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White Paper:
White Box Total Cost of Ownership

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Abstract

White box technology offers an opportunity for network operators in the National Research and Education Network (NREN) and R&E community to gain a certain level of independence from vendors as it prevents lock-in to a specific hardware or software vendor or platform. Beyond the strategic interest in a white box approach, there is an expectation of a reduction in the Total Cost of Ownership (TCO) of a white box router or network device. This document describes the different components of that cost and gives guidance on how to calculate the TCO.

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Executive Summary

Network operators constantly strive to improve their network. In this context, white box technology is an opportunity that is worth exploring. White box networking offers a certain level of independence from vendors as it prevents lock-in to a specific hardware or software vendor. It does so by enabling the user to choose a hardware and software platform separately and configure the device to their specific needs, cherry-picking only those elements that are needed for a given use case. Beyond the strategic interest in a white box approach, there is an expectation of a reduction in the white box router or network device cost, i.e. the Total Cost of Ownership (TCO). This document lists the different components of that cost and gives guidance on how to calculate the TCO. The TCO varies according to the use case (Customer Premises Equipment (CPE), Label Edge Router (LER), etc.). This document is coupled with an Excel spreadsheet [TCO_Calculator] that helps to make comparisons between several different solutions. An example calculation and comparison is presented in Appendix A.

1 Audience and Objectives

The intended audience for this document is NRENs and R&E institutions who are considering implementing white box technology. Its objective is to help them identify the components that contribute to the total cost of implementation and to compare those costs with traditional solutions. The comparison depends on the white box usage (use case). The purpose is not to provide analysis for every possible use case, but rather to present ideas and examples of how such a calculation could be done, allowing the reader to adapt it to their own context and use case. Every organisation is different; each one has a specific environment with specific constraints and specific resources. In this context, the aim is to present a possible methodology and examples for calculating white box technology Total Cost of Ownership (TCO) that can be used as a reference to help R&E institutions make decisions about an eventual white box production deployment.

2 TCO Calculation Methodology

The principles used to calculate Total Cost of Ownership (TCO) are:

- Identify and describe the components and parameters that influence the cost of white box technology implementation and are required to make the calculation.
- Make a fair comparison that includes equipment with similar capabilities, capacities and performance.
- Software comparisons must accurately consider the features each product provides. If feature gaps exist, the costs of supplementary software from the vendors or third parties must be included for a true comparison.
- In situations where there are no other reliable reference prices for the required equipment and services related to a particular institution, community or country, use vendors' global price lists (GPLs) with standardised discounts as a reference for comparison between different solutions.

In addition to the reference methodology presented here, there are several examples of TCO approaches related to network routers and white boxes that provide different points of view on how to do the calculation, including:

- Cumulus Networks:
  - "The Facts Behind the Myth" – blog post on TCO of bare metal vs. traditional networking [Cumulus_TCO1].
  - *Web-scale vs. Traditional Networking: Total Cost of Ownership Report* [Cumulus_TCO2].
- Cisco Meraki: "Infographic: Reducing Total Cost of Ownership" – blog post on TCO for Cisco Meraki [Cisco-Meraki_TCO].
- VMware: *VMware TCO Comparison Calculator: Methodology* – technical white paper [VMware_TCO].
- Chabot-Las Positas Community College District: *Information Technology Plan: Total Cost of Ownership* – document examining the industry approach for TCO for IT systems [CLPCCD_TCO].

3 Cost Breakdown Analysis

The Total Cost of Ownership (TCO) is an estimate of all the direct and indirect costs involved in acquiring and operating a product or system over its lifetime. It is usually calculated as the sum of capital expenditures (CAPEX) and operating expenses (OPEX).

CAPEX and OPEX are well-known concepts in the industry. One definition of these terms can be found at the Investopedia website:

> *Capital expenditures, commonly known as CAPEX, are funds used by a company to acquire, upgrade, and maintain physical assets such as property, buildings, an industrial plant, technology, or equipment. CapEx is often used to undertake new projects or investments by the firm. Making capital expenditures on fixed assets can include everything from repairing a roof to building, to purchasing a piece of equipment, to building a brand new factory.* [Investopedia_CAPEX]

> *An operating expense is an expense a business incurs through its normal business operations. Often abbreviated as OPEX, operating expenses include rent, inventory costs, marketing, payroll, insurance, step costs, and funds allocated for research and development.* [Investopedia_OPEX]

Table 3.1 below shows the different cost components considered for white box technology implementation, together with how frequently they occur and their category (CAPEX or OPEX).

Cost component	Brief description	Occurrence	Category
White box equipment	The server hardware or bare-metal devices.	1	CAPEX
Optical transceivers (Small Form-factor Pluggables (SFPs))	In some cases, they are not included by the hardware seller.	1	CAPEX
Hardware maintenance	Warranty due by the hardware seller. It could be basic or extended.	Lifespan – 1	OPEX
Network Operating System (NOS)	White boxes are ready to support any kind of NOS, from free, open source to commercial solutions that are available in the market.	1	CAPEX
NOS maintenance	NOS support provided by a vendor to the customer.	Lifespan, Lifespan – 1, depends on the case	OPEX

Cost component	Brief description	Occurrence	Category
Virtual environment licence (hypervisor)(optional)	When running a virtualised environment in a white box server a hypervisor will be necessary. There are free and paid solutions.	Lifespan	CAPEX or OPEX
Electrical power and cooling consumption	The equipment power consumption and cooling expenses in the facility.	Lifespan	OPEX
Operations activities	Manpower involved in operation and maintenance routines for a technology or solution. Everyday operational work.	Lifespan	OPEX
Hosting rack unit (optional)	For solutions intended for data centres where the price is based on the occupied space per rack unit.	Lifespan	OPEX
Onsite troubleshooting / remote support (optional)	This service could or could not be included when equipment is hosted by a data centre. It represents basic, uncomplicated tasks inside a data centre, such as a remote-hands service.	Lifespan	OPEX
System integration (optional)	An organisation hires external human resources to install, configure and maintain the equipment.	1	OPEX
Additional software licences (optional)	Any special licence needed in the device or any additional software to complement the functionality of the main equipment.	Depends on the case	CAPEX
Staff training	A new solution or technology might imply staff training.	1	OPEX
Others	Equipment insurance (equipment damage/theft and replacement costs); procurement; decommissioning (costs associated with the disposal of the old equipment); etc.	1	OPEX

Table 3.1: Cost components table

3.1 Calculation Parameters

The TCO calculation can vary according to different parameters, for instance, lifespan (hardware A may have a higher price than hardware B, but a longer lifespan, so overall would be cheaper than hardware B). The cost factors may vary from country to country, for instance, the average wage. The average wage is necessary in the “Operations activities” cost calculation. It is therefore important to take these parameters into consideration to make a fair comparison, as shown in Table 3.2 below:

Parameter	Measure	Cost factor scope
Lifespan duration	Years	Hardware, hardware maintenance, NOS maintenance
Average wage	Euro/year	Running operations staff

Table 3.2: Calculation parameters

3.2 Cost Detail Description

This section describes in more detail the cost components listed in Table 3.1.

3.2.1 Capital Expenditures (CAPEX)

3.2.1.1 *White box equipment*

A white box is a switch/router manufactured from commodity components that allows different Network Operating Systems (NOSs) to be run on the same piece of commodity hardware, decoupling the NOS software from the hardware. In some cases, the white box can be a specifically designed server playing the role of a router, which often implies using a hypervisor. The objective is to achieve more flexibility by providing a greater independence from the hardware and software vendors. In the same way as it is for other network devices, a basic set of interfaces is delivered with the box, but the hardware usually does not include the optical transceivers (e.g. SFP, XFP, SFP+, etc.) for optical interfaces, so these are ordered separately, potentially from the same supplier.

3.2.1.2 *Optical transceivers (SFPs)*

Small Form-factor Pluggable (SFP) network interface modules transform electrical signals to optical and vice versa. In order to communicate using fibre optics for data transmission, the network devices use optical modules directly connected to interface modules. In this way, the interface can support fibre optic transmission for higher bandwidth capacity in the interface. There are many types of optical modules, which differ by form factor and transmission capacity (e.g. SFP, SFP+, QSFP, QSFP28, XFP, OSFP, etc.). These optical modules are sold separately from networking devices.

Many networking equipment vendors require their customers to also use the optical modules from the same vendor, to ensure compatibility and in order to receive appropriate vendor support. In such scenarios, optical module costs can significantly impact the total cost of the solution.

Some vendors' equipment is not compatible with original equipment manufacturer (OEM) optical modules available in the market with significantly lower prices. At the same time, a lot of NRENs and R&E institutions have requested in their tenders that the equipment offered should support OEM optical modules in order to decrease the overall solution cost.

3.2.1.3 *Network Operating System (NOS)*

In the traditional networking model, the vendor's networking hardware comes with a proprietary Network Operating System (NOS) that only works on the vendor's specific hardware. Some traditional

vendors have complex licensing models. They provide many versions of a NOS according to the features required (MPLS, cryptography, etc.) and the cost of this NOS can vary according to the NOS version. Others sell the same full version of a NOS for different types of devices, even when the device does not include all necessary or sufficient hardware to run all features included in the NOS.

Disaggregation (white box technology) decouples hardware and software components and enables customers to mix components from different vendors, open-source projects, etc. Disaggregation potentially allows organisations to drive down costs while increasing flexibility. A white box as a bare-metal piece of hardware needs a specific operating system (i.e. NOS) to support its specific hardware (forwarding chipset).

The NOS price is another component that might affect the final cost depending on the chosen solution, from a free NOS to a commodity NOS available in the market. Licensing for a NOS should be considered from two different approaches: features and port bandwidth. For both white box and traditional vendors, if advanced IP features and MPLS are needed the cost may vary significantly between a standard (basic) and advanced licence. A standard licence could have a basic set of features for Layer 2/3 switching and routing. The licence choice depends on the use case (CPE, LER, IX, etc.). The other important factor that affects the licence cost is the bandwidth of the ports (1 Gbps, 10 Gbps, 100 Gbps, etc.), so even among the basic-set licences, there will be some variance in the final price of the licence depending on these factors.

Advanced licences are more related to distribution and core network L2/L3 equipment. Usually, this type of licence is necessary for an MPLS architecture deployment. It provides full support to Layer 3 routing protocols and MPLS features. Their cost is higher compared with the standard licences. As with a standard licence, the bandwidth of the ports will also add some variance to the final costs of the licence.

Given all the variables affecting NOS costs, it is not possible to provide a licence price in this document. However, examples of white box NOS costs, for Cumulus Networks software and Open Compute Network Operating System (OcNOS), are available from [Cumulus_NOSLicence] and [OcNOS_Licence] respectively.

3.2.1.4 *Virtual environment licence (hypervisor)*

This cost factor could be considered as CAPEX if paid once at the beginning or OPEX if paid annually. For implementations based on a server, a virtualised environment is necessary in order to run the virtual router (for instance a CPE) and the network virtualisation functions (NFVs) in the white box. In this case, one of the items that should be counted for the overall solution cost is the licence of the hypervisor running in the white box server device. The hypervisor cost in the market varies significantly and depends on the chosen solution (e.g., free Proxmox from KVM, vSphere from VMware, HyperV from Microsoft, etc.).

3.2.1.5 *Additional software licences*

Additional NOS features such as SNMP or telemetry monitoring, NETCONF, NetFlow, IPFIX, APIs, a Corba interface, MPLS features, etc., might result in additional costs for NOS licences. Some of these additional features, for instance, monitoring or management software tools, may require additional licences to support usage of these NOS features. This cost factor should count all additional software

licences beside NOS licences that might be required for a white box networking solution implementation in production environments.

3.2.2 Operating Expenses (OPEX)

3.2.2.1 *Hardware maintenance*

Usually, when buying equipment, a warranty is guaranteed for an appropriate and specific time period. The maintenance can include Guaranteed Restoration Time agreement with penalties. In the case of white box technology, this could also include firmware upgrade and extended support for different NOS integration.

3.2.2.2 *NOS maintenance*

This category represents the NOS software updates, security patches, new installations in the white box devices, regular requests and problem support, etc. This is the basic lifecycle for any software. In the case of white box technology, this could also include NOS support for new hardware chipsets and platforms.

3.2.2.3 *Electrical power and cooling consumption*

In principle, a white box device is a combination of basic and generic computer hardware, so the power and cooling consumption of a white box device is typically similar to that of a regular computer server or network device with similar capabilities. Information about calculating the average power consumption of a server (which is or could be the closest to a white box) is available at [Power_consumption]; information on the average price of electrical power in Europe (€0.2159 per kWh as at mid 2019) is available at [Price_consumption].

3.2.2.4 *Operations activities*

This cost component includes the manpower expenses used to keep the devices running and in operation. It is one of the main factors that influence and contribute to the OPEX calculation. It represents the everyday work and tasks performed by the staff (usually the operations and maintenance team) and includes tasks such as device monitoring, device updates, software patching, new configurations, new service instances, etc. In order to obtain the cost of these operations more accurately, the cost can be expressed as the hourly rate (salary of the staff) and the number of devices that can be handled by a single person. Some special solutions might imply a higher hourly rate because more specialised knowledge is required or, in the same way, fewer devices that a single engineer can maintain. This cost factor is highly dependent on the organisation itself, e.g. their processes, workflows, the size of the team of employees, operational practices, the level of knowledge inside the team, etc.

3.2.2.5 *Hosting rack unit*

In colocation hosting, charges are related to the rack unit space occupied by the device. The client owns the equipment, but since they do not have either space or suitable conditions for locating IT or networking equipment in their own facilities, they can lease space and rack at a data centre. The data centre will charge the client based on the number of rack units or entire racks to be occupied by the

client's equipment. This price includes the electrical power consumption, cooling, rack spacing, uninterruptible power supply (UPS), automatic fire detection and suppression systems, etc.

This cost factor is optional and it depends on the business model chosen by NRENs. For equipment hosting, some NRENs use the ICT rooms or data centres of their member institutions without any operational fees for equipment hosting. In contrast, some NRENs use professional colocation hosting services inside commercial data centres and in these situations, the hosting factor should be a part of TCO calculations.

Information on indicative prices of colocation in a data centre can be found at [Colocation_price1] and [Colocation_price2].

3.2.2.6 *Onsite troubleshooting / remote support*

For solutions intended in the cloud, having technical support onsite could be crucial. This service grants an intervention service onsite for routine and easy maintenance tasks, such as hardware maintenance, hardware restart or power-off, monitoring, cleaning, patching. Usually, such services are charged based on the hours of support.

3.2.2.7 *System integration*

In some circumstances, an organisation might engage an external company, such as a service integrator, to install, configure and maintain a technology on their behalf. After the project has been completed, the organisation might take over the operation and maintenance of the solution, but could also extend the initial arrangements by which operation and maintenance is undertaken by these external partners. This is an optional cost factor that is dependent on an NREN's or R&E institution's business model, and if it exists, it should be included in the TCO calculation.

3.2.2.8 *Staff training*

When a new type of solution or technology is introduced in a production network, the companies typically need to provide training for their operational staff. The training has a cost based on the type and number of employees, and it is dependent on the vendor of the solution. For this reason, the cost might vary between different technologies in the market. Also, it depends on the size of the team of employees, operational practices, the level of knowledge inside the team, the number of staff who assist with training, etc.

Information about the average cost of training is available from [Training_cost1] and [Training_cost2].

3.2.2.9 *Others costs*

In addition to the previously mentioned cost components, there are also other operating expense factors that influence TCO calculation. Generally, these factors have the same impact on the TCO of equipment no matter which technology is involved. If they exist, they should also be included in the TCO calculation. They might include:

- Equipment insurance (equipment damage/theft and replacement costs).
- Procurement (tender publication and response analysis, feature validation, etc.).

- Decommissioning (costs associated with the disposal of the old equipment):
  - Recycle fees for disposal of old electronics.
  - Environmental compliance reporting.
  - Disassembly and transport fees of equipment, etc.

4 Conclusion

Choosing a hardware or software solution always involves taking several dimensions and aspects into account. Technology, technical features, prior knowledge and experience, price range, existing solutions and systems are only some of them. For any of the solutions in scope, the Total Cost of Ownership is extremely important – primarily to business stakeholders, but it should also be recognised and considered by the technical teams. Also, TCO is not the only criterion for the hardware choice. Being locked in by a vendor is likely to be a drawback for flexibility. This document has proposed a method to calculate the TCO that will allow NRENs and R&E institutions to compare several solutions easily. It is only after looking at the TCO of a particular use case that the NRENs and R&E institutions can recognise clear benefits of the technology and decide whether to proceed with a production implementation.

Appendix A TCO Calculation Tables

An Excel spreadsheet was built, taking into consideration all the costs mentioned in this document [TCO_Calculator]. An example of a comparison between a white box server and a well-known vendor device is presented in the tables below to calculate the TCO for a router CPE (results are anonymised).

Costs	Variable	White box server 2 x 10 Gbps		Typical vendor CPE 2 x 10 Gbps	
		Value	Total	Value	Total
White box equipment / hardware	Price per device	1,300.00 €	1,300.00 €	3,000.00 €	3,000.00 €
	Number of devices	1		1	
NOS (licence)	Price per device	0.00 €	0.00 €	1,800.00 €	1,800.00 €
	Number of devices	1		1	
Optical transceivers (SFPs)	Price per piece	18.00 €	36.00 €	18.00 €	36.00 €
	Number of SFPs	2		2	
Virtual environment licence (hypervisor)	Price per device	0.00 €	0.00 €	0.00 €	0.00 €
	Number of devices	1		1	
Additional software licences	Price per device	0.00 €	0.00 €	0.00 €	0.00 €
	Number of devices	1		1	
Total CAPEX			**1,336.00 €**		**4,836.00€**

Table A.1: Router CPE use case TCO comparison – CAPEX

Annual costs	Variable	White box server 2 x 10 Gbps			Typical vendor CPE 2 x 10 Gbps		
		Value	Cost per year	Cost per lifespan	Value	Cost per year	Cost per lifespan
Electrical power and cooling consumption[1]	CPE consumption / year in kW/h	3,800	820.42 €	4,102.10 €	3,800	820.42 €	4,102.10 €
	Cost of kW/h	0.2159 €			0.2159 €		
	No. of years to consider	5			5		

Annual costs	Variable	White box server 2 x 10 Gbps			Typical vendor CPE 2 x 10 Gbps		
		Value	Cost per year	Cost per lifespan	Value	Cost per year	Cost per lifespan
Operations activities (payroll, personnel for monitoring, operations, applying updates)[2]	Hourly rate	17.00 €	707.20 €	3,536.00 €	17.00 €	707.20 €	3,536.00 €
	Number of machines maintained in prod. by 1 engineer	50			50		
	No. of years to consider	5			5		
Hosting rack unit	Monthly price per rack unit		0.00 €	0.00 €		0.00 €	0.00 €
	Number of rack units						
	No. of years to consider	5			5		
On site troubleshooting / remote support	Monthly price		0.00 €	0.00 €		0.00 €	0.00 €
	No. of years to consider	5			5		
NOS maintenance	No. of years to consider	4	0.00 €	0.00 €	4	0.00 €	0.00 €
Hardware maintenance	No. of years to consider	4	0.00 €	0.00 €	4	0.00 €	0.00 €
System integration	No. of years to consider	1	0.00 €	0.00 €	1	0.00 €	0.00 €
Staff training	Training cost per engineer		n/a	0.00 €			0.00 €
	Number of engineers						
Others	No. of years to consider	1	0.00 €	0.00 €	1	0.00 €	0.00 €
Total OPEX			**1,527.62 €**	**7,638.10 €**		**1,527.62 €**	**7,638.10 €**

Notes:

1. The consumption per year in kW/h (3,800 kWh annually) is based on [Power consumption] and [Price consumption].
2. The costs for "Operations activities" are based on the following assumptions and calculations: wage cost is estimated as 17€/hour; one engineer works 8 hours/day and 5 days per week, 52 weeks/year. "Operations activities" cost per year = ((17*8*5)*52) / 50 = 707.20€/year.Price_consumption

Table A.2: Router CPE use case TCO comparison - OPEX

	White box server 2 x 10 Gbps	Typical vendor CPE 2 x 10 Gbps
Hardware's lifespan (in years)	5	5
TCO total	**8,974.10 €**	**12,474.10 €**
Total savings %	**28**	

Table A.3: Router CPE use case – overall TCO comparison

According to the results obtained in this example, the TCO for a white box server represents a 28% saving compared with a typical vendor solution.

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Glossary

API	Application Programming Interface
CAPEX	Capital Expenditures
CPE	Customer Premises Equipment
GPL	Global Price List
ICT	Information and Communication Technology
IP	Internet Protocol
IPFIX	IP Flow Information Export
IX	Internet Exchange
LER	Label Edge Router
L*n*	Layer *n*
MPLS	Multi-Protocol Label Switching
NFV	Network Virtualisation Function
NOC	Network Operations Centre
NOS	Network Operating System
NREN	National Research and Education Network
OcNOS	Open Compute Network Operating System
OEM	Original Equipment Manufacturer
OPEX	Operating Expenses
OSFP	Octal Small Form-factor Pluggable
QSFP	Quad Small Form-factor Pluggable
R&E	Research and Education
SFP	Small Form-factor Pluggable
SFP+	Enhanced Small Form-factor Pluggable
SNMP	Simple Network Management Protocol
TCO	Total Cost of Ownership
UPS	Uninterruptible Power Supply
XFP	10 Gigabit Small Form-factor Pluggable