Power Saving Modes for GPON and VDSL2

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In the face of high energy costs and climate change concerns, power saving starts to play a central role in the design and operation of information and telecommunication equipment. This paper describes possible power saving modes for GPON and VDSL2 access technologies used in combination for next-generation fiber-to- the-cabinet deployment architectures. An evaluation of the proposed modes highlights the potential saving. Moreover we present some techno-social aspects of upcoming fiber-centric access technologies. There are massive power saving possibilities in industries such as transport, automated production, and business and residential buildings.

1. Introduction

Next generation information and telecommunication technologies (ICTs) play an important role in the reduction of climate change. By moving from copper-centric to fiber-centric network infrastructure and by including low power modes, notable improvements in power efficiency can be achieved by reducing the power needed to transmit, reduction of switching sites, and relaxed cooling conditions.

Moreover, future next-generation ICTs networks can help to adapt to the effects of climate by applications like environmental monitoring/alerting and by reducing carbon emission in related industry sectors.

Standardization bodies and equipment vendors have started to put low-power mode discussions high up on the agenda, to secure green network solutions in the near future complying with the European code of conduct on energy consumption of broadband equipment [1].

This paper introduces and discusses low-power saving mode proposals as currently discussed for digital subscriber lines (VDSL2) and passive optical networks (GPON) in ITU-T SQ15.

1.1 Global Warming

Man made changes in atmospheric concentrations of green house gases (GHG) such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), alter the energy balance of our global climate system. As reported in [2], human activities have increased global annual GHG emissions by 70% from 28.7 billion tons in 1970 to 49 billion tons in 2004 resulting in worrying primary effects such as global warming, widespread melting of snow and ice, and rising global sea level as depicted in Figure 1. The list of secondary effects reads like the apocalyptic bible book of revelation, including all kinds of cataclysms such as heat waves, drought, cyclones, fire, flooding, and epidemic plagues.

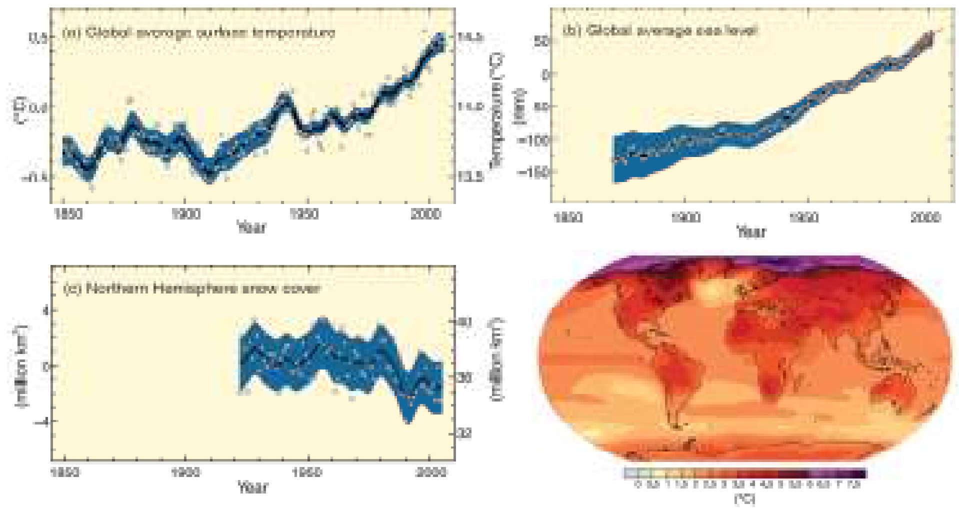

Figure 1: Changes in global average surface temperature, sea level, northern hemisphere snow cover for the period 1961-2004, together with a projected surface temperature 2100 on the globe, [1]

The major economic sectors emitting GHG include energy supply (25.9%), industry (19.4%), forestry (17.4%), agriculture (13.5%), transport (13.1%), residential and commercial buildings (7.9%) and waste (2.8%).

1.2 Effects of ICTs on Global Warming

Information and telecommunication technologies (ICTs) have a two-fold impact on climate change:

- Firstly (according to [1]), they are directly responsible for 2.5% of the global GHG emission, across above mentioned sectors such as energy supply, industry, waste, and residential/business buildings.
- Secondly, and even more important, ICTs have indirect impact by economic, social and technology effects impacting related industry areas.

Section 2 of the paper discusses the first bullet for access technologies like VDSL2 and GPON, whereas the second bullet is discussed in Section 3 of the paper.

2. Low Power FTTCabinet Solutions

2.1 Power Distribution in GPON ONT/ONUs

In order to understand the saving possibilities in GPON user equipment or FTTCabinet backhaul equipment, the power distribution within the device has to be investigated.

Typical flavors of GPON modems (ONTs) are data-only ONTs providing only Ethernet UNIs, ONTs hosting data and voice services such as POTS, and ONTs offering data, voice and RF video.

Typical average power figures for different types of ONT under load are listed in Table 1. The numbers represent the overall power consumption of the device including transformer losses and voltage stabilizers (power supply loss), whereas the number in brackets show the consumption of the electronic components.

Table 1: Average Power Consumption of Different ONT Flavours

Model	Features	Power Consumption in Watts
T060G	Data-only (4xFE)	7.36 (5.56)
T063G	Data, POTS	10.2 (6.51)
T067G	Data, POTS, RF video	11.67 (7.95)

A typical single family unit ONT comprises functional entities such as GPON related optical transceiver (diplexer or triplexer in case RF overlay is used), GPON media access functionality, ONT core functions implementing user data multiplexing, traffic management, ONT OAM control plane and interface interconnects. Depending on the feature set of the ONT, different UNIs can be hosted on the ONT such as voice IFs (POTS, SIP-based), data ports (Ethernet), MoCA interface, or video overlay interfaces, all comprising physical and link layer. Mostly, the ONT core functions with GPON MAC and some interface functionality reside in a system-on-chip hardware component.

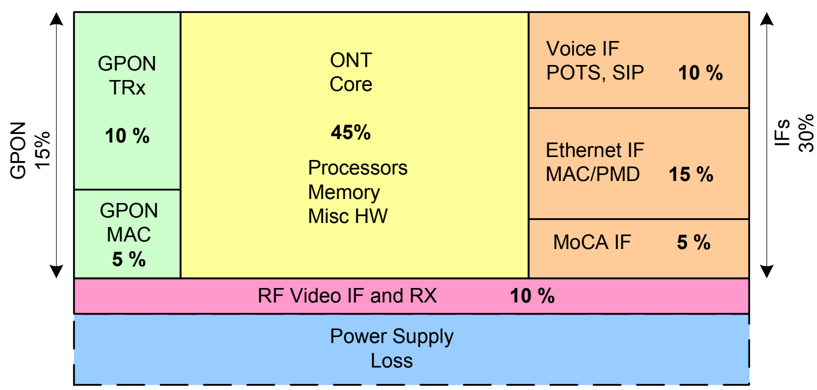

Figure 2: ONT Relative Power Distribution

Typically, the most power intensive components in an ONT are the devices UNIs and ONT core functions taking together roughly 75% of the overall power consumption, as depicted in Figure 2 for a fully equipped triple-play ONT. On average, the GPON-related part including PMD and GTC/GEM functions stands only for 15% (1 to 2 Watts) of the power consumption, resulting in a limited impact on direct power saving when sleep modes are introduced that switch off the GPON-related circuitry if not used.

It is more effective to shed power modularly, by shutting down functions in the ONT core if the corresponding interface functions are not used. This can be implemented in future generations to increase power efficiency of PON systems.

Both methods are described in the sequel.

2.2 Low Power Modes for GPON

In order to evaluate the saving potential of power saving modes currently under discussion for GPON, they are described and compared.

Sleep Mode

The basic idea behind a sleep mode for GPON is to switch off all PON related circuitry, including optics, SERDES, MAC, relevant packet processing, and storage engines when no traffic has to be transmitted.

As initially proposed in [5], an ONT/ONU decides to request to enter sleep mode based on status indicators, such as traffic flow activity, UNI status, upper layer activity control messages or external connected device indicators. In case the OLT grants the sleep mode request, the ONT/ONU stops processing any kind of data for a configured time period derived from the GPON frame counter. The OLT can prolong the sleeping period by putting waking ONTs back to sleep via a broadcast OAM message. A sleeping ONT can at any time request to wake-up if upstream traffic is waiting for transmission.

A typical power saving sequence is depicted in Figure 3. An ONU in operation can request sleep mode by sending a *sleep request* PLOAM message to the OLT. The OLT can place the ONU in sleep mode by responding with a unicast *sleep approval* PLOAM message containing the duration of sleep. On reception the ONU enters sleep mode and wakes up after expiration of the sleep duration receiving all data the OLT has buffered during the sleeping. The OLT can send ONUs back to sleep by broadcasting a *sleep cycle* PLOAM message. At any time, an ONU detecting activity can request to wake-up by sending a *wake-up request* PLOAM message to the OLT, which needs to approve with a unicast *wake-up approval* PLOAM.

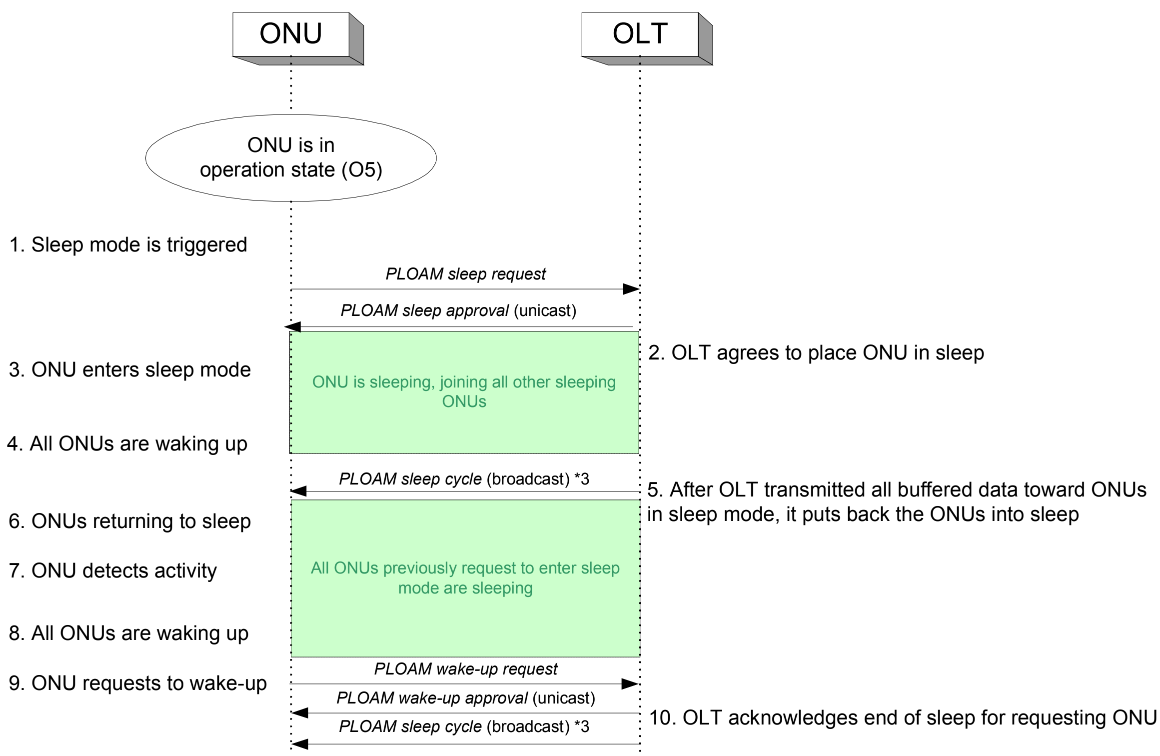

Figure 3: Power Saving Sequence

Since the ONTs do not even decode PLOAM when they sleep, the OLT must buffer any downstream data to its sleeping ONTs until they wake up.

Clearly, this kind of sleep mode has an impact on the service layer by causing delays. Downstream data such as incoming calls need to wait until the configurable sleep duration is over. Upstream data such as outgoing calls can be transmitted directly after acknowledged wake-up request of the ONT. Clearly, OLT and ONT need to buffer data during sleep mode which renders the scheme difficult to implement.

Power Shedding

The current GPON OMCI specification G.984.4 contains a power shedding mode. This mode offers the capability of shutting down unnecessary services in a power failure event in order to preserve a certain number of hours (e.g. 8) of battery power for defined minimum services (lifeline). In the current specification, the feature is modelled by UNI and could be extended to include ONT/ONU core functions to achieve notable power saving even when on AC power. A possible power saving mode based on power shedding could include the following features:

- ONU monitors the status of the UNIs based on reliable indicators such as physical link activity (e.g. loss of signal, loss of carrier) independent of the service layer
- UNI related core functions can be switched off in case the UNI is switched off
- GEM ports (excluding OMCI port) pertaining to switched off UNIs can be disconnected, stopping the flow into the ONT core functions and reducing traffic processing cycles. Disconnected ports stay provisioned and can be connected on UNI request.

2.3 Power Mode Efficiency

Comparing the power saving potential of both modes on data/POTS ONU results in relative saving figures for the modules, according to Figure 4. Clearly, power shedding is more effective than sleeping, since it mainly affects the PON related circuitry and not so much UNIs and SoC functions. An ONU sleeping 80% of the time, would reduce the power consumption by 30% (3 Watts savings).

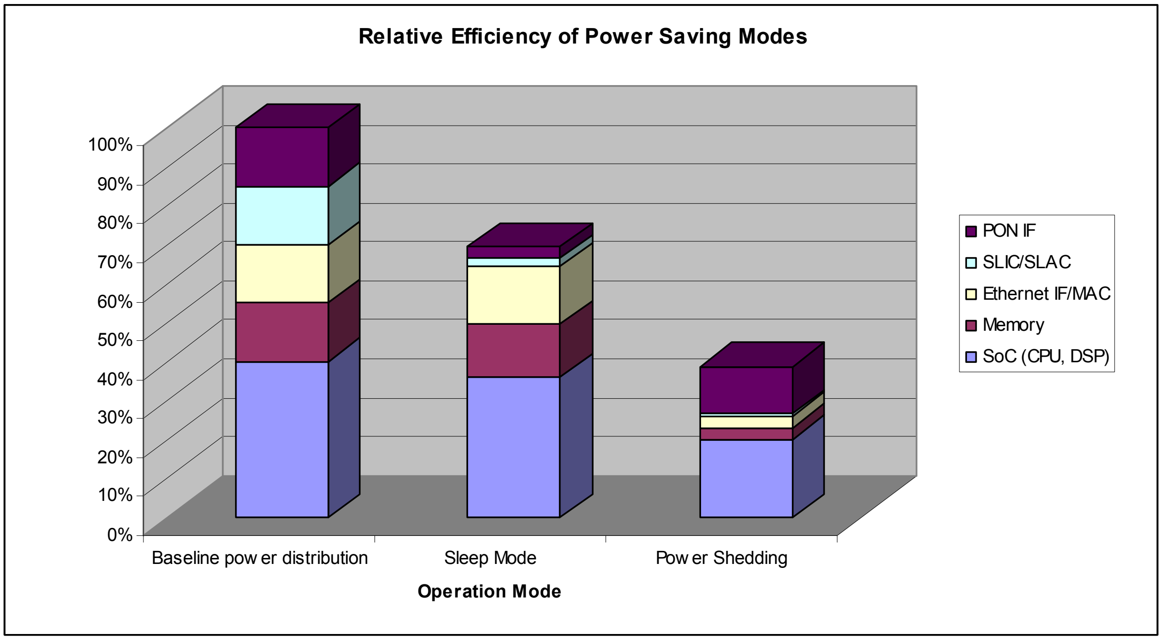

Figure 4: Power Saving Efficiency in both Modes

The efficiency of power shedding depends heavily on the traffic assumed. In the evaluation below, it is assumed that the voice interface is used 5% and the data interface 20% of the time. Under these conditions, 60% of the power can be saved (6 Watts savings).

Aggressive power shedding is twice as effective as the sleep mode. When combining both methods, 80% of the power could be saved.

2.4 Low Power Modes for VDSL2

The VDSL2 modem consists in general of the DSP, an analogue front end (AFE), and the line driver. In addition to this also a network processor (NP) contributes to power consumption.

Table 2 contains typical numbers for the power/line distribution for a VDSL2 DSLAM operating in 17a profile when the network processor has been excluded. The NP and memory would add around 0.5 Watts more per line resulting in an overall figure of 2.1 Watts.

Table 2: Typical power distribution in a VDSL2 DSLAM

VDSL2 profile	Total Power (W)	DSP (W)	Line driver (W)	AFE (W)
17a	1.6	0.6	0.5	0.5

The VDSL2 standard currently only supports a L3 low power state which deactivates the modem and stops transmission. Entering the mode requires user interaction to initialize the modem.

However, there is a discussion in ITU-T to introduce a L2 power saving mode similar to the one existent in ADSL2/ADSL2plus for VDSL2. This approach is described in the following section.

L2 mode

In ITU-T there are several proposals for a VDSL2 low power mode. The proposals are basically to define a low power mode similar to the L2 mode for ADSL2/2plus, but trying to handle some of the problems that have been identified with the L2 mode as it is defined for ADSL2.

The L2 mode in ADSL2 works in a way such that if there is no traffic ongoing the modem can decrease the data rate to a configured minimum to sustain lifeline services such as a VoIP channel. As a result the transmit power is reduced by stepping down the transmit energy per tone (PSD) as long as the SNR margin is sufficient to keep the required minimum rate and service quality (BER).

Entering the L2 mode with small steps of power reduction is done in a staircase scheme. In ADSL2/ADSL2plus leaving L2 mode is done in one large step of power increase to recover the full rate if needed as quick as possible to avoid delay and packet drop. The fast exit causes disturbance on neighbouring lines and can even lead to service outage due to line retrains. This behaviour conveyed that operators up to now do not use the L2 mode for ADSL2.

In VDSL2 an L2 must handle this L2-exit-issue because due to the higher bandwidth used on the copper line crosstalk problems are even more significant than in ADSL2/ADSL2plus.

For VDSL2 there are basically 2 proposals discussed on how to handle the L2 exit:

- One proposal is to turn off every Nth tone, resulting in a *comb power spectrum* with lower overall average power. The problem with varying crosstalk when lines enter and exit L2 mode in this proposal is solved by changing the way modems make their SNR estimation. Modems should have pre-knowledge about the tones that are used by a modem, and measure SNR on these tones to interpolate the SNR on intermediary tones that are turned off. The receiver would then calculate crosstalk from a tone, whether the tone is turned on or not. Obviously with such a solution the problem with varying noise level when modems enter or exit L2 mode would diminish. There are some issues with this method. It requires a change to the receiver’s SNR estimation method. Furthermore it requires that the tones during L2 mode should be predefined. There could also be an issue with predefined tones when there are noise sources like RFI that may vary in frequencies. However, this proposal is still under discussion in ITU-T SG15/Q4.
- The second solution would do a *slow-exit* by increasing the gains in a staircase way instead of a large step, giving the neighbouring modems a chance to adjust to the changed crosstalk situation by bit swaps. One of the objections to this method is that data buffers could overflow due to the time it takes to restore full data rate. The cure for that could be to have a traffic event detection mechanism give an “early warning” that data rate is about to

increase. The request sent to higher layers for increasing the data rate can be delayed until data rate is restored.

Potential power efficiency from an L2 mode

The power reduction by using an L2 mode would basically stem from the line driver. In a lab test on a typical VDSL2 modem it was found that the transmitted power to the line would be reduced from 14dBm (25mW) to -22dBm (6 mW) which gives reduction of around 12 %.

It turns out that that although the line driver power consumption is reduced by around 75 %, the power consumed by the DSP, AFE and the network processor is not, resulting in the low efficiency.

Again, it is evident that power reduction in a VDSL2 DSLAM will not come mainly from transmitting with lower power, but also from lowering the activity of the processing circuitry such as DSP, AFE as well as the NP.

In comparison to the power consumption in a potential L2 mode the power consumed in idle mode is around 50 % lower than in full power.

Of course this is because in idle mode the DSP is sleeping as well as part of the network processor. Unfortunately the time to wake up a modem from this state would require a retrain of the modem that could last up to 30s, and would be perceived by a user as too long a wait to make or receive a phone call. .

3. Side Effects of Next Generation ICTs

According to OECD [4], the main impacts of ICTs are demographic and labor force developments, globalization, trade and investment, economic development, consumption patterns, and technological change. The direct impact on demographic and labor force developments is assumed to be relatively small, but ICT enable also the development of other new technologies.

The socio-economic effects of ICT are quite obvious. ICT seems to boost efficiency (information and communication among different actors and machines, speed, geographic independence) resulting in price reduction and economic growth. ICT industry and services themselves lead to a restructuring of economies and societies, [6]. ICT has the character of an integrated and enabling technology, and thus contributes to macroeconomic phenomena and environmental indicators as highlighted in Table 3. Most areas could profit from next generation ICTs.

Table 3: *The future impact of ICT on environmental sustainability indicators in 2020, [6]*

	Total freight transport	Total passenger transport	Private car transport	Total energy consump.	Share of renewable electricity	Green-house gas emissions	Non-recycled municipal solid waste
Potential impact to:	reduce tkm	reduce pkm	reduce%	reduce TWh	increase%	reduce CO_2-eq. Mt	reduce Mt
Primary effects of ICTs	-	-	-	☹	-	☹	☹
ICTs in supply chain mgmt.	☺	-	-	☺	-	☺	☺
Tele-shopping	☹	☺	😐	😐	-	☺	😐
Telework & virtual meetings	-	☺	☺	☺	-	☺	-
Virtual goods	☺		-	☺	-	☺	☺
ICTs in waste mgmt.	-		-	-	-	-	☺
Intelligent transport systems	☹	☹	☺	☹	-	☹	-
ICTs in energy supply	-	-	-	😐	☺	☺	-
ICTs in facility mgmt.	-	-	-	☺	-	☺	-
ICTs in production process mgmt.	☺	-	-	☺	-	☺	☺
Mobile ICTs time utilisation effect	-	☹	☺	😐	-	😐	-

☹: *The projected impact on the environmental indicator is environmentally unfavourable*
☺: *The projected impact on the environmental indicator is environmentally beneficial*
😐: *The projected impact on the environmental indicator is small or environmentally neutral (the effect is less than ±1%)*
- : *The combination was not projected*

4. Conclusion

Low power modes for GPON and VDLS2 are technically feasible and under discussion in standardization.

Sleep modes for GPON and VDSL2 can reduce the power consumption by 10-30% depending on the service degradation (delay, packet drop, and client timeouts) acceptable for operators and users. When comparing the saving potential with development costs and service impact, sleep modes are unworkable.

Power shedding in a stand-by fashion can get the power down by 50-80% depending on the traffic patterns. Normal technology evolution and market pressures could lead to the introduction of low-power components supporting this kind of mode.

The relative savings of both modes together are in the order of the loss of power supplies needed to power the devices. In that view, power supply efficiency is a hot candidate to look into; same as POTS.

Changes in standards and development efforts are needed to put the modes into reality and vendors, operators as well as ICT-consumers will need to accept a “green-tax”, both in costs and service comfort.

Moreover, there is need of a serious discussion on how to use next generation communication technologies to reduce emission in GHG-heavy industries.

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