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

GPON power conservation

ITU-T G-series Recommendations – Supplement 45



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Supplement 45 to ITU-T G-series Recommendations

GPON power conservation

Summary

Supplement 45 to ITU-T G-series Recommendations consolidates the various GPON power-saving proposals in order to facilitate their consideration and comparative analysis from the perspective of the requirements satisfiability, on the one hand, and the overall system impact, on the other hand. This Supplement is formatted as a white paper encompassing the summary of the requirements gathering effort, the specification of the wide spectrum of potential solutions as well as their comparative analysis.

Source

Supplement 45 to ITU-T G-series Recommendations was agreed on 15 May 2009 by ITU-T Study Group 15 (2009-2012).

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.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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Supplement 45 to ITU-T G-series Recommendations

GPON power conservation

1 Introduction

Power conservation and carbon footprint reduction has been embraced by ITU as a necessary goal. ITU-T has been exploring potential solutions to improve power conservation through reduced power consumption and other techniques within optical access networks. These solutions can have an impact on improving equipment performance and service longevity in battery-powered operation, as well as on power conservation and CO₂ emissions in general. While this Supplement focuses on GPON power savings, the results are expected to be applicable at least in part to GEAPON as well as to NG-PON optical access.

Throughout the years 2006 and 2007, FSAN and ITU-T have run three rounds of requirement-gathering power-saving surveys. The results of those surveys have revealed two foci of power-saving efforts: improving the power consumption characteristics of the optical access equipment with the goal to reduce its contribution into greenhouse gas emissions and improving the performance of the optical access equipment in mains outage situations. The survey results have also demonstrated a considerable variability of the regulatory and operating environments where GPON is being or is planned to be deployed. Thus, the acceptable effect of any special power saving mode on perceived quality of service varies from "zero tolerance" approach and full operator control to allow a certain degree of trade-offs and users' freedom of choice.

To satisfy the requirements that may vary by region, operator and application, multiple power conservation methods can be proposed and need to be documented and analysed. Such methods differ in achievable savings, as well as in the amount of required system architecture and system provisioning changes. One possible approach to classification of such methods is based on the depth of impact upon the existing GPON transmission convergence (GTC) layer as defined in ITU-T G.984.3 (2008).

This Supplement is structured as follows. Clause 2 contains the condensed presentation of the FSAN/ITU-T GPON power savings survey results; the summary of principles and targets set by the EU Code of Conduct on Energy Consumption of Broadband Equipment, and the overview of the GPON power savings requirement profiles. Clauses 3, 4 and 5 contain the specifications of the proposed power saving techniques partitioned by their relation to the GTC layer into the following groups:

- techniques involving introduction of the new PLOAM messages or new embedded OAM fields;
- techniques involving changing the semantics of existing PLOAM messages or embedded OAM fields;
- one-sided techniques that avoid changes to the GTC layer.

Finally, clause 6 contains the comparative analysis of the proposed techniques with respect to the specified requirements and clause 7 presents the conclusions.

2 Power savings requirements

2.1 Survey results

2.1.1 Survey No. 1

The first ITU-T power consumption survey, which was answered by four companies, was conducted in early 2007.

Overall, while there was some scattering of data on many of the questions, there was not a sufficient response to say that any question had a consensus answer. Despite this difficulty, it seemed clear from the responses that power saving is of lesser priority than service quality, availability and interface variety. This led to the conclusion that power saving features should be carefully designed such that they would not sacrifice these other priorities.

2.1.2 Survey No. 2

Survey No. 2 was distributed in September 2007. It was addressed specifically to the operator community.

Four operators responded to the survey by the meeting deadline and one more provided the responses post factum. All would like an energy saving mode to economize on battery power for back-up of essential services such as telephony (two would like it to be same as the low power mode in the EU Code of Conduct on Energy Consumption of Broadband Equipment). The responders showed strong interest in a digital telephony interface of 300 kbit/s or less. All would like an energy saving mode; however, most required the trigger to be mains failure, rather than unused ports or lack of traffic. Some of the requirements were formulated:

- Same port shutdown sequence was agreed as suggested in the questionnaire.
- Programmable data rates (but no consensus on specific values).
- Less than 5-s recovery time to full power mode.

While patchy support was shown for the power save mode when traffic was light or ports remained unused, the decision was made for the vendors to focus on power saving for power backup under supply failure.

2.1.3 Survey No. 3

Survey No. 3 was formulated after the November 2007 meeting with the aim of clarifying the service requirements for the power saving performance under mains power outage. Four operators provided the responses, confirming the importance of the power savings theme; however, no consistent set of service requirements and acceptable trade-offs appeared as a result of the survey.

2.2 EU Code of Conduct on Energy Consumption

Code of Conduct on Energy Consumption of Broadband Communication Equipment (referred herein as BBCoC) is a document issued by the European Commission that sets out the basic principles to be followed by all parties involved in broadband equipment, operating in the European Community, in respect of energy-efficient equipment. All service providers, network operators, equipment and component manufacturers are invited to sign this document on a voluntary basis.

There have been three published versions of BBCoC:

- Version 1: Ispra, 19 July 2006;
- Version 2: Ispra, 17 July 2007;
- Version 3; Ispra, 18 November 2008.

The current version is available at:

http://re.jrc.ec.europa.eu/energyefficiency/html/standby_initiative_broadband%20communication.htm

The BBCoC defines the general principles of power savings in broadband equipment, provides the functional definitions of operation states, and sets the target power levels along with the time schedule for compliance. It classifies optical line termination (OLT) as network equipment and the optical network termination (ONT) as customer premises equipment of home gateway type.

Consider as an example two typical ONT¹ configuration styles as defined in the following table.

Table 1 – Typical ONT configuration styles

Typical ONT Configurations	Interfaces			
	GPON	GE	POTS	MoCA
Style 1	1	1	2	1
Style 2	1	4	2	0

The BBCoC would impose the following power level requirements on these ONTs.

Table 2 – Target power levels for a style 1 ONT

Function	Tier 2009/2010 1.1.2009-31.12.2010		Tier 2011 1.1.2011-31.12.2011	
	Low power state (W)	On state (W)	Low power state (W)	On state (W)
General functions + GPON interface	5.0	9.7	4.0	7.7
1 gigabit Ethernet port	0.3	1.7	0.3	1.3
Dual SLIC (FXS) (Note)	0.8	3.0	0.5	3.0
MoCA	0.4	4.0	2.0	2.5
Total equipment	10.1	18.4	6.8	14.5
NOTE – Assuming one interface is totally off in the low power state.				

Table 3 – Target power levels for a style 2 ONT

Function	Tier 2009/2010 1.1.2009-31.12.2010		Tier 2011 1.1.2011-31.12.2011	
	Low power state (W)	On state (W)	Low power state (W)	On state (W)
General functions + GPON interface	5.0	9.7	4.0	7.7
4 port gigabit Ethernet switch	1.5	4.5	1.2	3.7
Dual SLIC (FXS) (Note)	0.8	3.0	0.5	3.0
Total equipment	7.3	17.2	5.7	14.4
NOTE – Assuming one interface is totally off in the low power state.				

2.3 Requirements profile summary

As the surveys indicate, the ONU¹ power savings requirements can be associated with one of the two dominating underlying objectives. On one hand, the effort is driven by the emergency services support under the AC mains power failure and is targeted at the prolongation of the battery operation time. On the other hand, the requirements focus on conserving power in regular (mains

¹ The usage of the terms ONT and ONU throughout this Supplement follows the convention of ITU-T G.984.3 (2008). In addition, in the context of a particular reference discussion, preference is given to the term used within the specific reference.

powered) operations and minimizing the carbon dioxide emissions generated by information and communications technologies (ICTs). The key difference between the two objectives and the two associated requirements profiles is the degree of compromise on the scope and quality of service that is considered acceptable. There are also varying approaches to the degree of freedom delegated to the end user in asserting his or her preferences with regard to GPON functionality under power outage.

Individual operators may focus on only one or both of the two objectives in compliance, respectively, with the telecommunications regulations for the specific jurisdiction or the BBCoC. It has been observed that in many cases the existing regulations tend to suit the conventional copper plant (which provides power from the CO), and are yet to address the specifics of fibre access.

In the case of the wholesale open access model, the authority to establish the service requirements, priorities and the degree of end-user configurability may lie outside of the operator's decision-making domain, in which case the requirements may become subject to significant variability within the same access network.

3 Classification of power saving techniques

3.1 Taxonomy

In the course of the study within ITU-T, several power saving techniques have been proposed and discussed. While it is important to be able to view them in a systematic way, there is more than one way to classify those techniques. One classification criterion that has been applied initially to solicit the power saving proposals is the depth of the GTC layer impact. In the course of the discussion, it has appeared that a more meaningful criterion is the behaviour of the ONU receiver and transmitter while the ONU is in a power save mode.

From the point of view of the ONU receiver and transmitter behaviour, the proposals under discussion fall into the following three categories:

ONU power shedding is characterized by powering off or reducing power to non-essential functions and services while maintaining a fully operational optical link.

ONU Dozing is associated with additional powering off of the ONU transmitter for substantial periods of time on the condition that the receiver remains continuously on.

Finally, **ONU sleeping** means that both ONU transmitter and ONU receiver are turned off for substantial periods of time. The latter category is further subdivided into **ONU Deep Sleep**, whereby the transmitter and receiver remain off for the entire duration of the power save state sojourn, and the **ONU Fast Sleep**, where the power save state sojourn consists of a sequence of sleep cycles, each composed of a sleep period and an active period.

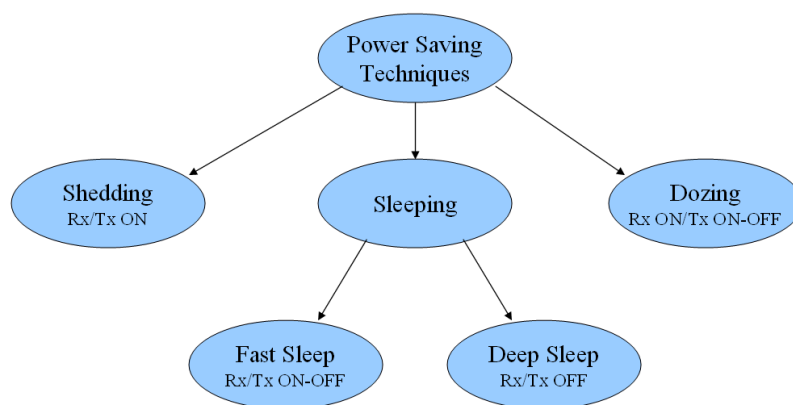


Figure 1 – Taxonomy of the power saving techniques

3.2 Unified approach to ONU power saving signalling

Most of the individual proposals presented to the group in the course of the study described the elements of the power save mode maintenance mechanism (OLT's support of a particular power save mode) coupled with the elements of the power save mode signalling mechanism (establishing transitions to and from a particular power save mode). Nevertheless, the group observed that the two mechanisms are largely independent from each other. That is, any given signalling mechanism can form a feasible combination with any maintenance mechanism (with the exception of power shedding, which may not require signalling), and the selection of an optimal power save approach or approaches can be partitioned into selection of the signalling mechanism and the selection of the maintenance mechanism.

The following power save signalling mechanisms have been discussed:

- PLOAM-based handshake utilizing new message type(s);
- Dying Gasp message modified to include extra diagnostic and status information;
- Dying Gasp message with redefined semantics prompting OLT to perform extra diagnostic actions;
- OMCI-based handshake;
- implicit state inference based on the prior negotiated capabilities.

The two subsequent clauses are devoted to consideration of the power save maintenance and power save signalling mechanisms, respectively.

4 Power saving maintenance mechanisms

4.1 Fast Sleep power saving technique

4.1.1 Editorial summary

This clause presents key aspects under consideration within ITU-T. The proposal introduces the Fast Sleep mode behaviour, advocating the synchronized sleep and active periods across all the ONUs in the Fast Sleep mode that can be achieved with a newly defined broadcast PLOAM message along with the PLOAM-based signalling method to manage the Fast Sleep mode transitions for the individual ONUs.

The present text differs from the original contribution in that it explicitly decouples the Fast Sleep mode signalling from Fast Sleep mode maintenance, and allows for single parameterized new power save signalling PLOAM type rather than requiring multiple new signalling PLOAM messages.

4.1.2 Fast Sleep mode maintenance

An ONU in the Fast Sleep mode alternates between sleep periods, when the optical transceiver is completely powered off along with all the non-essential functions and only the timing and activity detection functions remain active, and active periods when the optical transceiver as well as the necessary supporting functions are powered on. An active period and the subsequent sleep period constitute a sleep cycle.

The transitions from active periods to sleep periods and from sleep periods to active periods (wake-ups) are synchronized by all the ONUs in the Fast Sleep mode and are controlled by the OLT by means of Sleep PLOAM message. The Sleep message is a broadcast PLOAM message that is transmitted by the OLT at its discretion as soon as active period processing is completed, and that contains as a parameter the 30-bit superframe counter indicating the first frame of the next active period.

Upon receipt of a Sleep PLOAM, an ONU in the Fast Sleep mode starts the sleep period. While in a sleep period, the ONU maintains a free-running clock that generates a wake-up signal powering up the receiver in advance of the scheduled wake-up frame. The receiver wake-up lead time should be sufficient for the ONU to complete the Psync and superframe acquisition before the scheduled wake-up frame with reasonably high probability. The Fast Sleep mode maintenance states and state transitions are shown in Figure 2.

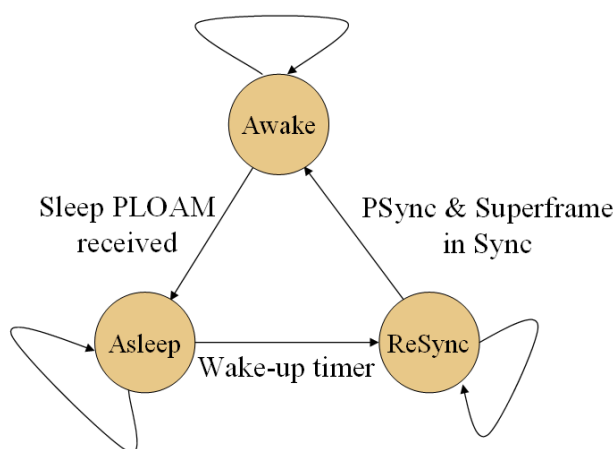


Figure 2 – Fast Sleep mode state transitions

The OLT buffers the incoming downstream traffic destined to the ONUs in the sleep period, delivering it upon ONU wake-up. This ensures the preservation of the downstream services for the power saving ONUs. The structure of the OLT buffers and the associated scheduling discipline have not been addressed by the original proposal and remain an open issue.

To provide for speedy recovery in case of possible state mismatch between the OLT and ONU, and to ensure that the ONU may promptly signal termination of the Fast Sleep mode whenever necessary, the OLT should provide regular PLOAM allocations to the subtending ONUs regardless of whether they are awake or asleep.

4.1.3 Specification impact

To provide support to the Fast Sleep power save technique, the TC layer standard should be extended to include the following:

- A new PLOAM message of Sleep type with a single parameter, a 30-bit superframe counter of the first frame of activity after the sleep period, and the semantics of putting all the Fast Sleep ONUs to sleep with the scheduled wake-up time specified by the parameter.
- A Fast Sleep mode power-save state machine and the associated descriptions.
- An accelerated transition path of the Activation state machine for Psync and Superframe acquisition on transition from the ReSync power save state to the Awake power save state.
- The implementation recommendations for the OLT use of the Sleep message and PLOAM allocations for the ONUs in Fast Sleep mode.

4.2 Deep Sleep power saving technique

4.2.1 Editorial summary

The Deep Sleep technique allows to achieve maximal power saving through powering off all the ONU functions and services except, perhaps, activity detection, at the expense of the loss of incoming downstream traffic and signalling. The ONU may wake up to a local stimulus only when the ONU is switched on, in the off-hook condition, or at the expiration of a locally maintained timer.

The transition into the Deep Sleep mode should be signalled to the OLT in order to avoid unnecessary alarming and operations support. Whereas the original proposal specified a modified Dying Gasp signalling method, other signalling techniques, such as OMCI handshake, can be applicable as well.

The Deep Sleep mode makes sense, for example, when the end user switches the ONU off, or when, from the service provider perspective, the loss of the incoming services can be tolerated. The behaviour is similar to a "virtual blue button", as the downstream channel is effectively shut down and the ONU is waking up on a local stimulus only; however, the service restoration time is expected to be much faster.

4.2.2 Deep Sleep mode maintenance

The ONU in a Deep Sleep has its optical transceiver completely powered off along with most other functions and services. The timing and activity detection functions may optionally remain active. The OLT should suppress the PON alarming for the given ONU, but retain GTC and MIB configuration. It may continue sending the downstream traffic (or, optionally, discard it) and provide upstream allocations, but it should consider the absence of the upstream traffic as normal. In order to support timely recovery of the ONU waking up on a local stimulus, the OLT shall allocate regular targeted (i.e., narrow) ranging windows to the sleeping ONUs.

4.2.3 Specification impact

To provide support to the Deep Sleep power save technique, the TC layer standard should be extended to include the following:

- An accelerated transition path of the Activation state machine for Psync and superframe acquisition and re-ranging on locally initiated wake-up.
- A targeted (reduced size) Quiet window allocation mechanism.
- The implementation recommendations on the application and frequency of the targeted Quiet window for the ONUs in the Deep Sleep mode.

4.3 Dozing power saving technique

4.3.1 Editorial summary

A Dozing mode is introduced as an alternative to the Fast Sleep mode of clause 4.1. A dozing ONU ignores upstream allocations as long as it has no traffic to send, while avoiding LOSi declaration by the OLT and keeping the downstream channel open and operational. The dozing ONU may instantaneously wake up on an OLT request as well as on a local stimulus.

4.3.2 Dozing mode proposal

The OLT and ONU recognize a Dozing mode. It behaves as follows:

- A dozing ONU wakes up instantly when it receives upstream traffic of any kind from a UNI or from an internal process that generates traffic, e.g., 802.1ag CCM generation. Internal processes that generate traffic also include OMCI responses and notifications and responses to directed PLOAM messages.
- The ONU optical receiver is powered up continuously. It recognizes all downstream flows. As well as delivering traffic to CPE, this permits the ONU to awaken instantly if it needs to respond to a request from the OLT.
- The OLT continually sends upstream grants to all TCONTs, but expects the ONU to respond only if the ONU has something to say. This permits the ONU to acquire bandwidth instantly when it has traffic to send.
- The OLT may send DBA status requests, but these requests do not wake up a dozing ONU. If the ONU awakens because it has traffic to send, it can request bandwidth dynamically by responding to the status request.
- Bandwidth grants should allocate some small capacity, on the order of 100 kbit/s, such that the ONU can transmit one or a few background packets without significant delay, for example, heartbeat or query responses.
- If bandwidth grants are such that a given ONU receives a contiguous time allocation for more than one TCONT, the ONU must either respond to its entire grant or to none of it. That is, the burst must either be fully formed or not sent at all. The ONU may independently accept or ignore grants that are not contiguous in time.

It may be noted that the IEEE MPCP allows an ONU to ignore a grant if it has nothing to send, with the exception that the OLT can send a *force report* grant, which requires a response.

4.3.3 Specification impact

To provide support to the Dozing power save technique, the TC layer standard should be extended to include the following:

- The implementation recommendations on the LOSi suppression.
- The implementation recommendations on the regularity of bandwidth allocation and periodicity of the allocations that require response to perform drift adjustment, thus preventing the need of re-ranging upon termination of the Dozing mode.

4.4 Power shedding

4.4.1 Basic method

The 2008 suite of ITU-T G.984-series Recommendations allows the ONU to perform controlled power shedding, that is, to switch off specific services when the ONU operates under battery power. The feature is controlled by the power shedding ME. Its specification is provided in clause 9.1.7 of ITU-T G.984.4. A set of *shedding classes* is identified, one shedding class for each interface type. For each shedding class, a statically specified time interval determines the time between the moment of AC power failure and the moment the support of the respective interface type is turned