Total Cost Modeling for VNF based on Licenses and Resources

Ghoshana Bista[1,2], Eddy Caron[1] [a] and Anne-Lucie Vion[2]
[1] *UMR CNRS - ENS Lyon, UCB Lyon 1 - Inria 5668, Lyon, France*
[2] *Orange, Pessac, France*

Keywords: License Cost, Simultaneous Active Users, Software Licensing, VNF, Software Cost, Cloudification, Softwarization.

Abstract: Moving to NFV (Network Function Virtualization) and SDN (Software Defined Network), Telco cloud architectures face four key challenges: interoperability, automation, reliability, and adaptability. All these challenges involve the optimization of resources; whether it is to increase the utilization of hardware resources (virtualization) or to deliver shared computing resources and functions in real-time (cloudification). Softwarization of networks is a consequence of telecom cloudification. Virtual Network Function (VNF) is protected by IPR (Intellectual Property Right) like any software, ensured by a license describing usage rights and restrictions at a given cost. Until now limited studies have happened in the economic dimension linked to softwarisation. Currently, the telco industry struggles to converge and standardize licensing and cost models. At risk: the network cloudification benefits could be swept away by poor management of resources (Hardware and Software). This article presents a preliminary model for optimizing the total cost of a VNF, based on the Resource Cost (RC) and License Cost (LC). This analysis is inspired by measurement and licensing practices commonly observed in the Telcos industries,i.e consumption and capacity.

1 INTRODUCTION

NFV aims to increase automation and network reliability for better and quicker service delivery. From the research and markets, the global NFV market is projected to grow from 12.9bn dollars in 2019 to 36.3bn dollars by 2024[1]. Also, 60 percent of service providers will adopt NFV in the next two year[1]. Service providers, more specifically telco companies, need to adapt to this shift quickly and efficiently. More than only technological challenges, historical telcos must face the arrival of large hyper-scalers, partners, and also aggressive competitors.

Service Providers will benefit from NFV if they can enable new services with a faster time-to-market, rapidly scaling resources up and down, lowering the costs. The key challenges facing NFV are thus linked with resource optimization. Success relies on the ability to monitor and use standards and interoperable resources: in other words, to mix and match various software components on standard COTS (Commercial -Off-The-Shelf) hardware.

As the network becomes software, failure in controlling software spending destroys the promises of NFV efficiency. The paradigm shift from equipment property toward SW (Software) Right To Use (SW RTU) is adding complexity in resource management. As SW is protected by IPR over a license, it becomes essential to ensure the compliance of SW deployments regarding acquired rights. As well, it becomes essential to optimize license costs. For this, one of the common practices in IT, extending to Network, is to practice Software Asset Management (SAM). Implementing end-to-end SAM guarantees that users buy all the licenses user need, only the license need: to avoid counterfeiting and waste.

SW license frames the rights and obligations of the CSP (Communication Service Providers) to use SW. License is associated with a cost (LC) which depends on the volume of rights granted. The volume granted and associated conditions of uses are contractually defined by one or several metrics. There are currently, no standards on metrics and their definition, they depend on the creativity of software providers. Which could facilitate every supplier of VNF to propose their metrics, model, and tools. And, this is being an intriguing and complex task for VNF services

[a] https://orcid.org/0000-0001-6626-3071

[1] https://www.f5.com/fr_fr/company/blog/why-nfv-is-more-relevant-than-ever

Bista, G., Caron, E. and Vion, A.
Total Cost Modeling for VNF based on Licenses and Resources.
DOI: 10.5220/0011079600003200
In *Proceedings of the 12th International Conference on Cloud Computing and Services Science (CLOSER 2022)*, pages 246-253
ISBN: 978-989-758-570-8; ISSN: 2184-5042

providers. Based on our observation on the telcos industries, metrics can be linked, among with usage, resource allocation, and resource consumption. Thus, it is not wiser to consider LC and RC independently, but we need to consider that LC can be dependent on the resources and vice versa.

In this paper, we propose a model to evaluate and optimize TCO (Total Cost of Ownership) of VNF deployment based on LC and RC. We base our model on two metrics; Simultaneous Active User (SAU) and Bandwith (BW) as we observed that they are well known in the telcos industries and can fit both resource consumption, allocation, and capacity
textitOur contribution:

- We formulate the software cost model for VNF based on LC, RC, and TC
- We introduce the concept of license reference, which is crucial to anticipate the LC, RC, and TC.
- We provide different methods for licensing and estimating its associated cost as LC, RC, and TC.

The rest of the paper is organized as follows: Section 2 provides our related work and background. Section 3 present our models and simulation and Section 4 concludes this research.

2 BACKGROUND AND RELATED WORK

2.1 Business Model

Our assumption of the business model is similar to (Ahvar et al., 2017), which is defined as (i) Service provider, (ii) Network operator, (iii) VNF provider, and (iv) User, customer or client, end-user. For us, a service provider (SP) is a telco company that provides communication services, network operator provides servers, and operates infrastructure. VNF provider is those that provide VNF and end-user are service users. Different entities have different roles but these can be changed or they can be operated by the same entities too. Total Cost (TC) is calculated based on LC (License Cost) and Resource cost (RC). Although resources cost occasionally includes LC and various other costs such as link, maintenance, upgrade, hardware cost. In this study, we considered only RC as VNF instances required to operate the necessary amount of license (license reference). License is an agreement that comes with rights and duties. The right is to use a certain amount of SAU or BW in the respective VNF and duties are to comply.

2.2 Related Work

Some researches were focused on optimizing the network cost and the network path most of them include LC as a constant entity. In (Mouaci et al., 2020) they have dealt with finding the best place of VNF for a better routing path for each demand this article helps our research for finding the placement of SFC (Service Function Chain). (Ahvar et al., 2017) had a significant impact on licensing but still, the authors did not focus on the licensing cost or providing better options for clients. In (Kiran et al., 2020) they developed VNFPRA problem which finds the optimal placement of VNFs in SDN/NFV-enabled MEC (Mobile Edge Computing) nodes to reduce the deployment and resource cost using genetic and mixed-integer problems. From this article, we get an idea about resource allocation. In (Liu et al., 2019) they focused on the placement of the VNF and traffic steering using network cost, node cost, and VNF placement cost. However, this article did not discussed the total cost and optimizing LC but has illustrated a good insight into in-network cost. In (Pham et al., 2017), Chuan Pham et al. formulated problems for joint optimization and traffic cost optimization using the Markov Approximation (MA) in which they added their matching approach called SAMA. This research helps us to get a proper idea of VNF instances, Although this work was huge and concrete, they have not considered license cost or overall total cost. In (Shi et al., 2015) authors focused on resources allocation of NFV components using Markov Decision Process and Bayesian learning which helped to dynamically allocate NFV components.

3 FROM SYSTEM MODEL TO SIMULATION

3.1 System Model

In this section, we provided cost models based on VNF and traditional ways.

3.1.1 Traditional Ways

The popular traditional model is a perpetual license and pay as you grow.

- Perpetual license: In this system users have to pay upfront then only users have the right to use the software. Depending upon the license entitlement user can upgrade and update their software. Since it is one-time pay generally it is highly expensive.

The dimension parameters used for a perpetual license are:

- LC_{prl}: One time cost, upfront payment for license.
- RC_{prl}: One time cost , upfront payment for resources.
- TC_{prl} : Total cost for perpetual license.

$$TC_{prl} = LC_{prl} + RC_{prl} \quad (1)$$

- Pay as you grow (PAYG): It is the model in which end-user have to pay according to their capacity increment, it can be usages based on resources, services, or others. There are lots of pay-as-you methods such as pay as you use, pay as you eat, pay as you go, but for us, it is paid as you grow, and grow here is in terms of SAU/BW. The dimension parameters used for the PAYG license model are:

- no_{SAU}= Number of SAU at a time.
- CS_{PAYG}: Unit cost per SAU for license.
- CSr_{PAYG}: Unit cost per SAU for resources.
- LCs_{PAYG}: License cost for SAU.
- RCs_{PAYG}: Resource cost for SAU.
- TCs_{PAYG}: Total cost for SAU using PAYG.

$$LCs_{PAYG} = Cs_{PAYG} \times no_{SAU}$$

$$RCs_{PAYGS} = CSr_{PAYG} \times no_{SAU} \quad (2)$$

$$TCs_PAYG = LCs_{PAYG} + RCs_{PAYG} \quad (3)$$

Now for the BW, dimension parameters are;

- no_{BW}: number of SAU at a time.
- CB_{PAYG}: Unit cost per BW for license.
- CBr_{PAYG}: Unit cost per BW for resources.
- LCB_{PAYG}: License cost for BW.
- RCB_{PAYG}: Resource cost for BW.
- TCB_{PAYG}: Total cost for BW using PAYG.

$$LCB_{PAYG} = CB_{PAYG} \times no_{SAU}$$

$$RCB_{PAYGS} = CSr_{PAYG} \times no_{SAU} \quad (4)$$

$$TCB_{PAYG} = LCB_{PAYG} + RCB_{PAYG} \quad (5)$$

One of the important points here not to forget is that these are actually business models, not actual licensing models, they are only used as license models due to lack of the standard license models and metrics. To fill this gap we proposed license models which ultimately help to construct optimized business models in a virtual environment, VNF.

3.1.2 Virtual Network Function

Our crucial problem was to find reliable and authentic methods for licensing which would ultimately help to model optimize the total cost in VNF. To address this task we used the two important license metrics that are SAU and BW (Bandwidth).

- SAU: SAU generally means simultaneous active users connected with VNF who are consuming some resources, and using services provided by VNF.
- BW: It is related to the amount of bandwidth-consuming/consumed by SAU.
- License reference: it is considered to be the estimated number of licenses required for the VNF system for a certain period.

We choose these metrics among the other existing metrics such as Transmission Per Second (TPS), Request Per Second (RPS), etc. because these metrics are convenient to measure the usages and scalable parameters. Using these two metrics we created two license reference (LR) models LR_{SAU} (Equation (6)) and LR_{BW} (Equation (7)) respectively for SAU and bandwidth, they can be formulated as follows;

$$\mathrm{LR_{SAU}} = \max_{\forall j \in D} \left(\sum_{\forall i \in V} average(SAU_i, j) \right) \quad (6)$$

Similarly using BW,

$$\mathrm{LR_{BW}} = \max_{\forall j \in D} \left(\sum_{\forall i \in V} average(BW_i, j) \right) \quad (7)$$

where, V = (1, 2,.....v) is a set of all concerned VNF (can be same or different type) in node. We define H as a set of hours (1, 2, 3, ..., h), D as a set of days (1, 2, 3, ..., d) and R as a set of License Reference (LR). LR corresponds to LR_{SAU} or LR_{BW} which we get from the Equations (6) and (7). Table 1 delineates the parameters use in our formulation. Our assumption for this research was that all VNFs were deployed properly in their respective places and they were functioning accurately in full capacity. These license references helped to generate an optimized total cost model which includes license and resource cost calculated as;

$$TC = RC_j + LC_j \quad (8)$$

Now, LC and RC can be calculated for capacity model for a day, $j \in D$ and $r \in R$, as:

$$LC_j^{ca} = \phi_r + \sigma_r \alpha_r \tau_r, \quad (9)$$

$$RC_j^{ca} = \theta_r + \delta_r \tau_r \beta_r \quad (10)$$

LC and RC can be calculated for consumption model for a day, j ∈ D, as:

$$LC_j^{cp} = \gamma_j \times \alpha_r, \quad (11)$$

$$RC_j^{cp} = \gamma_j \times \beta_r, \quad (12)$$

Table 1: Parameters use in problem formation.

r	A License Reference. $r \in R$,
ϕ_r	Pre-paid amount for License Reference (€),
τ_r	Surpass or exceed License Reference r,
α_r	Unit cost of license for License Reference r (€/SAU or Mbps),
σ_r	License factor for License Reference r,
θ	Prepaid amount for resources (€),
δ_r	Resources factor for License Reference r,
β_r	Unit cost of resources for License Reference r,
γ_j	License Reference for a day, $j \in D$,
LC^{ca}	License cost for capacity,
RC^{ca}	Resources cost for capacity,
LC^{cp}	License cost for consumption,
RC^{cp}	Resources cost for consumption.
D	As a set of days (1, 2, 3, ..., d)

Now, implementing these equations (6), (7) and (8) in different scenario, such as i) VNF instances scenario ii) Users dependent iii) Using flavour in nodes. These scenarios are depends on users, usages, and nodes.

3.2 Simulations

In this section, we deal with two types of use case scenarios and a real scenario.

3.2.1 Scenario 1: VNF Instances

In this scenario, we presented different available clients' usages like; Web, VoIP, and Online Game. We modified the table of (Pham et al., 2017) to adjust it to our model. For this scenario, users need to be aware of their requirements based on SAU or BW. Using SAU and BW the flavour base table is proposed on Table 2 and Table 3 which is supposed to meet the user's requirement. Importantly, license cost and resource cost mentioned in our tables are LC^{ca} and RC^{ca} i.e. license capacity and resources capacity cost.

So, if the traffic requirement is BW (65Mbps) for web services from Table 4 then for this services simulator proposed flavour E and for VoIP simulator proposed flavour D. Whenever exact traffic range requirement is not available simulator proposed higher value

Table 2: BW Flavour Table for Scenario 1 (VNF instances).

Flavour	BW (Mbps)	LC cost (K€)	vStorage (TB)	vRAM	vCPU	Redundancy	Resources cost (K€)
A	15	200	2	2 GB	2	1	170
B	20	250	3	2 GB	3	2	200
C	30	355	4	3 GB	4	2	285
D	50	435	4	3 GB	4	2	338
E	65	549	5	4 GB	4	2	420
F	Customize your needs						

Table 3: SAU Flavour Table for Scenario 1 (VNF instances).

Flavour	SAU	LC cost (K€)	vStorage (TB)	vRAM	vCPU	Redundancy	Resources cost (K€)
A	100	250	4	2 GB	2	1	100
B	150	350	4	3 GB	3	2	150
C	200	450	6	4 GB	4	2	215
D	250	550	7	5 GB	5	2	275
E	350	650	8	5 GB	5	2	325
F	Customize your needs						

Table 4: Service chain of different client usages with BW.

Client usage	Service Chain	Minimum Traffic Required (BW)	Minimum Traffic Required (SAU)
Web Services	NAT-FW-WOC-IDPS	65Mbps	165
VoIP	NAT-FW-TM-FW-NAT	35Mbps	200
Online Game	NAT-FW-VOC-WOC-IDPS	150Mbps	300

NAT: Network Address Translator, FW: Firewall, TM: Traffic Monitor, WOC: WAN Optimization Controller, IDPS: Intrusion Detection Prevention System, VOC: Video Optimization Controller

flavour, and for the last online game since users requirement is higher than the available option so users either can be satisfied with flavour D or the best option would be to customize their requirements with services provider, i.e. flavour E. So, in these kinds of situation simulator directly proposed flavour E. A similar phenomenon goes for SAU as well. For web services usage, flavour C was proposed from Table 3. Similarly, for VoIP, flavour C matched the requirement too and for the online game, flavour E covered the user's requirement. So using these flavours based tables the end-user can estimate the optimized total cost.

3.2.2 Scenario 2: Users

The second scenario depends on the user. In this research users were categorized in two types, ❶ Resources Know Users and ❷ Resources Unknown Users.

❶ Resources Known Users (RKU): These are the users who know the estimated amount of resources in terms of SAU/BW required for their system. In this scenario, flavour table was created based on SAU, BW like in previous Table 2 and Table 3, also in these tables total cost was introduced so that depending upon the user's budget they can choose flavours too.

For this evaluation, a simulator had been created named flavour selector where users can input the range of SAU, BW, and total cost depending upon their requirement our simulator will propose the approximate flavor. For example, if the SAU range given by the client is 100-120 our selector suggests flavor A from Table 5. Another case is a range between 130-160 then our selector suggests flavour B also whenever the user inputs range value then it will suggest customizing flavor, i.e. flavour E. Similar to BW, if the client provides the range of bandwidth between 18-20 Mbps the selector will propose flavour B from Table 6. Another interesting case is using total cost. For the total cost, we added the value of Resources Cost (RC^{ca}) and License Cost (LC^{ca}) as shown in column (9^{th}) in Table 5 and Table 6. So, depending upon the customer's budget simulator proposed flavour between SAU and BW. For example: if the client's budget range is from 800-900k€, the simulator provides flavour D from Table 5. Furthermore, if the range is from 600-700k€ then it could be from flavour C from SAU or BW table. So, to avoid the confusion of choosing between SAU and BW the simulator asks the client preference between SAU and BW. Thus, depending upon the client's needs simulator provides the result either from BW, SAU or cost.

❷ Resources Unknown Users (RUU): These are the users who don't have the estimated knowledge about resources requirements (SAU, BW) for their system. So for these types of users, a simulator was created to provide the users with several choices. At first, users need to provide their range after which the simulator will propose the least SAU value from the Table 5. If the user is not satisfied with that proposed then they can processed further simulator will propose from BW Table 6, least range from BW. If this range is also not satisfactory to the client requirement then the simulator proposed the mean value from the SAU flavour table, if this also fails to meet the user's needs the simulator proposed the mean value from the BW flavour table. After this, the simulator proposed the highest value of SAU and BW from SAU and BW flavour table respectively. So the simulator proposed from least to maximum flavour value from tables based on SAU, BW. Thus, our aim here is to provide as many options as possible to the user. Additionally, the offer can be made concerning the total cost as performed in RKU.

3.2.3 Scenario 3: Node Analysis in Real Scenario

For this analysis, we used the two techno-economic friendly models to estimate the LC, RC. They are capacity and consumption. To adapt these models from a business point of view we have considered some thresholds, constraints related to license and resources like license threshold, resources threshold, license factors, etc.

Table 5: SAU Flavour Table for Scenario 2.

Flavour	SAU	LC (K€)	vStorage (TB)	vRAM	vCPU	Redundancy	Resources cost (K€)	Total cost (K€)
A	100	250	4	2 GB	2	1	100	350
B	150	350	4	3 GB	3	2	150	500
C	200	450	6	4 GB	4	2	215	665
D	250	550	7	5 GB	5	2	275	825
E	350	650	8	5 GB	5	2	325	975
F	Customize your needs							

Table 6: BW Flavour Table for Scenario 2.

Flavour	BW (Mbps)	LC (K€)	vStorage (TB)	vRAM	vCPU	Redundancy	Resources cost (K €)	Total cost (K€)
A	15	200	2	2 GB	2	1	170	370
B	20	250	3	2 GB	3	2	200	450
C	30	355	4	3 GB	4	2	285	640
D	50	435	4	3 GB	4	2	338	773
E	65	549	5	4 GB	4	2	420	969
F	Customize your needs							

- Capacity: The capacity analysis is similar to prepaid service where a certain amount of cost is paid upfront to a certain capacity (license reference for our research) of VNF. When it surpasses the threshold extra costs will be incurred. The threshold can be a license or resource or both. In this research both LC and RC were estimated using unit cost and license reference using Equations (9) and (11). In this mode, once the capacity is increased it cannot be reversed even if the consumption (SAU/BW) is lower than the threshold.
- Consumption: Clients will pay for the resources they had consumed or will consume during a certain time. As a consequence, there is no contractual threshold limiting the user's ability to consume resources (SAU, BW). It was calculated using Equations (11) and (12).
- LC threshold: This is the threshold for calculating license cost. LC threshold was implemented for both LC^{ca} and LC^{cp}. In this research, wherever license is being used it includes both (LC^{ca}, LC^{cp}). It is defined at the time of negotiation of the contract based on estimated needs. If the uses exceed the threshold, the cost of a license is increased by 1.5, 2, 3, ..., n, which is known as license factor σ. The license threshold is based on LR.
- RC threshold: It is the threshold in the resources. Whenever a threshold is exceeded, it requires a careful evaluation to understand whether the exceeded threshold can be covered by a single resource or more. If it can be covered with one resource then our research will use resources factor (δ)=1, and if requires more than one it will be from 1,5, 2, 3, 4, 5, ..., n. This threshold is also dependent upon the LR. Alike the LC threshold, it

can be negotiable between the VNF provider and the SP.

- LC factor (σ): It is a multiplicative factor after exceeding threshold, σ= 1.5, 2, ..., n. License factor and resources factor were introduced here to create a proper business model because whenever the threshold is exceeded in the capacity model, the service provider will charge some extra amount.
- RC factor (δ): It is similar to the LC factor but it is in the resources aspect. δ= 1.5, 2, 3, ..., n.

So, now using all these metrics and equations (12) and (11) the total cost in *consumption model* becomes:

$$\max_{\forall j \in D} \sum (\alpha_r \gamma_j + \beta_r \gamma_j) \tag{13}$$

Similarly, from equations (10) and (9) total cost for *capacity model* became:

$$\max_{\forall j \in D} \sum (\phi_r + \sigma_r \tau_r \alpha_r + \theta_r + \delta_r \tau_r \beta_r) \tag{14}$$

A presumption was made that it will meet the QoS threshold, TH_f, i.e min $TC \leq TH_f$. TH_f is not a numerical value but a condition.

Now, for this situation, we considered a similar scenario as in (Malandrino et al., 2019) i.e ICA (Intersection Collision Avoidance). ICA issues the alert signal if any pair of them are about to collision. All the parameters which were adapted to replicate the business models are given in Table 7 and Table 8. This simulation is executed on the Intel(R) Core(TM) i7-6600U CPU @ 2.60GHz 2.81 GHz, 16GB RAM, Windows 10. For the sake of simplicity, we assume that resources can be scaled easily. We generated SAU and BW randomly on each virtual node, also known as Virtual Evolve Packets (vEPC) such as MME, SGW, PGW, etc. After the SAU and BW were generated in each vEPC we implemented our license reference model as in Equations (6) and (7) and obtain the Figures 2 and 6 for SAU and BW. After the estimation of license reference, we estimated the license cost using the Equations (9) and (11) and its result is shown in the Figures 3 and 7. After successfully evaluating the LC we analyze the RC using the Equations (10) and (12) with the help of the license reference as shown in Figures 4 and 8. Further, we estimated the total cost using Equations (13) and (14) which were shown in Figures 5 and 9. The experiment is carried out three times with three different random values for thirty days and its cumulative average results are presented in all figures.

3.2.4 Evaluation

Figures 2 and 6 show the estimated license reference based on randomly generated BW. Randomly generated BW is also shown in the figures with help of which pay as you grow and perpetual license and its related cost were estimated. We can see on both figures that daily BW is higher than the reference. It is due to licensing reference being based on hourly average, maximum over a day from all concerned VNF from Equations (6) and (7). Not to be confused that daily SAU and BW shown in figures are 24 hours con-

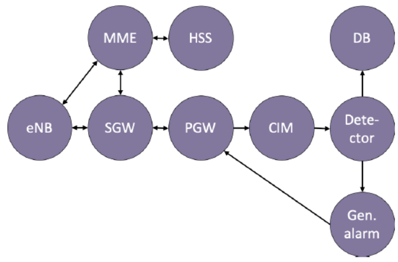

Figure 1: VNF graph of the ICA service.

Table 7: Simulation parameter for SAU.

Parameters	Value
License threshold for capacity	4725
Resource threshold for capacity	4725
σ for both capacity for SAU	1.5 (for LR less then 4725, 2 for LR >4725
δ	1.5 for SAU < 4725 and 2 for LR > 4725
θ	33000 (€)
ϕ	40000 (€)
SAU	500 add random(0,50), random(0,100) and random(10,1000)
α for SAU	10€ per LR for License
β for SAU	6€ per LR for Resource
CS_{PAYG}	0.01(€) per SAU
CSr_{PAYG}	0.04 (€) per SAU
LC_{prl}	500 (€)
RC_{prl}	800 (€)

Table 8: Simulation parameter for BW.

Parameters	Value
License threshold for capacity	65
Resource threshold for capacity	70
σ for both capacity for BW	1.5 (for LR less then 65, 2 for LR >65)
δ	1.5 for SAU < 70 and 2 for LR > 70
θ	700 (€)
ϕ	600 (€)
BW	random(5,10),random(10,20) and random(30,40)
α for BW	10€ per LR
β for BW	6€ per Resource
CB_{PAYG}	0.01 (€) per BW
CBr_{PAYG}	0.04 (€) per BW
LC_{prl}	500 (€)
RC_{prl}	800 (€)

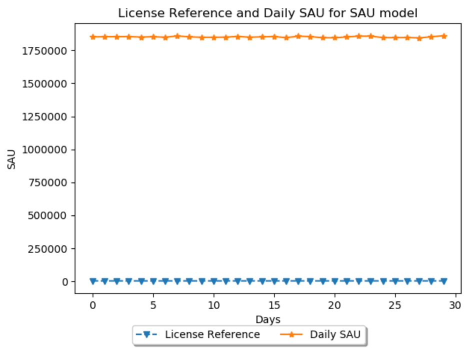

Figure 2: License Reference for SAU.

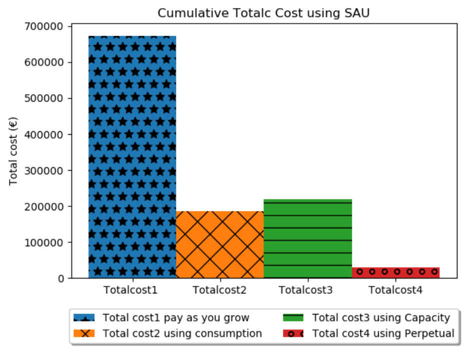

Figure 5: Cumulative Total cost using SAU.

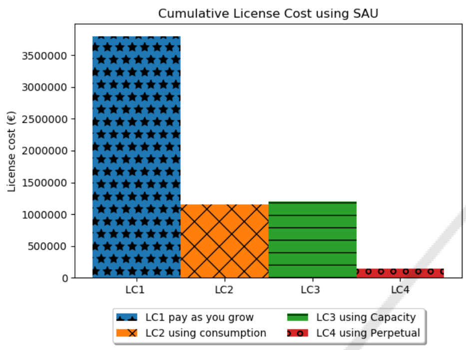

Figure 3: Cumulative License cost using SAU.

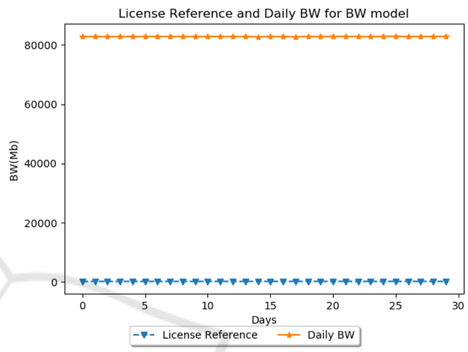

Figure 6: License Reference for BW.

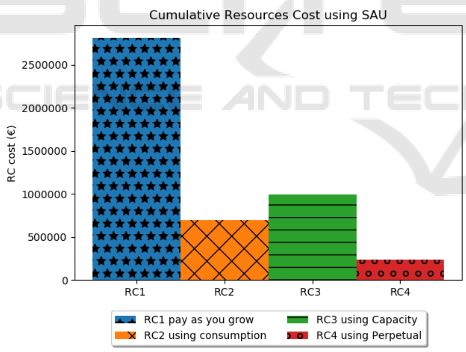

Figure 4: Cumulative Resource cost using SAU.

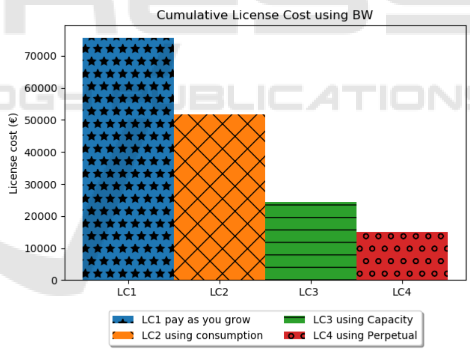

Figure 7: Cumulative License cost using BW.

sumption by ICA service. Figures 3 and 7 which are the cumulative license cost for 30 days we can see that license cost using perpetual is lower and license cost using pay as you grow is higher. An interesting case here is license cost using consumption and capacity methods these are lower than pay as you grow, among consumption and capacity, consumption has a lower cost than capacity. One can argue that since the perpetual cost is lower why not choose it but it is not beneficiary for the VNF services provider. Because the perpetual model did not consider the usages or resources consumption it is not fair for the VNF services provider. Now, coming back to our figures in contrast with LC of SAU, BW LC for consumption is higher and capacity is lower. Figures 4 and 8 show that the consumption model estimated the lower resources cost than the capacity in both SAU and BW. Figures 5 and 9 show the estimated total cost. Figure 5 is the total cost for the SAU here we can see that the consumption model estimated the lower cost than capacity. While the BW capacity model estimated the lower cost than consumption as shown in Figure 9. One of the interesting points we can depict from these figures is that when we use SAU as metrics with our models' consumption model estimated lower cost but in contrast of this when we use BW

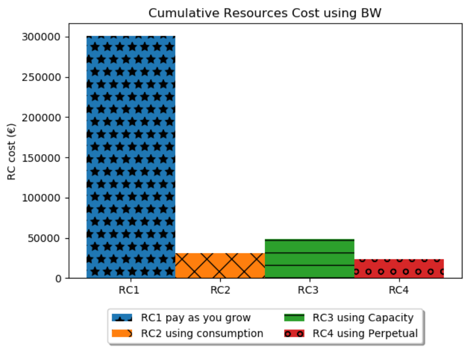

Figure 8: Cumulative Resource cost using BW.

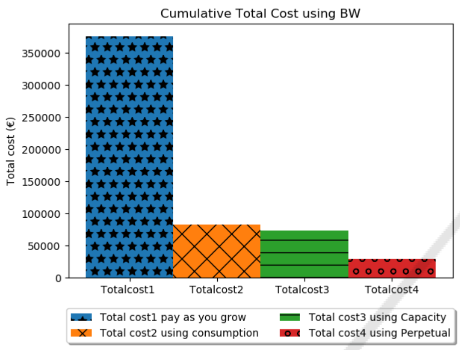

Figure 9: Cumulative Total cost using BW.

as metrics with our models capacity model estimated lower cost. This is due to the consumption of BW and the number of SAU can not be compared, these are two different metrics. SAU is a user connected with the VNF and BW is the consumption of bandwidth based on the SAU or services it consumes. This leads us to the point that licensing could be done in different ways depending upon the end-user requirement, scenario, and QoS parameters (throughput, bit-rate, etc). Also, different licensing metrics can be considered and depending upon the licensing metrics LC, RC, and TC cost can be optimized. Thus, in simulation for ICA when we use SAU as a metric consumption model generated an optimized LC, RC and when BW as a metric capacity model provided optimized LC and RC.

4 CONCLUSIONS

The study has tried to suggest several models that are relevant to the various scenarios. We compare the traditional ways of estimating total cost and our models (capacity and consumption). Results confirm that our model is far better than the traditional one. We also present different kinds of possible scenarios such as VNF instances and Users which have a huge range of requirements to be fulfilled. To meet the scenario requirement, we proposed the flavours methods (SAU, BW). For users, we presented a solution based on total cost, SAU, and BW. Secondly, we implemented our models in real VNF scenario ICA which clearly shows that our models outperform other traditional models it is because we introduced the concept of license reference based on SAU and BW. So, from all these, we can conclude that licensing is a complex task that depends not only on one factor or metrics but also on several metrics, users, services, and many others. We tried to include potential metrics and constructed a novel model. Thus, we assume that our models are not just limited to one scenario but could be implemented on different circumstances and topologies and will be helpful to estimate the optimized total cost. Our future work will be to enhance this model using DF, green energy, and implement it on the more complex VNF SFCs.

REFERENCES

Ahvar, S., Phyu, H. P., Buddhacharya, S. M., Ahvar, E., Crespi, N., and Glitho, R. (2017). Ccvp: Cost-efficient centrality-based vnf placement and chaining algorithm for network service provisioning. In *2017 IEEE Conference on Network Softwarization (NetSoft)*, pages 1–9. IEEE.

Kiran, N., Liu, X., Wang, S., and Yin, C. (2020). Vnf placement and resource allocation in sdn/nfv-enabled mec networks. In *2020 IEEE Wireless Communications and Networking Conference Workshops (WCNCW)*, pages 1–6. IEEE.

Liu, Y., Pei, J., Hong, P., and Li, D. (2019). Cost-efficient virtual network function placement and traffic steering. In *ICC 2019-2019 IEEE International Conference on Communications (ICC)*, pages 1–6. IEEE.

Malandrino, F., Chiasserini, C. F., Einziger, G., and Scalosub, G. (2019). Reducing service deployment cost through vnf sharing. *IEEE/ACM Transactions on Networking*, 27(6):2363–2376.

Mouaci, A., Gourdin, É., LjubiĆ, I., and Perrot, N. (2020). Virtual network functions placement and routing problem: Path formulation. In *2020 IFIP Networking Conference (Networking)*, pages 55–63. IEEE.

Pham, C., Tran, N. H., Ren, S., Saad, W., and Hong, C. S. (2017). Traffic-aware and energy-efficient vnf placement for service chaining: Joint sampling and matching approach. *IEEE Transactions on Services Computing*, 13(1):172–185.

Shi, R., Zhang, J., Chu, W., Bao, Q., Jin, X., Gong, C., Zhu, Q., Yu, C., and Rosenberg, S. (2015). Mdp and machine learning-based cost-optimization of dynamic resource allocation for network function virtualization. In *2015 IEEE International Conference on Services Computing*, pages 65–73. IEEE.