management information base (MIB) reset. The OLT uses the ONU management and control channel (OMCC) to discover the number of T-CONT instances supported by a given ONU and to manage those instances.

The *allocation identifier* (*Alloc-ID*) is a 14 bit number that the OLT assigns to an ONU to identify a traffic-bearing entity that is a recipient of upstream bandwidth allocations within that ONU. Such a traffic-bearing entity is usually represented by a T-CONT, but may also be represented by an internal non-managed structure.

Each ONU is assigned at least its default Alloc-ID and may be explicitly assigned additional Alloc-IDs per OLT's discretion.

To activate a T-CONT instance for carrying the upstream user traffic, the OLT has to map that T-CONT instance to an Alloc-ID which was previously assigned to the given ONU via the physical layer operations, administration and maintenance (PLOAM) messaging channel. Mapping of T-CONTs to Alloc-IDs is performed via the OMCC. The OMCC itself is mapped, in the upstream direction, to the default Alloc-ID. This mapping is fixed; it cannot be managed via the OMCI MIB and it should survive OMCI MIB reset.

Although in many cases there exists a one-to-one correspondence between T-CONTs and Alloc-IDs, it is the Alloc-ID, not a T-CONT, which is visible at the TC layer of the system.

5.11 Use of the terms bandwidth assignment and bandwidth allocation

The term "bandwidth assignment" refers to the distribution of the upstream PON capacity between the ONUs' traffic-bearing entities using certain isolation and fairness criteria. In static bandwidth assignment, the said criteria are based exclusively on the provisioned parameters of the traffic contracts, and the bandwidth is assigned on the timescale of the individual service provisioning. In dynamic bandwidth assignment, the activity status of the traffic-bearing entities is taken into consideration along with the parameters of the traffic contracts, and the bandwidth assignment is periodically refined.

The term "bandwidth allocation", on the other hand, denotes the process of granting individual transmission opportunities to the ONUs' traffic-bearing entities on the timescale of a single physical interface (PHY) frame. The process of bandwidth allocation uses the assigned bandwidth values as an input and produces the per-frame bandwidth maps as an output. It also accounts for PLOAM messaging and DBRu overhead requirements and the short-term disturbances associated with the creation of quiet windows for serial number acquisition and ranging purposes.

5.12 Use of the terms band and range

When used in the context of optical spectrum, both terms "band" and "range" generally denote a spectral interval in terms of frequency (f_{min}, f_{max}) or wavelength (λ_{min}, λ_{max}). Within the NG-PON2 context, the term "band" applies specifically to a spectral interval which covers all wavelength channels of a specific application (e.g., TWDM PON upstream band, narrow band option, shared spectrum band, G-PON downstream band), whereas the term "range" usually applies to a spectral interval corresponding to a single wavelength channel.

The operating bands are specified in wavelength terms as a matter of convenience for classification and reference purposes. The actual minimum and maximum wavelengths for an operating band should be calculated from the maximum and minimum wavelengths of the two outmost wavelength channels.

5.13 Transmitter enable control and associated transient times

Conceptually, TxEnable is a binary signal that controls a burst-mode ONU transmitter. The TxEnable signal must be asserted (active) for the ONU to transmit an assigned burst. The TxEnable signal is expected to be de-asserted (inactive) whenever no burst is assigned to the ONU. The Transmitter Enable transient time and Transmitter Disable transient time are the allocated time intervals which serve to accommodate any transient physical processes that may be associated, respectively, with assertion and de-assertion of the TxEnable signal. The maximum number of bits allocated for Transmitter Enable transient time and Transmitter Disable transient time are parameters of the ONU optical interface specification. Figure 5-6 shows the relationship between the level of the TxEnable signal (without loss of generality, active-high logic is assumed) and the associated transient times of the burst-mode transmitter. Within the scope of the ITU-T G.989-series of Recommendations, the definitions of the optical-power-related PMD parameters applicable to the burst-mode transmitters (mean launch optical power, extinction ratio, OOC-PSD, WNE-PSD) are referenced to the corresponding averaging intervals which are specified in terms of a transmitter's enabled/disabled periods and the associated transient times.

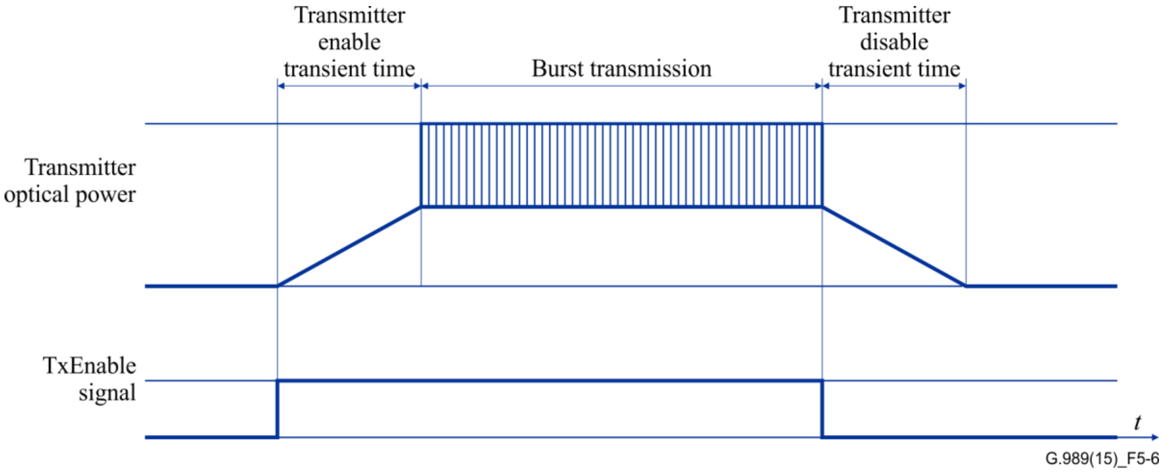

Figure 5-6 – The TxEnable signal and the associated transient times of a burst-mode transmitter

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