



Requirements for an energy efficient home gateway
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2 Acronyms and terminology

2.1 Acronyms

AC	Alternating Current
ADSL	Asymmetric Digital Subscriber Line
ALG	Application Layer Gateway
ATA	Analog Telephone Adapter
ATU	ADSL Transceiver Unit
AP	Access point
CAT-iq	Cordless Advanced Technology - Internet & Quality
CoC	Code of Conduct
CPE	Customer Premises Equipment
CPS	Common Power Supply
CPU	Central Processing Unit
DC	Direct Current
DECT	Digital Enhanced Cordless Technology
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexer
EEE	Energy Efficient Ethernet
ETH	Ethernet
EU	European Union
EuP	Energy Using Products
FTTH	Fibre to the Home
FP	Fixed Part (DECT base)
FXS	Foreign eXchange Station
GAP	General Access Profile
GPON	Gigabit Passive Optical Network
GUI	Graphical User Interface
HG	Home Gateway
HGI	Home Gateway Initiative
IEEE	Institute of Electrical and Electronics Engineers
IGMP	Internet Group Management Protocol
IP	Internet Protocol
IPTV	Internet Protocol Television
ITU-T	International Telecommunication Union – Telecommunication standardisation sector
LED	Light Emitting Diode
LAN	Local Area Network
LED	Light Emitting Diode

LPI	Low Power Idle
MAC	Medium Access Control
MIMO	Multiple-Input Multiple-Output
NAS	Network Attached Storage
NAT/NAPT	Network Address Translation/ Network Address Port Translation
NEMO	No Emission Mode
NTP	Network Time Protocol
PP	Portable Part (DECT handset)
PS	Power Supply
PtP	Point to Point
QoS	Quality of Service
RF	Radio Frequency
RMS	Remote Management System
SIP	Session Initiation Protocol
SSID	Service Set Identifier
STB	Set Top Box
TDMA	Time Division Multiple Access
UDP	User Datagram Protocol
UPnP	Universal Plug&Play
USB	Universal Serial Bus
VDSL	Very high speed Digital Subscriber Line
VoIP	Voice over IP
VPN	Virtual Private Network
WAN	Wide Area Network

2.2 Terminology

Energy efficiency: Consumption of the least amount of energy to perform a given task.

Low power mode: Generic term whenever the HG or a subcomponent is working with significantly lower power consumption than in its normal operational mode. This is normally associated with the HG, or a subcomponent thereof, processing only a very small amount of data.

Idle: The HG or a subcomponent is idle when it is on, but not transporting any data or performing any other processing. Idle is also considered as a low power mode

Definitions of the HG operational modes can be found in sections 8.2 and 8.4.

2.3 Definitions of requirements terms

The definitions of MUST and SHOULD in this document are as follows:

MUST	A functional requirement which is based on a clear consensus among HGI Service Provider members, and is the base level of required functionality for a given class of HG.
MUST NOT	This function is prohibited by the specification.

SHOULD Functionality which goes beyond the base requirements for a given class of HG, and can be used to provide vendor product differentiation (within that class).

Note: These definitions are specific to the HGI and should not be confused with the same or similar terms used by other bodies.

3 Structure of the document

The vision for an energy efficient home gateway is given in Chapter 4.

Chapter 5 summarizes the work done on energy efficiency by other bodies, especially the EU in its European Code of Conduct [3] which defines the power consumption targets for different types of broadband related equipment.

An increasing number of services are now supported, either directly or indirectly, on Home Gateways. These use one or more of the HG's subsystem/functional units, but only those subsystems required for the user's current activity should consume energy. In Chapter 6, use cases relevant to Energy Efficiency are defined, and the service and user experience requirements are stated.

To realize the vision, there is a need to divide the gateway into a number of discrete, and from an energy saving point of view, manageable subsystems/functional units. An assessment is given for each subcomponent on the available operational states, and the potential energy saving mechanisms. This can be found in Chapter 7.

In Chapter 8, the home gateway as a whole is considered and its operational modes are defined. Out of the multitude of possible active modes, a subset of example modes is defined in more detail, which can then be used for measuring the power consumption of the HG.

Note that Chapters 7 and 8 describe best practice information concerning available techniques for subcomponent and system level energy efficiency respectively, but they do not present requirements.

Chapter 9 lists the energy efficiency requirements for a home gateway.

4 Vision

The continuous improvement in the environmental performance of telecommunication products is becoming one of the industry's key objectives. One of the main topics to be addressed is the minimisation of energy consumption, even when the HG is in use.

The HGI supports the standardisation and regulatory activities that are applicable to home gateways. It is the HGI's objective, with regard to energy efficiency in the home, to specify home equipment, in particular the home gateway, to be as efficient as possible with regard to energy consumption. The standardisation and regulation activities with regard to home gateways are described in the next chapter.

The topic is important to both operators and vendors; home gateways and end devices with low energy consumption can be a key element in attracting new customers. The end customer has to pay for the electricity of all the devices in his home, therefore with rising energy costs, the interest in energy efficient devices will grow.

The home gateway is an always-on device, but it can have many different operational modes depending on the truly active functions (both hardware and software), so there is a wide range of opportunities to optimise its energy use.

The HGI considered the following ways of saving energy:

- Although the HG is in principle an always-on device, there may be times when the user does not need any of the services it provides. In this case the user can simply switch the device off. Note however that the increasing use of the HG to support voice, and utility applications related to Smart Grid, may make this option less appropriate.
- The HG should only consume power proportional to its level of activity. A more complex HG (containing more functions) will consume more than a simple HG, but introducing modularity and providing the ability for modules to be automatically switched on and off, may save considerable energy.
- Modules that are never used must have the ability to be permanently turned off (e.g. if there is no wireless device in the home, Wi-Fi could be turned off).
- Peripheral interfaces are only turned on when needed. However this must not significantly adversely impact the Customer Experience, and so the wake-up procedure must be fast, automatic, and triggered by both outgoing and incoming traffic (e.g. an incoming voice call). Both of the following functionalities are needed:
 - The core unit wakes up an interface.
 - An interface wakes up the core unit.
- In some cases putting parts of the home gateway into energy saving mode may have some slight impact on the user. For example, having to wait ~1 second before being able to make a telephone call via the DECT subsystem. Any such restrictions must be acceptable to the user.
- The central functions are subject to a number of energy saving measures (clock speed, memory management, LED control,...)
- The power supply should be as efficient as possible, and needs to be powerful enough to supply needs of the HG and all peripherals needing power-feeding from the HG..

The goals of the HGI regarding HG energy efficiency are as follows:

- To achieve very low power consumption when the HG is not transporting any user traffic (e.g. when it is idle).
- The HG must automatically enter a low power mode when it is idle.

- Transition from a low power mode to normal operation should occur on a sub-second timescale.
- The HG power consumption should be proportional to its level of activity.
- Each individual subcomponent should support low power modes.

To achieve this, chip and box vendors need to design the HG hardware and software with a strong focus on reducing energy consumption.

4.1 Energy efficiency in the HGI

The Residential Profile defined by HGI [1] contains a reference to the European Code of Conduct [3] and provides some non-mandatory requirements for energy saving with respect to “low power” and “on” modes of operation. Features and mechanisms that can be used to achieve the reference values set by the code of conduct are addressed in this document. The requirements are applicable to both HGI Release 2 and Release 3.

4.2 HGI Energy Efficiency Phases

The HGI has divided the work on energy efficiency into 3 phases as shown in Figure 1. The placement of the 3 phases within the HGI Releases is described in [2].

Phase 1 - Energy efficient Home Gateway

Optimize the home gateway energy consumption by analyzing the subcomponents of the home gateway and making use of the individual low power features of these components.

Phase 2 - Energy efficient Home Networking

Optimize the energy consumption of the communication and consumer electronics devices in the home connected to the home gateway. The goal is to achieve overall energy efficiency in the home network so that each device is running in an energy efficient manner. This may include mechanisms to control the power mode of individual devices by the home gateway.

As part of phase 2 the HGI has produced a specification for a Common Power Supply [7] which aims to allow a given end-user to re-use the same power supply when he changes his HG or other home networking devices.

Phase 3 - Home Energy Management and Control

Investigate potential solutions and business requirements for Home Energy Management and Control (Smart energy), which involve the home gateway in minimizing the energy consumption of many devices and appliances in the home. This can lead to energy savings on a much larger scale than can be achieved by home gateways alone; HG's tend to consume around 10 W while the average household consumption is at least several 100 Watts. The home gateway can serve as an enabler to monitor and control the large energy consumers in the home. This can be done both locally and remotely (using remote management capabilities such as TR-069 and proxy techniques to other protocols). Such an approach will allow holistic power management in the home, and thus a significant reduction in energy consumption.

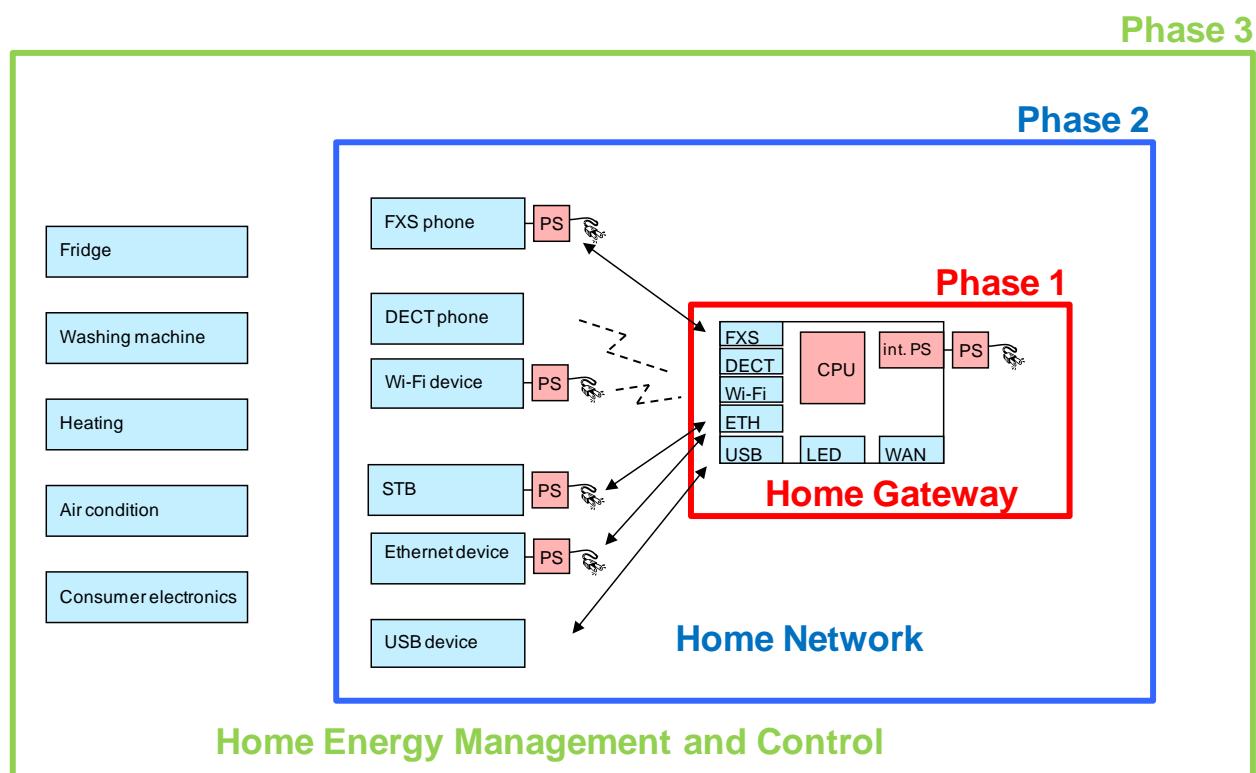


Figure 1: HGI phases towards energy saving in the home

5 Standards and regulations related to energy efficiency

The following sections describe the activities of various standardisation and regulatory bodies related to energy saving applicable to the home gateway and home network equipment.

5.1 EU Ecodesign requirements for Energy-Using Products (EuP)

Equipment sold in the EU has to comply with the EuP directives issued by the European Commission. The following 2 directives are relevant for home gateways.

5.1.1 Ecodesign requirements for standby and off mode electric power consumption of electrical and electronic household and office equipment

This directive [5] is applicable to electrical and electronic household and office equipment and thus includes HGs. The following definitions are extracted from the Directive:

- *'off mode' means a condition in which the equipment is connected to the mains power source and is not providing any function; the following shall also be considered as off mode:*
 - a) *conditions providing only an indication of off-mode condition*
 - b) *conditions providing only functionalities intended to ensure electromagnetic compatibility pursuant to Directive 2004/108/EC of the European Parliament and of the Council*
- *'standby mode(s)' means a condition where the equipment is connected to the mains power source, depends on energy input from the mains power source to work as intended and provides only the following functions, which may persist for an indefinite time:*
 - o *reactivation function, or reactivation function and only an indication of enabled reactivation function, and/or*
 - o *information or status display*
 - o *'reactivation function' means a function facilitating the activation of other modes, including active mode, by remote switch, including remote control, internal sensor, timer to a condition providing additional functions, including the main function*
- *'active mode(s)' means a condition in which the equipment is connected to the mains power source and at least one of the main function(s) providing the intended service of the equipment has been activated*

The power consumption allowed in off and standby is given in the following table:

Mode	1 year after the regulation comes into force = 1.1.2010	4 years after the regulation comes into force = 1.1.2013
Off and standby without display	1W	0,5W
Standby with display	2W	1W

Equipment shall, except where this is inappropriate for the intended use, provide off mode and/or standby mode, and/or another condition which does not exceed the applicable power consumption requirements for off mode and/or standby mode when the equipment is connected to the mains power source.

In the second phase (4 years after the regulation comes into force = 1.1.2013) **power management** is mandated:

- *When equipment is not providing the main function, or when other energy-using product(s) are not dependent on its functions, equipment shall, unless inappropriate for the intended use, offer a power management function, or a similar function, that switches equipment after*

the shortest possible period of time appropriate for the intended use of the equipment, automatically into:

- *standby mode, or*
- *off mode, or*
- *another condition which does not exceed the applicable power consumption requirements for off mode and/or standby mode when the equipment is connected to the mains power source.*

5.1.1.1 Applicability of EuP standby and off mode requirements for home gateways

The standby mode is not appropriate for a HG as its main function is to provide network connectivity which is needed all the time. Thus to comply with this EuP directive, an HG either needs to implement an on/off button, or the reason why the off mode is not appropriate for a given type of HG has to be declared. Such reasons could include voice support, (e.g. not having to physically switch the HG back on in order to make or receive an 'emergency' call) and Smart Grid applications where 24hr monitoring and control may be needed.

5.1.2 Ecodesign requirements for no-load condition electric power consumption and average active efficiency of external power supplies

This regulation [6] mandates for AC/DC external power supplies a no-load power consumption of less than 0.3 W and the following efficiency levels:

Rated output power	Average active efficiency
$P_0 \leq 1.0 \text{ W}$	$0.480 \cdot P_0 + 0.140$
$1.0 \text{ W} < P_0 \leq 51.0 \text{ W}$	$0.063 \cdot \ln(P_0) + 0.622$
$P_0 > 51.0 \text{ W}$	0.870

The requirements of this regulation are aligned with the CoC for external power supplies version 4. These regulations have been taken into account within the CPS requirements document [7].

5.2 EU Codes of Conduct on Energy Consumption

The HGI supports the EU CoC initiative and is a major contributor to the CoC for broadband equipment. As the operational modes and power targets documented in the EU CoC are closely related to the requirements in this document, the EU CoC is described in the following sections in some detail, and the most relevant targets for HGs have been reproduced.

A "Code of Conduct" (CoC) is not a regulation, but a recommended code of practice promoted by the European Commission. It is based on a voluntary commitment by those companies who have signed a given CoC.

With the EU standby initiative, the European Commission wants to improve the energy efficiency of electrical equipment while either off, or in standby. In order to achieve this goal, several Codes of Conduct have been developed. The following documents are currently available:

- Code of Conduct for Data Centres
- Code of Conduct for Digital TV Services
- Code of Conduct on Energy Consumption of Broadband Communication Equipment [3]
- Code of Conduct on Efficiency of External Power Supplies [4]
- Code of Conduct on AC Uninterruptible Power Systems (UPS)

For an HG, the CoC for Broadband Communication Equipment is the most relevant. The aim is to reduce power consumption of broadband equipment in order to limit its environmental impact. This CoC

has been in force since July 2006. It covers both the customer side (with special emphasis on HGs) and access network side equipment.

5.2.1 Code of Conduct on Energy Consumption of Broadband Communication Equipment Version 3

The HGI has contributed actively to the CoC version 3 document and at the time of publication of this document is contributing to CoC version 4, mainly on the customer premises sections. The HGI's modular approach for the calculation of the targets has been adopted by the CoC. The HGI supports the CoC and has adopted the concepts described therein.

The CoC for broadband equipment defines power consumption targets measured at the AC mains input. For an HG the following targets have been defined:

Power values for home gateway central functions plus WAN interface

Home gateway central functions plus WAN interface	Tier 2009/2010: 1.1.2009- 31.12.2010		Tier 2011: 1.1.- 31.12.2011	
	Low-Power-State (W)	On-State (W)	Low-Power-State (W)	On-State (W)
ADSL/ADSL2/ADSL2+	4,2	5,0	2,6	3,8
VDSL2	5,5	7,5	3,5	6,0
Fast Ethernet WAN (100Base-T)	2,9	4,2	2,5	3,3
Gigabit Ethernet WAN (1000Base-T)	4,0	7,0	3,2	6,2
Fibre Ptp Ethernet WAN (100/1000Base-BX or FX)	3,4	7,1	2,9	5,6
GPON	5,0	9,7	4,0	7,7

Power values for home gateway LAN interfaces and additional functionality

Home gateway LAN interfaces and additional functionality	Tier 2009/2010: 1.1.2009- 31.12.2010		Tier 2011: 1.1.- 31.12.2011	
	Low-Power-State (W)	On-State (W)	Low-Power-State (W)	On-State (W)
Fast Ethernet switch, up to 4 ports	0,8	2,2	0,6	1,8
1 Fast Ethernet port	0,3	0,5	0,3	0,4
Gigabit Ethernet switch, up to 4 ports	1,5	4,5	1,2	3,7
1 Gigabit Ethernet port	0,3	1,7	0,3	1,3
Wi-Fi interface single IEEE 802.11b/g or 11a radio	1,0	2,0	0,7	2,0
Wi-Fi interface single IEEE 802.11n Draft 2 radio (and other proprietary pre-n solutions)	1,0	2,5	1,0	2,5
Wi-Fi interface dual (2.4GHz and 5GHz) IEEE 802.11n Draft 2 radio (and other proprietary pre-n solutions)	2,0	5,0	2,0	5,0
Alternative LAN technologies (HPNA, MoCA, POF...)	4,0	4,0	2,0	2,5

Powerline	4,0	4,0	2,5	3,0
FXS	0,8	1,5	0,5	1,5
FXO	0,4	0,9	0,4	0,9
DECT GAP	1,0	1,65	0,75	1,65
DECT CAT-iq	1,0	2,0	0,75	2,0
DECT charging station for DECT handset in slow/trickle charge	0,5	0	0,4	0
USB	0,3	0,3	0,25	0,25

The home gateway power consumption targets are computed from the components according to the configuration (profile) of the home gateway and the values of the individual components are summed. Only the overall value has to be met.

The revision of Version 3 of the CoC is ongoing, with a target date for the publication of Version 4 set for Q4 2010

5.2.2 Code of Conduct on Efficiency of External Power Supplies (Version 4)

As most HGs are powered by an external power supply, this CoC is also relevant. It is also aligned with the EuP. For an HG, it specifies less than 0.3 W consumption in no-load condition as detailed in the following table:

Rated Output Power (P_{no})	No-load power consumption From 1.1.2009
$0.3 \text{ W} < P_{no} \leq 50 \text{ W}$	0.3 W
$50 \text{ W} < P_{no} \leq 250 \text{ W}$	0.5 W

In active mode the following values apply:

Rated Output Power (P_{no})	Minimum Four Point Average Efficiency in Active Mode From 1.1.2009
$0 \text{ W} < P_{no} \leq 1 \text{ W}$	$\geq 0.48 \cdot P_{no} + 0.140$
$1 \text{ W} < P_{no} \leq 49 \text{ W}$	$\geq 0.0626 \cdot \ln(P_{no}) + 0.622$
$49 \text{ W} < P_{no} \leq 250 \text{ W}$	≥ 0.870

Active mode efficiency is defined as the simple arithmetic average of efficiency measurements made at 25%, 50%, 75% and 100% of the full rated output power.

5.3 ETSI EE

This body is working on the following documents related to energy saving:

- DTS/EE0018 Measurement methods and limits for Energy consumption of End-user Broadband equipment (CPE)
- DEN/0021 Measurement method for energy consumption of Customer Premises Equipment (CPE)

HGI is collaborating with ETSI EE on the definition of the measurement method for home gateways.

5.4 ITU-T

The L2 mode for ADSL2 and ADSL2+ is defined in the following ITU-T recommendations:

- G.992.3: Asymmetric digital subscriber line transceivers 2 (ADSL2)
- G.992.5: Asymmetric digital subscriber line (ADSL) transceivers – Extended bandwidth ADSL2 (ADSL2plus)

5.5 Broadband Forum

This body has issued the following documents related to energy saving:

- TR-202 - Guidelines for the use of existing ADSL2/2plus L2 (low power) parameters.

5.6 DECT Forum

This body has issued the following documents related to energy saving:

- DF_CAT-iq T_001 V1.5_2010-04-24 DF_CAT-iq Feature Requirements V1.5

It is intended to incorporate all power save modes (referred to in section 7.5.4 of this document) into the DECT CAT-iq 2.1 standard.

5.7 ETSI DECT-NG

This body has issued the following documents related to energy saving:

- ETSI TS 102 527-3 V1.2.1 (2010-04) Digital Enhanced Cordless Telecommunications (DECT); New Generation DECT; Part 3: Extended wideband speech services which contains the No Emission Mode.

5.8 IEEE

This body is working on the following document related to energy saving:

- 802.3az Energy Efficient Ethernet

5.9 Energy Star

This body has issued the following document relevant for energy savings in home gateways:

- ENERGY STAR Program Requirements for Single Voltage External AC-DC and AC-AC Power Supplies

This body is working on the following document relevant for energy savings in home gateways:

- ENERGY STAR Test Procedure for Determining the Power Use of Small Network Equipment

6 Services and user experience

This chapter details how the active services in a home network may impact energy consumption and also impose requirements on the energy saving features. Generally speaking, the more energy that needs to be saved the bigger the impact on user experience. So there is always a trade-off between energy consumption and user experience/inconvenience. An example is waiting 1 second before being able to make a telephone call via a DECT subsystem.

6.1 Services in a home network

Today most customers only use a limited set of services. The basic services offered are:

- Broadband connection (e. g. Internet access via a wired and/or wireless terminal)
- Communication (especially VoIP)
- Entertainment (including IPTV)

Local home network traffic is increasing significantly as more and more homes are equipped with some type of home network. A central printer or central storage for all kinds of data is becoming popular. Examples of local home network services are:

- Mass storage access (USB or LAN, i.e. networked attached storage (NAS))
- Printer access
- Data exchange with other PCs (gaming etc) or NAS
- Remote access services: Data exchange with remote PCs

As it is very difficult to find a “one size fits all” solution, individual services are defined first. In future, more and more users will use a combination of these services, and additional services will be developed. More devices will be connected to the HG. This raises the following difficulties for energy saving in the home network:

- All services must be supported
- There will be shorter periods with no traffic
- Therefore it gets more difficult for the HG to enter low power modes

6.2 Service use cases

During the day the HG transitions through several modes depending on the actual usage of the supported services. While there may be long periods in the 24 hour day when no services are consumed (e.g. during the night), at certain times many, if not all, services will be concurrently active. Even during times where no services are actively being consumed, it is possible that devices will exchange signalling or keep-alive messages.

The general assumption is that all the subcomponents (described in chapter 7) which are not required to support a service (or a service mix) can be put separately and independently into an energy saving mode.

Refer to section 6.6 for the general principle regarding wake up latency.

6.2.1 Broadband connection access use cases

The broadband connection access use cases deal with users who only have basic Internet connectivity.

6.2.1.1 Internet access via PC

The user wants Internet access only and has 1 PC connected via Ethernet to the HG. The PC is switched off most of the day (20 hours). During this time there is no traffic on the LAN side (from the PC) and the HG should be in an energy saving mode.

When the PC is switched on the user expects to access the Internet as soon as the PC has started up. Therefore the HG must recognize when the PC is switched on (e.g. when the Ethernet link becomes active) and provide the necessary functionality to enable the user to access the Internet (e.g. establish a PPP session, obtain an IP address etc.)

6.2.1.2 Internet access via Wi-Fi enabled device

The user wants to access Internet services using a Wi-Fi device. The HG is in an energy saving mode as long as no Wi-Fi client is connected and there is no traffic on the Wi-Fi side. The Wi-Fi access point in the HG only sends beacons to allow clients to connect to the Wi-Fi network.

The HG must recognize when a Wi-Fi client is activated and wants to connect to the Wi-Fi access point. The additional delay imposed by the energy saving mechanisms before the user is able to access the Internet should be no more than 1 second.

6.2.2 Communication/VoIP use cases

The VoIP use cases cover voice-only customers who don't use other services via the HG.

6.2.2.1 VoIP only: FXS connected phone

One phone is connected to the FXS port of the HG. The phone is on-hook most of the day (22 hours). The SIP client in the HG sends periodic SIP register messages over the WAN connection (e.g. UDP, 500 bytes, every 120 seconds). The user must be able to make outgoing calls or receive incoming calls with a maximum additional delay caused by the energy saving mechanisms of 1 second.

6.2.2.2 VoIP only: Ethernet connected IP phone or ATA

One IP phone is connected to an Ethernet port of the HG. The phone is on hook most of the day (22 hours). The SIP client in the IP phone or ATA sends periodic SIP register messages over the HG's WAN connection (e.g. UDP, 500 bytes, every 120 seconds) to keep the NAT open. The user must be able to make outgoing calls or receive incoming calls with a maximum additional delay caused by the energy saving mechanisms of 1 second.

6.2.2.3 VoIP only: DECT connected phone

One DECT phone is registered to the DECT base station in the HG. There is no call in progress during most of the day (22 hours). The SIP client in the HG sends periodic SIP register messages over the WAN connection (e.g. UDP, 500 bytes, every 120 seconds). The user must be able to make outgoing calls or receive incoming calls with a maximum additional delay caused by the energy saving mechanisms of 1 second. It must also be possible that the DECT subsystem is connected via USB (DECT Dongle).

6.2.3 Entertainment /IPTV use case

A STB is connected via Ethernet to the HG. The STB is in standby most of the day (20 hours). During this time the STB may send keep-alive messages (e.g. UDP, 300 bytes, every 3 seconds). When a scheduled programming is initiated from the WAN side it must be able to reactivate the STB.

In the evening the children are back at home and want to watch TV and switch on the TV and STB. The IPTV stream must appear on the screen with a maximum additional delay caused by the energy saving mechanisms of 1 second.

6.2.4 Remote access use cases

Remote Access: Establish a remote access connection

A user in a remote location wants to create a remote access connection to the home. There is no remote access connection running on the HG. The user from a remote location must be able to establish a remote access connection with a maximum additional delay caused by the energy saving mechanisms of 3 second. Periodic keep-alive signalling needs to be sent to keep the remote access connection up once it is established.

Remote Access: Remote access media transfer

A user in a remote location with an established remote access connection wants to transfer information to/from the home, for example uploading/downloading pictures or viewing a security camera.

The user from a remote location with an active remote access connection must be able to transfer media with a maximum additional delay caused by the energy saving mechanisms of 1 second.

6.2.5 Local home network services use case

These use cases describe services that are not delivered over the WAN connection but run locally over the user's home network. Typically here there will be long periods of inactivity, so that energy efficient implementation can have a strong impact.

6.2.5.1 USB mass storage

A USB mass storage is connected to the USB port of the HG. The user accesses the storage on his laptop which is connected via Wi-Fi to the HG. During very long periods there is no activity.

When the user wants to share some pictures with a friend the mass storage device must be detected (presented to the user) and access to the files must be possible within 3 seconds.

6.2.5.2 LAN printer sharing

A printer is connected to the USB port of the HG. The user is connected to the HG via Wi-Fi.

When the user wants to print a document the printer must be detected and printing process must have a maximum additional delay caused by the energy saving mechanisms of 3 seconds.

6.2.5.3 Media sharing

A NAS is connected to an Ethernet port of the HG. The user is connected to the HG via an Ethernet port.

When the user wants to share some pictures with a friend the NAS must be detected and access to the files must be possible within 3 seconds.

6.3 User experience requirements

As an HG is a very complex system it is not easy for the average broadband customer to understand. Most users are either unwilling or unable to configure settings on their HG. This should be taken into account when considering the degree of user interaction, but at the same time more experienced and/or ecologically interested users should be allowed to configure the more advanced energy saving mechanisms; expert, manual intervention is likely to produce the greatest reductions in energy consumption.

Three different user types can be distinguished:

1. The Standard user, who either does not care about the settings of the HG, or does not understand the system well enough to make modifications.
2. The Interested user, who has some basic knowledge of gateway functionality.
3. The Expert user who would like to fine-tune the behaviour of sub-systems.

The Standard user must not need to intervene in the process of saving energy, so all subsystems must go into energy save mode automatically.

The Interested user should be able to activate/de-activate pre-programmed behaviour with easy-to use configuration (e.g. by choosing from a limited number of energy saving levels: low, medium and high). A configuration assistant might be used to determine usage/user behaviour e.g. which subsystems are normally used, which of the subsystems could be put in energy save mode, which subsystems can be turned off permanently.

The Expert user should be able to configure all the energy saving settings (including timings) in the HG via a 'local management portal', but should be made aware of any potentially negative performance implications of certain settings. For example, the Expert users should be able to configure periods (start time, end time, day of the week, etc.) during which certain interfaces are enabled and disabled (e.g. disabling the Wi-Fi interface during the night). He should be able to define which interfaces or ports are active during which periods. By completely shutting down certain subsystems or individual ports more energy savings can be achieved than by a purely automatic approach where some basic functionality still

needs to be provided to detect activity. Additionally the expert user may deliberately choose more aggressive energy saving options in the full knowledge of the adverse impact on user experience (e.g. longer reaction times), so he can tailor the trade-off between energy efficiency and performance.

6.3.1 User interaction requirements

Configuration of energy saving features by the user must be possible via the HGs 'local management portal' (web GUI). In addition some functions, (e.g. turning on and off the Wi-Fi interface) could also be controlled via a DECT handset or a phone connected to the home gateway port.

The user must have a way to know which mode the HG is in; this may influence his service expectations and also provide reassurance that no energy is being wasted. Therefore the HG should provide some visual indication that it is in an energy saving mode. Potential indicators are:

- LEDs e.g. by switching off all LEDs except one, or by changing the colour of an LED.
- DECT handsets, e.g. status messages and/or icons displayed on the screen of connected DECT handsets

For troubleshooting purposes the user must be able to switch off all energy saving mechanisms via the HG 'local management portal' (web GUI).

Additionally for the Wi-Fi interface, an on/off button may be desirable; turning off the Wi-Fi interface is the most significant single action that can be taken to save energy.

6.4 Remote management requirements

In order to facilitate remote management and/or remote diagnostics, all subsystems which are able to change their state must be able to be controlled individually via remote management. As general principle the state of each individual subsystem may be remotely readable and changeable. Detailed requirements in this regard will be defined in a subsequent version of this document.

Any user configurable energy saving parameters should also be accessible through remote management.

It should be possible to remotely deactivate all energy savings mechanisms for specific applications like remote diagnostics etc. After the intervention, the HG should return to its original configuration.

6.5 Service requirements

It is important to consider the behaviour of not just the HG itself, but also those devices (e.g. STB or media server) which consume services delivered via the HG. If the complete system ("connected home") is not designed as a whole, it may prevent the HG from ever transitioning to a low power mode. This topic will be handled in Phase 2 (see chapter 4.2) where energy efficiency in the connected home will be investigated.

6.5.1 Periods when the user does not need any service

During periods that the user does not need any service, he should be able to switch the HG completely off by either a hard mechanism (e.g. a button) or a soft method (power management/planning). This may be used during the night or for vacation absences.

Depending upon the operator's business case and service set, the HG may need to be a truly always-on device where it is not desirable that the user can switch off the HG. In such a scenario, it is even more important that the HG enters an energy saving mode during periods where no service is being consumed.

6.5.2 Internet access (wired and wireless) requirements

Auto activation by user traffic must be possible on all interfaces. In addition the user should be able to define active periods for certain interfaces e.g. the Wi-Fi is turned off completely at 11 pm every day and switches on again at 7 a.m.; note however that this would not be appropriate if the HG was supporting a Guest Access service. In the enabled periods, the Wi-Fi would behave as described below.

6.5.2.1 LAN interface

LAN interfaces should be in low power mode if no devices are connected to them. When all ports are inactive, then some common functions may also go into low power mode, if this provides significant additional energy savings.

The HG must support autonomous wake up, i.e. if the PC is switched on the HG activates the Ethernet interface. It must be possible to activate and deactivate each LAN port separately.

6.5.2.2 Wi-Fi interface

The Wi-Fi interface should go in a low power mode when no traffic is present, but it should still be possible to see the SSID and associate to the Wi-Fi network (i.e. beacons must still be sent).

As soon as traffic needs to be transmitted via Wi-Fi this should be possible without noticeable delay.

6.5.3 Communication/VoIP requirements

As the connectivity for voice devices has many options: FXS, DECT, LAN and USB, the HG should be aware which interfaces are actually going to be used, in order to turn on/off the correct ones.

VoIP incoming call

- Inbound voice callers should not obtain ring tone until the phone is actually ringing; there should be silence on the caller side until far-end ringing is initiated.
- The phone must ring when an incoming call is received with a maximum additional delay of 1 second.

VoIP outgoing calls:

- When the phone comes off hook it must be possible place a call with a maximum additional delay of 1 second.

VoIP signalling messages

- It must be possible to exchange signalling messages at any time (e.g. SIP register messages to keep the NAT open). The impact of VoIP keep-alives will be studied in phase 2 to ensure they do not prevent the HG ever going into low-power mode.

VoIP USB DECT dongle

- The USB port should remain activated when used for a VoIP service (e.g. DECT dongle).

6.5.4 IPTV requirements

STB standby mode: To support the STB's standby mode and the VCR functionality, it must be possible for the STB to send and receive keep-alive pings and notifications at any time. The impact of IPTV keep-alives will be studied in phase 2 to ensure they do not prevent the HG ever going into low-power mode.

A 1 second of additional delay is acceptable for a TV service LAN interface to be reactivated.

6.5.5 Local home network service requirements

As LAN services may generate keep-alive traffic, the system design must ensure that the impact on energy consumption is as low as possible.

For example, keep-alive signals from DLNA servers are sent as UPnP SSDP discovery messages (UDP, multicast). For these, a minimum time between messages of 30 minutes (i.e. SSDP message must not be sent more frequently than 30 minutes) is specified in the standard, but the actual time interval is vendor implementation specific and the time between SSDP messages can be much shorter.

6.5.5.1 USB connected devices

The USB ports should be in low power mode when no traffic is present. If nothing is connected to a USB port it should use minimal or no power.

The USB port should be activated by the respective service. This could be for example a USB DECT dongle being activated by the VoIP service, or a USB storage device by any access (e.g. media sharing).

USB devices must be accessible with a maximum additional delay of 1 second.

6.6 Timing requirements

As a general principle, any energy saving action should have no noticeable impact on the delivery of a service, i.e. the perception of service availability must not be impaired by the implementation of energy efficiency mechanisms.

Expert users should have the possibility to change the timing values, while Standard and Interested users should not need to have to change any timing values.

6.6.1 Wake up timing

The additional latency (delay) for locally initiated services should be no more than 1 second when the HG is in a low power mode.

The additional latency for remotely initiated services (when the HG is in a low power mode) should also ideally be no more than 1 second, but a figure of no more than 3 seconds may be acceptable if this is simpler to implement or produces a greater energy saving.

6.6.2 Inactivity timer

While some subcomponents can switch to an energy saving mode immediately after a certain trigger, others may need to wait for certain period of inactivity in order to avoid instability. This value must be configurable via the Remote Management Platform/ACS and should be configurable via the HG 'local management portal' (web GUI).

7 Home gateway decomposition

This chapter outlines the basic subcomponents of a home gateway and lists the basic states in which these subcomponents can be from a power perspective. It then describes the possible energy saving mechanisms available for each of these subcomponents. The sections in this chapter serve as best practice examples of energy saving, but are not binding unless they have explicit associated requirements in Chapter 9. HG vendors could implement the additional features which are not currently covered by explicit requirements in order to provide product differentiation.

In addition to the states themselves, additional guidance is given on useful triggers so that the HG can automatically transition between the various states. Again not all of these are covered by explicit requirements in Chapter 9, but these triggers have been carefully considered bearing in mind the need to minimise the impact of power saving on Customer Experience, and so should be seriously considered by any vendor wishing to implement this additional functionality. Some of the power savings are not quantified because of the dependency on the detailed architecture of individual HG designs, but the triggers may well be used by Service Providers to test what power-save functionality has actually been implemented and to measure the impact of each triggered state change.

7.1 Overview of functional blocks of the HG

A home gateway is composed of several subcomponents as shown in Figure 2. Most of the HG hardware components have two or more states, corresponding to different power consumption and service levels.

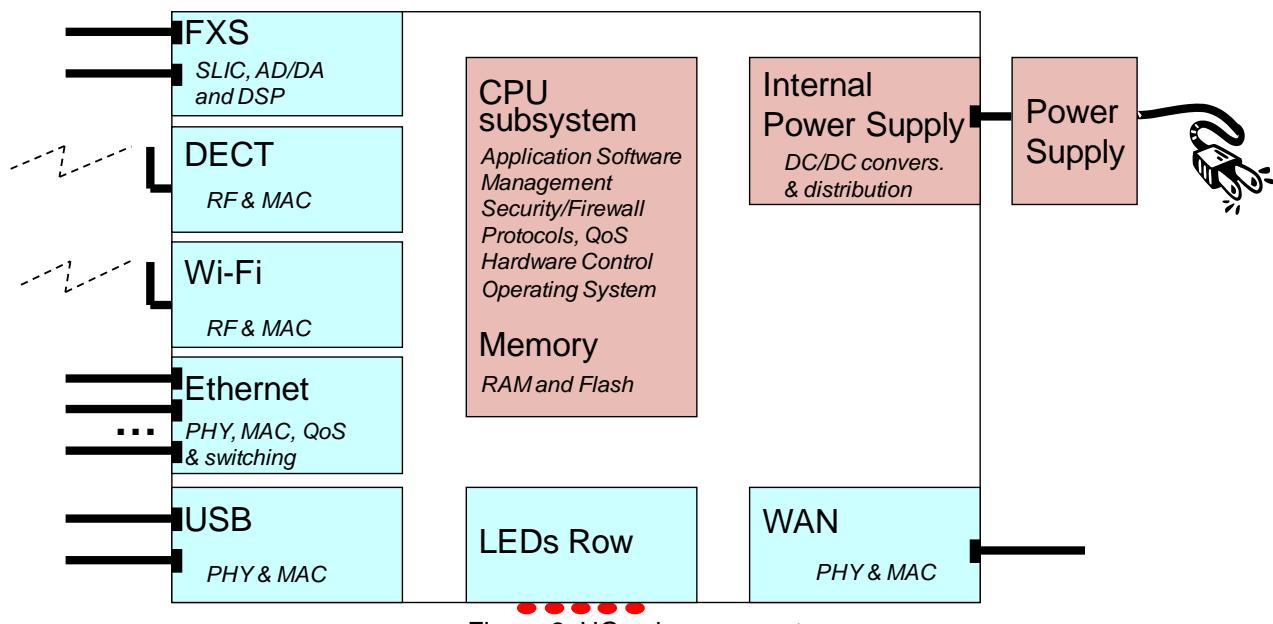


Figure 2: HG subcomponents

The hardware subcomponents can be divided into two main blocks:

Common functions	Interface functions
Power supply (internal + on-board), CPU subsystem and memory	WAN, Wi-Fi, Ethernet, DECT, FXS, LEDs, etc.

7.2 Power adapters and power conversion

The subsystem required to power the HG normally consists of an external power adapter, plus on-board DC/DC converters.

The DC voltage of external power supplies for home gateways is not yet standardized. Commonly found DC voltages are 12V and 15V, but for some high-end gateways, higher voltages are used. The variation is mainly due the availability of a wide variety of home gateway types which range from a simple modem, to high-end gateways with a large number of ports and wireless access points, and the need to power directly attached peripherals (e.g. via USB), or devices (e.g. a POTS telephone). Given this variety, many different maximum power consumptions are possible.

From the energy efficiency viewpoint, it is important that the power supply is as efficient as possible for a given home gateway system. There are minimum values imposed on the efficiency of external power supplies (see sections 5.1.1.1 and 5.2.2).

CoC values are specified at the 230V AC outlet, thus when comparing them with the on-board power consumption of a subcomponent the power conversion efficiency must be taken into account:

$$CoC_value = \frac{On_board}{ACDC_eff \cdot DCDC_eff}$$

7.2.1 External power adapters

HGs typically use an external power adapter which converts from AC to DC. External power adapters are covered by the EuP and CoC (see sections 5.1.1.1 and 5.2.2) which set the target no-load power consumption and the average active efficiency level (depending on the rated output power of the power adapter as illustrated in Figure 3).

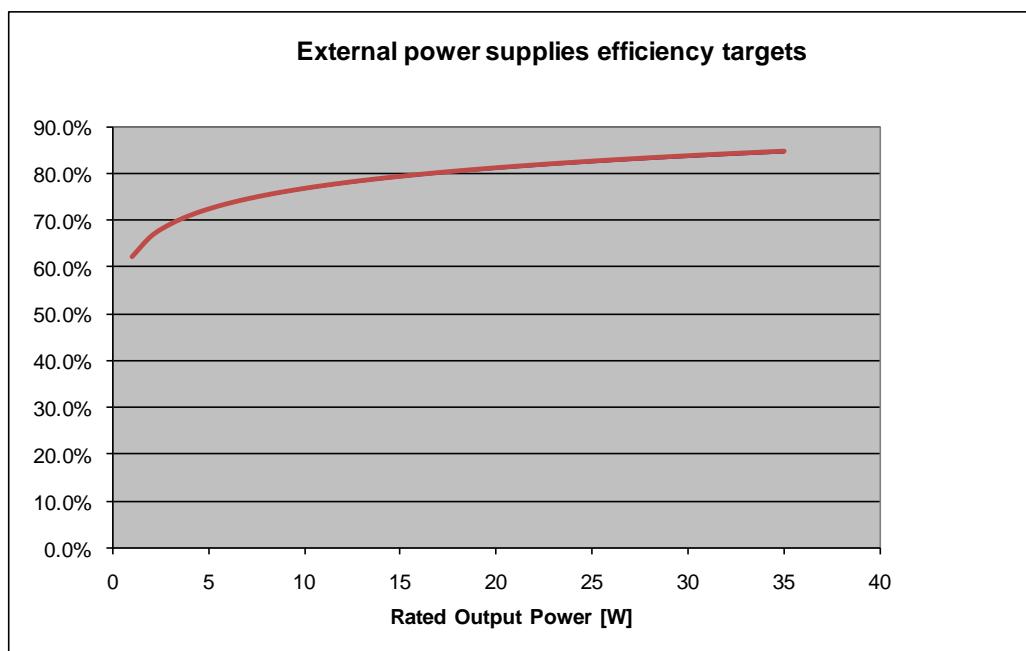


Figure 3: EuP required external power supply efficiency

As the efficiency of the power adapter contributes directly to the overall power consumption it is necessary to use power adapters with a high conversion efficiency.

The best practice figures in the EuP document are:

- No load: 0.1W
- Average active efficiency: 89%

The HGI has defined a specification for a common power supply [7], which covers operating conditions, requirements on efficiency and guidelines on connectors.

7.2.1.1 Considerations about a 5V power supply for home gateways

From the viewpoint of energy consumption, it is important to bring the power consumption down (and this means both voltage and current). This can be achieved by using more energy efficient components in the home gateway. However there are certain components for which the voltages are fixed by standards, e.g. USB needs 5V, and an analogue POTS telephone needs 48V (and enough power for the required REN REN (Ringer Equivalence Number)).

Since there are methods for boosting the voltage, in principle there is no technical problem with feeding circuits that require higher DC voltages than the input voltage. However in practice, circuits demanding higher currents may lower the feeding voltage to the point where it is below the specified voltage limit.

As most components of a home gateway need 5V or less, it is interesting to consider a 5V external supply. The introduction of 5V power supply for HGs would lead to a double benefit:

- Improving the gateway energy efficiency,
- Reducing the surface and volume of the HG board and casing.

By using a 5V supply, the energy efficiency can be increased due to the following reasons:

- better efficiency in deriving the core low voltage; it is challenging to build an efficient DC/DC conversion stage with a high input to output ratio (e.g. 12V to 1V). Choosing 5V as the input voltage eases this problem. Typically, the increase in efficiency is from ~70% (12V to 1V) to ~90% (5V to 1V). This means a 300mW gain on a 1V rail consuming 1W.
- better efficiency in feeding the 5V gateway rail; the 5V rail is usually used to power the HG's USB ports. Using 5V as the input voltage allows direct feeding of the USB ports without any DC/DC conversion. Consequently, the conversion losses of a 12V approach are eliminated. The USB device consumption may vary from a few mA to the specified limit of 500mA, although external HDDs may actually draw 700mA on start-up. Ensuring a good efficiency over this large range is difficult. Typically, a gateway may have 85% efficiency for a 12V to 5V at 1A and 60% at 100mA, meaning losses ranging from 300mW to 900mW. This means a reduction in power consumption of 900mW would be achieved by using the 5V approach.

The 5V approach reduces the surface and volume of the HG board and casing for the following reasons:

- Surface: the 12V to 5V conversion stage is removed. This means fewer components and thus a PCB area saving.
- Volume: energy efficiency benefit is synonymous with reduction in power consumption. It therefore means less heat needs to be dissipated which allows to the HG volume to be reduced.

However it should be noted that there are also some drawbacks to the use of a 5V power supply:

- The voltage drop in the cord from power supply to the home gateway board may be critical for correct functioning of USB devices, which only function properly at 5V +/- 0.25V. For a 2m cord (2x0.75mm² conductors) there is a loss of about 1.16W at 5V/3.5A. This 1.16W is lost energy, just heating the cord. As a rule of thumb, it can be concluded that 5V power supplies should only be used for home gateways consuming less than 15W.
- Some functions can be provided better and more cheaply with higher input voltages. Implementing dying gasp, xDSL line drivers, feeding USB, and the 48V POTS generation can all be done in 5V powered home gateway, but at a cost and this could lead to more expensive devices, especially at the higher end.

A number of these issues may disappear in the long term; fibre will tend to replace xDSL, VoIP will be used instead of FXS, chips will operate at lower voltages and less power, and current consuming hard drives will be replaced by solid state memories. Therefore the 5V power supply may become a realistic option for future energy efficient gateways which use these new technologies.

7.2.1.2 Considerations for power supplies above 12V for home gateways

For high-end gateways including xDSL, FXS ports, Gigabit Ethernet, DECT, DECT charging station, Wi-Fi, multiple USB ports, NAS applications etc., a power supply above 12V is beneficial from an energy efficiency perspective. The benefits include:

- the voltage drop in the cord from the power supply to the home gateway can be significantly reduced. Assuming a 2m cord of $2 \times 0.75 \text{ mm}^2$ (0.1 Ohm) the loss in the cord is as shown in the below table:

Secondary voltage/ power	10W	15W	20W	25W	40W	60W
5V	0.4W	0.9W	1.6W	2.5W		
12V	0.07W	0.156W	0.27W	0.441W	1.1W	2.5W
19V	0.028W	0.062W	0.11W	0.169W	0.4W	0.9W

With thinner cables the loss is even higher.

- the voltage regulator to generate the FXS voltages (e.g. ringing voltages up to 120V) can be realized more cost effectively based on higher input voltages. This is even more important for higher ringer loads (up to 5 REN).
- to realize the dying gasp for xDSL the voltage headroom is significantly higher at higher supply voltages ($E=C \cdot \Delta U^2 / 2$), which allows smaller and cheaper capacitors.
- a higher supply voltage for the xDSL line driver allows a transformer ratio closer to 1:1 which gives less attenuation for the received signals (alternatively you need a second coil in the receive direction). This leads to better SNR and higher reach.
- the efficiency of AC/DC step-down converter increases with increasing secondary voltage (assuming the same technology). In general, the higher the ΔU [=abs(Uout-Uin)], the lower the efficiency.

7.2.2 Internal power supply (DC/DC conversion)

Two components are used for internal voltage level conversion: DC/DC converters and LDO (low drop out regulators).

Just as with external power supplies, two methods can be used: linear or switched-mode. With switched-mode, the DC/DC conversion efficiency is typically between 75% and 98%. Linear DC/DC conversion efficiency is much lower at around 30%.

Example switched DC/DC conversions are:

12V to 3.3V
12V to 1.5V
12V to 5V (USB)
12V to 48V (42V) for ringing voltage for FXS

A low-dropout or LDO regulator is a DC linear voltage regulator which operates with a very small input-output differential voltage of e.g.

3.3V to 2.5V
3.3V to 1.8V
3.3V to 1.2V

The higher the voltage drop and the current, the more inefficient the converter gets; heat is dissipated according to the product of the output current and the voltage drop. The efficiency for linear and LDO is in the range 25-40%.

The idle current of optimized LDOs, when either shut down or when not delivering significant amounts of load current, is about 75 to 150 μA , whereas typical regulators draw several mA.

As the efficiency of the power conversion contributes directly to the overall power consumption, it is necessary to design for high internal power conversion efficiency and the following is recommended:

- Use switched rather than linear power converters
- Minimize the number of cascaded power conversions

7.3 CPU subsystem

The CPU subsystem consists of the CPU core and any logic blocks that directly support the CPU. The CPU core is responsible for running application and management software, as well as being involved in other functions such as security/firewall, networking, QoS, and hardware control. These responsibilities can be classified as control plane (applications software, management) and data plane (routing, bridging, security/firewall).

The CPU subsystem consists of much more than just a basic CPU. There are typically:

- One or more embedded CPU core(s) (MIPS, ARM, x86, ...), caches, MMU (memory management unit), SRAM (static random access memory)
- Memory controller, Direct Memory Access units (DMAs).
- On Chip Network, clock distribution, interrupt system, timers.
- Peripheral blocks, general purpose I/O, serial and parallel port (to control on-board chips and access flash).

Ideally the instantaneous energy expenditure of the CPU subsystem should match its actual workload. The power consumption of the CPU subsystem is dependent on:

- The architecture and software optimization
- The balance between performance/reaction time and energy efficiency
- The dynamic system and CPU load
- The implementation of adaptive power modes

CPU power can be dynamically adapted without jeopardizing user experience. Negative impact on the real-time behaviour must be avoided (timers, delay, etc.). Possible ways to enhance the energy efficiency of the CPU subsystem include:

- Implementing an intelligent energy controller along with policies to provide voltage and frequency scaling to reduce both static and dynamic power consumption. The system needs to be aware of the workload and respond in kind.
- Using an embedded CPU that supports a low power wait instruction.
- In the case of multiple CPU cores and depending on the silicon technology used, power gating can be used to shut down cores that are not required.
- Energy efficient chip design, increased integration and density.

7.3.1 Example for a CPU subsystem architecture

Figure 4 shows an example CPU subsystem architecture. The most important blocks of the CPU subsystem are one or more CPU cores with related caches, interrupt controller, external memory controller, buses, DMA handler, timers, bridges etc.

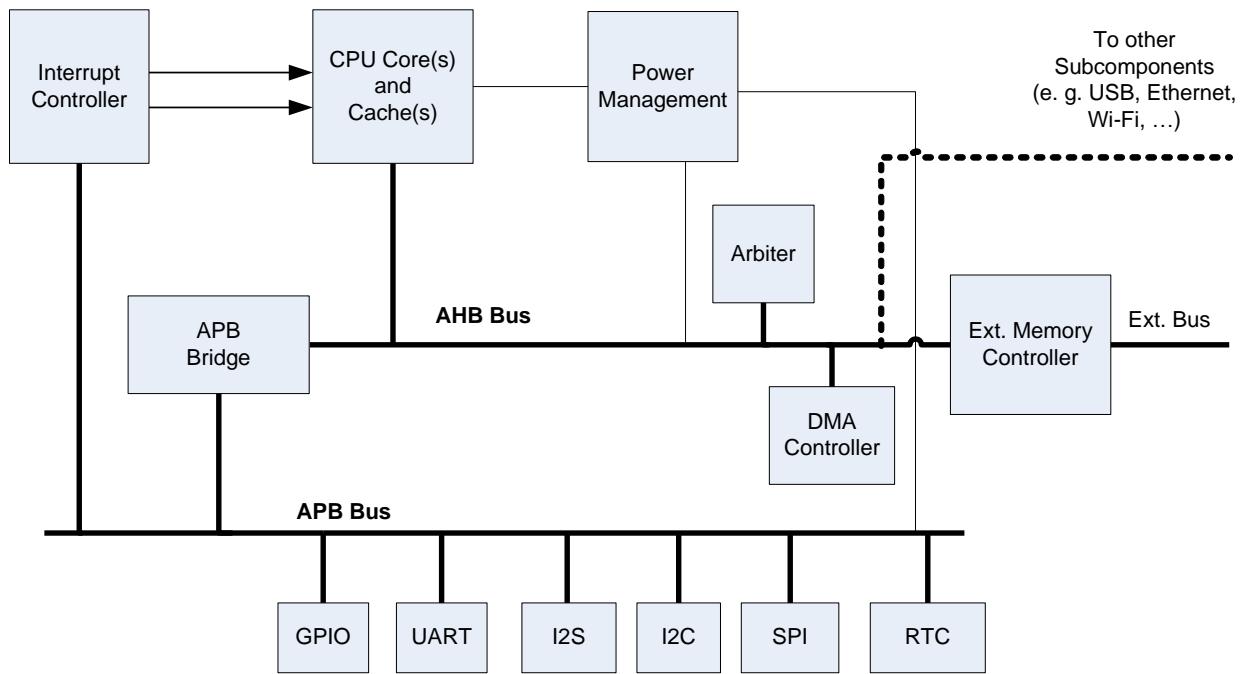


Figure 4: Example CPU subsystem architecture

7.3.1.1 Power management block

The power management block supplies clock and voltage to the CPU and peripherals. Each peripheral subcomponent provides power saving modes controlled by the software running on the CPU core, or autonomously. The granularity of on-chip clock and voltage distribution is architecture dependent. In some systems, where the CPU clock voltages are significantly higher than those of the rest of the system, it might be necessary to have separate voltage regulation for the CPU core as depicted in the figure below.

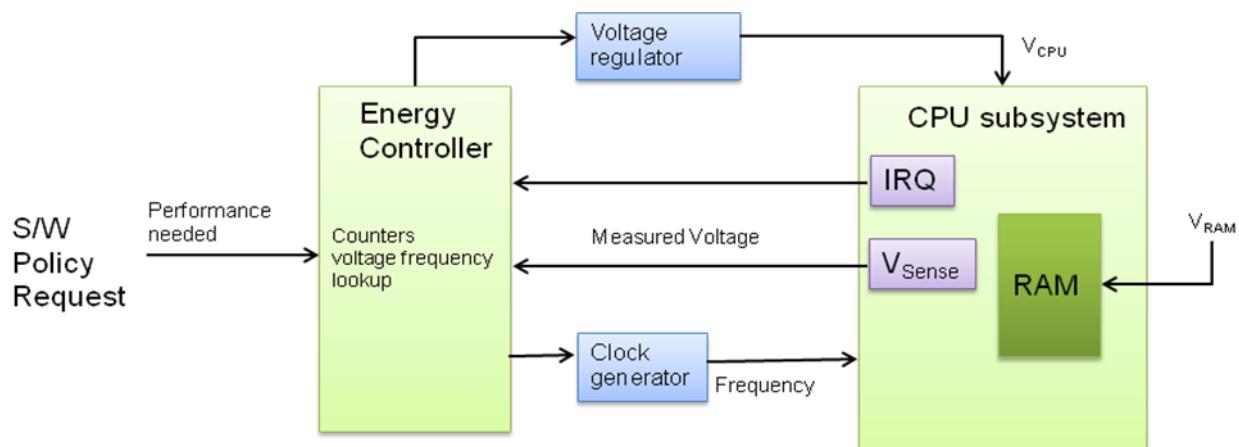


Figure 5: Example implementation of energy controller interfaced to a CPU

7.3.1.2 Example CPU subsystem operation modes

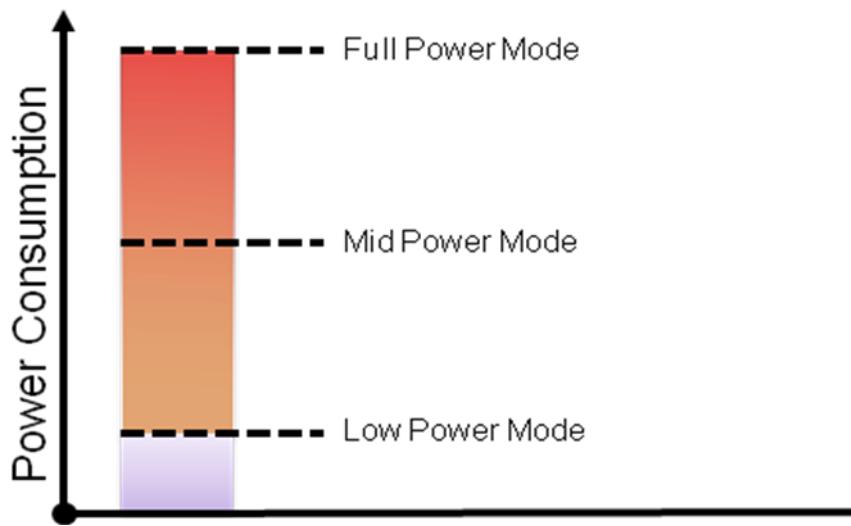


Figure 6: Example CPU power modes

Based on the example in Figure 6 the following power modes can be supported:

- Full Power mode
 - CPU voltage and frequency are at the nominal operating point.
 - Software actively measures loading of the HG and looks for opportunities to transition to a reduced power consumption mode.
- Mid Power mode
 - Frequency and/or voltage of the CPU subsystem are reduced.
 - Software actively measures loading of the HG and looks for opportunities to transition to a reduced power consumption or higher performance mode.
- Low Power mode
 - CPU subsystem is running on minimum clock and/or voltage and only reacting to interrupts and keep-alive packets, active state information is stored.
 - In multi-core systems, at least one of the cores is shut down. When a CPU is powered down, there is no power consumption due to the CPU and the internal logic except the wake-up logic and retention RAMs. Note: the sleep and wakeup operations may require a significant number of cycles to store and restore the context, so the transition into the low power mode must only occur when activity has fallen below a threshold for a certain time.

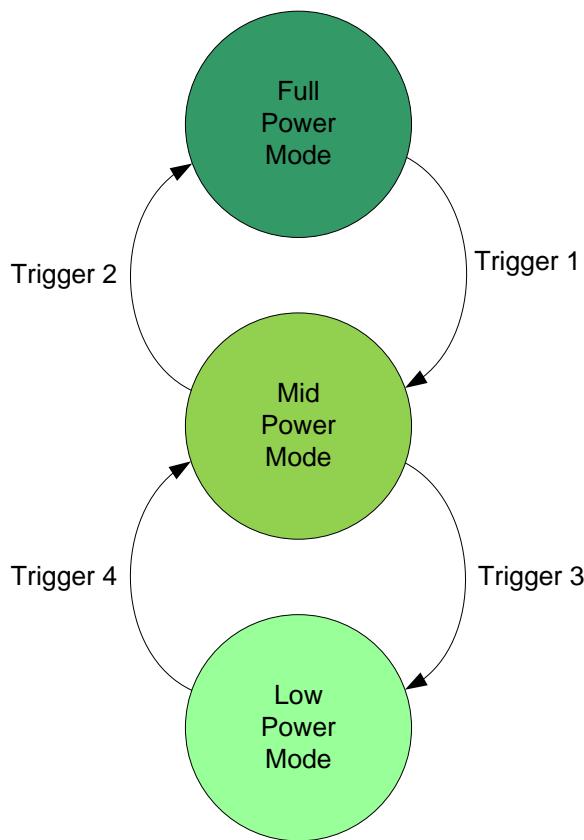


Figure 7: Example of CPU power state diagram

Example CPU subsystem use cases and mapping to operational modes are detailed in the following table which applies to a simple scenario without HW acceleration for routing or bridging.

Mode	Scenario	CPU
Low Power	Middle of the night, no data, but sufficiently fast response to a phone call (VoIP) is required	CPU logic powered off, state stored externally. Less than 10ms to power up e.g. in the event of a VoIP call.
Mid Power	Moderate amount of traffic	CPU running at reduced frequency and/or voltage
Full Power	Heavy user traffic, lots of session setups and tear downs	CPU running at rated voltage and frequency

7.3.1.3 Example CPU subsystem triggers and power consumption related actions

This is a simplified scenario without HW acceleration for routing or bridging, and assumes 2 separate CPU cores, one for the data plane and one for control plane. The below Table lists various triggers that could be used for transitioning between the various modes:

Trigger	Data plane	Control plane	Comments
Trigger 1: transition from full power mode to mid power mode	Packet counters detect that traffic flow is at less than 50% capacity for several seconds	Control plane CPU performance counters indicate that CPU is idle more than 50% of the time	Should be seamless to reduce performance

Trigger 2: transition to full power mode from mid power mode	Increase in the rate of incoming packets cause on-chip buffers to start filling up. Software increases frequency of the data plane core.	CPU counters indicate that control plane is approaching >55% utilization.	Should be seamless to increase the performance.
Trigger 3: transition from mid power mode to low power mode	Packet counters detect that traffic flow is at less than 5% capacity	CPU counters indicate that the CPU is nearly 100% idle	Need to be able to power up control plane fast enough if there is a flood of control data
Trigger 4: transition from low power mode to mid power mode	Increase in the rate of incoming packets detected by means of implementation. Software increases frequency of the data plane core.	Data plane CPU detects packets that need to be processed by the control plane. Wake up the control plane CPU.	Control plane has to power up fast enough so that internal buffers do not overflow.

7.4 WAN interfaces

The WAN interface options of HGI Residential Profile V. 1.0 are the following:

- ADSL/ADSL2/ADSL2+
- VDSL2
- 100Base-TX

In addition to the HGI residential profile V1.0 WAN interfaces, it is also important to consider the higher bit rate interfaces that may be included in future HGs:

- 1000Base-T
- GPON
- 100Base-BX (or FX)
- 1000Base-BX (or FX)

Unfortunately the majority of these WAN technologies are expected to run in full power mode all the time, and even during periods where there is no user traffic, they send idle packets to keep the link up.

7.4.1 DSL

First-generation ADSL transceivers (ADSL1) do not have low power features. Second-generation ADSL2 has highly configurable power management modes (or more correctly referred to as link-states) that help reduce overall power consumption while maintaining ADSL's "always-on" functionality for the user. These link-states include:

- L2 low-power link-state which enables statistical power savings at the ADSL transceiver unit in the central office or exchange (ATU-C) by rapidly entering and exiting low power link-state based on the amount of traffic running over the ADSL connection.
- L3 low-power link-state which enables overall power savings at both the ATU-C and the remote ADSL transceiver unit (ATU-R) by entering into sleep/stand-by link-state when the connection is not being used for extended periods of time (i.e. user asleep, modem asleep).

The L2 link-state is one of the most important innovations of the ITU-T ADSL2 standard [11]. ADSL2 transceivers can enter and exit the L2 low power link-state based on the amount of WAN side traffic over

the ADSL connection. When large files are being downloaded, or video media is being streamed, ADSL2 operates in full power link-state (called L0 link-state) in order to maximize the download speed. When WAN traffic volume decreases, ADSL2 systems can then transition into L2 low power link-state, in which the data rate is significantly decreased and the overall power consumption is reduced at the ATU-C, saving significant power on the DSLAM side.

Currently the ITU-T G.992.3/5 standards do not address power saving in the upstream direction - there is no L2 mode upstream. This is because the total transmit power upstream (18 mW for ADSL1 and ADSL2+) is substantially lower than that launched downstream (100 mW for ADSL1, higher for ADSL2+). Since L2 mode makes its power saving by reducing the launch power, the scope for an L2 mode to offer significant power saving at the CPE is small.

While in L2, the ADSL2 system can rapidly re-enter L0 and increase to the maximum data rate as soon the user initiates a file download or requests a video stream. The L2 entry/exit mechanisms and resulting data rate adaptations are accomplished without any service interruption or even a single bit error, and as such, are not noticed by the user. However, the setting of the parameters governing the temporal behaviour of the entry into and exit from L2 link-state is critical. There are two primary issues associated with the L2 link-state that require careful consideration by designers and implementers:

- The sudden increase in crosstalk generated by large changes in ATU-C transmitter power levels when transitioning from L2 link-state to L0 link-state (hence the need to use a well chosen floor for the lowest PSD associated with L2 link-state).
- The fluctuating crosstalk caused by entry/exit from L2 link-state (and hence the need for long time constants).
- The unbounded delay that can occur when low-bit rate traffic is carried by the ADSL2 system whilst in L2 link-state.

These issues are well understood by ADSL designers and work is being undertaken in the ITU-T SG15 Q4 to address these limitations in future enhancements to the ADSL standards. However, the current L2 link-state must be used with care for energy efficiency reasons, as described in the Broadband Forum guideline (TR-202) [14].

The L3 link-state is a total sleep mode where no traffic can be communicated over the ADSL connection. When the user returns to go on-line, the ADSL transceiver requires approximately three seconds to re-initialize and enter into steady state communication link-state. This link-state is not considered useful by network operators other than at the time of provisioning of an ADSL2 line.

Figure 8 shows the power management states defined in ITU-T G.992.3/5 and the transitions between them.

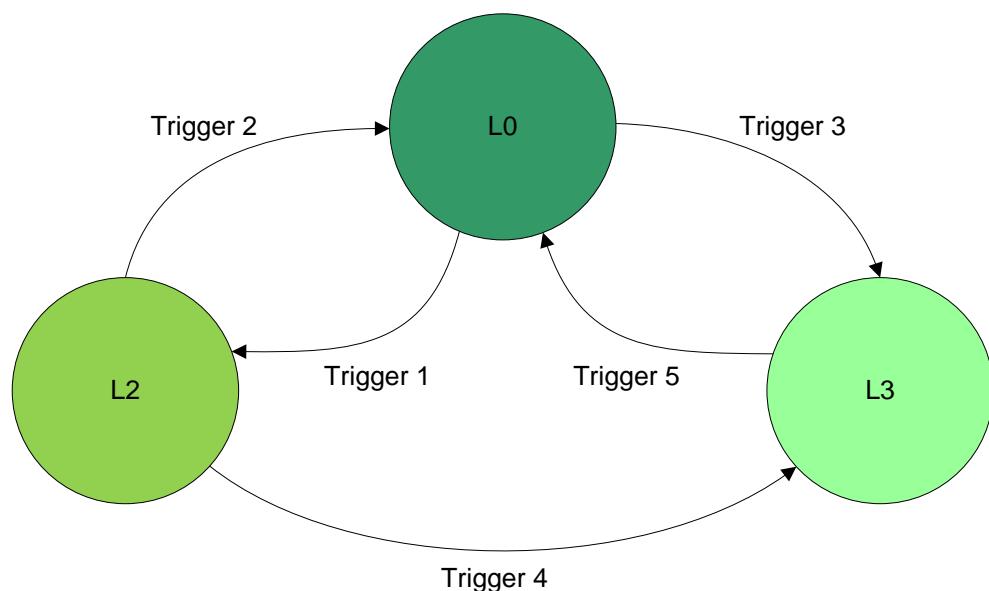


Figure 8: State diagram of ADSL2 power management states

Trigger	Description
Trigger 1	Triggered when user traffic is low for a period - criteria not specified in detail
Trigger 2	Triggered by either: <ul style="list-style-type: none"> • data rate exceeds L2 rate • need to do bit-swap e.g. in response to change in noise PSD • need to do SRA e.g. in response to running out of margin even after bit-swap optimisation • need to do orderly shutdown from L0 state
Trigger 3	Triggered by user request for orderly shutdown e.g. powering off
Trigger 4	By user request for orderly shutdown e.g. powering off - directly instead of first returning to L0
Trigger 5	By re-initialisation e.g. after powering up

The L2 power state does not bring any power reduction in the CPE. Nevertheless it contributes to a cleaner environment because of the saving in energy on the central office side.

L3 power link-state does save energy in the CPE but has the problem that there is no automatic re-activation mechanism for the home gateway.

ITU-T standardized VDSL2 does not currently have an equivalent power saving link-state. This is an area for further study in ITU-T SG15 Q4.

7.5 LAN interfaces

One of the main purposes of a HG is to act as an intermediary between the WAN and LAN interfaces. An HG usually has a number of different LAN interfaces.

7.5.1 LAN Ethernet interfaces

Figure 9 shows the state diagram for an Ethernet port. The EEE (LP_Mode) state at the bottom of the figure is only available for Energy Efficient Ethernet enabled ports.

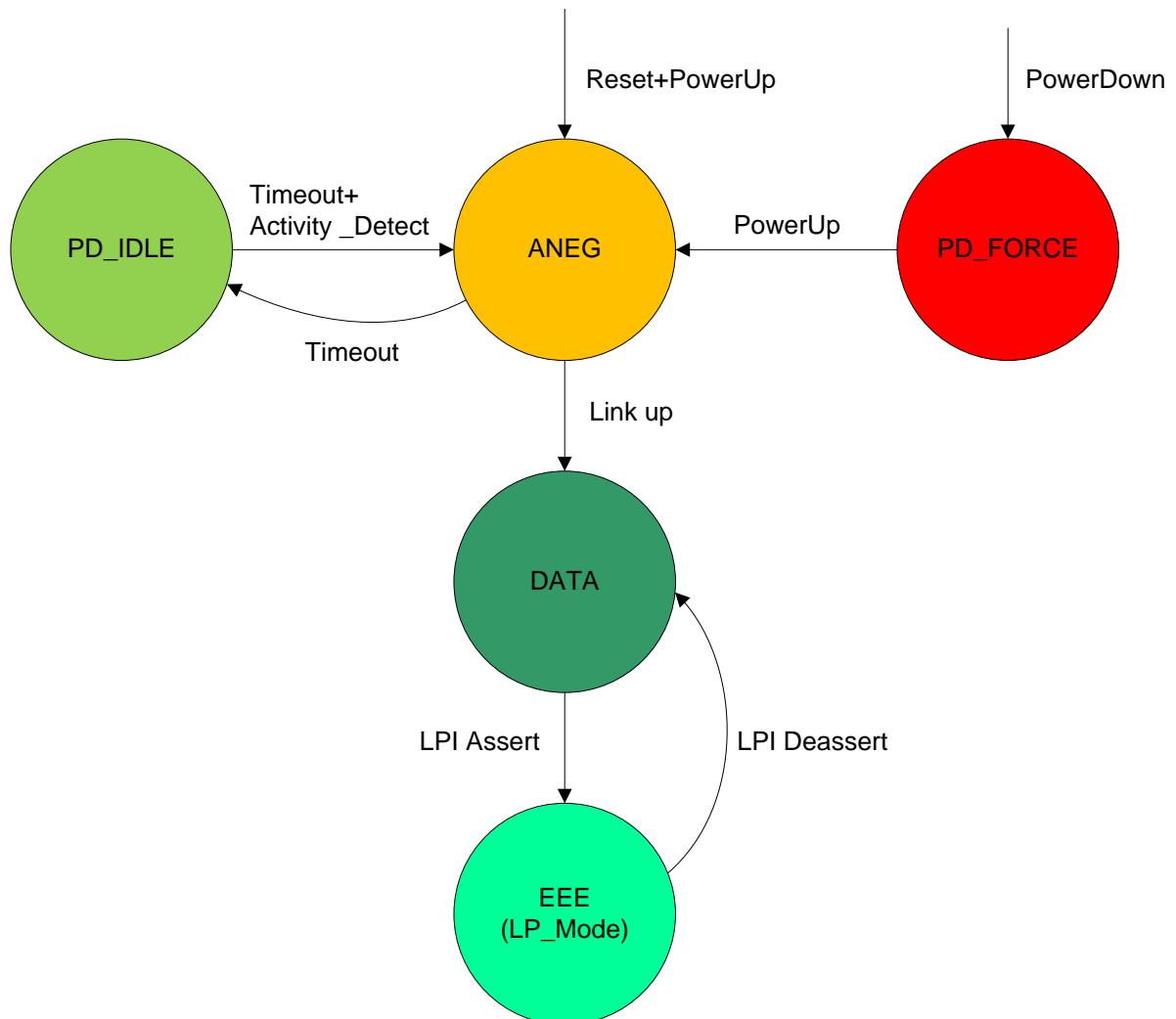


Figure 9: Ethernet state diagram

State	Description
PD_IDLE	Perform power savings while there is no active Ethernet link, but only monitoring activity for instantaneously connected link-partners
ANEGR	Perform Auto-Negotiation according to IEEE802.3
PD_FORCE	Maximum possible power-down compliant to IEEE802.3-22.2.4.1.5
DATA	State used for data transmission where either data packets or IPG/Idle (IPG=Inter-Packet Gap) symbols are transmitted.
EEE (LP_Mode)	New state defined in EEE used during periods of no data transmission to allow system power reduction between data packet bursts.

7.5.1.1 Standby power down mode (PD_FORCE)

IEEE 802.3-2008 [12], clause 22.2.4.1.5 defines the Ethernet power down mode.

This feature allows PHY ports to be put into standby power down mode, by setting a bit in one of their registers. In this mode, the chip itself does not make any attempt to detect any kind of activity and go back to normal power state. The only way to get out of this mode is by clearing that bit, or resetting the chip.

As can be seen this is a crude power down mode. Without additional software assist, this mode is only useful to implement functionality where Ethernet ports are powered down during the “night hours”, for example.

7.5.1.2 Auto power down mode (PD_IDLE)

The transceiver enters power down mode when no energy on the line is detected anymore. When in power down mode, the transceiver automatically wakes up after a certain period of time (which can be selected from a few discrete values, typically below 10 seconds) to send link pulses. Transceivers continuously “listen” to the line, so the link will come up even when both ends support auto power-down. If energy is detected, the transceiver automatically comes out of power down mode and back into normal operation. If no energy is detected, the transceiver goes back to power down mode, either immediately, or continues testing for energy on the line for a selectable time interval (usually below 1 second).

Note that while this mode will allow for energy savings in the case where a particular port is not connected to a cable (either at the local end or the remote end), it will not provide any energy savings if a cable is connected at the local and remote end and the Ethernet link is active, even if there is no traffic on the line.

7.5.1.3 Energy consumption adjustment based on cable length (in DATA)

For cable lengths shorter than the maximum specified in the standard, there is an increased noise margin because the data rate for Ethernet LAN ports is predefined and constant. Therefore it is possible for LAN ports to adapt their power level in such a way that this additional noise margin is sacrificed to save power. However these power saving mechanisms must not violate the requirements of IEEE802.3 [12] in order to maintain interoperability with legacy LAN equipment.

7.5.1.4 IEEE Energy Efficient Ethernet (LP_MODE)

In 2007 the IEEE started a new task force, 802.3az [13], called “Energy Efficient Ethernet” (EEE), with the following objectives:

- Define a mechanism to reduce power consumption during periods of low link utilization for the following PHYs:
 - 100BASE-TX (Full Duplex)
 - 1000BASE-T (Full Duplex)
 - 10GBASE-T
 - 10GBASE-KR
 - 10GBASE-KX4
 - 1000BASE-KX (added July 2008)
- Define a protocol to coordinate transitions to or from a lower level of power consumption
- The link status should not change as a result of the transition
- No frames in transit shall be dropped or corrupted during the transition to and from the lower level of power consumption
- The transition time to and from the lower level of power consumption should be transparent to upper layer protocols and applications
- Define a 10 megabit PHY with a reduced transmit amplitude requirement such that it shall be fully interoperable with legacy 10BASE-T PHYs over 100 m of Class D (Category 5) or better cabling to enable reduced power implementations.
- Any new twisted-pair and/or backplane PHY for EEE shall include legacy compatible auto negotiation.

Low Power Idle

The basic principle to save energy in Energy Efficient Ethernet is the Low Power Idle concept as described in the following points:

- MAC (or LPI-Agent) can switch the PHY into LP_Mode during periods of low-link utilization, i.e. within a “long” interpacket gap. It does so by asserting LPI

- An LPI-Assert is transferred using proper signalling to the link-partner PHY which also transits into LP_Mode
- The LPI-Assert is passed to upper layers on the link-partners receive side using proper signalling over the MII in order to allow for additional power-savings on system level
- During LP_Mode the PHY is expected to consume only marginal IDLE power
- In case new data is to be transmitted either MAC (or better: LPI-Agent) de-asserts LPI causing the PHYs to exit the LP_Mode. This transition takes 16.5 μ s for 1000Base-T and 30 μ s for 100Base-TX
- For reasons of link-down surveillance and link-maintenance the link-partners perform a QUIET/REFRESH cycling during LP_Mode. The QUIET period is approximately 20ms for 100base-TX and 1000base-T whereas the REFRESH period is 200 μ s nominally thus achieving a 100:1 ratio.
- The PHY power-savings within the LP_Mode is achieved during the QUIET period

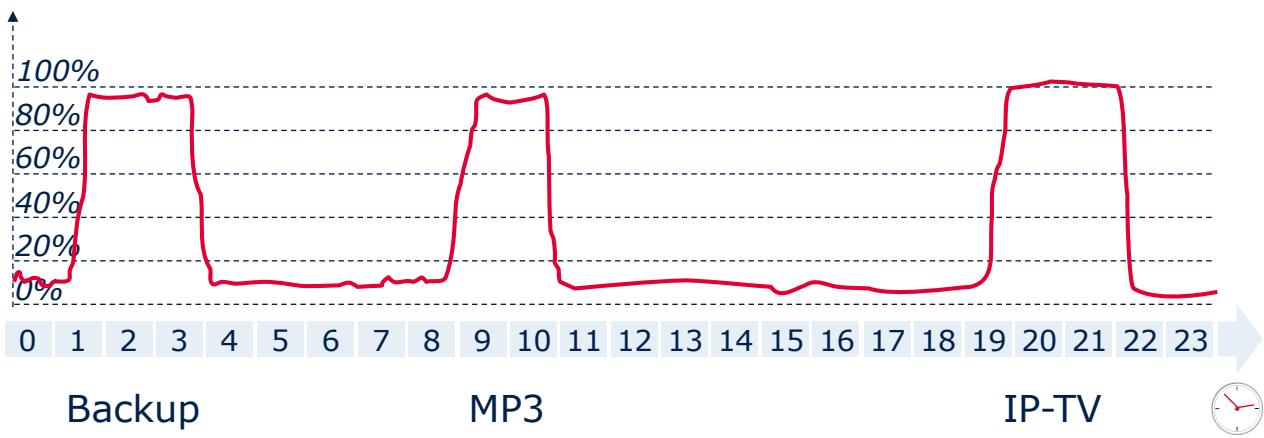


Figure 10: IEEE 802.3az enables load dependent power consumption

Operating states

State	Description
Active state (= DATA)	Existing state used for data transmission where either data packets or IPG/Idle symbols are transmitted. (IPG=Inter-Packet Gap)
Low-Power state (= LP_Mode)	New state used during periods of no data transmission to allow system power reduction between data packet bursts.

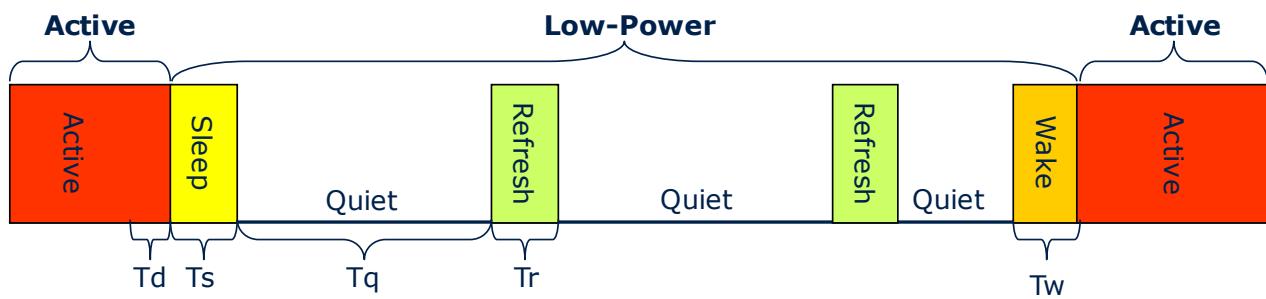


Figure 11: Low power periods in IEEE 802.3az

New line signals of EEE

Signal	Description
Sleep	Signal to inform remote link partner of entry into Low-Power state.
Quiet	Minimal energy mode for PHY power reduction during Low-Power State.

Refresh	Signal periodically transmitted during Low-Power state for PHY to maintain timing recovery and/or coefficient synchronization.
Wake	Signal to inform remote link partner of entry back into Active state. Provides remote link partner sufficient time to turn ON and get ready to receive data.

Interaction of EEE with the system:

- LPI events are passed to higher layers via xMII interface codes.
- Link Layer Discovery Protocol (LLDP) can be used to negotiate longer system wake times for increased power-efficiency of the whole system.
- EEE parameters are exchanged during Auto-Negotiation.
- System initiated LPI via the MAC interfaces. The PHY behaves as a slave transparent but not invisible to the upper layers.
- EEE is interoperable with legacy equipment though not saving power in these scenarios.

7.5.2 Wi-Fi

Figure 12 shows the main blocks of the Wi-Fi subcomponent:

- 802.11 MAC: Adapter of 802.11 protocol
- Radio: Frequency conversion, transferring base band signals to radio frequencies at 2.4GHz or 5GHz
- Power amplifier (PA) and front end:
 - Amplify the radio signal to transmit
- Low noise amplifier (LNA)
 - Receive signal from antennas

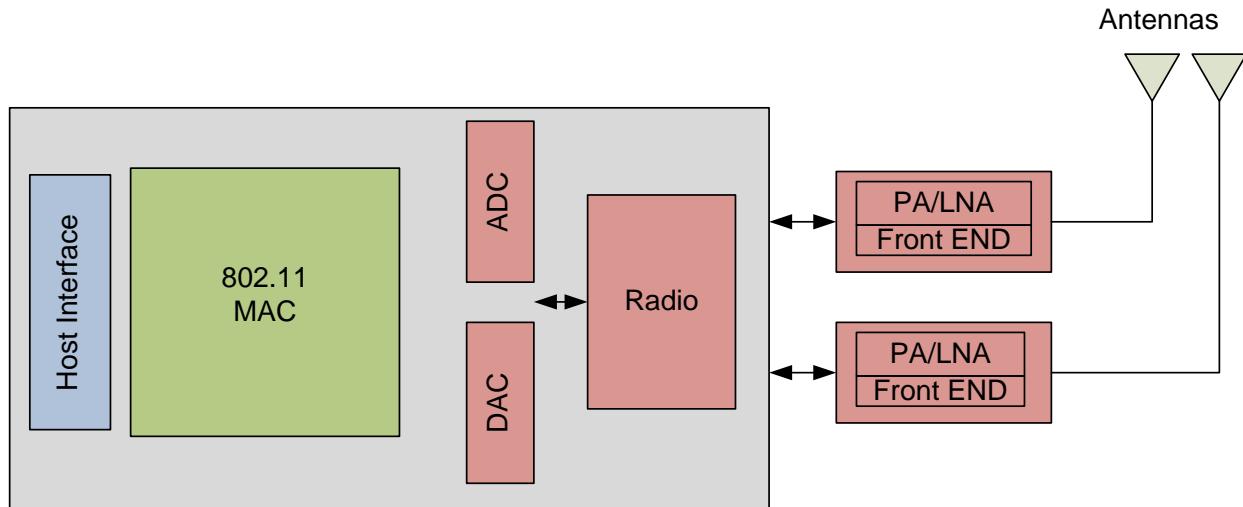


Figure 12: Architecture example for the Wi-Fi interface

Figure 13 shows an example of the power allocation for a 2x2 11n interface with on-chip PAs in transmit and receive mode.

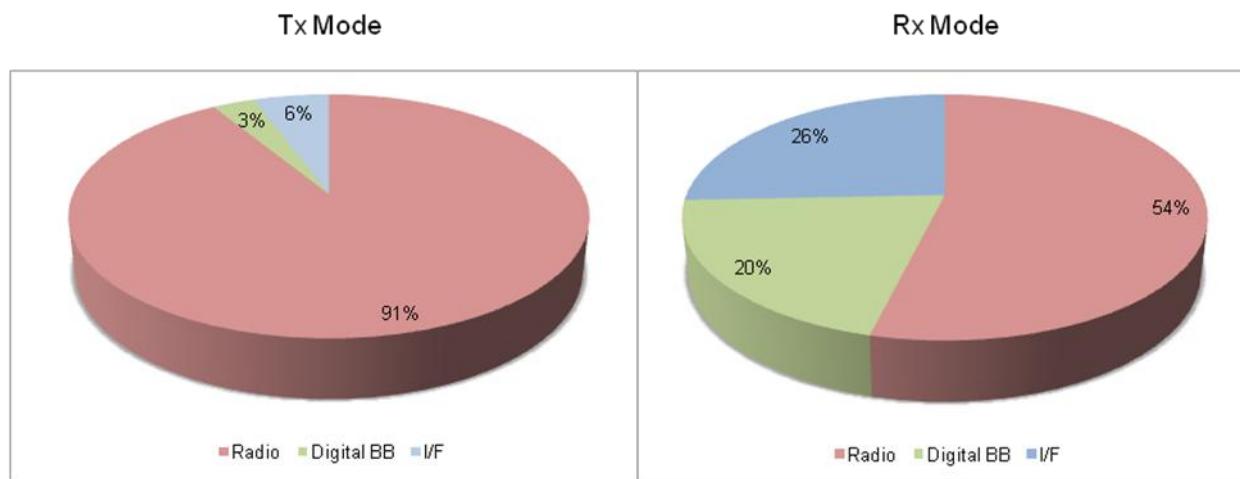


Figure 13: Wi-Fi interface power allocation for transmit and receive modes

The following table and Figure 14 describe the operational modes of a Wi-Fi access point:

State	Description
Off	Turned off manually or controlled by software Entire Wi-Fi module is not powered No RF
Beacon only	No user traffic on Wi-Fi Only beacons are sent by the AP
Low	Some minimal traffic is still transported on Wi-Fi
Full	Maximum transmitting power Minimum Beacon interval All PAs working No energy saving methods working, all modules working normally

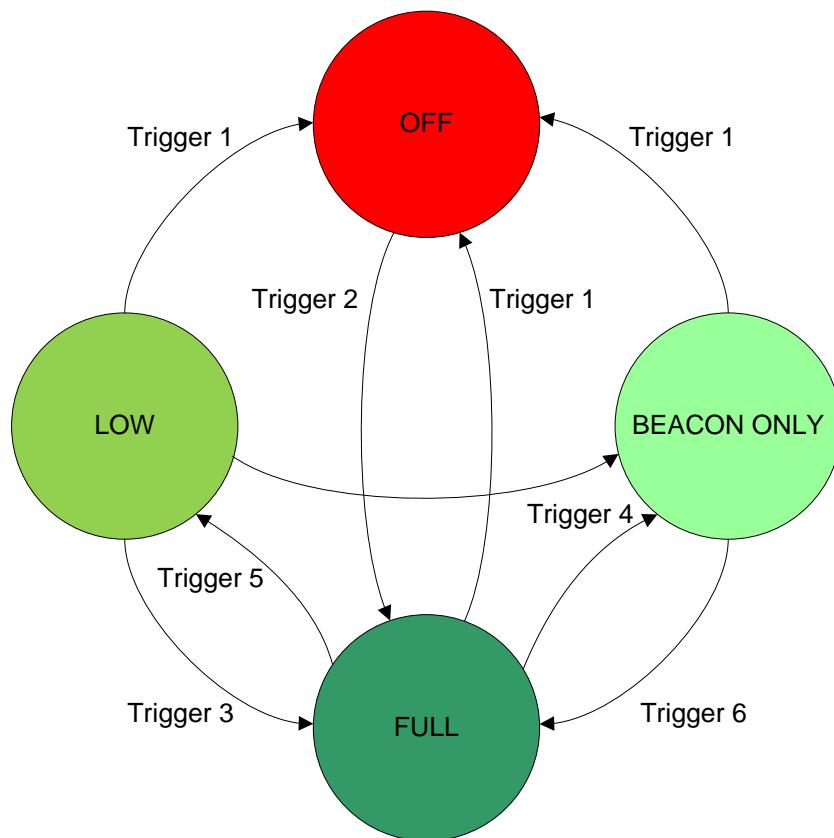


Figure 14: Wi-Fi power state diagram

Trigger	Description
Trigger 1	From all other modes to Off Turned off physically by button or controlled by software: on demand or automatically, i.e. time scheduled
Trigger 2	From Off to Full Reset or Powered on (physically by button or by software)
Trigger 3	From Low to Full Traffic throughput is higher than the capacity of Low Mode (i.e. above a certain threshold)
Trigger 4	From Full or Low to Beacon Only No data traffic after defined interval
Trigger 5	From Full to Low Traffic throughput is lower than the capacity of Low Mode (i.e. below a certain threshold)
Trigger 6	From Beacon Only to Full Woken up by data traffic

There are several ways to reduce the power consumption of the Wi-Fi interface. Most of the available mechanisms are only intended to save energy on the client side (i.e. for battery powered devices). On the access point side, the following can be done at the Wi-Fi chipset level:

- Shutting down internal components: MIMO systems have multiple PHYs inside the ASIC and may even have multiple MACs. Shutting down the internal PHYs with their AFEs can save up to 0.5W per PHY. Switching off the PA when not transmitting any traffic.
- Not using external memory: When in beacon only mode, the system's software can be locked inside the cache and will not access the external DDR/SDRAM. This can save 0.3W.

- Reducing the CPU speed while in beacon mode: Wi-Fi chipsets that have network processors inside them can reduce the CPU clock to a fraction of its normal speed.

Other possible low power mechanisms:

- Dynamic transmit power adjustment: Reducing transmit power - the system should adjust its transmit power according to the channel properties towards each of the clients. Wi-Fi APs that can adjust the transmit power on a packet by packet basis can transmit with low power to nearby clients and with high power to distant clients.
- Longer beacon intervals: Since the beacon packet duration is only a few 100s of microseconds and its usual period is 100 ms, its effect on power consumption is not significant.
- Mechanisms to completely turn off the Wi-Fi interface
 - via Wi-Fi on/off button
 - via some code typed on a phone
 - via some scheduled function configured via the web user interface
- Automatically power down the Wi-Fi interface when no clients are associated and periodically wake up to send beacons and detect association requests
- Improved circuit design techniques for lower power: switched capacitor filters, dynamic voltage scaling, coarse and fine grained clock gating, linearized Tx power amplifiers

It is generally possible to trade off WLAN performance for lower power consumption. The largest power consumers are the radio and radio front end, and performance (throughput over range) can be traded for lower power.

7.5.2.1 MIMO Power Save

Citation from IEEE Communications magazine (April 2009):

An 802.11n device with multiple radio transceivers can have significantly higher power consumption than legacy devices. To somewhat mitigate this problem, the 802.11n proposal defines the MIMO power save protocol and power save multi-poll (PSMP) protocol. With MIMO Power Save mode, the 802.11n radio can downshift from MIMO to SISO (Single input single output) either statically (Static MIMO Power Save) or dynamically (Dynamic MIMO Power Save). In Static MIMO Power Save, the client device turns off all but one radio and notifies the access point (AP) of the change. Upon notification, the AP restricts all its transmissions to this "low-power" client to single stream transmissions until further notice. In Dynamic MIMO Power Save mode, the client powers down all but one radio, but powers them back up dynamically at the request of AP. The protocol allows the AP to send a packet requesting the client to turn on all its radios before initiating any multi-stream transmission. This feature enables clients to save power at the cost of additional signalling overhead needed to reconfigure the client back in MIMO mode. Static power save results in much larger reduction in power than dynamic power save at the cost of data rate. PSMP protocol is a MAC level scheduling mechanism, which allows the client to be in a low power sleep state for most of the time.

MIMO Power save in the 802.11 standard was not designed to operate on the AP. As with so many other things in 802.11, the AP was expected to have all of its MIMO transceiver chains ready to go at all times. Therefore, the 11n standard does not define signalling, nor conditions, under which the AP can tell clients that it is going to shut down receive chains and will only be able to receive single stream packets.

7.5.3 FXS

Figure 15 shows the state diagram for an FXS port. LOW POWER (= On hook) is the most common state for residential phones and the FXS ports they are connected to, and therefore offers the biggest opportunity to save power.

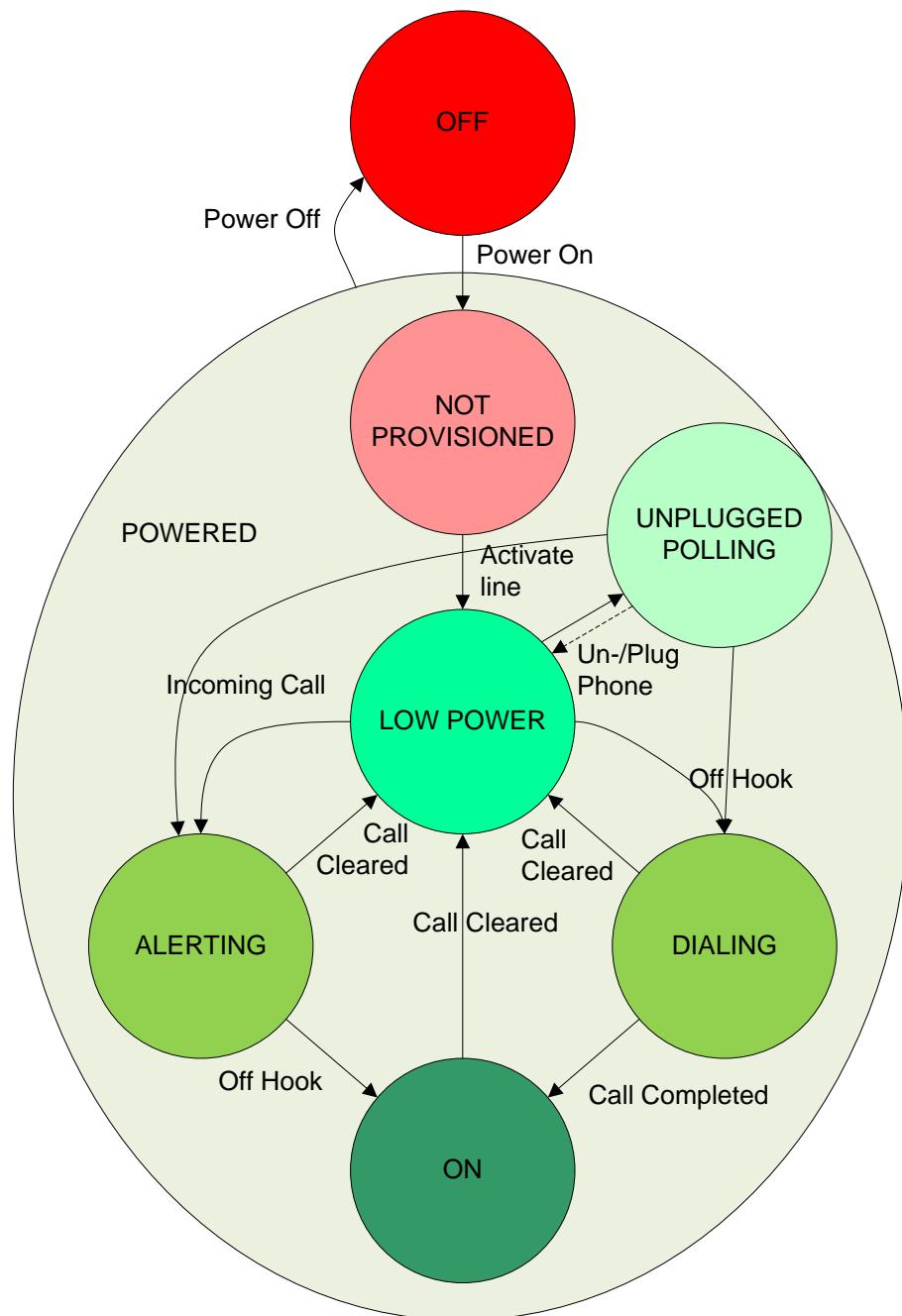


Figure 15: FXS power state diagram

The following table contains the state descriptions and energy saving considerations:

State	Description	Energy saving considerations
OFF	the FXS port is not powered	
NOT PROVISIONED	is the state entered from the OFF state before the line is provisioned or activated.	<p>The FXS port is inactive and provides no power to phone line. Residual power is dominated by logic level devices and local power supplies needed to generate FXS line voltages. Independent control and power down of high voltage supplies is desirable:</p> <ul style="list-style-type: none"> • Fixed high voltage supplies can waste up to 100mW

		<ul style="list-style-type: none"> • Fully disabling these supplies can reduce power to <10mW
LOW POWER	is the state entered when the line is provisioned, at which point the system should be able to make and accept calls over the FXS interface.	LOW POWER is a key state, as the FXS port typically spends most of the time in this state, but still provides voltage and current to the phone line. On hook power consumption is largely dependent on FXS silicon (subscriber line interface circuits SLIC / subscriber line access circuits SLAC) design.
UNPLUGGED POLLING	is the state entered when there is no phone connected to an FXS port	If there is no phone connected to an FXS port there is a more than 60% (e.g. for a 3s polling interval, configurable) saving potential compared to the LOW POWER mode due to a reduced duty cycle (allowing fast off-hook detection and immediate alerting). See details below.
ALERTING	is the state entered when an incoming call is received directed to this FXS port. The phone is ringing.	Ringing requires significant power for a relatively short time. Ringing power consumption depends on REN (Ringer Equivalence Number) load, 'battery' voltage and battery DC-DC converter design.
DIALING	is the state entered when initially going Off-Hook to make an outgoing call. The call is being setup.	In this state the FXS port provides voltage and current to the phone line but it only occurs during a very short time.
ON	is the state entered when a call is connected and there is communication between two subscribers over the FXS port. The call is in progress.	In this state the FXS port provides voltage and current to the phone line. Off hook power consumption is lower with less loop resistance (shorter loop length), also depends on what current limit (if any) is used. It is also silicon and battery DC/DC converter design dependent.

7.5.3.1 FXS Phone Plug Detection

Going beyond the Low Power On-Hook mode, FXS Phone Plug Detection allows the automatic identification of FXS ports without connected phones. The savings compared to the Low Power On-hook mode mainly depend on the polling interval. Based on a proposed 3s polling interval, the power consumption is less than 40% of the Low Power mode power consumption. By doing this, the FXS Phone Plug Detection also significantly improves the user experience as FXS ports aren't required to be manually enabled/disabled anymore. Figure 18 depicts the details.

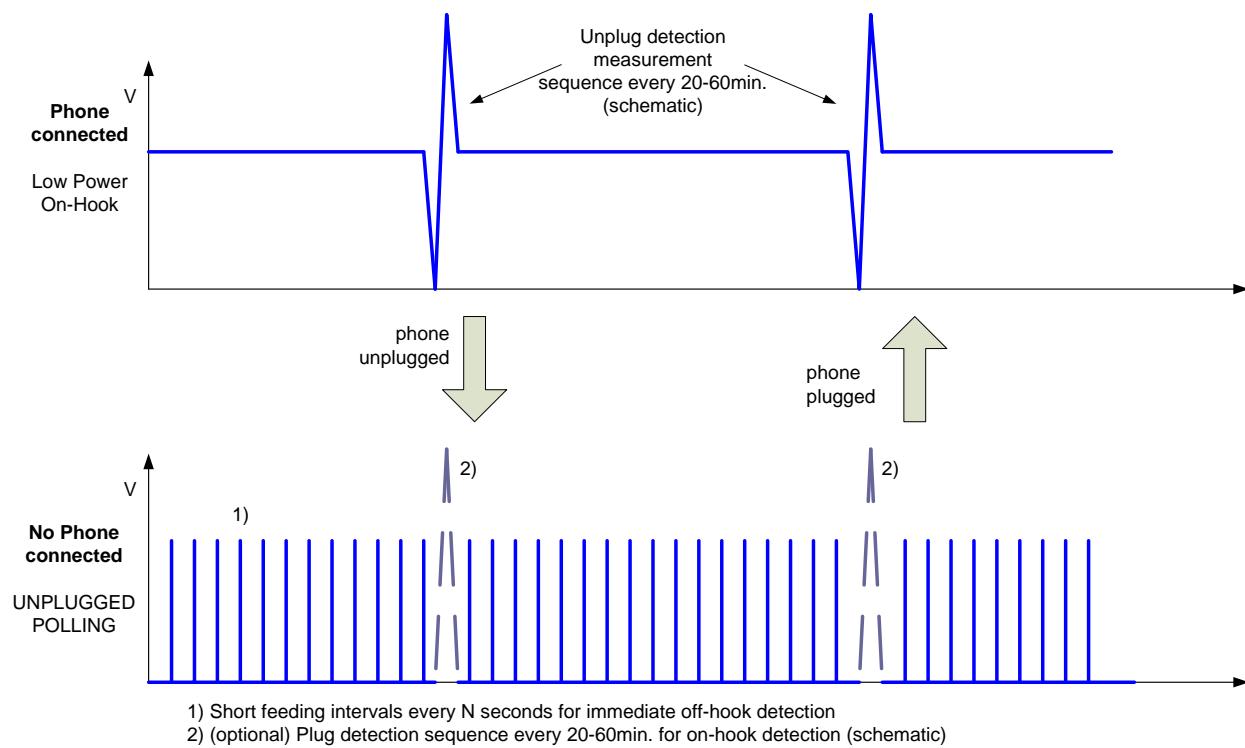


Figure 18: FXS Phone Plug detection

Starting in the Low Power On-Hook state, a special measurement sequence is run to detect open FXS ports or the unplugging of a phone. The energy consumption is insensitive to the unplug detection delay; it is negligible compared to the up-time of the gateway. Therefore an interval of 60 minutes (configurable) is suggested. The measurement sequence must be designed in such way that it doesn't irritate the user, e.g. it must not trigger connected phones to ring or lights to flash.

Once the measurement sequence detects an open FXS port the UNPLUGGED POLLING state is entered. Three transitions out of the UNPLUGGED POLLING state must be considered:

- In the case of an incoming call, the FXS port must be enabled immediately (entering the ALERTING state) by the signalling protocol stack.
- Off-hook detection is fast. Depending on the polling interval (suggested 3-5 seconds) in which the line feeding (Low Power On-Hook state) is enabled for a very short time compared to the polling interval, an off-hook phone can be detected on average within 1.5 to 2.5 seconds. This is the case when a user attaches a phone for the first time and wants to set up a call.
- Optionally a newly plugged-in phone can be detected in on-hook state using the same measurement sequence as for the unplug detection. The power consumption for the measurement sequence is significantly higher than in the Low Power On-Hook state. The power consumption of the combined measurement sequence (for phone plug detection) and disabled state should of course be significantly lower than the power consumption in a continuous Low Power On-Hook state without phone detection. In order to have the best energy advantage, the on-hook plug test is suggested to be performed at intervals of 60 minutes).

The vast majority of phones will be accurately detected in an on-hook state. Nevertheless it should be noted that a very small number of phones may go undetected, requiring the user to perform the procedure of activating the FXS port via the user interface or remote management (TR-069). Phones that may go undetected include:

- Non standards compliant phones with very small (for instance smaller than 20nF) on-hook capacitance..
- Phones allowing off-hook only if the line is fed might not be detected. Without line feed, these phones do not sense a line in use or disconnected status and do not allow an outgoing call attempt.
- In rare cases modems or fax machines might not wait for a dial-tone but start dialling after a delay. In such cases, the first dial attempt after plugging the fax/modem might fail. Subsequent dial attempts will not be impacted.

7.5.4 DECT

A DECT (Digital Enhanced Cordless Technology) CAT-iq telephone system has been incorporated as an optional feature in HGI Residential profile v1.0.

A DECT system consists of a portable part (PP = DECT handset) and a fixed part (FP = DECT base). According to the requirements the fixed part can be connected as a USB module inserted into a USB interface of the HG or alternatively the base IC can be integrated into the HG. An example of a DECT interface architecture is shown in Figure 16.

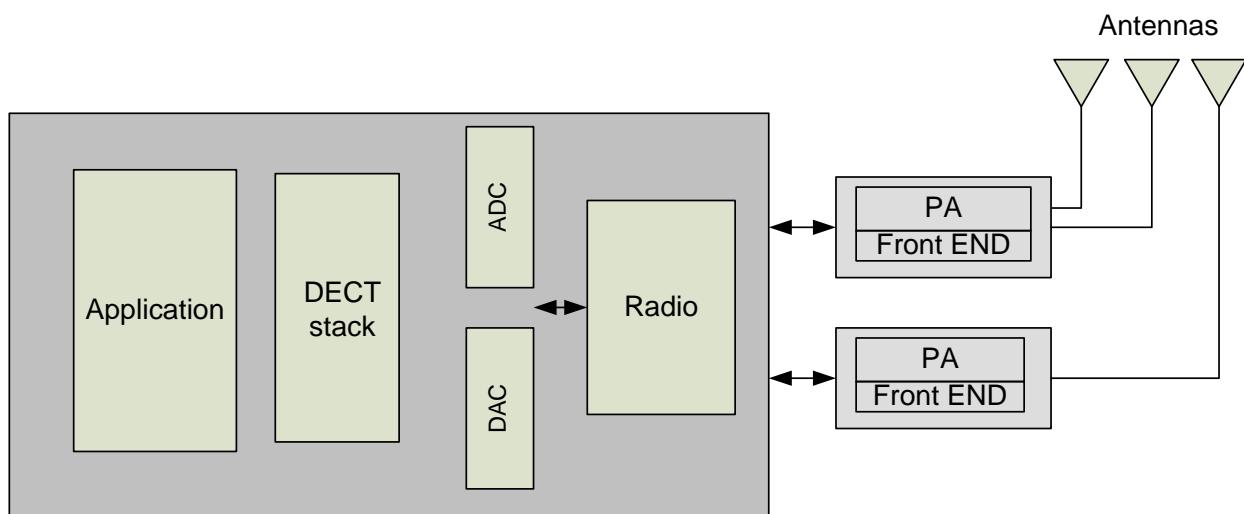


Figure 16: Architecture example of the DECT interface

There are 2 possible mechanisms to connect a portable part (DECT handset) to the fixed part (DECT base)

1. GAP
2. CAT-iq

GAP stands for Generic Access Profile and has been defined to allow third party handsets to connect to a DECT base with limited functionality. No standardized power saving mechanisms are supported by this profile.

CAT-iq stands for Cordless Advanced Technology, Internet and Quality and has been defined to ensure interoperability between handsets and bases from different manufacturers. The level of interoperability is defined in dedicated profiles (1.0, 2.0, 2.1, 3.0). A standardized no emission mode is included in the 2.0 profile, as an optional feature.

7.5.4.1 Standard Operation (without power saving modes)

DECT is a TDMA system. The base or handset transmits a signal only during the time slots that are allocated to it, in general at a level slightly lower level than the maximum allowed 250 mW. The base (as shown in Figure 17) transmits a beacon signal during the idle time to allow remote handsets to remain

synchronized and be able to take a call immediately. The average output power resulting from these modes of operation is around 120 mW during a call and around 6-9 mW in idle mode (most of the time).

The handset (as shown in Figure 18) does not transmit at all during idle periods. The transmitted power of the handsets is around 120 mW in active mode (during calls) and virtually zero in idle mode (most of the time).

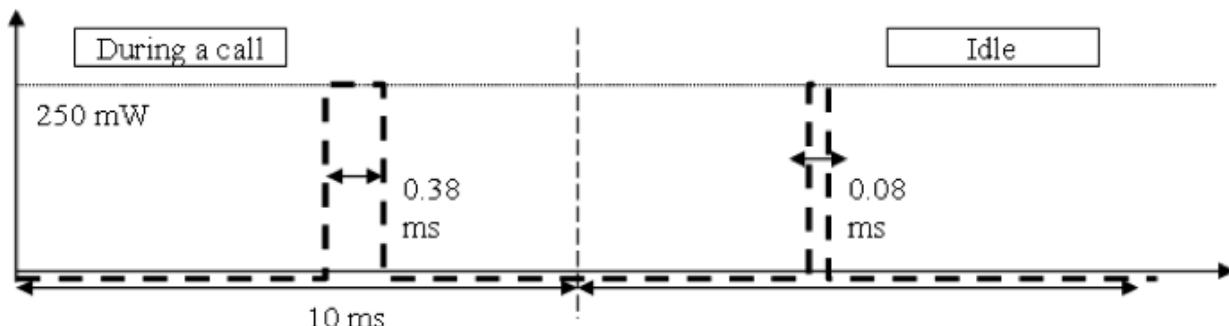


Figure 17: DECT base transmission cycle

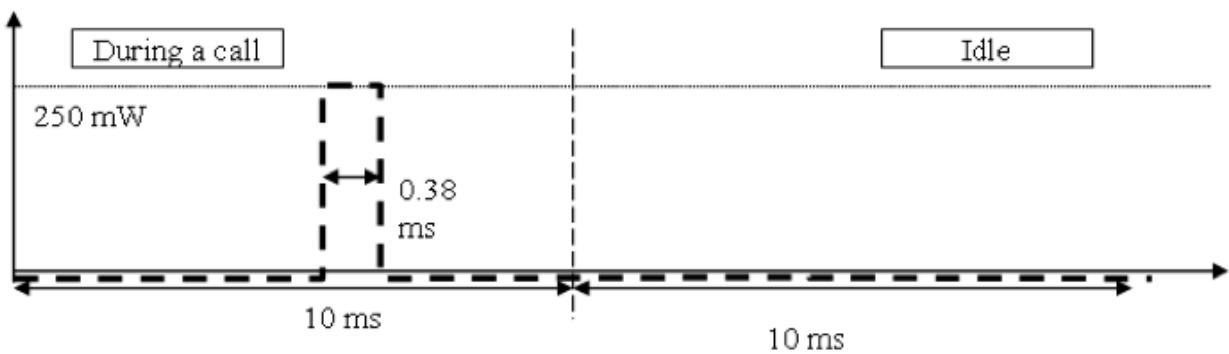


Figure 18: DECT handset transmission cycle

7.5.4.2 Power saving modes for DECT cordless systems

In a DECT system there are the following possible power saving modes of operation:

1. Handset ECO (auto adjusting handset mode)
2. Base ECO
3. Manual ECO (half range mode)

It is important to note that mode 2 is not standardized and requires the same proprietary implementation in handset and base. Mode 1 and 3 are local functions in handset or base and do not require any special communication between handset and base.

In addition to these power saving modes, there is also the no emission mode (NEMO) which does not save energy, but minimizes emitted radiation.

7.5.4.2.1 Handset ECO mode (auto adjusting handset mode)

In this mode the handset adjusts transmit power while a call is in progress.

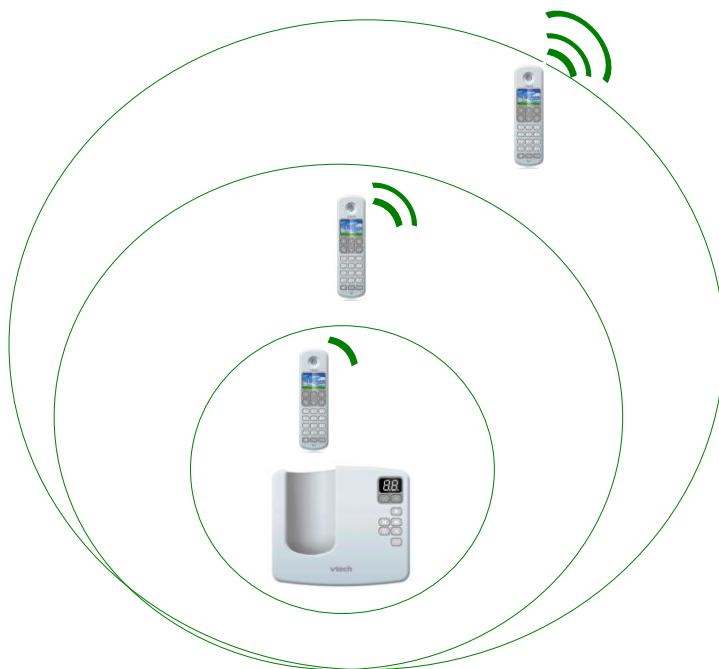


Figure 19: DECT handset ECO mode

During a conversation, the handset will monitor the distance (link quality via bit error rate monitoring and level measurements (RSSI)) and automatically adjusts its own RF transmission power (Figure 19). The transmission power of the base will not be altered. The receiving information can be judged by RSSI value (from handset and base). Different power levels can be implemented. This mode also works in a multi-handset environment.

Total energy saving depends on how close the handset is to base. In a typical implementation the handset reduces its transmission power in 3-5 steps, typically the reduction in power consumption for the handset is approx. 10-15%, however the maximum reduction can be up to 30%.

7.5.4.2.2 Base ECO mode

When there is no call in progress and the single handset is put on its base cradle (Trigger 3 in Figure 20), the base PA transmit power can be set to the lowest power to reduce RF radiation and save power. In this mode only one handset is allowed to be registered to the base, as the remaining transmission power is only strong enough to keep the link to the handset which is based in the cradle.

Base power is turned on again if:

- Trigger 1: Handset is taken out of the cradle
- Trigger 2: Incoming call signalling is received

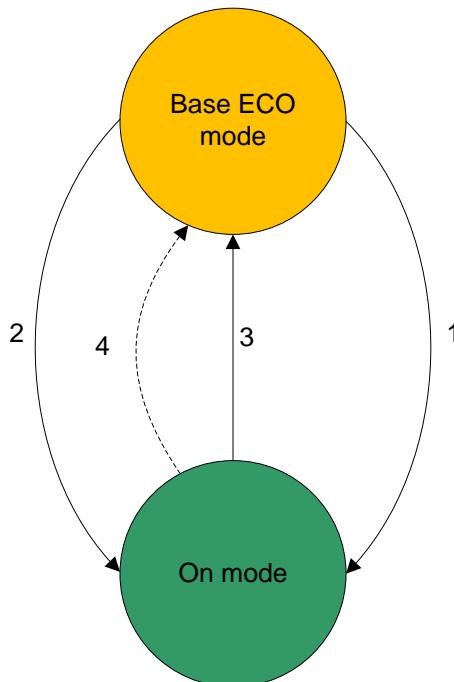


Figure 20: Base ECO mode state diagram

Trigger	Description
Trigger 1	Handset removed from the cradle
Trigger 2	Incoming call request
Trigger 3	Handset is put on the cradle (no call activity)
Trigger 4	Call unanswered or rejected

The reduction in power consumption for the base may vary depending on the implementation, in a typical environment it is approx. 10-20%. Handset power consumption is not affected.

7.5.4.2.3 Manual ECO mode (half range mode)

The user can manually select the range of his cordless phone (Figure 21). Use case: the user lives in a small apartment and does not need the full range of DECT. In this mode the base transmission power is reduced which results in a reduction of 5-10% in the energy consumption of the base unit.

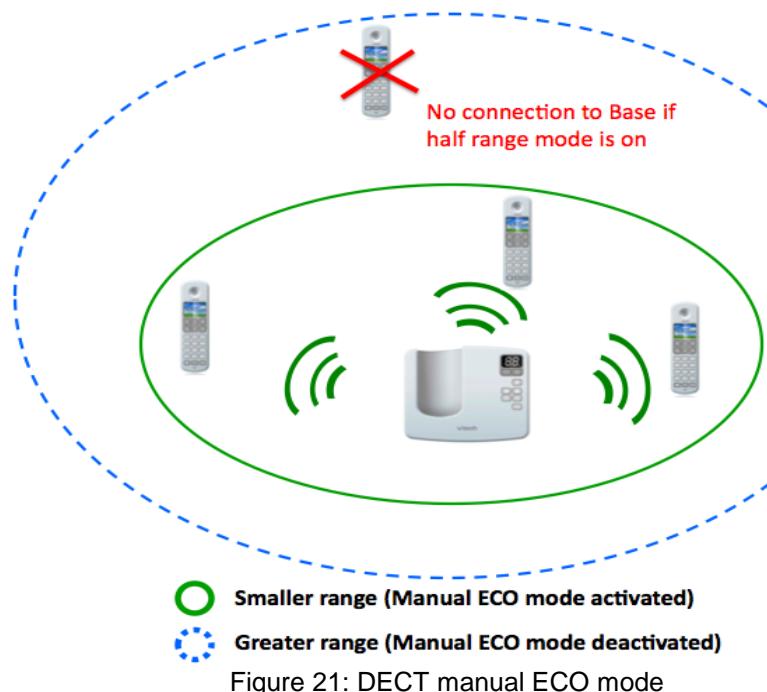


Figure 21: DECT manual ECO mode

7.5.4.2.4 No emission mode (NEMO)

The 'no emission' mode means completely deactivating all transmitters when the system is idle. The main focus of this mode is to minimize the emitted radiated power of the system and does not lead to energy savings. The power consumption in the handset increases as it has to listen more often for the beacon.

This mode is standardized, so it is interoperable between different vendors. All handsets which are attached to the gateway need to support this mode before it can be enabled. It is an optional feature of CAT-iq 2.0.

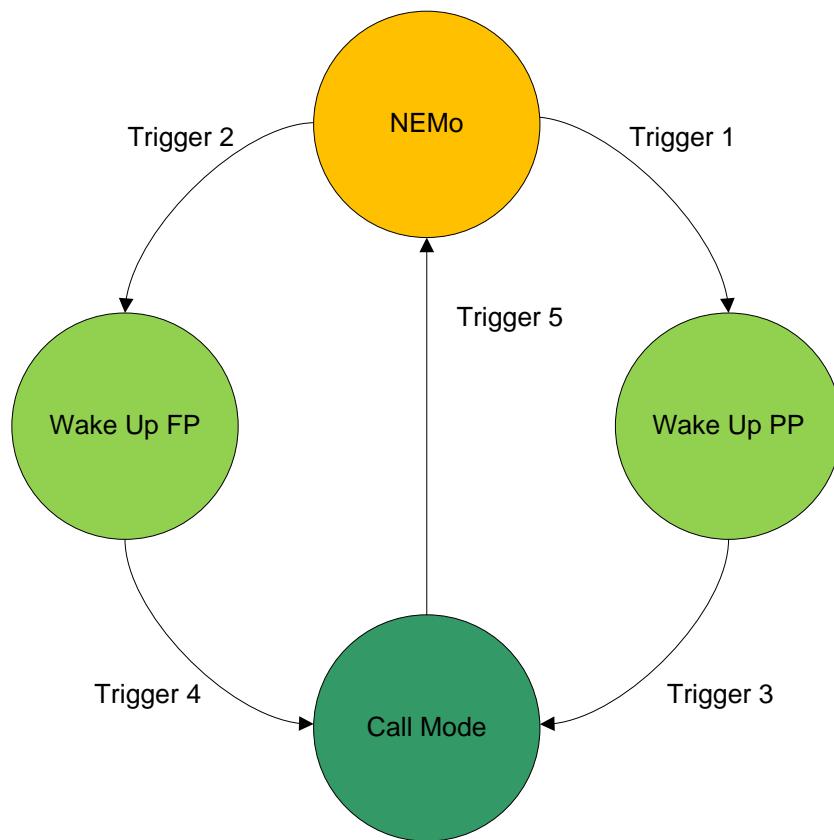


Figure 22: CAT-iq no emission mode state diagram

Power down is negotiated with all system-members (handsets) and an algorithm is provided that guarantees an acceptable, short resynchronisation time, if any member requires an RF connection. If due to, for example, an incoming call (Trigger 1 in Figure 22), the base needs to wake up the handset (PP) in order to resume normal operation, the base will perform a scan of available handsets and re-establish the link between handset and base.

If a handset wants to end 'no emission' mode due to an outgoing call request (Trigger 2), it will send a request to the base to re-establish the link.

In general the system needs approx. 1 second to transition from 'no emission' mode into call mode.

Trigger	Description
Trigger 1	From no emission mode to wake up PP (handset) Outgoing call request
Trigger 2	From no emission mode to wake up FP (base) Incoming call request
Trigger 3	From wake up PP (base) to call mode Link between FP and PP established
Trigger 4	From wake up FP (base) to call mode Link between FP and PP established
Trigger 5	From call mode to NEMo System idle for a tbd period of time

7.5.5 Universal Serial Bus (USB)

Energy saving can be achieved for USB devices that are fully controlled by the HG and don't initiate data requests themselves (such as USB memory sticks, USB printers, etc.). Devices that do initiate data

requests (such as a VoIP phone or DECT dongle) should remain in normal operation mode and not power-down.

The following table describes the states described in Figure 23.

State	Function	Triggers	Power Consumption
Disabled	USB port provides no function/no device detection	Configure manually or through scheduling	No consumption
Disconnected	Detection is on, but no device is plugged in	IN : unplug OUT: plug-in	Almost no consumption
Idle	Device is plugged in, but no data passing	IN: device plugged in and idle OUT: data request (the transition from IDLE to ON occurs in a few ms) or device unplugged	Power consumption is determined by the connected device
On	Device is plugged in and functioning	IN : data request and device is plugged in OUT: device unplugged and no data access	Power consumption is determined by the connected device

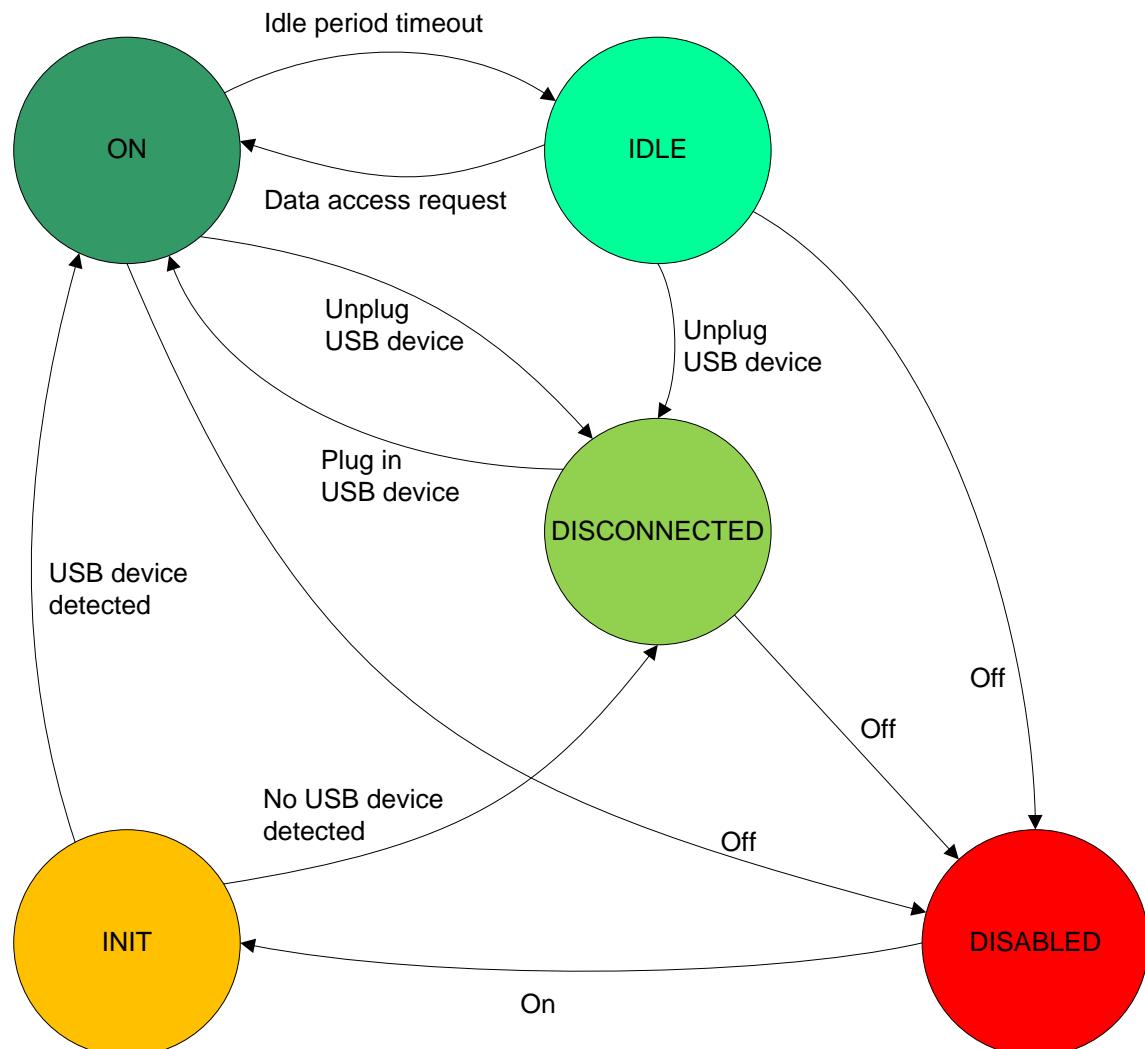


Figure 23: USB master power state diagram

The following table shows the power consumption of a typical USB host controller in the different states.

State	Full-speed (12 Mbps)	High-speed (480 Mbps)
Disabled	0W	0W
Disconnected	1mW	1mW
Idle	100mW	280mW
On	115mW	360mW

To get the overall USB power consumption figure the power consumption of the USB controller and of the connected USB device have to be added. The following table contains the power consumption on the USB port for some examples of USB connected devices.

State	Flash Memory (1G)	Hard disk (2.5" 80G)	Mouse	Wi-Fi-dongle (11g)
Disabled	0W	0W	0W	0W
Disconnected	0.05W	0.05W	0.05W	0.05W
Idle	0.1W	1W	0.05W	0.3W
On	0.25W	3W	0.1W	0.6W

Power feeding: the USB specification defines a maximum of 2.5W (5V @ 500mA), but the actual power consumption depends on the connected peripheral and can be higher than the maximum specified for non-conforming devices such as hard disks which require a high start-up current.

Possible low power mechanisms for the USB port include:

- Powering down unused ports: this is not very effective as a port consumes little energy when nothing is connected (Disconnected state).
- Suspend mode (500µA): this standardized mode is only relevant before unplugging a device (i.e. during a very limited time), and therefore will have little impact on energy consumption.
- Simulation mode:
 - Cut power off, but indicate to the user that it is still active
 - Periodically poll to see if device is still connected
 - Go to On mode if there is a data access request

7.6 Light Emitting Diodes

There are typically a number of Light Emitting Diodes (LED) on a home gateway which serve as visual indicators for power, xDSL communication, Internet connectivity, Ethernet port connectivity/activity, Wi-Fi, VoIP, DECT, Power saving, etc. One single LED can have different meanings, dependent on its mode e.g.:

- Multi-colour
- Blinking/solid on
- Off

This chapter will show that there are useful energy savings to be made with regard to LEDs. The potential areas for saving being:

- The use of low energy consumption LEDs

- Controlling the current of the LEDs so that the brightness is just sufficient in the ON state
- Switching off the LEDs when not useful to the user.
- Providing a user interface to control the use of the LEDs.

7.6.1 LED energy consumption savings

A typical indicator LED has a forward voltage range between 2 and 4 Volts DC. A typical drive current for indicator LEDs is between 6 and 20 mA. Indicator LEDs typically consume 12 - 80 mW. A modern home gateway (HG) can have 15 or more indicator LEDs. The consumption of 15 LEDs is 180 - 1200 mW, which for a 15 W gateway can be up to 8% of the total consumption. This is far from negligible, and so various methods are described in the next sections which can reduce the LED power consumption.

7.6.2 Use of low energy consuming (green/red/yellow) LEDs

As noted in the previous section, there are both low energy and high energy consuming LEDs. In addition to the LED type, the colour also impacts the energy consumption; red and green LEDs consume much less (approx. a factor 2) than white or blue ones. If more brightness is required, this will also result in higher consumption.

7.6.3 Dimming LEDs and drive current issues

A LED is current-driven: the brightness is proportional to the current up to a maximum brightness. However at the low end of the current range, the LED may become unstable resulting in flicker or a change in colour. So dimming by simply reducing the (steady state) current should be avoided. On the other hand, pulse width modulation is a technique that can be used to reliably dim an LED to any percentage of its nominal brightness. By pulsing the LED, it transitions between on and off, and the relative time spent in the two states determines the apparent brightness. This method however may require a pulse modulation controller per LED, which would have a cost impact.

The brightness should be sufficient to make it obvious to the user that the LED is on, but implementations should be such that the minimum current is used to achieve the required brightness in daylight conditions, and stability.

7.6.4 Switching Off LEDs when not useful (LED ECO mode)

The LED indicators provide useful information, but a lot of their value is during power up and transition states, so the user knows when it is appropriate to try and do something. There is also some value in indicators in normal operation e.g. showing traffic activity, port activation etc. Indicators are also very useful when troubleshooting. However not all the indicators may be relevant all of the time. An overview of commonly used LED indication functions is given in the following table. There can be a number of transient LED meanings, depending upon the function. In general they vary from function to function and from product to product, but in the present context the indication 'Transient' is enough.

Function/service management state	Function/service operational state	Traffic condition	LED behaviour	Mode	Energy saving applicable
Enabled	Active (normal)	Traffic	Flickering	steady	yes
		No traffic	ON	steady	yes
	Transient	No traffic	Transient indication code	-	no
		Startup unsuccessful	OFF or error code	-	no
Disabled	Inactive (OFF)	No traffic	OFF	steady	-

The grey shaded indications are the most important to the user. These either show the HG is initializing in some way, or that there is an error condition.

However, in normal operation, even indicating the presence of traffic by flickering an LED is of limited value to the user, since he is looking at the monitor not the HG as everything is working normally. This situation therefore offers some potential for energy saving; the HG could go into LED ECO mode, switching the LEDs to OFF.

However in order to ensure that the user is still made aware of transient or error states, the use of ECO mode must be subject to some rules:

- All system functions represented by the LEDs must be in a steady state (as indicated in the table above) before entering ECO mode,
- When any function is in a transient or error state, all the LED indicators must be reactivated (exit LED ECO mode)
- After the system has entered the LED steady state mode (i.e. all the functions with an LED indicator are steady), a period T_L should elapse before the system enters the LED ECO mode, in order to give the user time to check that the startup activity was indeed successful

It is highly desirable, when switching LEDs off, to have a single (low energy) LED turned on to indicate that the system is in LED ECO mode and so functioning normally even though all the other LEDs are off. If this is not done, the user may think the HG is broken and the operator will get a lot of help desk calls. This has to be avoided for both cost and energy reasons; help desk calls consume a lot of energy.

So an additional ECO mode LED indicator must be used to indicate to the home user that HG is operating normally.

A state diagram of the system behaviour for LED ECO mode is shown in Figure 24.

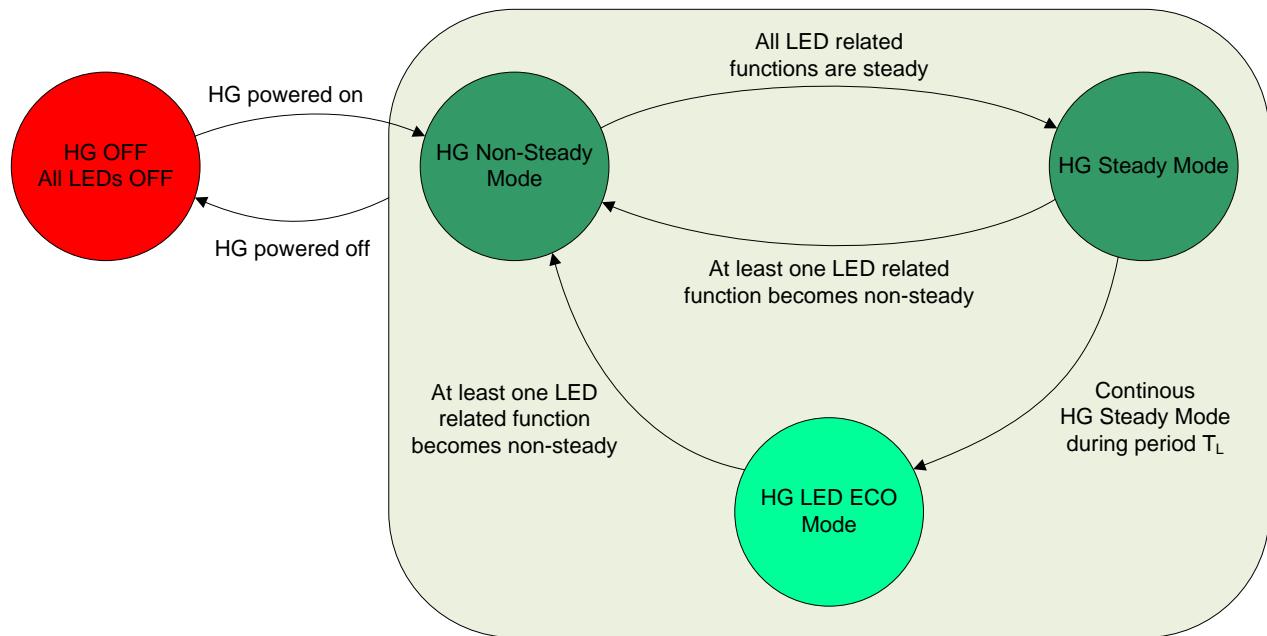


Figure 24: LED based ecostate diagram

At system start-up, all functions are in transient states, so the HG is in Non-STEADY mode. After some period of time, the functions will get into their normal active state. The HG then enters the STEADY mode, and a timer T_L is started, in order to give the user time to check normal operation. After the T_L timeout period, all the LEDs are switched off, except the LED-ECO-Mode one which is turned on.

If, at any time, a transient state or an error occurs, all LEDs are re-enabled to display their actual state. The LED-ECO-mode LED is switched off.

The HG home administrator should be able to control the following. A conceptual user interface for administration of the LED ECO mode is shown in Figure 25

- Enabling/disabling LED ECO mode (default: enabled)
- Selection of the functions/LEDs that are applicable for LED ECO mode (e.g. the user might always want to be able to check the Wi-Fi function), the LED-ECO-mode LED itself cannot be disabled
- Configuration of the time period T_L between system steady mode and ECO LED mode

LED ECO mode enabled <input checked="" type="checkbox"/> (check or uncheck)							
<ul style="list-style-type: none"> • ECO mode LEDs: Tick a minimum of 2, preferably more or all 							
LED1	LED2	LED3	LED4	LED5	LEDx	LEDy	All
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="radio"/>
<ul style="list-style-type: none"> • Lead time before entering LED ECO mode <input type="text"/> minutes 							

Figure 25: Example user interface for LED control

In conclusion, the use of LED ECO mode during normal operation of the home gateway can reduce the HG's LED energy consumption to that of a single, low-power LED.

8 HG operational modes

While the previous chapter looked at the individual subcomponents of a HG in order to identify their operational states and potential power saving, this chapter considers the HG as whole. It describes the power management capabilities of a home gateway and lists a range of events that trigger actions related to energy saving. In addition the operational modes of a home gateway are defined. Due to the large number of possible active modes it only details some examples of active operational modes which correspond to the most common likely sets of states of the individual subcomponents. Some of these correspond to the states defined in the EU CoC. These modes may well be used by Service Providers when testing HGs, or even used as part of a procurement specification. The sections in this chapter serve as best practice examples of energy saving, but are not binding unless they have explicit associated requirements in Chapter 9

8.1 Power management of the HG

The power management function of the HG contains all the functions handling system/module power ON/OFF control and efficient energy management.

The HG ON/OFF button, or module specific (e.g. Wi-Fi) buttons are not strictly part of the power management system, but the power management system is able to monitor the power state of such modules.

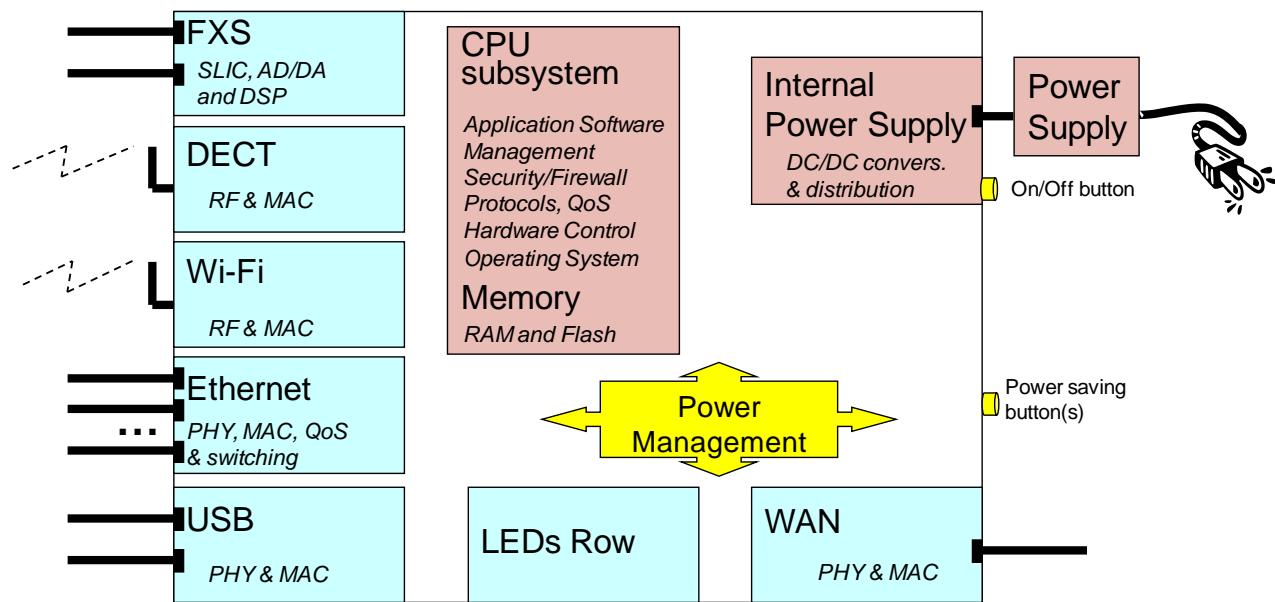


Figure 26: HG power management

Power management functions include (but are not limited to):

- Checking and presenting via the local user interface or remote management the power state of systems and modules
- Providing a power management scheduler to configure various power saving modes (e.g. Wi-Fi off between 8-12h) via local or remote management
- Automatically switching off the entire system at configurable times (e.g. between 23h and 7h every night)
- Allowing manual control over power saving mode via a power saving mode button (e.g. toggling between power saving mode and normal operation)
- Detecting traffic on interface modules and the router/bridge

- Providing a mechanism/algorithm to detect the absence of traffic for both modules and the entire system
- Performing automatic switching to the predefined or configured power saving state(s) in the absence of traffic
- Performing the power saving state actions for each module (e.g. disabling an interface after a device is disconnected), or for the whole system (e.g. reducing clock speed)
- Implementing mechanisms to detect the presence of connected devices in a timely manner
- Performing power management of LEDs

Subcomponents should normally act independently, each going autonomously to its lowest power consumption mode, based on lack of activity (after an appropriate delay). In certain circumstances, the central power management function will enforce a transition to a specific mode (e.g. to shut down at night). The central power management function can also wake up modules.

8.1.1 Transitioning methods

The transition between operational states can occur due to a multiplicity of triggers which can be categorized into two groups:

1. **Automatic triggers** that do not require any involvement from the user:
 - Traffic thresholds (traffic detected or no traffic detected during x seconds/minutes)
 - Via remote management (e.g. before a TV recording starts, the CPE can be brought to full power mode)
2. Triggers with **manual user intervention**: mainly to enter/trigger low power modes, wake up should also be possible via the automatic methods described above
 - Push button: e.g. to explicitly put the HG into standby or to turn off Wi-Fi or other components
 - Scheduled low power periods: based on time of the day (configurable by the user via web interface)

A list of relevant triggers can be found in section 8.5.

8.2 HG operational modes

The following main operational modes can be identified for a home gateway. These are based on the EuP definitions (see chapter 5.1). It is important to stick to the EuP definitions because those are mandatory for electronic household equipment (such as a HG) sold in the European Union.

- Disconnected: all connections to mains power sources of the HG are physically removed or switched off at the mains outlet.
- Off: the HG is connected to the mains power source and is not providing any function other than the ones below:
 - an indication of off-mode condition
 - functionalities intended to ensure electromagnetic compatibility (EMC directive 2004/108/EC)
 - an on/off switch
- Standby: the HG is connected to the mains power source, depends on energy input from the mains power source to work as intended and provides only the following functions, which may persist for an indefinite time:
 - reactivation function, or reactivation function and only an indication of enabled reactivation function

- information or status display
- Active: the HG is connected to the mains power source and at least one of the main function(s) providing the intended service of the HG has been activated

The HG will be in active mode most of the time. In active mode, there will be a large number of sub-modes that are also considered to be active modes. These sub-modes correspond to the possible combinations of active subcomponents. The low-power state and the on state defined in the CoC for broadband equipment are also examples of active modes.

Standby is not appropriate for a HG (or any other networked equipment) as standby mode cannot be exited on the basis of network activity (on the basis of the EUP definition), which is essential for an HG. Networked standby which is not yet part of the EuP Directive will become appropriate when its definition and functionality are added. It is likely that this will be the appropriate HG mode when none of the services is active. However in order to achieve significant energy savings in this mode, technology developments are needed to make the remote reactivation via network signals for all the various kinds of network interface possible.

Off mode can be simply achieved by integrating an ON/OFF switch into the HG. However in certain cases it may not be desirable for the user to switch the HG off e.g. when voice, utility services, security services or guest access are being provided. Therefore some service providers may not want to have an ON/OFF button on their HG.

The state diagram in Figure 27 shows how transitions between these modes can happen.

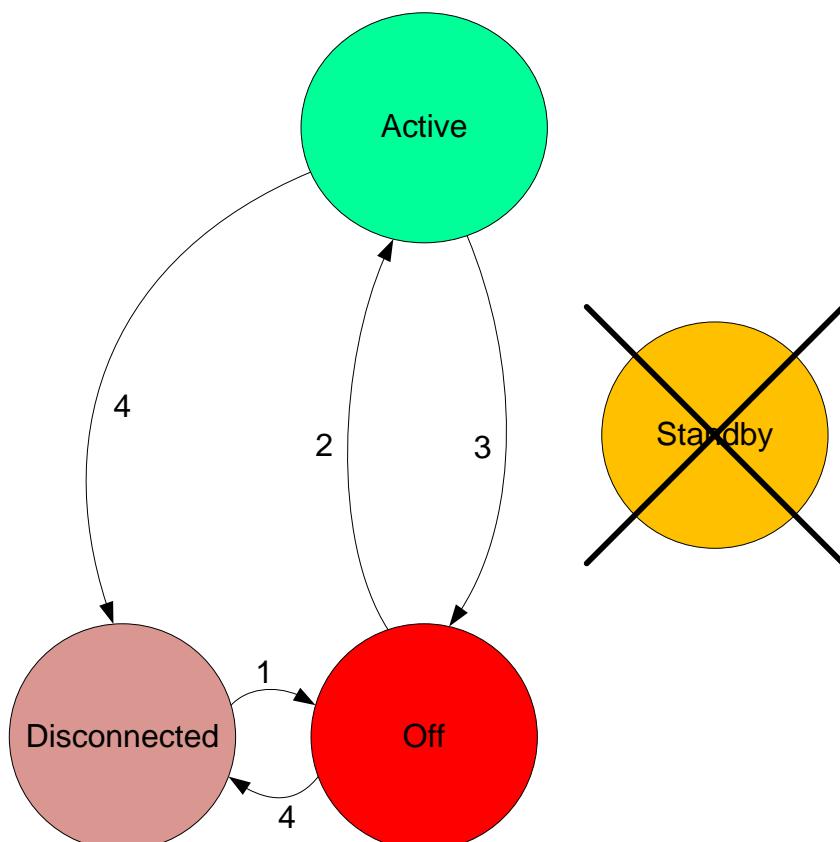


Figure 27: HG operation modes state diagram

Trigger	Description
1	connect the HG to the mains (i.e. connect the power supply to the mains and the HG to the power supply)
2	switch the HG on (should take less than 30 seconds to reach the active mode)

3	switch the HG off
4	disconnect the HG from the mains (e.g. by removing the power supply from the mains or by unplugging the power supply from the HG)

8.3 Non active modes

In disconnected mode, the external power adapter is disconnected from the AC mains outlet.

In off mode the external power adapter is connected to the mains AC outlet and the HG, but the HG is switched off.

Standby mode is not applicable for a HG for the reasons outlined in section 8.2.

Networked standby would allow the HG to go into a mode of very low energy consumption when there is no traffic to be transmitted but still being able to detect traffic on any connected interface and then transition to active mode. Exact definitions and power consumption targets for networked standby are not yet agreed. Studies on networked standby are currently being performed in EuP Lot 26 [10] and it is expected that regulation will come into force by about 2012. Even when networked standby is defined, it may well be difficult for an HG to comply assuming that the energy consumption in networked standby is considerably lower than that of an active mode (i.e. of the order of 1W).

8.4 Example active modes

The following table lists some HGI examples of active modes. These examples are covered in this document, but there are many more possible active modes for a HG, depending on the level of interface activity at a given time. The HGI examples include the CoC-defined states, but several other states have also been added.

Name	Functional states
CoC LOW POWER with Wi-Fi off	<ul style="list-style-type: none"> - FXS: on-hook - Core (CPU, memory) low power - Wi-Fi: OFF - Ethernet : no link established - WAN (xDSL): low power if available
CoC LOW POWER	<ul style="list-style-type: none"> - FXS: on-hook - Core (CPU, memory) low power - Wi-Fi: ON with no clients connected - Ethernet: no link established - WAN (xDSL): low power if available
KEEP ALIVE with Wi-Fi off	<ul style="list-style-type: none"> - FXS: on-hook - Core (CPU, memory) low power - Wi-Fi: OFF - Ethernet : 1 link established but only keep alive messages (500 bytes every 3 seconds) are transmitted, 3 ports with no link - WAN (xDSL): low power if available
KEEP ALIVE	<ul style="list-style-type: none"> - FXS: on-hook - Core (CPU, memory) low power - Wi-Fi: ON with no clients connected - Ethernet : 1 link established but only keep alive messages (500 bytes every 3 seconds) are transmitted, 3 ports with no link - WAN (xDSL): low power if available
CoC ON	<ul style="list-style-type: none"> - FXS: 1 active call - Ethernet : 4 ports with links established, traffic on all ports - Wi-Fi: client connected with traffic
3PLAY	<ul style="list-style-type: none"> - FXS: 1 active call - Ethernet : 4 ports with links established, traffic on all ports - Wi-Fi: 2 clients connected with traffic - USB: host active, USB storage stick (2GB) connected

The first 4 modes can be categorized as low power modes (see also Figure 28) as there is no or only a very small amount of traffic handled by the HG.

The general guiding principle should be that only the interfaces which have activity/traffic or which are necessary to fulfil current user requests should be put into active mode. All other subcomponents should stay in energy saving modes in order to achieve minimal energy consumption. The HG should be able to smoothly transition between those active modes without the need for user intervention.

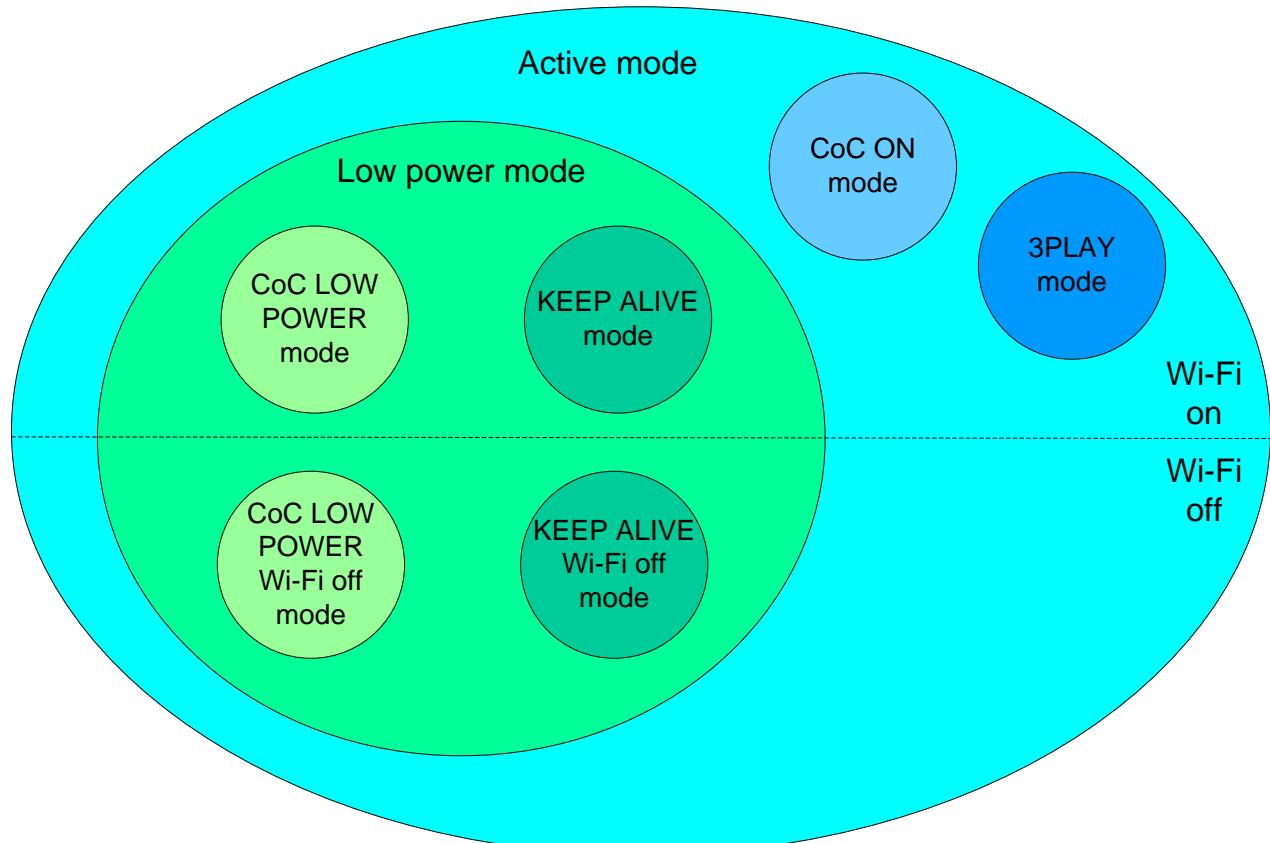


Figure 28: Home gateway active power modes

8.5 Triggers and power consumption related actions

The following list contains triggers for the transition between the active states. A HG with power management features must be able to act on all of these triggers by performing the actions described in the fourth column within the time period defined in column 5. These triggers cause transitions between active modes. As only a subset of all possible power modes has been defined in 8.4 more than one trigger may be needed to trigger a transition between the modes in Figure 28.

Trigger	Service	Initiated by	Action related to power consumption	Timing requirement	Impact on power consumption
On hook	Voice	User	Put the voice subcomponent into low power mode	< 10 seconds	↓
Off hook	Voice	User	Provide voice service → e.g. exit voice subcomponent low power mode	< 1 second	↑
Incoming call	Voice	Remote user /network	Provide voice service → e.g. exit voice subcomponent low	< 1 second	↑

			power mode		
Disconnect phone from FXS port	Voice	User disconnecting phone	Power down the FXS port	not critical (20 to 60 minutes)	↓
First off hook detection after connecting a phone to FXS port	Voice	User	Detect this connection and activate the FXS port	< 3 seconds	↑
Ethernet link down	All (data, IPTV, VoIP e.g. for a VoIP phone)	User disconnects or powers down a connected device	The Ethernet port on the HG enters the auto-power down mode	< 10 seconds	↓
Ethernet link establishment request	All (data, IPTV, VoIP e.g. for a VoIP phone)	User connects or powers up a connected device	The Ethernet port on the HG must detect the link establishment request and leave the auto-power down mode	< 3 seconds	↑
Ethernet port idle	Data, IPTV	Automatically when no traffic is passed	Ethernet port in LP_mode	According to IEEE 802.3az timing	↓
Traffic detected on Ethernet port	Data, IPTV	Automatically when traffic needs to be transmitted	Ethernet port leaves LP_mode	According to IEEE 802.3az timing	↑
Wi-Fi disabled	Data	User: pushes Wi-Fi on/off button or has configured a Wi-Fi off period using the GUI	Power down the Wi-Fi subcomponent (there is no automatic power up from this mode)	< 10 seconds	↓
Wi-Fi enabled	Data	User: pushes Wi-Fi on/off button or has configured a Wi-Fi off period using the GUI that has ended	Power up the Wi-Fi subcomponent mode	Wi-Fi network available in < 10 seconds	↑
Wi-Fi idle	Data	Automatically when no traffic is passed for 2 minutes	Wi-Fi subcomponent in low power mode	< 10 seconds	↓
Wi-Fi client associated	Data	User: starts the laptop and connects to AP	Wi-Fi subcomponent leaves low power mode	< 1 second	↑
Traffic detected on Wi-Fi	Data	Automatically when traffic needs to be transmitted	Wi-Fi subcomponent leaves low power mode	< 1 second	↑
Unplug USB device from USB port	Data	User	The USB port enters the DISCONNECTED mode	< 10 seconds	↓
Plug in device to USB port	Data	User	The USB port enters the ON mode	< 3 seconds	↑
Start of an user defined (e.g. via GUI) low power	All	User	Turn off subcomponents (as configured) e.g.	< 10 seconds	↓

period			Ethernet ports 2-4 plus Wi-Fi		
End of an user defined (e.g. via GUI) low power period	All	User	Turn on subcomponents (as configured)	< 10 seconds	↑
Temporary remote deactivation of power saving mechanisms	All	Network/call center agent	Deactivate all power saving features for trouble shooting	< 10 seconds	↑
Remote activation of power saving mechanisms	All	Network/call center agent or automatic after temporary period ends	(Re)activate power saving features after trouble shooting	< 10 seconds	↓

9 Energy efficiency requirements for the HG

The following tables list requirements for an energy efficient HG. They contain the energy saving related functionalities described in chapters 7 and 8 that a home gateway MUST or SHOULD fulfil. In chapters 7 and 8 more background information as well as additional energy saving features can be found.

9.1 Power management requirements

N°	Requirements
R.1	The HG MUST support power management functionality forcing its subcomponents to the mode of lowest power consumption that can still support the set of active services. This MUST be based on automatic activity level detection and MUST NOT require any user intervention.
R.2	The HG MUST have an on/off switch, except where the HG needs to provide always on services (e.g. some types of voice services, utility services, security services or guest access)..
R.3	It MUST be possible for the user to configure at least 10 periods (by specifying the days of the week when it is applied and the start and end time) during which the HG will operate with only a subset of interfaces active (for example during the night). The mode transition MUST be completed within 10 seconds of the programmed start or end time.
R.4	It MUST be possible to configure which interfaces are active or inactive during the periods defined in R.3 (e.g. only Ethernet port 1 active and all other ports plus Wi-Fi disabled).
R.5	It MUST be possible to individually deactivate (completely power down) and activate (power up) LAN side interfaces (e.g. Ethernet port 2 and FXS port 1) via local UI or remote management. It MUST NOT be possible to power down all interfaces (so that the user can't lock himself out, i.e. at least one LAN interface must remain active).
R.6	It MUST be possible to deactivate all power saving mechanisms for troubleshooting via local UI and remote management. This MUST occur within 10 seconds of the command being received.
R.7	It MUST be possible to (re)activate the power saving mechanisms that have been deactivated in R.6 via local UI and remote management. This MUST occur within 10 seconds of the command being received.

9.2 User information requirements

N°	Requirements
R.8	The HG SHOULD provide some visual indication (e.g. LED) of which operational mode the HG is in.
R.9	The HG SHOULD record the relative power consumption (e.g. in percentage of the max. HG power consumption) over time.
R.10	The HG SHOULD be able to log the operational mode of all subcomponents over time.

R.11	<p>The HG SHOULD support a LED ECO mode (as described in 7.6.4) including the provision of a dedicated ECO mode LED.</p> <p>LED ECO mode MUST be exited as soon as a related transient state or error occurs</p> <p>It SHOULD be possible to enable/disable LED ECO mode. The selection of LEDs and the period T_L SHOULD be configurable via local UI and remote management.</p>
R.12	<p>In the case where the HG is in LED ECO mode the HG SHOULD provide an alternative way to check the system status (e.g. via local UI).</p>

9.3 Subcomponent requirements

N°	Requirements
R.13	The HG MUST use low-power LEDs (max. 50mW).
R.14	The HG Ethernet interfaces SHOULD adapt their port power based on actual cable length while maintaining standards compliance.
R.15	The HG Ethernet interfaces MUST be compliant with Energy Efficient Ethernet (IEEE 802.3az).
R.16	The HG MUST be able to auto-power down a LAN Ethernet port when no electrical signal is detected for a period of 10 seconds so that Ethernet ports with no devices connected will be powered down. The HG MUST periodically send out link pulses while the port is in auto-power down mode.
R.17	The HG MUST detect when an electrical signal is present on a powered down Ethernet port (i.e. if a device gets connected) and activate the port again within 3 seconds.
R.18	It MUST be possible to disable the Ethernet auto-power down feature (R.16) via local UI and remote management on a per port basis.
R.19	The HG MUST have a physical Wi-Fi on/off button. The Wi-Fi interface MUST be powered down or reactivated within 10 seconds of the button being pressed.
R.20	<p>Operating the Wi-Fi on/off button MUST override any scheduled actions (as specified in R.3 and R.4), i.e.</p> <ul style="list-style-type: none"> if the Wi-Fi interface is off, pushing the Wi-Fi on/off button MUST power it on until the button is pushed again or the next scheduled Wi-Fi off period begins if the Wi-Fi interface is on, pushing the Wi-Fi on/off button MUST power it off until it is enabled again by pushing the Wi-Fi on/off button
R.21	It MUST be possible to configure the Wi-Fi transmit power (e.g. to 4 predefined levels such as 100%, 75%, 50% and 25%) via local UI and remote management.
R.22	The Wi-Fi interfaces SHOULD go into a low power mode (e.g. power down RF chains in MIMO systems) when no user traffic is transmitted for a configurable period (e.g. 2 minutes).
R.23	When in low power mode (as in R.22) the Wi-Fi interface MUST be able to handle user traffic within 1 second by leaving the low power mode.

R.24	The voice subcomponent (FXS or DECT) MUST be put into a low power mode within 10 seconds of an on-hook trigger.
R.25	The voice subcomponent (FXS or DECT) MUST be able to provide voice service within 1 second of an off-hook trigger or incoming call.
R.26	The HG SHOULD be able to detect a phone or other device connected to a FXS port and disable the port automatically if nothing is connected. The default time interval between checks MUST be 60 minutes. This parameter MUST be configurable.
R.27	The technique used to detect if a device is connected to the FXS port (R.26) MUST NOT cause connected phones to ring or lights to flash.
R.28	If R.25 is implemented the HG MUST periodically check if a phone is connected to a FXS port which is in UNPLUGGED POLLING state and activate that port again on average within 3 seconds after going off hook.
R.29	It MUST be possible to disable the FXS auto-power down feature (R.24) on a per port basis and to configure the related timing parameters via local UI and remote management.
R.30	Any DECT interface MUST support the base ECO mode as described in 7.5.4.2.2.
R.31	Any DECT interface MUST support the manual ECO mode (half range mode) as described in 7.5.4.2.3. The configuration of the power level MUST be possible via local UI and remote management.
R.32	The instantaneous energy expenditure of the CPU subsystem MUST scale with its actual workload; this implies at least 3 power modes.
R.33	CPU core(s) MUST support the low power wait instruction.
R.34	The CPU core(s) SHOULD have power management with, for example, frequency and/or voltage scaling and software policies to dynamically adapt to changes in workload.
R.35	The CPU subsystem SHOULD control the power modes of other subcomponents (e. g. USB, Ethernet, etc.) depending on their load (if not controlled autonomously).
R.36	In multi-core implementations, unused CPU cores SHOULD go to their lowest power mode.
R.37	The external power adapter MUST fulfil all the mandatory requirements defined in HGI document RD0015 "Energy Efficiency and Ecodesign requirements for a common power supply (CPS) for home gateway, home networking equipment and end devices" [7].

9.4 Energy target requirements

N°	Requirements
R.38	The HG MUST meet the appropriate Tier 1 power consumption targets of the applicable ¹ version of the Code of Conduct on Energy Consumption of Broadband Equipment.

¹ See the Code of Conduct for the definition of applicable in this context

R.39	<p>The HG MUST meet the following power consumption targets for the modes defined in this document (see section 8.4) in addition to the ones defined in the Code of Conduct on Energy Consumption of Broadband Equipment:</p> <ul style="list-style-type: none">• 3PLAY: CoC ON + 1W• KEEP ALIVE: CoC LOW POWER + 0.5W• KEEP ALIVE with Wi-Fi off: CoC LOW POWER - 0.5W• CoC LOW POWER with Wi-Fi off: CoC LOW POWER - 1W
R.40	<p>The HG SHOULD meet the appropriate Tier 2 power consumption targets of the applicable version of the Code of Conduct on Energy Consumption of Broadband Equipment.</p>

10 References

- [1] Home Gateway Initiative HGI-RD001-R2.01: Home Gateway Technical Requirements: Residential Profile, , 29/04/2008
- [2] Home Gateway Initiative HGI-GWD020-R3: Guide to HGI Documents
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