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Operational energy Efficiency for Users (OEU); Energy Consumption Measurement of Operational Technical Equipment of Copper and Optical Fixed Access

Reference

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Keywords

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Foreword

This Group Specification (GS) has been produced by ETSI Industry Specification Group (ISG) Operational energy Efficiency for Users (OEU).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

Further to the 1997 Kyoto protocol [i.6], the European Commission issued Directives in order to improve the energy consumption of telecommunication services.

Fixed Broadband Access constitutes one of the most important ICT areas of energy consumption. Therefore suppliers and users of information and communication technology (ICT) equipment are obliged to implement "Green" tools (meters, indicators) to monitor the energy efficiency of their networks.

The main target of ETSI ISG OEU is the development of the present document defining appropriate energy consumption measurements for operational technical equipment of copper and optical access loop as well as technical Measurement Key Performance Indicators (KPIs) to be used for operational Fixed Access Network.

The present document has been developed by ISG OEU members and is supported by the CTO Alliance/CRIP to define the most efficient tools.

It is expected that the present document will influence the development of new specifications on energy consumption, measurements of operational technical equipment of copper and optical fixed access under the responsibility of ETSI TC EE.

Several standards and technical documents have been taken into account during the development of the present document including EC Mandate M/462 [i.1], ETSI ES 203 215 V1.2.1 [1], JCGM 100:2008 [2], ETSI TS 105 174-1 [i.2], ETSI TS 105 174-4-1 [i.3], ETSI TS 105 174-5-1 [i.4] EC DG JRC Code of Conduct for Broadband Networks [i.5], and Kyoto Protocol [i.6].

1 Scope

The present document proposes Key Performance Indicators (KPI) applicable by vendors in laboratories or by operators in operational situations. The scope of the present document is exclusively dealing with the **Multi-Service Access Node** MSAN, configured for both Fiber to the Home (FTTH) and Digital subscriber line (DSL) usages.

Considering the foreseen implementation of energy consumption meters embedded in the MSAN allowing real time knowledge of energy consumption, clause 4 proposes the operational KPIs which should be managed by the Network Management System (NMS).

The present document proposes engineering KPIs to evaluate and to model on-field energy consumption.

The present document is structured in three clauses:

1) Listing the key parameters which have most impact on the power consumption.

2) Defining a MSAN power consumption model when it is used as a *digital subscriber line access multiplexer* (DSLAM) to obtain a green Operational KPI, according to the key parameters.

3) Defining the methodology for an *optical line termination* (OLT).

To be noted:

The DSLAM is a Digital Subscriber Line Access Multiplexer that could be split in three sets:

- ATM DSLAM: A DSLAM with an internal ATM bus (which supports xDSL services).
- IP DSLAM: A DSLAM with an internal IP bus.
- GE DSLAM: Equipment with GE uplink card.

The OLT (Optical Line Termination) is an equipment with internal IP bus which provides FTTH services.

The MSAN which is an equipment with internal IP BUS, provides either DSL services or POTS services or GPON services or any mix together.

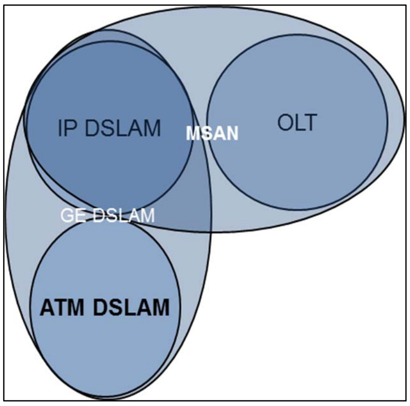


Figure 1: Definition of nodes

In the present document, only the following terms will be used: DSLAM, OLT and MSAN.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are necessary for the application of the present document.

[1] ETSI ES 203 215: "Environmental Engineering (EE); Measurement Methods and Limits for Power Consumption in Broadband Telecommunication Networks Equipment".

[2] BIPM: "Evaluation of measurement data - Guide to the expression of uncertainty in measurement" from Working Group 1 of the Joint Committee for Guides in Metrology (JCGM/WG 1).

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] EC Mandate M/462: "Standardisation mandate addressed to CEN, CENELEC and ETSI in the field of ICT to enable efficient energy use in fixed and mobile information and communication networks".

[i.2] ETSI TS 105 174-1: "Access, Terminals, Transmission and Multiplexing (ATTM); Broadband Deployment and Energy Management; Part 1: Overview, common and generic aspects".

[i.3] ETSI TS 105 174-4-1: "Access, Terminals, Transmission and Multiplexing (ATTM); Broadband Deployment and Energy Management; Part 4: Access Networks; Sub-part 1: Fixed access networks (excluding cable)".

[i.4] ETSI TS 105 174-5-1: "Access, Terminals, Transmission and Multiplexing (ATTM); Broadband Deployment and Energy Management; Part 5: Customer network infrastructures; Sub-part 1: Homes (single-tenant)".

[i.5] European Commission DG JRC: "Code of Conduct on Energy Consumption of Broadband Equipment".

[i.6] Kyoto protocol to the United Nations Framework Convention on Climate Change (1997).

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

broadband: high-capacity transmission technique using a wide range of frequencies, with an ability to simultaneously transport multiple signals and traffic types

NOTE: The medium can be coaxial cable, optical fiber, twisted pair, DSL local telephone networks or wireless broadband.

energy consumption: energy, in watt hour, consumed by equipment

power saving: gap between the power consumption feature off and feature on

3.2 Symbols

For the purposes of the present document, the following symbols apply:

KPI_{MSAN}	MSAN energy consumption (watt.hour) / (average connected ports over the considered period * considered period (hour))
P_{total}^{0}	total power consumption of the MSAN (DSLAM or OLT) with no LT cards.
P_{L3}^{M}	total power consumption of the DSLAM if all the slots are occupied by LT card but there are no HGW (Home Gateway) connected to line cards
P_{L0}^{M}	total power consumption of the DSLAM if all the slots are occupied by LT card and all the port are linked to a HGW in L0 mode
P_{L2}^{M}	total power consumption of the DSLAM if all the slots are occupied by LT card and all the port are linked to a HGW in L2 mode
P_{0}^{M}	total power consumption of the OLT if all the slots are occupied by LT card but there are no ONU
P_{1}^{M}	total power consumption of the OLT if all the slots are occupied by LT card and all the ONU are trafficking on the ports with SFP
$P_{1/2}^{M}$	total power consumption of the OLT if all the slots are occupied by LT card and all the ONU are sleeping on the ports with SFP
P_{fixe}	Power consumption of the fixed part issued from generic elements (power supply, fans, system and control boards)

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ATM DSLAM	DSLAM with internal ATM bus
ADSL	Asymmetric Digital Subscriber Line
ATM	Asynchronous Transfer Mode
BBCoC	Broadband Code of Conduct
CO	Central Office
CPE	Customer Premises Equipment
CPU	Central Processing Unit
DSLAM	Digital Subscriber Line Access Multiplexer
EC DG JRC	European Commission Directorate General Joint Research Centre
EE	Energy Efficiency
EER	Energy Efficiency Ratio
FAN	Fixed Access Node (note that it is different to fan in lower case)

FT	France Telecom
FTTH	Fibre To The Home
GE	Gigabit Ethernet
GPON	Gigabit Passive Optical Network
GW	Giga Watt
HGW	Home Gateway
ICT	Information and Communication(s) Technology
IP	Internet Protocol
IT	Information Technology
JCGM	Joint Committee for Guides in Metrology
KPI	Key Performance Indicator
LPM	Low Power Mode
LT	Line Termination
MDF	Main Distribution Frame
MSAN	Multi Service Access Node
NMS	Network Management System
NT	Network Termination
OLT	Optical Line Termination
ONU	Optical Network Unit
ONT	Optical Network Termination
PON	Passive Optical Network
SFP	Small Factor Pluggable
VDSL	Very high bit-rate Digital Subscriber Line

4 On-field KPI

The whole equipment consumption divided by number of connected subscriber port (active or not) presents the energy performance of MSAN in the network.

In particular, this ratio can show the interest of the MSAN sustainable features such as automatic port/borad shutdown, L3 mode or L2 mode.

KPI_{MSAN} (watt/connected port) = MSAN energy consumption (watt.hour) over the considered period (day, week, month, and year) in hour divided by the |sum of (connected ADSL port(1) + connected VDSL port(1) + connected ONU (1))*(period in hour)].
(1) Average number of port connected over the considered period.

5 Key parameters to evaluate the energy consumption

5.1 Generality

Tables 1 and 2 provide a non-exhaustive list of "basic" parameters describing the power consumption of the MSAN. The parameters are divided into three classes:

- low impact (L.I);
- average impact (A.I);
- high impact (H.I).

The classes may give a good approximation of the MSAN power consumption.

A refinement of these classes with complementary tests and results will enable the operators and the suppliers to confirm the class of the parameters.

These parameters will be used in the variables and coefficients of the KPIs defined in the follow-up.

NOTE 1: Temperature (T°) dependence of the power consumption covers the full chassis and boards (including the LT ones) with fans adjusted speed and individual on/off feature. It may be a criteria in itself in a given configuration at a given traffic load, to ask for the power consumption for a range of T°. This is applicable for DSL and Optical links.

NOTE 2: Dependence to voltage should be clarified since the converter efficiency belongs to the shelf/chassis (but also the cards). This should read 'supply voltage'.

In tables 1 and 2, the colour code is:

- Red: when the parameter will be an internal element of the equipment (for instance, the number of cards or the number of SFP modules).
- Black: when it will be linked to the host site (for example, the temperature or the Voltage) or out of MSAN. These last key parameters will depend on many of the country's conditions (for instance, the average copper loop length).

5.2 DSL impacting parameters

Table 1: DSL impacting parameters

	Impacting basic Parameters	Impact level	Comments
Impacting the Line card	Copper length	H.I	Average length: according to the country and its network.
	Diameter of cable	L.I	In general, 0,4 mm. But, also 0,5 mm or 0,8 mm.
	Number of connected home gateways (synchronized and not synchronized)	H.I	A home gateway can be synchronized or not. For instance, a customer can choose to switch off the modem during the night thus the power consumption is different.
	Customer traffic profile	A.I	High or low according to the low power mode are used or not.
Impacting the share part (fan / NT card)	Number of line card	H.I	LT cards generate heat dissipation, so the more LT cards inserted in the shelf, the higher the fan speed.
	Traffic	L.I	Possible impact on CPU and fan speed.
	Master shelf when in cascade	L.I	Power consumption can grow due to higher fan speed and additional optical port usage (for connection to slave nodes).
	Number of deports/extensions	A.I	New extensions require additional optical Ethernet ports and can cause higher CPU load due to increased traffic.
Other impacting element	Host Site temperature	A.I	The higher the temperature at CO, the higher the fan speed and power consumption, of course the host site temperature needs to comply with the temperature range of the equipment.
	Supply Voltage	A.I	In general, between 40 V to 57 V.
NOTE: Concerning the traffic impact, when the DSL port is active (modem is synchronized), it consumes more energy than when it is not connected (modem is not synchronized).When the DSL port (or card) is unused and enabled it also consumes energy.			

5.3 FTTH impacting parameters

Table 2: FTTH impacting parameters

	Basic parameters	Impact level	Comments
Impacting the Line card	Optical budget class *Fixed or pluggable modules B+ or C+*	L.I	
	Number of PON ports per card: un-provisioned / In Stand-by mode (no traffic) / Active	H.I	The number of plugged SFP modules should be seen for the line cards with modules pluggable.
	Number of ONT per active port	L.I	It is suggested to ask for the exact ONU to fill the port data bandwidth capability.
	Customer traffic / traffic forwarding capacity used	L.I	Low impact with the current cards. Suggestion to the supplier to ameliorate the power consumption per line card.
Impacting the Common part (fan / NT card)	Number of line cards	H.I	Fan and NT impact
	Traffic	L.I	NT impact
	Number of HGW	A.I	Fan impact
	Number of deports/extensions	A.I	Fan impact
Other impacting element	Host Site temperature	A.I	The higher, is the host site temperature, the higher is he FAN speed and power consumption.
	Supply voltage	A.I	Between 40 V to 57 V (in 48 V).

5.4 Some words on the error and uncertainty

This clause is a reminder that the KPIs represent an approximation of the reality. This clause underlines the fact that the measurements on equipment e.g. an operator's network, will never provide the exact figure of its power consumption.

Two origins of this difference with the real values are examined.

The basic notion of a KPI:

- It is an indicator, an approached value (at the level zero or one of a limited development). The previous clause details the elements to be taken into account with relevant explanations.
- In an operator's network, there are many different MSAN, each of them having its own configuration, so only the embedded energy metering can provide whole data. For energy modelling, only an average or representative element is considered.

In addition, the uncertainties of the measurements should be highlighted. They are due to different measurement equipment, the technical environment or the climatic conditions. This remark is valid for the in-field measurements as for the lab measurements. Then, a sample of measurements on the measured element(s) has to be set up:

- Measurement on a set of elements or sets of measurements on some equipment.
- Its size will allow choosing the better statistic law (normal law and student law, for example).

The present document will not detail the method to calculate the uncertainty (please refer to statistics and probability rules).

6 MSAN in DSLAM modelling

6.1 Coefficients and variables

6.1.1 Coefficients

MSAN consumes different amounts of power depending on the state and number of each card in the shelf. For the follow-up, we consider four states:

STATE I:

There are no LT cards.

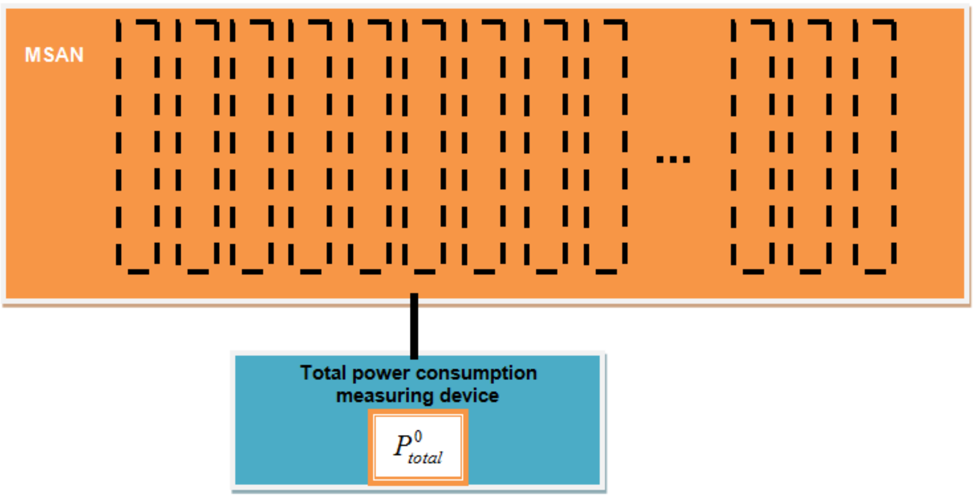


Figure 2: MSAN witout LT cards

STATE II:

All the slots are occupied by a LT card but there is no CPE/.

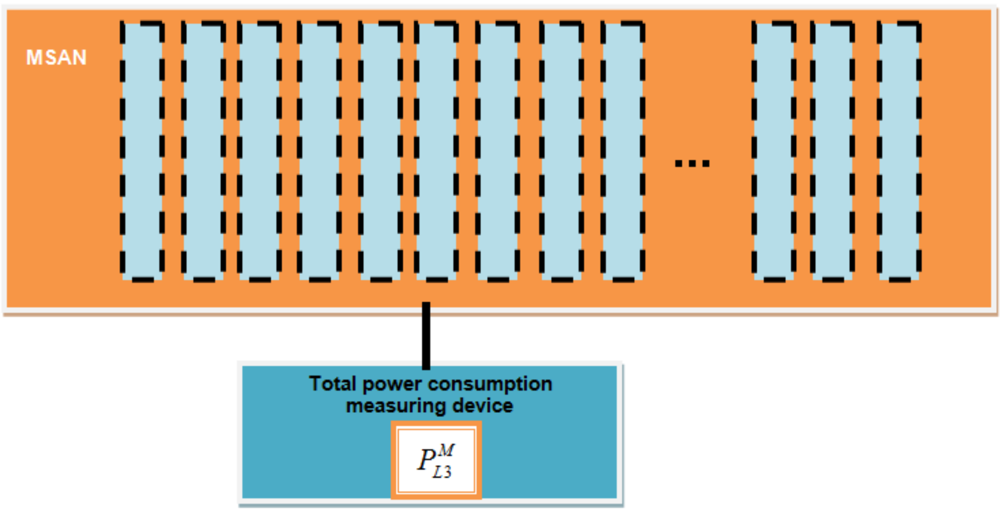


Figure 3: the slot are occupied but without CPE

STATE III:

All the slots are occupied by a LT card and all the ports are linked to a CPE in L0 mode.

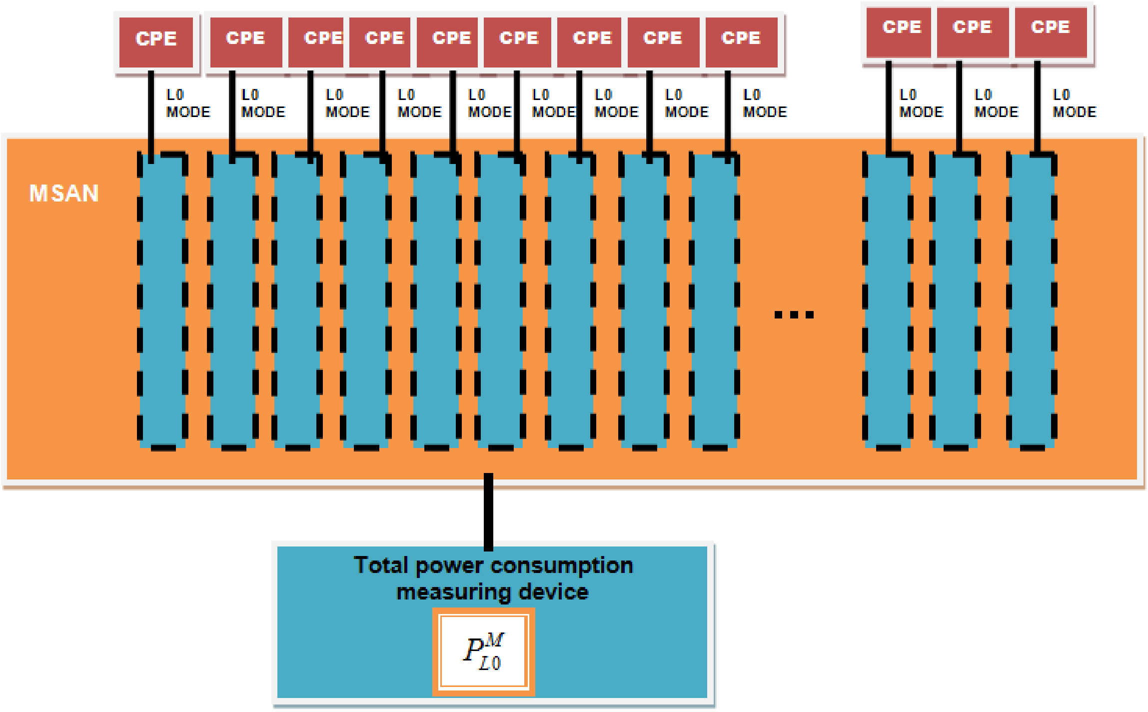


Figure 4: All the ports are in L0 mode

STATE IV:

All the slots are occupied by a LT card and all the ports are linked to a CPE in L2 mode.

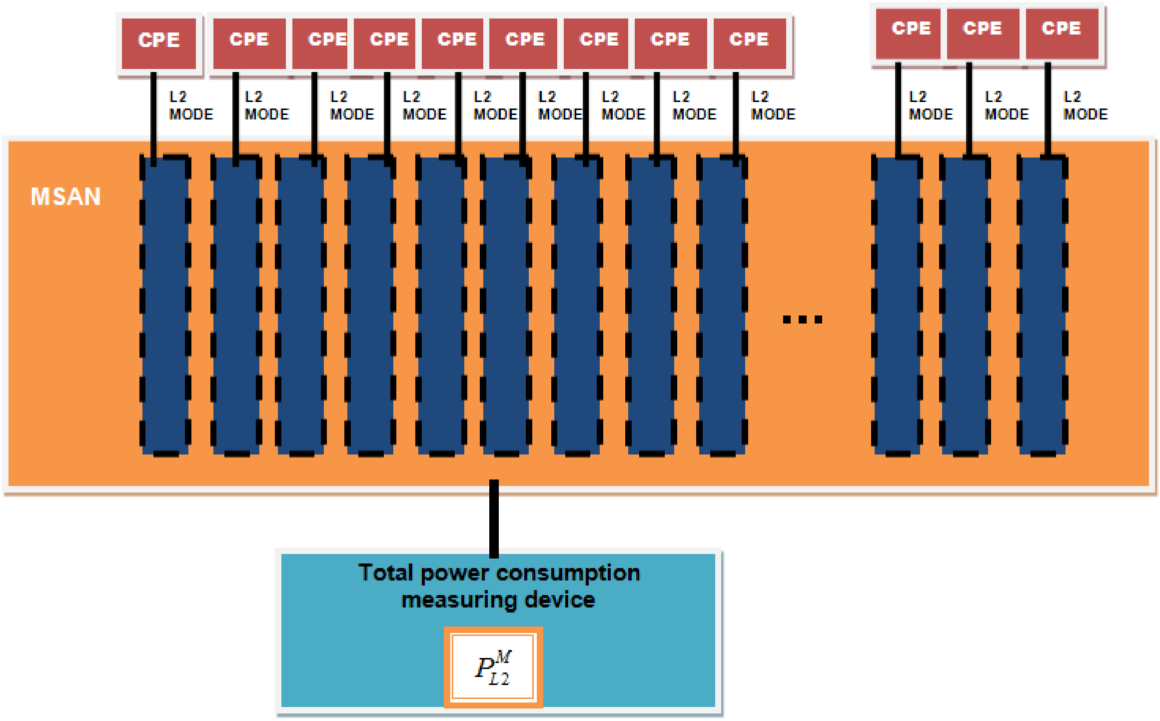


Figure 5: All the ports are in L2 mode

These four states will define 4 coefficients in the follow-up: $P^0_{total}, P^M_{L3}, P^M_{L2}, P^M_{L0}$.

6.1.2 Variables

In the network, different cards can be in different states in the same shelf so, additionally three variables shall be defined:

- X: The % of the ports with DSL modem (it is equal to the number of CPE on the number of ports per card).
- Y: The % of the ports synchronized among the ports linked to a CPE.
- Z: The % of the port (with a CPE) in L2 mode (for VDSL2, Z = 0).

We also need to define two integer variables:

- N, the number of LT cards in the shelf.
- M, the number of slots dedicated to LT cards.

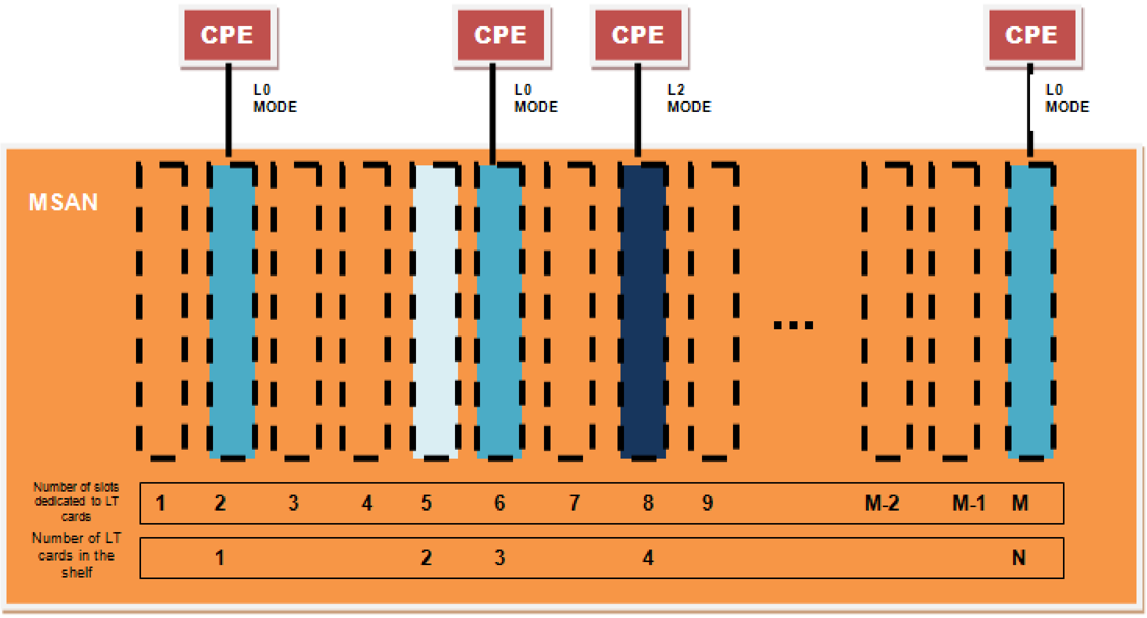


Figure 6: MSAN including all the previous cases

6.1.3 Parameters, coefficients and variables

The impacting elements seen in clause 5 will be used as parameters in the coefficients or the variables. A beginning of an explanation is given in table 3:

Table 3

	Impacting basic Parameters	Will be used in the
Impacting the Line card	Copper length	Coefficients
	Diameter of cable	Coefficients
	Number of connected home gateways	Variables
	Number of synchronized home gateways	Variables
	Customer traffic	Variables
Impacting the Common part (fan / NT card)	Number of line cards	Coefficients
	Traffic	Coefficients
	Master shelf when in cascade	Variables
	Number of deports/extensions	Variables
Other impacting element	Central Office temperature	Coefficients
	Supply Voltage	Coefficients

6.2 DSL_power KPI definition

We define KPI_{DSL_Power} as sum of measured power with different coefficients.

$$KPI_{DSL\_Power} = AP^{0}_{TOT} + BP^{M}_{L0} + CP^{M}_{L2} + DP^{M}_{L3}$$

Coefficients A,B,C,D are equal to:

$$A = \frac{M-N}{M} \quad B = \frac{NXY(1-Z)}{M} \quad C = \frac{NXYZ}{M} \quad D = \frac{N-NXY}{M}$$

The mathematical calculation, to get the formula in Watt:

$$KPI_{DSL\_Power} = KPI_{DSL\_Power}(N,M,X,Y,Z)$$

$$= \frac{(M-N)}{M} P^{0}_{total} + \frac{N}{M} \left[(1-XY) P^{M}_{L3} + X.Y.ZP^{M}_{L2} + XY(1-Z) P^{M}_{L0} \right]$$

The VDSL2, model will be simpler while a low power mode dedicated VDLS2 is not defined. Currently the L2 mode is variable, Z, is equal to 0. For the VDSL2, the formula will be able to simplify as follows:

$$KPI_{VDSL\_Power} = KPI_{VDSL\_Power}(N,M,X,Y,0)$$

$$= \frac{(M-N)}{M} P^{0}_{total} + \frac{N}{M} \left[(1-XY) P^{M}_{L3} + XY.P^{M}_{L0} \right]$$

NOTE: Examples are presented in annex A.

6.3 Operational values and KPI

This definition of a KPI allows to define an operational value per network affiliated and per supplier:

- each country has got its own values for the variables X, Y and Z;
- each MSAN has got its own values for the coefficients defined in the formula.

Moreover, to refine the results in the country, it also allows defining different KPI_{DSL_Power} per kind of DSLAM (master or slave). In this case, if the average number of extensions per master MSAN on a same MDF site is known, it is easy to compute the first $KPI^{site}_{DSL\_Power}$. Thus, it is possible to introduce the parameter "Number of deports/extensions" for the extensions in a same site.

Concerning certain functions like the Vectoring, there are two abilities to manage it, "system level" and "board level". Thus, this vectoring functionality could be taken into account:

- either the used method is "the system level" and it is centralized by a supplementary card on the DSLAM. Then, for the KPI calculation, this card could be included in the common part of the DSLAM (see table 3); or
- the used method is the "board level" and it is distributed in each VDSL card. Then, the power consumption on the VDSL2 card with vectoring will be different (normally superior) to the VDSL2 power consumption without it. In a first approximation, this distributed solution should only impact the line cards.

7 The MSAN in OLT modelling

7.1 Coefficients and variables

7.1.1 Coefficients

The MSAN in the OLT model consumes different amount of power, depending on the state and number of each card in the shelf. For the follow-up, consider four states:

STATE I:

There are no LT cards.

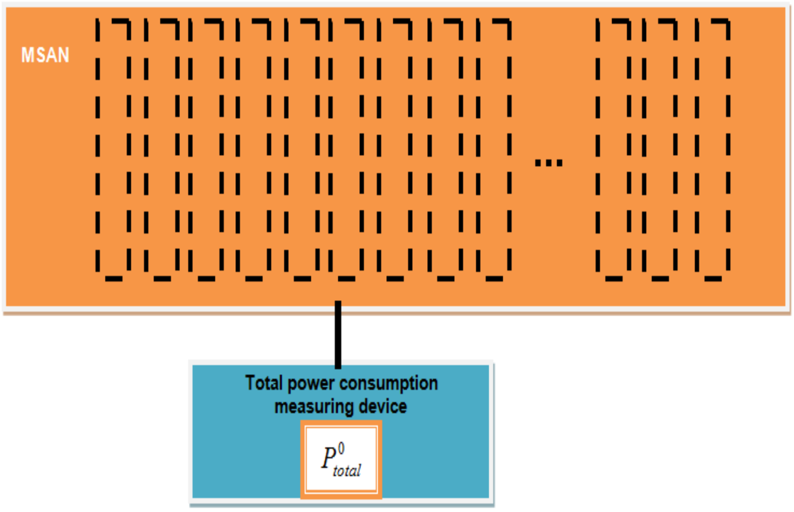


Figure 7: OLT without LT cards

STATE II:

All the slots are occupied by the LT card but there are no ONU.

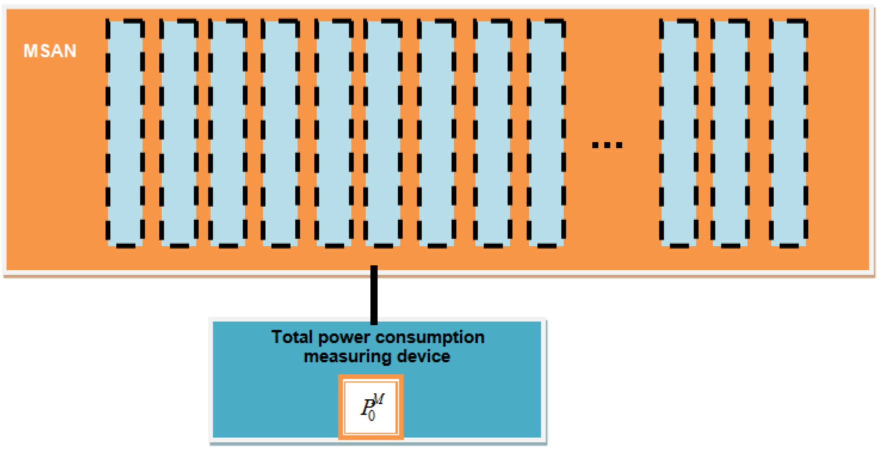


Figure 8: All the slots are occupied but no ONU

STATE III:

All the slots are occupied by the LT card and all the ONU are trafficking on the ports with SFP.

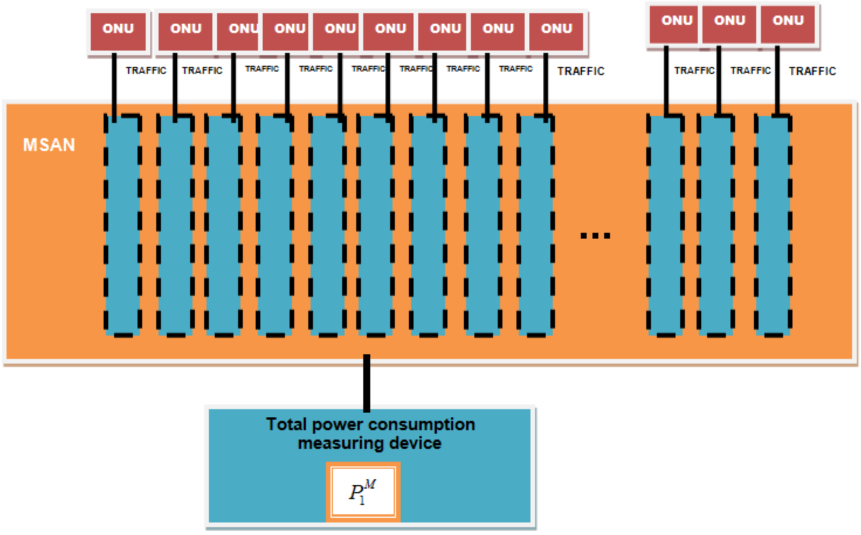


Figure 9: The ports are occupied and the ONU are trafficking

STATE IV:

All the slots are occupied by the LT card and all the ONU are sleeping on the ports with SFP.

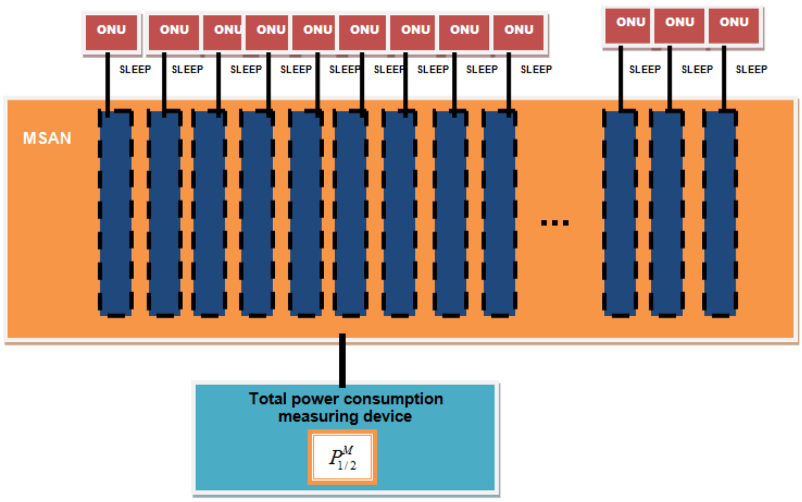


Figure 10: The ports are occupied and the ONU are sleeping

These four states will define 4coefficients in the follow-up: $P^0_{total}, P^M_0, P^M_1, P^M_{1/2}$.

7.1.2 Variables

The notion of sleep mode on the OLT is introducing with no notions of synchronization, as DSL. Then, for a port, we limit ourselves to define two new variables. To keep a certain homogeneity with variables in the previous clause:

- X: the average percentage of ONU per port, that is X = n/C with C = 64 or 128.
- Z: the average percentage of ONU in sleep mode per port.

We need also to define two integer variables:

- N, the number of LT cards in the shelf.
- M, the number of slots dedicated to LT cards.

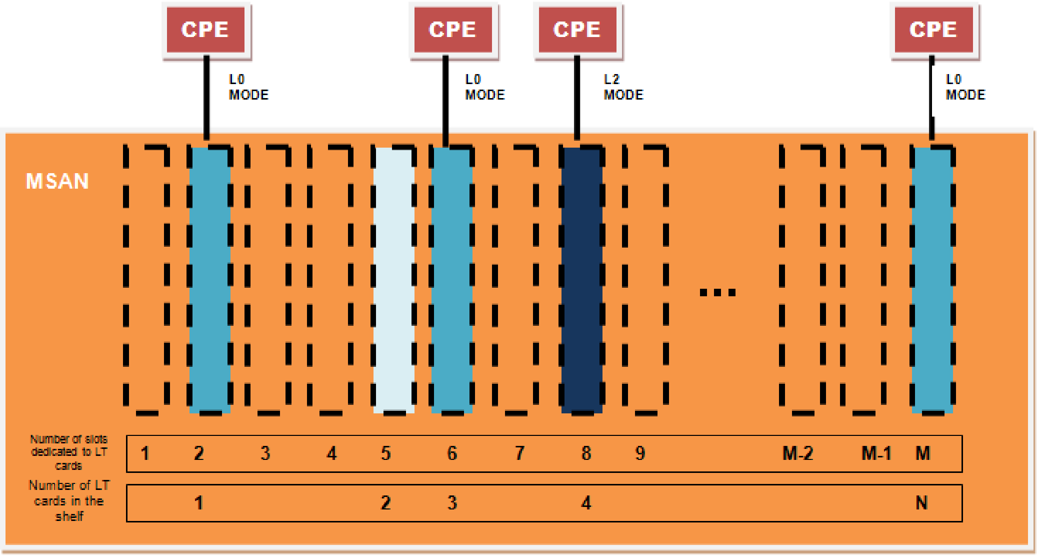


Figure 11: OLT are including all the previous cases

7.1.3 Parameters, coefficients and variables

The impacting elements seen in clause 5 will be used as parameters in the previous coefficients or the previous variables. A beginning of explanation is given in table 4.

Table 4

	Impacting basic Parameters	Will be used in the?
Impacting the Line card	Optical budget class	variables
	Fixed or pluggable modules B+ or C+	variables
	Number of PON ports per card: Unprovisioned /In Stand-by mode (no traffic) / Active	variables
	Number of ONT per active port	variables
	Customer traffic / traffic forwarding capacity used	variables
Impacting the Common part (fan / NT card)	Number of line cards	variables
	Traffic	variables
	Number of CPE	variables
	Number of deports/extensions	coefficients
Other impacting elements	Central Office temperature	coefficients
	Supply voltage	coefficients

7.2 GPON_power KPI definition

Define KPI_{GPON_Power} as sum of measured power with different coefficients.

$$KPI_{GPON\_Power} = AP_{TOT}^{0} + BP_{0}^{M} + CP_{\frac{1}{2}}^{M} + DP_{1}^{M}$$

Coefficients A,B,C,D are equal to:

$$A = \frac{M-N}{M},\ B = \frac{N(1-X)}{M}, C = \frac{NXY}{M}, D = \frac{NX(1-Y)}{M}$$

The mathematical calculation for the formula in Watt:

$$KPI_{GPON\_Power} = KPI_{GPON\_Power}(N,M,X,Y)$$

$$= \frac{(M-N)}{M} P^{0}_{total} + \frac{N}{M}\left[(1-X)P^{M}_{0} + X.Y.P^{M}_{1/2} + X.(1-Y)P^{M}_{1}\right]$$

With: $$P^{M}_{k} = P^{M}_{fixe} + \sum_{i=1}^{M}\left((S-S(i))P_0 + \sum_{j=1}^{S(i)} P_{ij}(k)\right)$$ k= 0, ½ or 1

and S(i) is the number of SFP modules on the GPON LT card i.

NOTE: Examples are presented in annex B

7.3 Further remarks

- This definition of a KPI allows defining an operational value per network affiliate and per supplier, according to the precision that we want:
  - each country has got its own values for the variables X, Z;
  - each MSAN has got its own values for the coefficients defined in the formula.
- Moreover, in the same country, the forecast of the KPI evolution is allowed based on forecasts and its internal architecture of the OLT equipment.

8 Methods to obtain the variables and coefficients values

8.1 Coefficients

There are different methods to obtain the coefficients of the previous formulas.

They can be measured in (operator or suppliers) labs with representative values of parameters (see the tables above to know the main parameters), or, measured on-field.

Table 5 gives some (non exhaustive) pros and cons for each methods.

Table 5

	Pros	Cons
In labs	• Possibility to rapidly change the values of parameters and the structure of the node (number and type of card etc.). • Easy to repeat the tests	• Not really operational • Necessity of knowing very well the parameters in the network
On-field	• Really operational	• Difficult to find some representative nodes • Impossible to change the composition of the node • Difficult to manage the possible changing of the technical environment in the measured site • Install equipment of measurement in the site(s).

8.2 Variables

The variables (X, Y and Z) are linked to the network. These average variables need to extract some elements of inventory or profile of traffic on the network.

For the variable, X, the value of this parameter is relatively stable during minimum one week. An inventory on the equipment is sufficient to have an average value.

For the variables, Y and Z, it is necessary to follow the network during, at least, a complete day or several days in a representative week. These parameters are linked to the customer usages, hour per hour:

- When the customer switches off/on the modem (night and day, working hours, etc.).
- The customer's type of traffic during the day (TV, Peer-to-Peer, only internet or Voice, etc.).

These average variables could be obtained thanks to the tools which follow the profile of traffic.

9 Towards indirect KPIs

9.1 Network KPI (example with FAN modelling)

The KPI as defined above is able to compute a first network KPI, named $KPI_{network}$ in the follow-up. This indicator is expressed in Giga Watt (GW).

The measured network determinates the DSLAM and the OLT. In order to compute the KPI for each, the inventory of each network is mandatory.

If D and O are respectively the number of DSLAM and OLT in the measured network:

$$KPI_{Network\_Power} = \sum_{k=1}^{D} n_{DSL}^{k}.KPI_{DSL\_power}^{k} + \sum_{k=1}^{O} n_{GPON}^{k}.KPI_{GPON\_power}^{k}$$

With:

n_{DSL}^{k}= The number of nodes for the k^th^ type of DSLAM in the seeing network, k= 1 to D

n_{GPON}^{k}= The number of nodes foe the k^th^ type of OLT in the seeing network, k= 1 to O

NOTE: This KPI does not take into account the technical environment. To introduce this last point, it is needed to know its energy efficiency. Some different average KPI: per node, per port or per customer could be defined. Hereafter, some example with the nodes:

$$kpi_{Network\_Power} = \frac{\sum_{k=1}^{D} n_{DSL}^{k}.KPI_{DSL\_power}^{k} + \sum_{k=1}^{O} n_{GPON}^{k}.KPI_{GPON\_power}^{k}}{\sum_{k=1}^{D} n_{DSL}^{k} + \sum_{k=1}^{O} n_{GPON}^{k}}$$

- And, on the sub-network DSLAM, for example:

$$kpi_{sub\_Network\_Power}^{DSL} = \frac{\sum_{k=1}^{D} n_{DSL}^{k}.KPI_{DSL\_power}^{k}}{\sum_{k=1}^{D} n_{DSL}^{k}}$$

9.2 Proposal on Energy Efficiency (EER) KPI

The EER; Energy Efficiency Ratio, is defined as the ratio between the capacity and the power consumption, in kbps/Watt. This KPI indicates a first approach of the evolution of the usages regarding to the improvement of the technology.

The denominator, the power consumption, will be able to be defined with the previous KPIs. The capacity - that is the numerator - will have to be clarified. It could be:

- either, the throughput effectively offered to the users, named $EE_{Offered}$; or
- the throughput effectively used by them, named EE_{Used}.

The EER of access transmission nodes have to be correctly defined prior to implementation of the current described process.

A theoretical formula of the EER_{Used} could be yearly and according to the introduction of new green features and the evolutions of usages.

Thus, for the ADSL technology:

- For the state II in clause 7.1, that is all the ports in L3 mode, T_{L3} is almost 0 kbit/s (idem for the state I: T_0 = 0 kbit/s).
- The value of ATPRT parameter being chosen in the network for the ports in L2 mode, T_{L2} defines the reduced throughput for equipment in the state IV (in clause 7.1).
- The average value of the traffic per customers measured in the network for the ports in L0 mode, T_{L0} defines the full throughput for equipment in the state III (in clause 7.1).

NOTE: T_{L2} and T_{L0} could be measured directly with the help of the traffic generator in labs.

The formula for this expression:

$$EER_{Used\_ADSL} = \frac{\left(\frac{M-N}{M}\right).T_0 + \frac{N}{M}\left((1-X).T_{L0} + XYZ.T_{L2} + XY(1-Z).T_{L0}\right)}{KPI_{DSL\_Power}}$$

Finally:

$$EER_{Used\_ADSL} = \frac{B.T_{L0} + C.T_{L2}}{KPI_{DSL\_Power}} \quad \text{With: } B = \frac{N}{M}XY(1-Z) \text{ and } C = \frac{N}{M}XYZ$$

Annex A (informative): DSL Operational examples

Examples on a big shelf (16 slots) for the ADSL.

EXAMPLE 1: In the country 1, currently, Z= 0, Y = 90 % and X = 85 %. N = 7.

Thus: $$KPI_{ADSL\_Power}^{country1} = KPI_{ADSL\_Power}^{country1}\left(7,16,0.85,0.9,0\right) = \frac{9}{16}P_{total}^{0} + \frac{7}{16}\left[(1-0,77)P_{L3}^{M} + 0P_{L2}^{M} + 0,77(1-0)P_{L0}^{M}\right]$$

And: $$KPI_{ADSL\_Power}^{country1} = \frac{9}{16}P_{total}^{0} + \frac{7}{16}\left[0,24P_{L3}^{M} + 0,77P_{L0}^{M}\right]$$

Finally: $$KPI_{ADSL\_Power}^{country1} = 0,56P_{total}^{0} + 0,10P_{L3}^{M} + 0,33P_{L0}^{M}$$

In the same way, in country 2 with Z= 0, Y = 93 % and X = 72 %. N = 6.

$$KPI_{ADSL\_Power}^{country2} = 0,63P_{total}^{0} + 0,12P_{L3}^{M} + 0,25P_{L0}^{M}$$

EXAMPLE 2: To introduce the LPM features in country 1 network, it is necessary to observe the CPE profile per day and to estimate the Z function e.g. Z = 50 %.

The formula becomes:

$$KPI_{ADSL\_Power}^{country1-LPM} = KPI_{DSL\_Power}^{country1}\left(7,0.85,0.9,0.5\right) = \frac{9}{16}P_{total}^{0} + \frac{7}{16}\left[(1-0,77)P_{L3}^{M} + 0,38P_{L2}^{M} + 0,77(1-0.5)P_{L0}^{M}\right] = \frac{9}{16}P_{total}^{0} + \frac{7}{16}\left[0,24P_{L3}^{M} + 0,38P_{L2}^{M} + 0,38P_{L0}^{M}\right]$$

And then: $$KPI_{ADSL\_Power}^{country1-LPM} = 0,56P_{total}^{0} + 0,10P_{L3}^{M} + 0,17P_{L2}^{M} + 0,17P_{L0}^{M}.$$

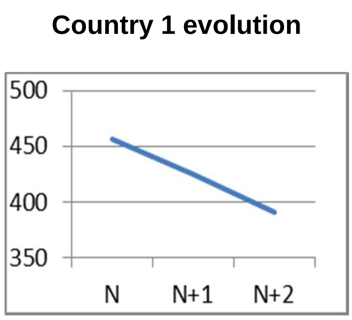
For country 2: $$KPI_{ADSL\_Power}^{country2-LPM} = 0,63P_{total}^{0} + 0,12P_{L3}^{M} + 0,13P_{L2}^{M} + 0,13P_{L0}^{M}.$$

These formulas can be completed with a concrete calculation.

For the two previous countries and with a supplier coefficient, table A.1 shows two levels of evolution linked to the operator's network: introduction of the low power mode function on a same card and introduction of the new card between the year N and the year N+1.

Table A.1: evolution of DSL KPI with 2 kinds of countries

		LT card (year N)		**LT card (year N+2)**	
		Country 1	**Country 2**	**Country 1**	**Country 2**
Coefficient(s)	empty	110,5	110,5	110,5	110,5
	ADSL L3	428,9	428,9	542,5	542,5
	ADSL L2	856,1	856,1	736,1	736,1
	ADSL L0	1 048	1 048	897,7	897,7
KPI calculation					
W/o L2 mode	KPI - N	457	385	*418*	*362*
With L2 mode	KPI - N+1	425	361		
With L2 mode	KPI - N+2	425	361	391	341
		L2		**"L2 + new card"**	
Savings		**-7 %**	**-6 %**	**-16 %**	**-12 %**



During the year N+2, it is possible to follow the evolution of the two cards and their associated savings.

EXAMPLE 3: With the following example, it is possible to establish a parallel between these KPI and the BBCoC (Broadband Code of Conduct) values.

Application to FT example. Keep the X, Y, Z values for country 1 but fill all the slots with LT cards. Then:

$$KPI_{ADSL\_Power}^{BBCoC-country1} = \frac{0}{16} P_{total}^{0} + 1.\left[0{,}24P_{L3}^{M} + 0{,}38P_{L2}^{M} + 0{,}38P_{L0}^{M}\right]$$

and: $KPI_{ADSL\_Power}^{BBCoC-country1} = 0{,}24P_{L3}^{M} + 0{,}38P_{L2}^{M} + 0{,}38P_{L0}^{M}$.

With the BBCoC V4, the maximum values per period are known. For instance, on the 2011-2012 tier and with P ports per shelf:

- P_{L0}^{M} = 1,2xP
- P_{L2}^{M} = 0,8xP
- P_{L3}^{M} = 0,4xP

Then: $KPI_{ADSL\_Power}^{BBCoC-France}$ = (0,4×0,24 + 0,8x0.38 + 1,2×0,38)*P

Finally: $KPI_{ADSL\_Power}^{BBCoC-country1}$ =0,86×P W

And, per port: $\boxed{kpi_{ADSL\_Power}^{BBCoC-Country1} = 0{,}86 \text{ W/port.}}$

In the same way, for country 2: $\boxed{kpi_{ADSL\_Power}^{BBCoC-Country2} = 0{,}80 \text{ W/port.}}$

Main Remarks and limitations:

1) These last values allow today to give a target for country 1 and country 2. This calculation will have to be updated according to the parameters but also the BBCoC tiers values.

2) This last value is available for country 1 because the external parameters (in back) are almost in line with the BBCoC proposals. It will not be the case for all the affiliates.
For example, country 2 it is important to be careful because its average copper loop length is equal to 1 500 m (and not 3 km).

Annex B (informative): GPON operational example

Examples on a big shelf (16 slots).

EXAMPLE 1: In country 1, during the year N, all the GPON line cards are directly installed with all the needed SFP modules then, $\forall i = 1...16$, S(i) = 8 = S. Moreover, there is no sleeping mode and Y = 0.

The number of ONT per port could be very low (for example, a beginning of deployment).

X =0,1 in average. An average number of GPON line cards per shelf would be 15 (due to the policy of deployment architecture). The formula becomes:

$$KPI_{GPON\_Power}^{Country1-today} = \frac{1}{4}P_{total}^{0} + \frac{3}{4}\left[0,9.P_0^{16} + 0,1.P_1^{16}\right] = \frac{1}{4}P_{total}^{0} + \frac{27}{40}.P_0^{16} + \frac{3}{40}.P_1^{16}$$

To finish with this example, to complete these formula with some concrete calculations.

E.g. two countries:

- the previous case, country1;
- and a second country.

For example, its architecture could be different and this other country could be deploying the GPON technology for several years.

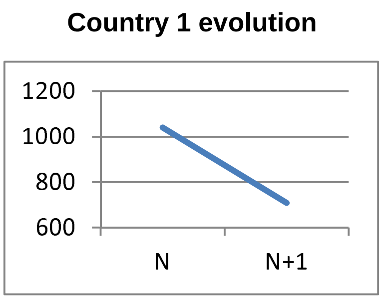
Thus, for instance, in year N, X=0,4 and an average number of GPON line cards per shelf is equal to 10. The formula will be different to the country 1.

- For the year N+1, the variable X could evaluate (see table B.1).

Introduction of the supplier's coefficients in the formula. Table B.1 shows the savings when changing the initial line card by a more efficient line card between the year N and the year N+1.

Table B.1: evolution of FTTH KPI with 2 kinds of countries

		LT card (year N)		LT card (year N+1)	
		Country 1	**Country 2**	**Country 1**	**Country 2**
Variable	Cards	15	10	15	10
	X	0,1	0,4	0,2	0,5
Coefficient(s)	Empty	56,6	56,6	56,6	56,6
	GPON 0	1 093,4	1 093,4	733,4	733,4
	GPON 1	1 221,4	1 221,4	829,4	829,4
KPI calculation					
W/o sleep mode	KPI	1 041	745	709	510
				"new card"	
	Savings			**-32 %**	**-31 %**



During the year N+1, one can follow the impact of the introduction of new line cards but also the increase of the number of customer (ONT) per PON port on the energy savings.

EXAMPLE 2: This example can be seen as the BBCoC - FT example. Keeping the X, Z values for the country 1 but filling all the slots with LT cards.

Z = 0 and X = 0,1.

Then: $KPI_{GPON\_Power}^{BBCoC-country1} = \left[0,9.P_0^{16} + 0,1.P_1^{16}\right]$.

Here, the BBCoC does not give the indication on the difference between PON ports fully equipped with ONU and without ONU.

EXAMPLE 3: Consider the S(i) = s for each GPON card and, all the ONU with traffic consumes the same energy. Same number of ONU on all the SFP modules, defining $P_{SFP}(k)$ with k = 0,1/2,1 as the power on the SFP.

Then: $$P_k^M = P_{fixe}^M + \sum_{i=1}^{M}\left((S - S(i))P_0 + \sum_{j=1}^{S(i)} P_{ij}(k)\right) = P_{fixe}^M + M(S-s)P_0 + M.s.P_{SFP}(k)$$

Moreover, if s = S:

$$P_k^M = P_{fixe}^M + M.S.P_{SFP}(k) \text{ thus:}$$

$$KPI_{GPON\_Power} = \frac{(M-N)}{M}P_{total}^0 + \frac{N}{M}\left[(1-X)P_0^M + X.Z.P_{1/2}^M + X.(1-Z)P_1^M\right]$$

$$= \frac{(M-N)}{M}P_{total}^0 + \frac{N}{M}\left[P_{fixe}^M + M.S.\left((1-X).P_{SFP}(0) + X.Z.P_{SFP}(1/2) + X.(1-Z).P_{SFP}(1)\right)\right]$$

Conclusion:

$$KPI_{GPON\_Power} = \left[P_{fixe} + N.S.\left((1-X).P_{SFP}(0) + X.Z.P_{SFP}(1/2) + X.(1-Z).P_{SFP}(1)\right)\right]$$

History

Document history		
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