Techno-economic analysis of Cloud Computing supported by 5G: A Cloud vs On Premise based solutions comparison

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Abstract. Cloud computing has gotten a lot of press in the IT world because it allows users to have instant access to a shared pool of configurable computer resources with no effort on their part. It is now being discussed as an enabler for more flexible, cost-effective, and powerful mobile network implementations in the communication technology (CT) sector.In this paper, a techno-economic analysis of a Cloud-based solution compared to an On-premise based one is developed. The technologies are analyzed in a technical way. Mathematical models that help determine the models' pricing is analyzed. What is more, several experiments are conducted determining if the advantages and profits outweigh the disadvantages of each proposed solution. Also, the way 5G helps scale all these processes is analyzed. Finally, this article analyzes the conclusions of the work, as well as the result of the techno-economic study that was carried out, to explain to the reader the overall benefits provided to users by exploiting the Cloud Computing technology.

Keywords: Cloud, On premise, Sensitivity Analysis, 5G, Cost Models

1 INTRODUCTION

Wireless networks, cloud, and mobile computing are rapidly growing in the field of Mobile Cloud Computing. With the significantly expanded limits of the fifth generation of mobile networks (5G) versatile organizations, Mobile Cloud Computing (MCC) administrations are relied upon to observe a time of the fast turn of events and become another focal point concerning portable services [1]. It is expected that individuals' work examples and ways of life in a future continually interconnected society, will be drastically altered by MCC. Future applications will be empowered by 5G, and MCC will significantly affect pretty much every part of computerized life.

The introduction of Cloud Computing is imperative in 5G, which is confirmed by research in the field. All major companies in the field of technology (e.g. Microsoft,

Google, Amazon, Yahoo, etc.) have already created their own Cloud Computing Services, which offer huge profits at a significant cost [2]. The Cloud empowers another way to send, cooperate and utilize fundamental undertaking applications. In any case, the seemingly immediate structure contributes to complexity [3].

Several papers have been released. In [4] it is pointed out that the "softwarization" of 5G is imperative and becomes a reality through new technologies, such as Software Defined Networking (SDN), Network Function Virtualization (NFV), and Cloud Computing (CC). In this context a cost model for estimating capital expenditure (CAPEX), operating expenditure (OPEX) and the total Cost of Ownership (TCO) for the proposed architecture is provided. Study [5] focuses on the comparison of many active and proposed technical pricing models and the advantages and disadvantages of each are pinpointed. The comparison is based on many aspects such as fairness, price approximation, and more. Additionally, paper [6] fosters a techno-financial structure for Cognitive Radio (CR) innovation and contrasts a current model for SDN networks.

In this paper, the main focus is the analysis and representation of the benefits of an organization/company. A cloud-based solution, for the deployment of a data center, is chosen against an on premise-based solution. The advantages of Cloud Computing are analyzed and combined with the benefits 5G networks could provide.

The remaining part of this paper is organized as follows: In Section II the proposed models/arrangements are examined and clarified. In Section III the proposed monetary models are summed up. In Section IV the experimentation boundaries are selected. In SectionV conclusions are summed up and future investigation in the field is proposed.

2 PROPOSED MODELS

The five categories (on-premise, hosted, public cloud, private cloud, and hybrid) are the main options offered alongside the installation in a corporate environment (On-Premises) or in a Cloud environment of one (hosted or Software as a Service (SaaS)). The main advantages and disadvantages of these models are identified and a more detailed comparison is proceeded, which concerns a techno economic study in a medium-sized business that is interested in choosing between On-Premise data center implementation and Cloud-based implementation through a provider.

In addition to the initial investment, there is a monthly cost for the use which concerns the license of the system (this cost is the same in both implementation scenarios) and the monthly cost of the machines that host it. It is fully explained in paper [7]. In the on-premise installation, this cost consists of the maintenance costs of the equipment and the cost of energy for its operation while in the cloud this cost is summarized in the price that the company pays to the provider of cloud services.

In the category of cloud installation, apart from the choice of a hosted solution in several cases (depending on the Cloud provider), there is the possibility of using the system as SaaS. In this scenario, the customer is also exempted from the cost of renting the machines that will host the system and paying the provider (who is the system manufacturer himself) the price for the use of the system.

In this section, the proposed solutions are analyzed in a technical way.

2.1 Cloud Based Solution

Cloud-based solutions (or 'cloud' for short) stands for on demand delivery of computing resources over the Internet. On a pay-for-use-basis, you can get access to as many resources as you need such as storage space, software and applications, networks, and other on-demand services. There are three types of cloud-based systems: (IaaS): Infrastructure as a service allows you to rent storage, networks, virtual machines, servers, etc. from a cloud service provider. This is usually contracted as pay as you go. (PaaS): Platform as a service provides you with a "space" to build, deliver, test, and manage various apps. This way, you can focus on software development, instead of creating and managing the underlying infrastructure. (SaaS): Software as a service refers to the delivery of cloud-based software solutions. The cloud provider hosts the app as well as the infrastructure. They also take care of software maintenance and upgrades.

Cloud-Based solution differs from on-premises. An association has everything in-house in an on-premise arrangement, while in a cloud arrangement, an outcast provider is able to provide all that. This allows associations to provide according to circumstances and sufficient increase or decrease depending on overall usage, customer needs, and improving a correlation.

Disruptive digital technologies like cloud computing have produced a new kind of employee: the cloud worker. Cloud workers spend more than half their day working in cloud based business apps, moving seamlessly between different devices. A cloud-based worker utilizes virtual advancement to have a company's applications offsite. There are no capital expenses, data can be upheld up regularly, and businesses simply need to pay for the resources used. [8] For those that plan strong augmentation for an overall reason, the cloud is more appealing since it grants interface to customers, associates, and various associations wherever with minimum effort. In Fig. 1, a Cloud-Based Architecture is presented.

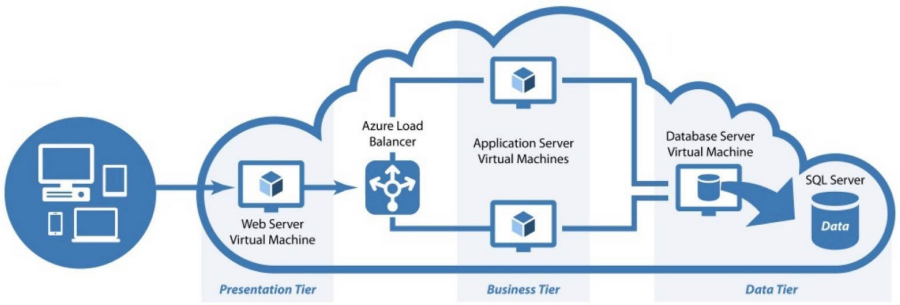

Fig. 1. Cloud Based Architecture

2.2 On Premise Based Solution

Whether or not a company places its applications in the cloud or regardless of whether it decides to keep them on premises, data security will be essential. However, the decision

may at this point be made concerning whether to house their applications on-premise or not. Furthermore, realizing that information is situated inside in-house workers and IT framework may likewise provide more genuine feelings of serenity in any case.

On-premise programming necessitates that an endeavor buys a permit or a duplicate of the product to utilize it. Since the actual product is authorized and the whole example of programming dwells inside an association's premises, there is by and large more prominent insurance than with a distributed computing foundation.

The disadvantage of on-premise conditions is that expenses related to overseeing and keeping up with all the arrangements involves can run dramatically higher than in a distributed computing climate. An on-premise arrangement needs in-house worker equipment, programming licenses, mixed capacities, and IT representatives close by to help and oversee potential issues that might emerge. Besides the proportion of help that an association is at risk for when something breaks or not working. In Fig. 2, an On Premise Based Architecture is introduced.

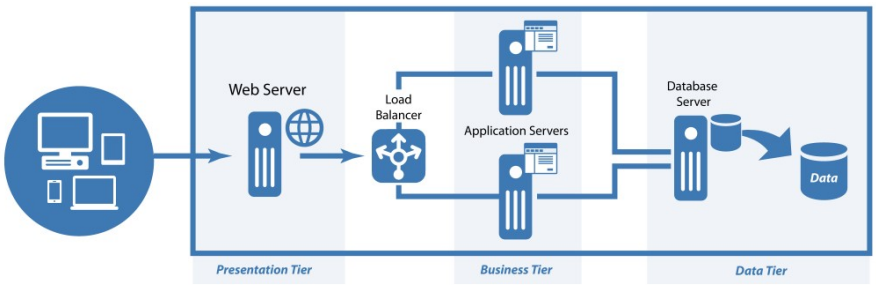

Fig. 2. On Premise Architecture

Figure 3 below, presents a comparison chart of on-premise versus cloud Property Management System (PMS):

	ON-PREMISE PMS	CLOUD PMS
Deployment	Data stored on a server located at the property. The program is installed on each computer from which the PMS is accessed.	Data stored on a secure, shared server at the vendor's data center. Users access the PMS though a Web browser (online).
Technical Requirements	▪Workstations (computers) •Data server/s (ideally a dedicated server) •Compatible operating system (e.g. Microsoft Windows) •Back-up servers and hard drives •Network cards and switches/hubs •Terminal/Citrix server (for remote access and central reservations) •Interface computers	•Workstations (computers or mobile devices) •Internet connection •Web browser (e.g. Google Chrome or Mozilla Firefox or Microsoft Edge)
Data Security	Responsibility of the property	Responsibility of the PMS vendor
Pricing & Costs	•Licencing fees (typically per workstation) •Maintenance fees •Hardware and IT infrastructure costs → CapEx	•A one-time setup fee •Subscription pricing (typically per room per month) → OpEx

Fig. 3. Comparison chart of On-premise versus Cloud

3 PRICING MODEL

In this section, the proposed solutions are considered following a cost perspective. The scenario that concerns the techno-economic study is about a medium-sized enterprise that is interested in implementing an activity of Data Center and choosing between on-premise implementation and cloud based implementation through a provider. Two different solutions will be analyzed. There is a solution concerning a Cloud-Based model and another one concerning an OnPremise based model.

In every pricing model, there are a few explicit expenses. Scientifically, there are the Capital (CAPEX) and the Operational (OPEX) Expenditures [9]. The CAPEX incorporates every cost made ahead of time during the execution time in the organization. These uses incorporate a wide range of costs that are identified with the structure of the organization, for example, essential hardware, locales, and so forth. Then again, the OPEX has to do with costs that are required for the framework's day-to-day activity, the board, and coordination. The (TCO) is the aggregate sum of cash that should be paid to get a particular innovation and is the amount of CAPEX and OPEX. [10]

The purpose of the analysis is to highlight the advantages and benefits of implementing a cloud-based model. So looking at the relevant research, analysis, and writing, the initial study concludes with the values in the Table below where a cost comparison

is made between the two implementations. The parameters considered crucial to the calculation of CAPEX and OPEX are represented in the tables shown in Figure 4 and 5.

Cserver * NoS	The cost of each server on the total need
Cne * Nne	The cost of a each network equipment on the total need
Cst * Nst	The cost of each storage need on the total need
Cstb * Nstb	The cost of each backup storage on the total need
Cst(os) * Nst(os)	The cost of software on the total need
CstB * NstB	The cost of database software on the total need
Cst(mg)*Nst(mg)	The cost of management software on the total need
Clabor * Nlabor	The cost of labor on the total need
Cestate * Nestate	The cost per square ft on the total

Fig. 4. CAPEX Calculation Parameters

3.1 Cloud Based Solution

1. CAPEX = *Cserver * NoS + Cne * Nne + Cst * Nst + Cstb * Nstb + Cst(os) * Nst(os) + CstB * NstB + Cst(mg) * Nst(mg) + Clabor * Nlabor + Cestate * Nestate*
2. OPEX = *Ccp * Nhr + Cst * Nst + Cbw * Nbw + Css Nss + Cim * Nim + Csm * Nsm + Ce* Ne + Crent * Nrent + Com * Nom + Cppu * Nppu*
3. TCO = CAPEX (Cloud Based) + OPEX (Cloud Based)

3.2 On Premise Based Solution

1. CAPEX = *Cserver * NoS + Cne * Nne + Cst * Nst + Cstb * Nstb + Cst(os) * Nst(os) + CstB * NstB + Cst(mg)* Nst(mg) + Clabor * Nlabor + Cestate * Nestate*
2. OPEX = *Ccp * Nhr + Cst * Nst + Cbw * Nbw + Css* Nss + Cim * Nim + Csm * Nsm + Ce* Ne + Crent * Nrent + Com * Nom + Cppu * Nppu*
3. TCO = CAPEX (On premises + OPEX (On premises

Ccp * Nhr	The cost of computing power per kilowatt hour
Cst * Nst	The cost of network equipment
Cbw * Nbw	The storage cost per unit price
Css * Nss	The cost of an employee's salary on the number of employees
Cim * Nim	The cost of infrastructure maintenance over the total cost
Csm * Nsm	The cost of maintaining the software over the total cost
Ce* Ne	The cost of electricity per year
Crent * Nrent	The cost of renting per sq.m. on the number of sq.m.
Com * Nom	The cost of other maintenance per year
Cppu * Nppu	The percentage of profits from pay per use services

Fig. 5. OPEX Calculation Parameters

4 PARAMETER SELECTION

The table in Fig. 6 incorporates every boundary and factor that is identified with the valuing models. These variables are based on previous research activities and are thoroughly explained in the tables shown in Fig.4 and Fig 5. Also, value ranges are decided on the SA, that is utilized for the exploratory examination. SA is a notable method, where a few boundaries of an item are broken down and it is shown if they influence a financial model and how much effect they have on this model. This procedure helps demonstrate which network boundaries ought to be diminished.

4.1 Cost Comparison

In this section, the cost comparison of the two different models is presented similarly to the way shown in [11] and also in [12]. Studying the Table in Fig. 6 it is noted that different costs for both implementations can significantly affect the final cost, [13] , in both CAPEX and OPEX since, if they are looked separately, their importance is better understood. [14]

Examples of these cost-depended factors are displayed in the two sections following.

4.2 On Premises solution cost adjustments

As seen in Fig. 7, the cost of Servers increases proportionally if there emerges a need for more servers. Which in turn causes CAPEX costs to increase accordingly as seen in

	On-premises				Cloud Based			
	Unit	Quantity	Per Unit	Total	Unit	Quantity	Per Unit	Total
CAPEX (initial)				**3.110.000,00 €**				**90.000,00 €**
Server	Nos	100	4.000 €	400.000 €	Nos	0	0 €	0 €
Network Equipments	Nos	50	1.000 €	50.000 €	Nos	0	0 €	0 €
Storage	TB	50	3.500 €	175.000 €	TB	0	0 €	0 €
Storage (Backup)	TB	350	1.500 €	525.000 €	TB	0	0 €	0 €
Software (OS + IIS)	Nos	100	2.500 €	250.000 €	Nos	0	0 €	0 €
Software (DB)	Nos	100	15.000 €	1.500.000 €	Nos	0	0 €	0 €
Software (AV + Mgmt)	Nos	100	300 €	30.000 €	Nos	0	0 €	0 €
Labor for Start	€/resource	10	18.000 €	180.000 €	€/resource	5	18.000 €	90.000 €
Real Estate	€/sft	0	1.000 €	0 €	€/sft	0	0 €	0 €
OPEX (annual)				**999.000 €**				**717.000,00 €**
Computing Power	€/hr	0	0 €	0 €	€/hr	3000000	0,16 €	480.000,00 €
Storage	TB	0	0 €	0 €	€/GB	0	0,12 €	0,00 €
Bandwith	€ /annum	3	20.000 €	60.000 €	€/GB	0	0,18 €	0,00 €
Staff Salary	staff/annum	8	28.000 €	224.000 €	staff/annum	4	28.000 €	112.000,00 €
Infrastructure Maintenance	% of total cost	35	7.000 €	245.000 €	% of total cost	0	0 €	0,00 €
Software Maintenance	% of total cost	35	5.000 €	175.000 €	% of total cost	0	0 €	0,00 €
Electricity	€ /annum	1	90.000 €	90.000 €	€ /annum	0	0 €	0,00 €
Rent for Real Estate	€/sft/annum	1000	100 €	100.000 €	€/sft/annum	0	0 €	0,00 €
Other Maintenance	€ /annum	3	35.000 €	105.000 €	€ /annum	0	0 €	0,00 €
Pay-per-Use Savings	%	0	0 €	0 €	%	25	5.000 €	125.000,00 €
TOTAL				**4.109.000,00 €**				**807.000,00 €**
Savings				**3.302.000,00 €**				

Fig. 6. Cost Comparison

Fig. 8. Thus considered, the plan on the server needs should be extensive and forward-looking in order to avoid future costs depended on server units.

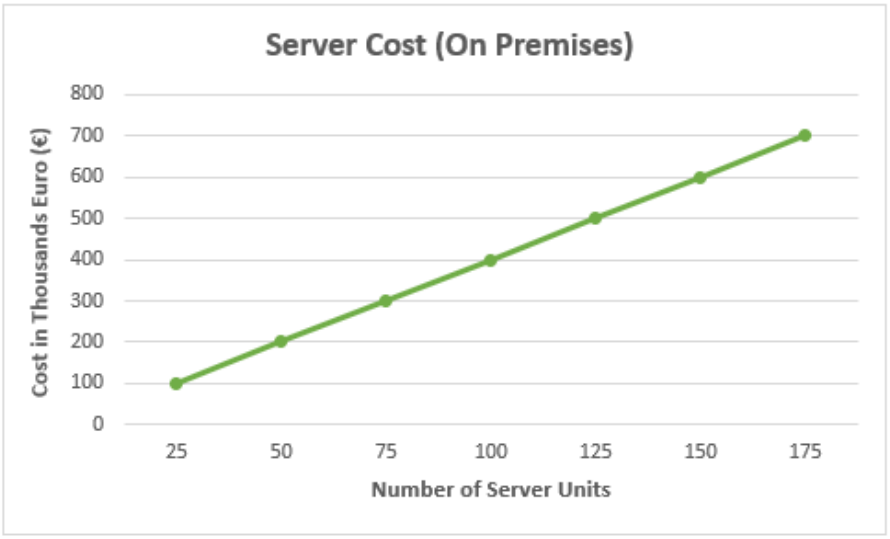

Fig. 7. Server Cost Impact

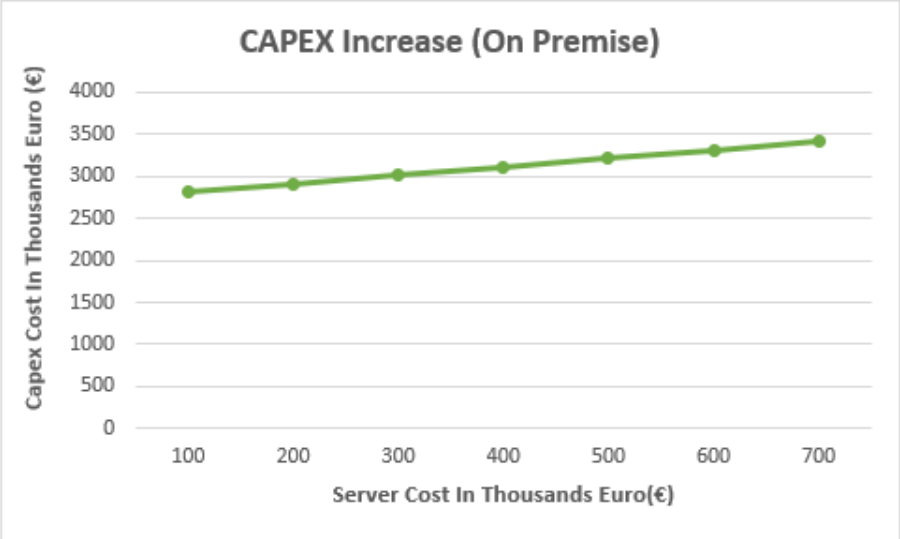

Fig. 8. CAPEX Cost Increase due to Server Cost

4.3 Cloud Based solution cost adjustments

As seen in Fig. 9, the cost of Computing Power is directly related to the price per kilowatt-hour (kWh) which may differ in each operating range. Which in turn can lead to significant increases in the overall OPEX, as shown in Fig. 10.

4.4 Performance Evaluation

Based on the above decribed facts, a very detailed research and market investigation should take place before the final decision because the cost per kilowatt-hour varies between places and even cities is over 4 times larger than in the Cloud-Based solution we propose. The Cloud-based solution offers more adaptability and versatility and is less dependent on unpredictable factors. The results are displayed in Fig. 11 and Fig. 12 for consideration. It is finally found that the difference in the two implementations is significant in terms of cost, especially if this is observed in the depth of 4 years. Cloud-Based implementation is significantly superior to the On-Premise, something that is reflected in Fig. 9. To summarize the experimental comparison, it is obvious that a Cloud-based solution is more efficient in the final choice. The cost of an On-Premise solution varies and is strongly dependent on multiple factors that are not always controllable by the side that implements the solution. Surely the fact the cost of both solutions may be less after 4 or 5 years is something to be considered in the long run, but in a shorter-term case, the Cloud-based solutions dominate over the On-Premise based ones.

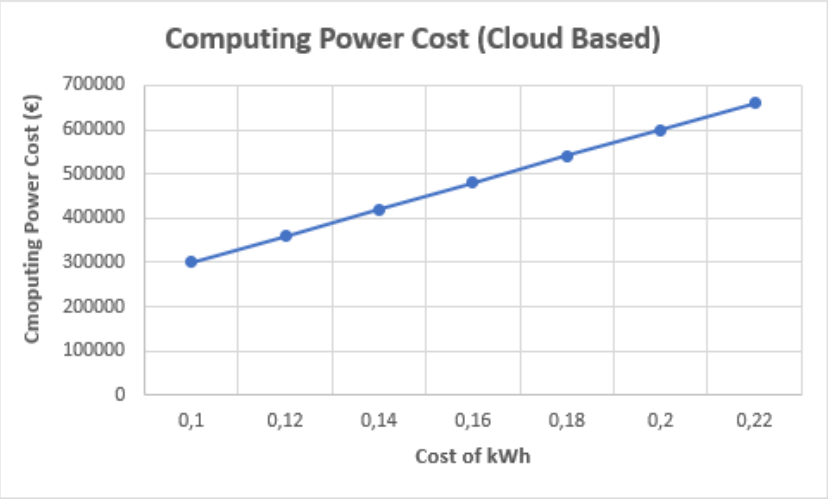

Fig. 9. Computing Power Cost Impact

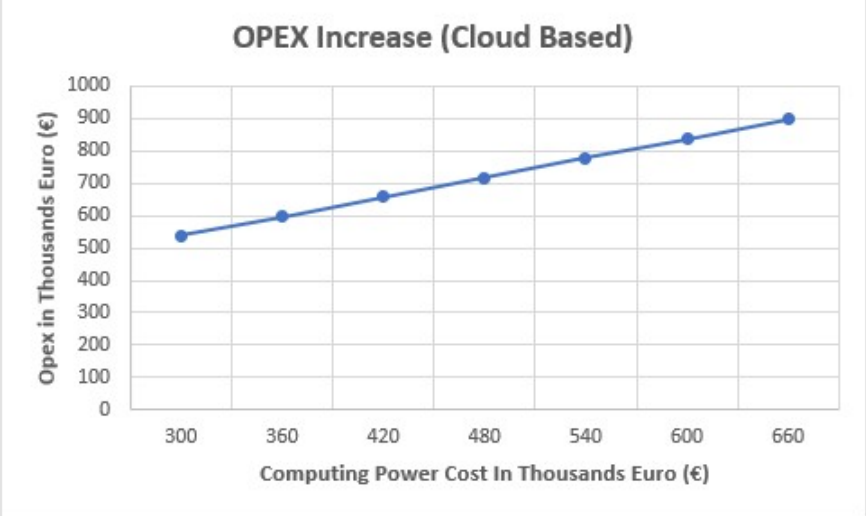

Fig. 10. OPEX Cost Increase due to Computing Power Cost

	On-premises				Cloud Based			
	CAPEX	OPEX	Cost		CAPEX	OPEX	Cost	
YEAR - 1	3.030.000 €	999.000 €	4.029.000 €		90.000 €	717.000 €	807.000 €	
YEAR - 2	-	999.000 €	5.028.000 €		-	717.000 €	1.524.000 €	
YEAR - 3	-	999.000 €	6.027.000 €		-	717.000 €	2.241.000 €	
YEAR - 4	-	999.000 €	7.026.000 €		-	717.000 €	2.958.000 €	

Fig. 11. 4-Year plan cost estimates

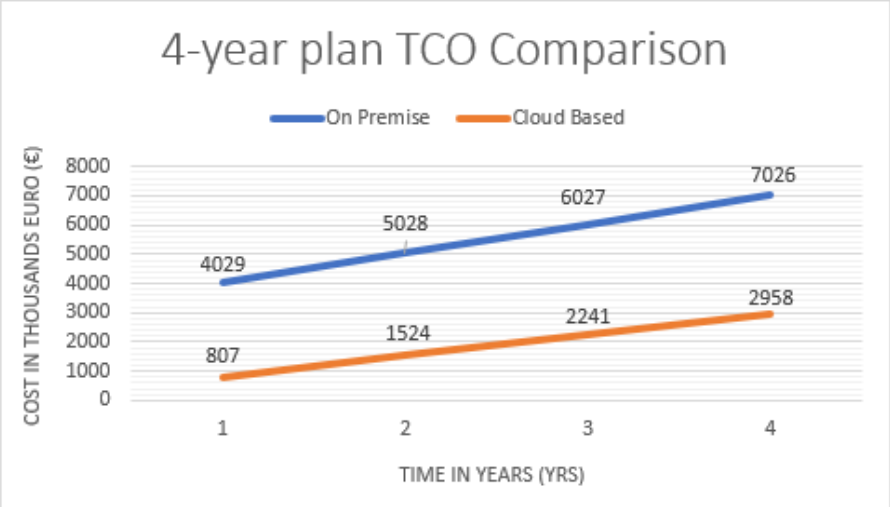

Fig. 12. 4-Year plan TCO comparison

5 5G and Cloud Computing

What 5G brings to the above though? Up to here, we evaluated the benefits cloud computing offers against On-premise solutions. But how 5G is related to that and why is mentioned in this paper? The combination of 5G speed with cloud computing's powerful tools and flexibility is likely to herald a new generation of computing capability. Shift or moving towards cloud storage and cloud computing is a developing and fundamental peculiarity nowadays and in these pandemic conditions, its need is more crucial. Information Technology (IT) is at a critical juncture in history, when the transformation to a digital future is unavoidable, in the technological era in which we now live. As of today, more than half of the world's population is linked, which is amazing, but it is only the tip of the iceberg. Through 5G and beyond networks, "everything that can be connected will be connected".

Regarding Cloud Computing now, it simply means bringing cloud technology closer to the end-user to reduce latency, boost downstream bandwidth, and decrease upstream bandwidth. This allows telecommunication providers to deliver services considerably more quickly, giving them the agility they need to compete. Cloud computing allows for faster analysis and response times by utilizing automation tools that act on local data. With the introduction of 5G, all network/telco services will operate similarly to cloud-based services, benefiting from deployment agility, scalability, and other benefits. [15]

In terms of some actual benefits of the 5G introduction to Cloud Computing, wireless connectivity environments, such as factories, have largely relied on wired technologies to get the appropriate network reliability, predictability, and latency characteristics. [16] Wired networking technologies are expensive to install, require real estate, and need maintenance. Private 5G has the potential to replace wired technologies in these sensitive environments. Moreover, environments such as farms, oil fields, and mines may not even have connectivity, to begin with since they are not well suited to wired technologies. Such environments can take advantage of Private 5G for solid networking connectivity. The next compelling benefit of 5G+ cloud computing is the promise to save operating expenses (OPEX). For a factory, this could be via robotics control, autonomous vehicles, AI/ML (Artificial Intelligence / Machine Learning) quality inspection, IoT management, and more. For hospitals, it could be through radiology anomaly detection at the edge. For precision agriculture, it could be via drone control and IoT management. Video surveillance applications could be used for retail store security to slash costs. Smart building applications could cut energy costs and optimize space utilization with 5G+.

6 CONCLUSIONS & FUTURE WORK

In this paper, a comparative study was presented between the two different implementations for the creation and operation of a data center. The advantages of a CloudBased architecture in combination with the capabilities of 5G networks were presented, which incorporate various state-of-the-art technologies. With the proposed architecture the disadvantages of on-premise implementation are mainly summarized in the financial costs of this option.

The comparative study leads to the conclusion that cloud based implementation is more economical than on-premise since, for this example, it generates a profit of €4,000,000. Even if a significantly larger amount is added to the cloud based implementation - of the order of €500,000 indicatively - as migration cost, again the difference in costs, especially in a four-year plan as described above, is significant.

In future research aspects of increased TCO in CloudBased solutions must be researched according to opinions saying that after 5 or 6 years on a Cloud-Based solution the cost may increase a lot, meeting On-Premises solutions finally. This comes as a result of the increasing yearly cost of Cloud Storage needed for the purposes [17].

Cloud checking as a Service requires more investigation and evaluation to gain a better understanding of cloud facilitated apps. There are opportunities for improvement in the areas of up time, consistency, weaknesses, occurrences, combination, and so on. Managing the use of multi-cloud framework administrations will become increasingly

important in the future. Especially if On-Premise is doomed in the long term due to suppliers' narrow-minded motivations.

Cloud-based arrangements, namely SaaS arrangements, provide a flexible and accessible option for accessing continual data whenever and wherever it is convenient. Because they rely on a pay-as-charges-arise evaluating strategy, the association/organization benefits from lower upfront costs for equipment and programming, as well as adaptability that allows us to change the arrangement as the company demands change.

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