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Title:	Proposed Revisions for simplifying power saving modes in G.987.3		
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Introduction

Currently in G.987.3, there are 2 methods for saving ONU powers at PON TC layer. One is called doze, and the other is called cyclic sleep. As according to its definition and description, doze mode is known as with less power efficiency but fast response while the sleep mode is with more power efficiency but less response.

There are some considerations raised in Q2 whether we do always need 2 power saving methods or we can have a much more simple way for implementing power saving. Some previous contributions submit ideas on this question. Here this contribution as well proposes a combination of the advantages of both modes in order to flexibly obtain the expected balance between the power efficiency and response time.

Another point to account for is the current progress of transmitter driver technology. Chips are now commercially available that offer very fast enable/disable times. The Maxim MAX3643 gives 5.5us enable and 0.375 us disable times. The Micrel SY88216 gives a 10us enable time. The Mindspeed M02069 can enable and disable in 1us. This makes dozing far less attractive, as the ONU can turn off its transmitter even during normal operation. For this reason, we aim to deprecate dozing as stand-alone mode or feature.

At the same time, we understand that they may be some vendors who are slow to implement the new hardware functionality. Such implementers might still find value in the dozing idea. This can be catered to by expanding the usage of the Loss of burst for ONU[i] (LOBi). By making

this alarm threshold configurable, the OLT can give the ONU increased latitude to ignore grants that it does not want to use. The ONU need only respond to enough grants to avoid being declared lost.

The main design of this combined and simplified power saving mode (or to say a “simplified sleep mode”) is as follows:

(1) To remove the dozing states and their associated transitions from the current recommendation.

From the point of view of the OLT, the ONU will only be engaging in Sleeping. If the ONU chooses to not turn on its transmitter on every waking cycle, that will not be explicitly visible to the OLT.

(2) To facilitate the condition while ONU sojourns in sleep mode: extend the value of Clobi to tolerate more missing bursts; that is, the detection of LOBi should be more flexible and tolerable to missing bursts while power saving mode;

Proposal

Therefore, as above, in the whole standard referred to power saving, in both G.987.3 and G.988,

- Doze mode should be eliminated; cyclic sleep mode should be modified into “simplified sleep mode”. Therefore, all the signalings, state machines and transitions should be simplified as well.
- the LOBi detection condition should be modified as required.

1) It’s proposed to make the following changes to section *14.2.1 Items detected at OLT*, G.987.3

Type		Description			
		Detection conditions	Actions	Cancellation conditions	Actions
LOBi	Loss of burst for ONU <i>i</i>	Failure to delineate, for any reason, N consecutive scheduled bursts from ONU <i>i</i> when not exempt by power management state machine. (Replaces conditions previously known as LOSi and LOFi.) It should be noted that the threshold for LOBi (N) should be configurable. In normal cases, 4 consecutive frames is enough; however, under certain conditions, e.g. power saving mode activated, this threshold should be kept as a specific counter (e.g. Clobi for power saving) and set by the OLT to the ONU as according to actual tolerated missing frames.	At the discretion of the OLT; may include waiting extra soak time; changing the allocation schedule; deactivating or disabling the offending ONU, or executing a rogue ONU diagnostic procedure. Reporting of the LOBi condition should be qualified by any DG received.	A scheduled burst from ONU <i>i</i> successfully received.	

2) It's proposed to make the following changes to clause 11.3.4.5 Sleep_Request message

11.3.4.5 Sleep_Request message

An ONU sends Sleep_Request to signal its intention to change power saving modes. Clause 16 defines the use and function of this message in detail.

Octet	Content	Description
1-2	ONU-ID	

Octet	Content	Description
3	0x10	Message type ID "Sleep_Request".
4	SeqNo	Always 0.
5	Activity_level	0- Sleep_Request (awake). 1- ~~Sleep_Request (doze). Doze request, ONU receiver active — During low-power periods of doze mode, the ONU can receive downstream traffic.~~ Deprecated. 2- Sleep_Request (sleep). Cyclic sleep request, ONU receiver inactive – During low-power periods of cyclic sleep mode, the ONU cannot receive downstream traffic. Other values reserved.
6-40	Padding	Set to 0x00 by the transmitter; treated as "don't care" by the receiver.
41-48	MIC	Message integrity check

- 3) It's proposed to make the following changes to *section 16 ONU power saving management*, G.987.3

16 ONU power management

For a variety of reasons, it is desirable to reduce the power consumed by an ONU as much as possible:

- Over time, the natural evolution of technology tends toward more efficient realizations of given functions, a tendency that is offset, at least to some extent, by increasing levels of functionality and speed.
- If there is a way for the ONU to determine that a subscriber interface is idle, it is desirable for the ONU to power down the circuitry associated with that interface, while retaining the capability to detect subscriber activity on that interface. The details vary as a function of the interface type.
- The extent of feasible power reduction depends on the acceptable effect on service. The maximum possible savings occurs when a subscriber intentionally switches off an ONU, for example, overnight or during a vacation.
- During failures of AC power, some degradation of service is generally acceptable. To conserve backup battery lifetime, it is desirable for the ONU to power down circuitry associated with all interfaces, except those considered to provide essential services. Different operators and customers may have different definitions of essential services, and may wish to prioritize the time when the interfaces are powered down. This feature, which is known as power shedding, is described in [ITU-T G.988].

The preceding techniques for power management are a matter of ONU design and subscriber and operator practice, and are beyond the scope of this Recommendation.

This clause addresses ~~two additional~~ **the** means of power management, which do require TC layer support.

~~One~~ **This** is called ~~doze mode~~; the other is referred to as cyclic **simplified** sleep mode. ~~Both~~ **and is** ~~are~~ statically provisioned through OMCI, and ~~either or both of these latter modes~~ may be combined with any or all of the other power reduction techniques.

All ITU-T G.987.3-compliant implementations are expected to support **the simplified sleep mode** ~~the doze mode~~. Support of the cyclic sleep mode is optional for both OLT and ONU.

16.1 Power management configuration and signalling

The OLT uses OMCI to discover the ONU's power management capabilities and to configure its power management attributes and modes. To control the power management behaviour of a given ONU, the ONU and the OLT maintain a pair of power management state machines. The ONU state machine and the corresponding OLT state machine operate in partial state alignment. The primary signalling mechanism used to coordinate the ONU and OLT state machines is based on the PLOAM messages. The output PLOAM messages are generated and queued for transmission at the time of state transitions. The states of both ONU and OLT state machines can be classified into two mutually exclusive subsets: the full power states and the low power states. Only the state transitions between the full power and low power state subsets generate an output PLOAM message. If the sojourn in the target state of a transition is controlled by a timer, the timer is not started until the actual transmission of the message. As a secondary signalling mechanism used to speed up or wake up a sleeping ONU, the forced wake-up indication bit is carried within a BWmap allocation structure.

16.2 Power management parameter definitions

Table 16-1 defines the essential intervals, timers and counters. Parameters known to both ONU and OLT are exchanged via OMCI [ITU-T G.988]. Parameters local to the ONU or the OLT are defined only for use in the description below.

Table 16-1 – Power management parameters

Parameter	Description	Defined by	Known to
Isleep	Isleep is the maximum time the ONU spends in its Asleep or Listen states, as a count of 125 microsecond frames. Local wake-up indications (LWIs) in ~~both Asleep and Listen states or remote events in Listen state~~ may truncate the ONU's sojourn in these states.	OLT	ONU, OLT
Tsleep	Local timer at ONU. Upon entry to Asleep state, the ONU initializes Tsleep to a value equal to or less than Isleep. Secondary internal timers may be required to guarantee that the ONU will be fully operational when it enters aware state after an interval not to exceed Isleep.	ONU	ONU
Iaware	Iaware is the minimum time the ONU spends in its Aware state before transitioning to a low power state (~~Asleep or Listen~~), as a count of 125 microsecond frames. During the Iaware interval, local ~~or remote~~ events may independently cause the ONU to enter the ActiveHeld state rather than returning to a low power state.	OLT	ONU, OLT
Taware	Local timer at ONU, initialized to a value equal to or greater than Iaware once downstream synchronization is obtained upon entry to Aware state. Taware controls the dwell time in aware state before the ONU re-enters one of the low power states.	ONU	ONU
Itransinit	Complete transceiver initialization time: The time required for the ONU to gain full functionality when leaving the Asleep state (i.e., turning on both receiver and transmitter), measured in units of 125 μ s PHY frames, and known by design. The value of zero indicates that the sleeping ONU can respond to a bandwidth grant without delay.	ONU	ONU, OLT

Table 16-1 – Power management parameters

Parameter	Description	Defined by	Known to
~~Itxinit~~	~~Transmitter initialization time: the time required for the ONU to gain full functionality when leaving the Listen state (i.e., turning on the transmitter while the receiver has remained on), measured in units of 125 μs PHY frames. The value of zero indicates that the dozing ONU can respond to a bandwidth grant without delay.~~	ONU	ONU, OLT
Talerted	Local timer to bound the time that the OLT state machine remains in an alerted state before entering the AwakeForced state. If the ONU that the OLT attempts to wake up has been sleeping, Talerted should be initialized to at least Isleep + Itransinit + round-trip delay + tolerances for Rx synchronization, bandwidth grant irregularities, and processing time. ~~If the ONU that the OLT attempts to wake up has been dozing, Talerted should be initialized to at least Itxinit + round-trip delay + tolerances for bandwidth grant irregularities and processing time.~~	OLT	OLT
Clob _i	Counter of missing upstream bursts in OLTs AwakeForced(i) state for loss of signal defect for ONU <i>i</i> . If Clob _i expires, the OLT declares LOB _i against ONU <i>i</i> .	OLT	OLT

Table 16-1 – Power management parameters

Parameter	Description	Defined by	Known to
Ter_i	Local handshake timer at the OLT that defines the latest instant at which an upstream burst is expected from sleeping or ~~dozing~~ ONU i . The OLT reinitializes and starts this timer when the OLT's state machine for the given ONU transition into the LowPower state and each time an upstream burst is received from the ONU while in that state. If Ter_i expires, the OLT declares a handshake violation and attempts to force the ONU awake. To determine the initial value of Ter_i , the OLT is responsible to consider the provisioned Isleep interval and any possible effects of transceiver initialization, synchronization, and irregularities in the bandwidth grant cycle.	OLT	OLT
Ihold	Minimum sojourn in the ActiveHeld state.	OLT	ONU, OLT
Thold	Local timer at the ONU that is initialized to Ihold upon transmission of SR(Awake) after entry into ActiveHeld state and that enforces the minimum sojourn in the ActiveHeld state.	ONU	ONU

16.3 Power management state machine specifications

The power management behaviour of a given ONU is controlled by a pair of state machines residing at the OLT and the ONU. While the state nomenclature of the OLT machine is similar to that of the ONU machine, the two state machines operate in just partial state alignment. The lock-step state tracking is not an objective of the protocol.

16.3.1 ONU state machine

The ONU power management states along with their corresponding semantic description are listed in Table 16-2. The set of input events is represented in Table 16-3. The state transition diagram is illustrated in Figure 16-1. The normative specification of the state transitions and outputs are given in Table 16-4.

Table 16-2 – ONU power management states

State	Semantics
ActiveHeld	The ONU is fully responsive, forwarding downstream traffic and responding to all bandwidth allocations. Power management state transitions do not occur. The minimum sojourn in this state is enforced by the Thold timer. Upon entrance to this state, the ONU sends a Sleep_Request (Awake) PLOAM message. On the state diagrams, this is abbreviated as SR(Awake).
ActiveFree	The ONU is fully responsive, forwarding downstream traffic and responding to all bandwidth allocations. Power management state transition requests are a local decision.
Asleep	The ONU shuts down both its receiver and transmitter, retaining the ability to wake up on local stimulus. This state persists for a specified duration Isleep if not truncated by the arrival of a local stimulus LWI. Before exiting this state, the ONU ensures that it is fully powered up, synchronized, and capable of responding to both upstream and downstream traffic and control.
~~Listen~~	~~The ONU receiver is on; the transmitter is off. The ONU listens to the downstream signal and forwards downstream traffic, while retaining the ability to reactivate the transmitter on local stimulus or receipt of SA(OFF) from the OLT. This state persists for a specified duration Isleep if not truncated by the arrival of a local stimulus LWI or receipt of SA(OFF) or FWI from the OLT. Before exiting this state, the ONU ensures that it is fully powered up and capable of responding to both upstream and downstream traffic and control.~~
~~DozeAware~~ SleepAware	Both ONU receiver and transmitter remain on. This state persists for a specified duration Iaware if not truncated by the arrival of a local stimulus LWI or receipt of SA(OFF) from the OLT. The ONU forwards downstream traffic and responds to all grant allocations. It is the responsibility of the OLT to transmit bandwidth allocations containing the PLOAMu flag with frequency sufficient to ensure that an aware ONU sees at least one.

Table 16-3 – ONU state machine inputs

Input categories	Input	Semantics
PLOAM events	Sleep_Allow(ON)	The OLT grants permission to the ONU to exercise ~~any~~ power management mode and leaves the selection of doze or cyclic sleep mode to the ONU's discretion.

Table 16-3 – ONU state machine inputs

Input categories	Input	Semantics
	Sleep_Allow(OFF)	The OLT withholds consent to exercise a power management mode.
Bit-indication event	Forced wake-up indication (FWI)	Transmitting FWI as a flag of an allocation structure, the OLT requires immediate wake-up and transition to a full power state.
Timer events	Thold expiration	The event applies in the ActiveHeld state, controlling the minimum sojourn in the state.
	Taware expiration	The event applies in ~~DozeAware and SleepAware~~ states, controlling the sojourn in the states.
	Tsleep expiration	The event applies in Asleep and Listen states, controlling the sojourn in the states.
Local events	Local sleep indication (LSI)	The ONU has no local reason to remain at full power and is willing to exercise the ~~cyclic sleep~~ power management mode.
	~~Local doze indication (LDI)~~	~~The ONU has no local reason to remain at full power and is willing to exercise the doze power management mode.~~
	Local wake-up indication (LWI)	A local stimulus prevents the ONU from exercising ~~any~~ power management mode.
NOTE – The LSI, ~~LDI~~ , and LWI events are conceptually derived from the ONU's ternary stimulus status level (Awake/Sleep/ ~~Doze~~) and correspond to the events of the level change or, in case of ActiveFree state, to the sampled value at the time of the transition. The specific criteria for the local stimulus definition remain out of scope of this Recommendation.		

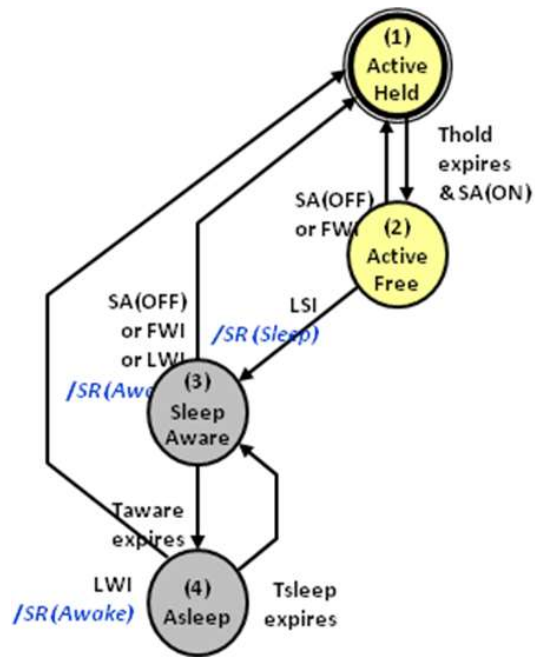


Figure 16-1 – ONU state transition diagram (initial state circled)

Table 16-4 – ONU state transition and output table

Inputs	ONU power management states					
	(1) ActiveHeld	(2) ActiveFree	(3) SleepAware	(4) Asleep	(5) DozeAware	(6) Listen
FWI	*	→ (1)	→ (1) /SR(Awake)		~~→ (1)~~ /SR(Awake)	~~→ (1)~~ /SR(Awake)
SA (OFF)	*	→ (1)	→ (1) /SR(Awake)		~~→ (1)~~ /SR(Awake)	~~→ (1)~~ /SR(Awake)
SA (ON)	→ (2)	*	*		*	*

	Upon Thold exp. (Note)					
LWI	*	*	→ (1) /SR(Awake)	→ (1) /SR(Awake)	~~→ (1)~~ ~~/SR(Awake)~~	~~→ (1)~~ ~~/SR(Awake)~~
LSI		→ (3) /SR(Sleep)	*	*		
~~LDI~~		~~→ (5)~~ ~~/SR(Doze)~~			*	*
Tsleep exp.				→ (3)		~~→ (5)~~
Taware exp.			→ (4)		~~→ (6)~~	
* Indicates a self-transition. ■ A shaded cell means that the input is not applicable in the given state. NOTE – An ONU remains in the ActiveHeld state for at least Ihold upon entry into that state regardless of the SA message parameter value indicated by the OLT. The minimum sojourn in the ActiveHeld state is controlled by timer Thold that is initiated to Ihold upon ONU's entry into the ActiveHeld state. When Thold expires, the ONU executes a transition into to the ActiveFree state if the latched value of SA message parameter is ON or as soon as SA (ON) message is received.						

1.1.1 16.3.2OLT state machine

The OLT power management states along with their corresponding semantic description are listed in Table 16-5. The set of input events is represented in Table 16-6. The state transition diagram is illustrated in Figure 16-2. The normative specification of the state transitions and outputs is given in Table 16-7.

Table 16-5 – OLT power management states

State	Semantics
AwakeForced	The OLT provides normal allocations to ONU i, forwards downstream traffic, and expects a response to every bandwidth grant. The OLT declares the LOB_i defect on detection of $Clob_i$ missed allocations. On transition into this state, the OLT sends a Sleep_Allow (OFF) PLOAM message, thus revoking its permission to the ONU to enter a low power state.
AwakeFree	The OLT provides normal allocations to the ONU, forwards downstream traffic, and is ready to accept a power management transition indication from the ONU. On transition into this state, the OLT sends a Sleep_Allow (ON) PLOAM message, thus granting the ONU a permission to enter a low power state ~~at its own discretion~~. The OLT expects a response to every bandwidth grant, and in case of missed allocation transitions to the AwakeForced state, where LOB_i condition can be eventually declared. There are two stable state combinations involving the AwakeFree state of the OLT state machine: the ONU state machine can be either in the ActiveFree state or in the ActiveHeld state.
~~LowPowerDoze~~ LowPowerSleep	The OLT supports the ONU in a low power state. The OLT provides normal allocations to the ONU but expects only intermittent responses from the ONU to bandwidth grants, as defined by various timers. ~~In the low power doze state, the OLT forwards downstream traffic;~~ in the low power sleep state, the OLT may buffer downstream traffic. If timer Ter_i expires before the OLT receives a burst from ONU i, the OLT recognizes a handshake violation and goes to the AwakeForced state.
~~AlertedDoze~~ AlertedSleep	The OLT attempts to wake up the ONU. Having sent Sleep_Allow (OFF) message on transition to the state, the OLT sets the FWI bit in every allocation to the ONU along with the PLOAMu flag. The OLT forwards, discards or buffers downstream traffic for the ONU, just as it did during the immediately preceding ~~LowPowerDoze or~~ LowPowerSleep state. The OLT goes to the AwakeForced state if it receives a burst from the ONU that includes a Sleep_Request (Awake) PLOAM message or if timer $T_{alerted}$ expires.

Table 16-6 – OLT state machine inputs

Input categories	Input	Semantics
PLOAM events	~~SleepRequest(Doze)~~	~~The ONU informs the OLT of its intent to exercise the doze power management mode.~~
	SleepRequest(Sleep)	The ONU informs the OLT of its intent to exercise the cyclic sleep power management mode.
	SleepRequest(Awake)	The ONU informs the OLT of its intent to remain at full power.
Timer events	Ter _i expiration	~~The event occurs only in the LowPowerDoze and LowPowerSleep states indicating the violation by the ONU of the provisioned low power timing parameters.~~
	Talerted expiration	~~The event occurs only in AlarmedDoze and AlarmedSleep states indicating the ONU's failure to wake-up upon OLT's demand.~~
Local events	Local wake-up indication, OLT-LWI	Local wake-up indication and its inverse indicate, respectively, the presence and the absence of a local stimulus to maintain the ONU at full power.
NOTE – The OLT-LWI event and its inverse are conceptually derived from the OLT's binary stimulus status level and correspond to the stimulus level change. The specific criteria for the local stimulus definition remain out of scope of this Recommendation.		

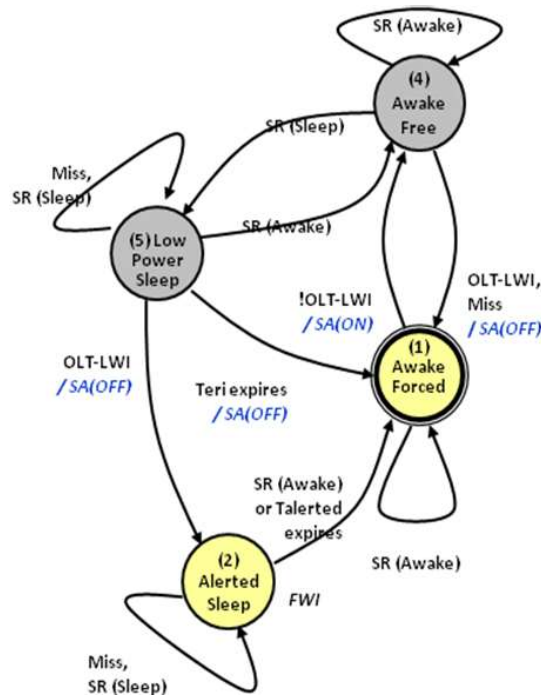


Figure 16-2 – OLT state transition diagram (initial state circled)

Table 16-7 – OLT state transition and output table

Inputs	OLT power management states					
	(1) Awake Forced	(2) Awake Free	(3) Low Power Sleep	(4) Alerted Sleep / FWI	(5) Low Power Doze	(6) Alerted Doze / FWI
SR (Awake)	*	*	→ (2)	→ (1)	⇒ (2)	⇒ (1)
SR (Sleep)	* /SA(OFF) (Note 1)	→ (3)	*	*	⇒ (1) /SA(OFF) (Note 2)	⇒ (1) /SA(OFF) (Note 2)
SR (Doze)	* /SA(OFF) (Note 1)	⇒ (5)	→ (1) /SA(OFF) (Note 2)	→ (1) /SA(OFF) (Note 2)	*	*

Allocation miss	*	→ (1) /SA(OFF)	*	*	*	*
OLT-LWI ON	*	→ (1) /SA(OFF)	→ (4) /SA(OFF)	*	~~→ (6)~~ /SA(OFF)	*
OLT-LWI OFF	→ (2) /SA(ON)	*	*	*	*	*
				(Note 3)		(Note 3)
Taltered exp.				→ (1)		→ (1)
Ter _i exp.			→ (1) /SA(OFF)		~~→ (1)~~ /SA(OFF)	
NOTE 1 – An exception from the subgraph rule; an output may help to stabilize the state machine in case the condition is caused by a lost SA(OFF) message. The output is not shown on the FSM diagram. ~~NOTE 2 – Direct transitions between Doze mode and Cyclic Sleep mode are disallowed. When the OLT receives a request to execute such a transition, it attempts to regain state machine synchronization by waking up the ONU. The transitions are not shown on the diagram for the sake of compactness.~~ NOTE 3 – This is a situation when the OLT initiates a wake-up, but the OLT-LWI is cleared before the ONU is awoken. In this case, the OLT, instead of cancelling the wake-up process and attempting to immediately revert to a low power state, insists on waking the ONU up with the intent to re-enter a low power state via states AwakeForced and AwakeFree.						

16.4 Management transactions during low power mode

The ONU can receive and act on downstream management traffic at any of the three channels described in clause 6.3, except when it is in its Asleep state. The OLT is responsible for understanding when the ONU can be expected to receive downstream management traffic, or to deal with the possibility that the ONU does not receive such traffic.

If the ONU receives embedded OAM commands such as DBRu or PLOAMu when it cannot respond immediately, i.e., when it is in its asleep or listen states, it ignores the commands. It is the OLT's responsibility to allow for extra response delays if it sends PLOAM or OMCI commands to an ONU that may be incapable of responding within the normal time.

In the context of ~~cyclic~~ **the simplified** sleep, particularly, the OLT may choose to force the ONU awake before conducting management transactions.

The OLT is permitted to send unidirectional management transmissions at any time, including

Profile, Deactivate_ONU-ID, Disable_Serial_Number, and Sleep_Allow PLOAM messages. The OLT must be prepared for the possibility that a sleeping ONU does not receive the transmission. For the purposes of this clause, an ONU sleeps only when it is in state O5. When the OLT understands that the ONU is not in state O5, for example, because the ONU is only newly discovered or has not yet registered, the normal ranging and assignment transactions occur without regard to the power saving state model.

NOTE – It is possible that an ONU in states O1 or O2 might also wish to ~~doze or~~ **the simplified** sleep, as a way of conserving power while waiting for turn-up. This would involve a much simpler state model, and would require no exchange of information between OLT and ONU, externally visible merely as delayed discovery. Such a possibility is beyond the scope of this Recommendation.