Capacity Expansion and Modernization of Core Network Elements Running on ATCA Platform

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***Abstract* — Actual telecommunications research topics are focusing on cloud-based Virtual Network Functions (VNFs). Less attention is given to the capacity expansion and optimization of existing Physical Network Functions. However, operators try to maximize their return of earlier investments too, even when they started to deploy cloud-based VNFs already. In the migration path of core network elements from vendor specific hardware to cloud, the ATCA (Advanced Telecom Computing Architecture) hardware can be considered as an intermediate step. ATCA is not a proprietary or vendor specific hardware, it is often referred as 'commercial off-the-shelf' platform. This paper reviews modernization, expansion, and upgrade possibilities for existing ATCA deployments that increase capacity and support easier migration to cloud later. In the presented network examples - as a case study - Telecommunication Application Server deployments are analyzed.**

***Keywords* — 5G; 4G; VoLTE, cloud; VNF; ATCA; PNF; TAS; MSS; load-balancing; capacity; virtualization; pool.**

I. Introduction

The versatile requirements of 5G [1] mandate a sliced architecture with Virtual Network Functions (VNFs) that can be quickly provisioned to run on virtual compute, store and network resources. This makes the telco infrastructure operate as cloud-based service [2], [3]. The latest Commercial-off-the-Shelf (COTS) platforms for telecom applications are being built on designs influenced by Open Compute Project, Intel Rack Scale Architecture, carrier-grade servers, and Advanced Telecom Computing Architecture (ATCA): many similar but incompatible hardware designs, a fragmented market with several standardization organizations and open source projects [4]-[9].The virtualized network infrastructure using SDN and NFV is now expected to provide a common software platform. Furthermore, the used virtualization technology is changing while initially virtualization focused on virtual machines [10], nowadays containers get more traction [11], [12].

With the actual launch of the fifth generation (5G) mobile networks and the continuously growing fourth generation (4G) coverage, the mobile landscape is changing very quickly [13]-[15]. The use of second generation (2G) networks is clearly decreasing, and the use of 3G networks does not grow any further (Fig. 1) [16]. Obviously, the migration from legacy Physical Network Functions (PNF) based deployments to cloud-based deployments will not happen at once [17], [18]. It is expected that PNFs and cloud-based deployments will co-exist, as it is not economical to swap PNFs well before the end of their lifecycle.

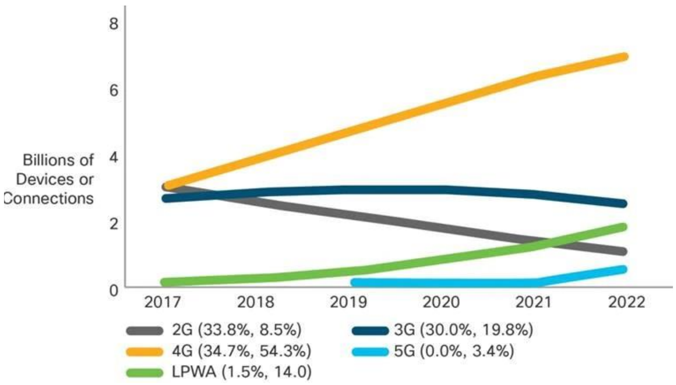

Fig. 1. Wireless subscribers' technology, source: [16]

To support the hybrid environment (i) the resource management of cloud-based deployment must consider PNFs [19] and (ii) recent PNF deployments serving 4G are further developed [20]. It can be assumed that these PNF deployments are ATCA based PNFs [8], see Fig. 2a. Note that even though cloud based ATCA hardware exist [21], those are not considered here.

In this paper, we show capacity expansion examples of ATCA based PNFs and possible modernization steps in the favor of easier migration towards cloud core. In the presented examples Telecommunication Application Server (TAS) and Mobile Switching Center Server (MSS) PNFs are shown, as those have significant presence in current deployments, see Fig. 2b and 2c. Note that in the relevant standards [22]-[25] the TAS is often called as 'Telephony Application Server'.

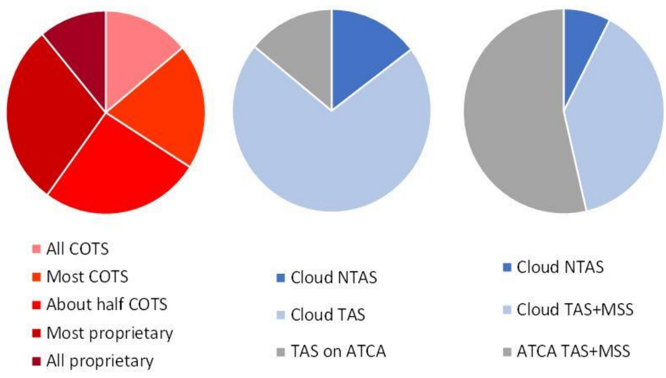

Fig. 2. a.) 2016 market outlook [8], b.) current split of TAS deployments, c.) current split of TAS-MSS deployments

II. TELECOMMUNICATION APPLICATION SERVERS IN VOLTE

In the actual Voice over Long-Term Evolution (VoLTE) and IP Multimedia Subsystem (IMS) networks, TAS enables high definition voice and video calls, messaging, and rich multi-media services [22-26]. The VoLTE solution is a standard compliant implementation of LTE and IMS service architecture [27], [28]. TAS products implement a combination of functions and roles: Multi-Media Telephony Application Server (MMTel AS), Service Continuity and Centralization AS (SCC AS) [27], IP Short Messaging Gateway (IP-SM-GW) [28], Media Resource Function (MRFC), and intelligent network functions (IM-SSF). The voice and video over LTE solution build up on the 'One Voice initiative', as described in GSM Association's reference documents IR.92 [23], IR.94 [24], IR.51 and IR.64 [25], enabling operators to deliver rich communication services over LTE. The multifunctional TAS has a modular architecture (Fig. 3).

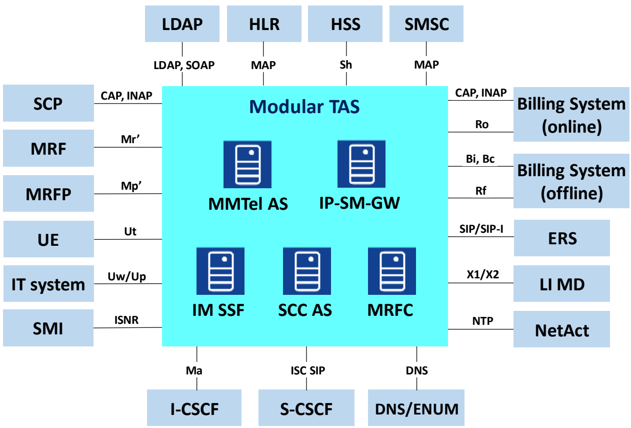

Fig. 3. Standard functionalities and standard interfaces of TAS

Joint VoLTE and Voice over WiFi (VoWiFi) deployments offer efficient reuse of network resources and may provide rich services for the subscribers. Operators may choose to deploy untrusted VoWiFi and direct access either separately, or together and may introduce VoWiFi in conjunction with, or on the top of existing VoLTE. Subscribers may benefit the diverse services with a common service provider and single subscription.

III. CORE ELEMENT DEPLOYMENTS ON ATCA PLATFORM

5G and 4G-VoLTE/IMS networks benefit from VNFs deployed on the cloud: flexibility for slicing, scaling, licensing, etc. [3], [20], [29]. The telco-cloud delivers already the required technical and economical solution for cloud deployments [15]. However, there is still a significant portion of the core network elements running on proprietary or on ATCA hardware [9], [20]. In Fig. 2b the estimated hardware (HW) and platform split is shown: the statistics were collected from more than 60 operators in the timeframe of 2017-2020 (beside the live deployments, testbeds, trials, and pilots are also counted where commercial launch happened before 2020). As seen, about 14% of the actual TAS deployments are still running on ATCA. ATCA deployments can be further divided into ACPI4 (first delivery) or new ACPI5 installations. ACPI stands for the Advanced Configuration and Power Interface specification. ACPI 4.0 was released in 2009, ACPI 5.0 in 2011, ACPI 6.0 in 2015, respectively. ACPI 6.3, the latest release came in 2019 [30]. The main parameters of the different blade types are summarized in Table I. Fig. 4 shows the ATCA cabinet, the ATCA shelf and two blade types (ACPI4 and ACPI5) [31].

The cloud VNFs shown in Fig. 2b and 2c are mostly running either on VMware or on OpenStack. The HW platform is typically from an IT manufacturer (e.g. Hewlett-Packard or Dell), but telecommunication equipment vendors deliver datacenter HW too (e.g. Nokia's AirFrame [20]). Latest cloud-native NTAS VNF deployments form the increasing slice in Fig. 2b and 2c, meanwhile the first two slices are continuously shrinking.

TABLE I. MAIN PARAMETERS OF ATCA ACPI BLADES

Blade type	ACPI4-A [a]	ACPI4-B	ACPI5-A	ACPI6 [b]
CPU socket(s)	1 x CPU	1 x CPU	2 x CPU	
processor cores	quad core	six-core	eight-core	
virtual CPUs (vCPUs)	8	12	16	
hyper-threaded vCPUs	16	24	32	
max. memory [GigaByte]	24	48	128	

a. Old blade type that is not delivered any more, may still run in field deployments.
b. Not yet used in ATCA MSS, nor in TAS deployments.

As seen in Fig. 2, there is a significant portion of ATCA based PNFs still running in live networks / in the field. This ATCA portion is significantly higher if we count the MSS deployments too. Even though cloud MSS is available since several years, the migration speed of earlier (either vendor specific or ATCA platform based) MSS deliveries to cloud is relatively moderate. Fig. 2c shows that about 54% of the deployments are still on ATCA if MSS and TAS PNFs are counted together. (Statistics are collected from more than 100 operators. As being a quickly changing and sensitive data, exact figures or operator names cannot be given in the charts.)

Fig. 4. ATCA cabinet, one ATCA shelf and ATCA blade examples [31]: ACPI4-A/B and ACPI5-A. For the main parameters see Table I.

IV. MODERNIZATION AND MIGRATION POSSIBILITIES OF ATCA DEPLOYMENTS

There may be several reasons why to expand the lifetime of earlier ATCA deployments. Naturally, the reliable operation of TAS and MSS based on ATCA platform is one of these [32]. In case of MSS one clear reason is the slowing tendency of traffic increase in legacy 2G/3G networks (Fig. 1), which may not justify urgent investments business or cost-wise. Supposed that feature parity exists for the relevant features in the core network, various MSS NEs can operate in one pool: PNFs running on ATCA and VNFs running on cloud can form a common MSS pool. This allows in-service network expansion and smooth migration to the cloud. But on the other hand, this also extends the lifetime of PNFs running on earlier vendor specific or ATCA platforms. Such a migration scenario is shown in Fig. 5. In the example, two legacy MSS PNFs form a pool to serve the traffic. As traffic is increasing, the MSS 3 is added to the pool. The new MSS is on cloud platform, and it has higher capacity than the legacy MSS 2 and has Load Balanced (LB) configuration. From the two legacy MSS PNFs the better one, MSS1 that is already load balanced, is kept in the pool. MSS 2 is removed, that had a non-load balanced configuration. Finally, the removed MSS2 HW can partially be re-used for the capacity upgrading of MSS1 (supposed both legacy MSSs are on ATCA platform).

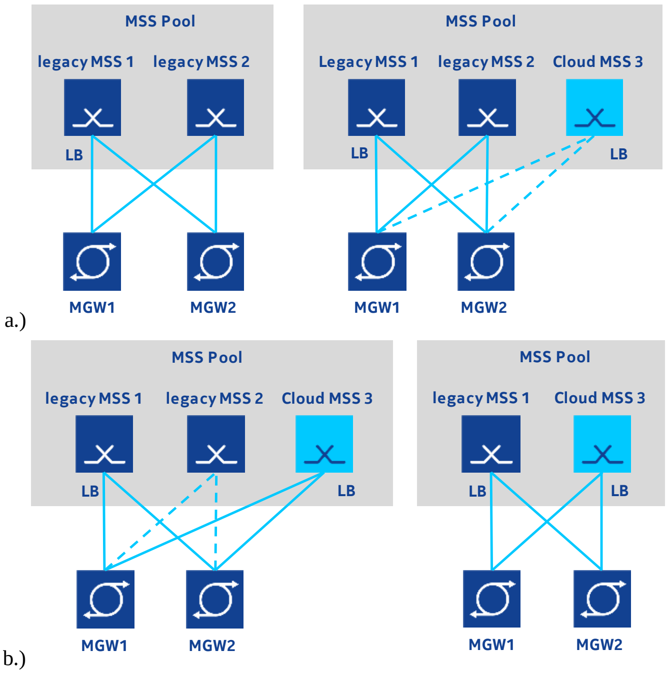

Fig. 5. MSS migration scenario in four steps with PNFs and VNFs in common pool, a.) step 1&2, b.) step 3&4.

There are multiple ways of modernizing and upgrading an ATCA platform based PNF for capacity increase. The main possibilities are:

- hardware expansion:
  - shelf expansion and/or
  - adding new blades,
- software (SW) upgrades:
  - application SW and
  - platform/embedded SW,
- renewal or addition of capacity licences [29],
- connectivity for load balancing [33], [34],
- traffic separation (e.g. separating Operability and Maintenance (OAM) and Control Plane (CP)),
- virtualization of units [35]-[37].

HW expansion is a straightforward step by means of adding more blades, or, when the shelf becomes full, allocating an entire new shelf to the NE inside the rack. In some cases, SW upgrade also results in capacity increase. A newer SW release may distribute some functions over the business logic that were centralized earlier. Replacing older ATCA blades with new ATCA blades or mixing the different blade types is usually not recommended. This is due to the different redundancy methods what a the PNF may use [32]. In case of a blade outage, failover happens to a spare blade. It is expected that the spare blade has the same amount of RAM and CPU (i.e. not less), depending on the different units and their redundancy scheme used. Instead of blade renewals, rather pool expansion is recommended (similarly as shown in Fig. 5) by adding a new PNF with the new blade type. Load balancing and virtualization is explained in the next two parts of the paper.

A. Load Balancing and Traffic Separation

The concept of traffic distribution and load balancing is shown in Fig. 6. For simplicity in Fig. 6 only one IP traffic Distributor Unit (IPDU) is drawn and only Signaling Units (GISUs) are connected. Naturally, a network element has more IPDUs and several different business logics behind, as shown in Fig. 7. Load balancing has several advantages, first of all, it hides the business logic and the internal architecture of the network element. This modernization step results in moderate gain in terms of capacity, but it moves the architecture of the existing TAS a step closer to cloud or new cloud-native architectures.

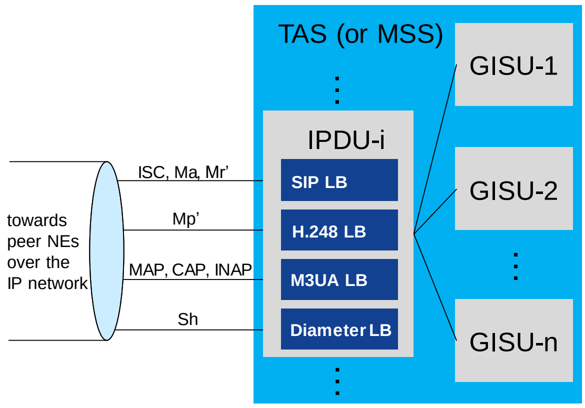

Fig. 6. IP traffic distribution and load balancing example: one IPDU hosts multiple LBs for SIP, H.248, M3UA and Diameter traffic.

From network planning point of view, it is easier to handle a smaller amount of IP addresses for the external connections, meanwhile internal IP addresses can be selected for a pre-defined subnet. Thus, configuration for network or NE growth is faster by simply adding new business logics only. This is illustrated in Fig. 7, where H.248 traffic between TAS and Media Gateway (MGW) is routed over traffic dispatchers.

Adding new signaling units (ISUs in MGW or GISUs in TAS in this example) can be a quick configuration step, without the need of external IP network re-planning and reconfiguration.

Traffic separation can be achieved when a few IPDUs are selected for a set of traffic types. Typical example of traffic separation is having separate IPDUs for OAM traffic and CP IPDUs for Control Plane traffic [33].

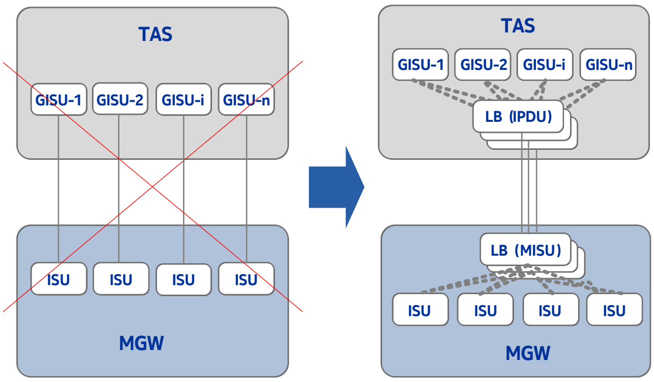

Fig. 7. Load balancing example on Mp' interface [33], [38]

B. *Capacity Increase by Virtualization*

Virtualization started earlier than telecommunication NEs moved to the IT-cloud. On ATCA platform, blades can operate as virtual units (VMUs) and can host multiple functional units [26], [33]-[36]. In very early ATCA deployments some units were native [36], [37]. In Fig. 8 such a two-shelf TAS is shown. As seen in Fig. 9, virtualizing the native units (four IPDUs, three charging unit pairs (CHU) and the CMMs (Central Memory and Marker units), several new signaling units (11 new GISUs) and subscriber database units (5 new VLRU pairs) could be added into the same shelves. One unit (the GPLU) is virtualized by adding its pair resulting in better availability [32], [36].

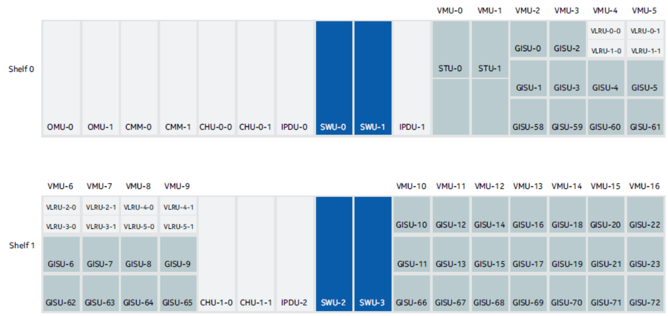

Fig. 8. Configuration with native units (light grey: full blades) and virtualized (dark grey: multiple units/blade) units. [37]

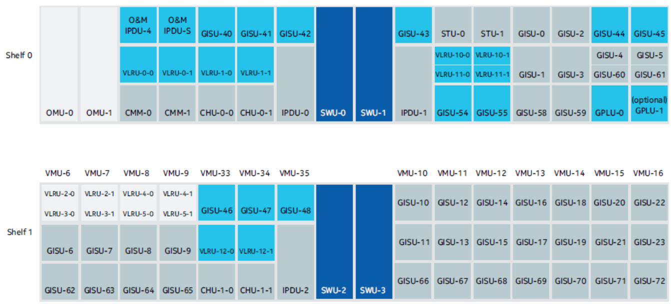

Fig. 9. Capacity expansion by native units migrated to virtualized ones (except OMUs, the Operation and Maintenance Units) [33], [37].

Finally, a network example is shown in Fig. 10. The blue line shows the increasing number of registered VoLTE subscribers over two years. The red trendline indicates the amount of Busy Hour Call Attempts (BHCA) handled by the PNF. As seen, when the TAS capacity limits were reached in the network, the PNFs were upgraded: the native units were migrated to virtual ones [17]. The points represent real network measurements from different periods of the day. (Note, that spreading is due to the logs collected at different times: some points indicate very low BHCA values in the upgrade period, as upgrade preferably happens in low traffic times. Neighboring NEs handle higher traffic than usual, if traffic is off-loaded from the upgraded PNF. After virtualizing the native units, several additional functional units were added. As seen in Fig. 10, after the successful upgrades and capacity licence expansions, both the VoLTE traffic and subscriber amount continued to increase.

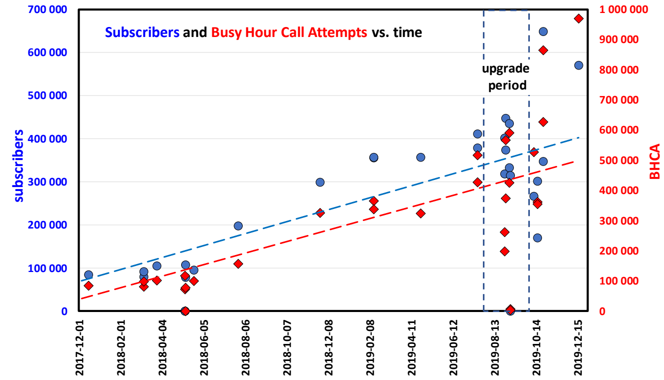

Fig. 10. Measured VoLTE traffic increase after native TAS units were virtualized and licences upgraded to increase PNF capacity

V. Conclusions

Cloud in IT has several well-known benefits: resource pooling, flexible capacity, improved availability, and obviously cost savings. Even though telco has somewhat different requirements [20], cloud is considered as the general solution for the versatile 5G services by utilizing technologies like NFV and SDN. However, virtualizing and softwarizing everything is not always the most economical solution [39]. Migrating the core network to the cloud is not just a technical, but also a business decision [15]. In some networks, the actual VoLTE traffic may not require urgent upgrades. Operators with existing deployments obviously try to maximize the return of their earlier investments before investing into new technology. As 2G and 3G traffic are expected to decline [16] and in many cases the service is phased out to reuse the radio spectrum, the existing infrastructure can serve that traffic without major changes. However, 4G traffic is increasing and 4G will co-exist with 5G. The utilization of the PNF deployments serving 4G is important for operators, and these are mainly ATCA deployments. The paper presented scenarios where the lifetime of earlier ATCA based NE deployments was extended. A successful ATCA upgrade project was shown, where the capacity of TAS PNFs were significantly increased by virtualization and by adding new units. Native units have been virtualized and so new functional units could be added to the existing ATCA blades [37].

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REFERENCES

[1] NGMN, "NGMN 5G White Paper", 2015. [Online]. Available: https://www.ngmn.org/wp-content/uploads/NGMN_5G_White_Paper_V1_0.pdf . [Accessed: Jan. 24, 2020].

[2] P.Rost *et al.*, "Mobile network architecture evolution toward 5G", *IEEE Communications Magazine*, *vol. 54*, *no. 5*, *pp. 84-91*, May 2016.

[3] Telecom Infra Project, "Creating Ecosystems for End-to-End Network Slicing", 2018. [Online]. Available: https://telecominfraproject.com/wp-content/uploads/E2ENS-Phase1-Whitepaper-October2018-1.pdf [Accessed: Feb. 14, 2020].

[4] S.Saphiro, "Data Center Design: Which Standards to Follow?", January 2016. [Online]. Available: https://www.datacenterknowledge.com/archives/2016/01/06/data-center-design-which-standards-to-follow [Accessed: Feb. 14, 2020].

[5] Telecommunications Industry Association, "Telecommunications Infrastructure Standard for Data Centers", ANSI/TIA-942-A, 2012.

[6] Open Compute Project, "Proposed Charter For Modular Data Center Subproject", 2018. [Online]. Available: https://telecominfraproject.com/wp-content/uploads/E2ENS-Phase1-Whitepaper-October2018-1.pdf [Accessed: Feb. 14, 2020].

[7] J.Pavlat and B.Lewis, "AdvancedTCA - Evolution and beyond", [Online]. http://picmg.mil-embedded.com/articles/advancedtca-evolution-beyond/, [Accessed: Feb. 14, 2020].

[8] Heavy Reading, "COTS, ATCA & White box user survey – Executive summary", [Online]. Available: http://www.heavyreading.com/details.asp?sku_id=3432&skuitem_itemid=1670 . [Accessed: Feb. 14, 2020].

[9] PICMG, "AdvancedTCA base specification", ECN 3.0-3.0-001, April 20 2015. [Online]. Available: https://www.picmg.org/wp-content/uploads/ECN001_PICMG_ATCA_3_0_R3_0-RELEASED-2015-04-20b.pdf. [Accessed: Feb. 14, 2020].

[10] ETSI, "GS NFV-MAN 001; Network Functions Virtualisation (NFV); Management and Orchestration", V1.1.1, 2014-12. [Online]. Available: https://www.etsi.org/deliver/etsi_gs/NFV-MAN/001_099/001/01.01.01_60/gs_NFV-MAN001v010101p.pdf [Accessed: Feb. 14, 2020].

[11] 5G-PPP Software Network Working Group, "From Webscale to Telco, the Cloud Native Journey", July 2018. [Online]. Available: https://5g-ppp.eu/wp-content/uploads/2018/07/5GPPP-Software-Network-WG-White-Paper-23052018-V5.pdf [Accessed: Feb. 14, 2020].

[12] Cs.Rotter, L.Farkas, G.Nyíri, G.Csatári, L.Jánosi, R.Springer, "Using Linux containers in telecom applications", *Proceedings of ICIN'2016, Innovations in Clouds, Internet and Networks, pp.234-241*, Paris, France, February 2016.

[13] A.Hilt, "Availability and Fade Margin Calculations for 5G Microwave and Millimeter-Wave Anyhaul Links", *MDPI Applied Sciences, vol.9, no.23, 5240*, December 2019. [Online]. Available: https://www.mdpi.com/2076-3417/9/23/5240 [Accessed: Feb. 14, 2020].

[14] L.Giorgi, G.Bruno, J.Nijhof, P.J.Urban, G.V-Ilosera, F.Ponzini, J.Ladvánszky, "Subcarrier multiplexing RF plans for analog radio over fiber in heterogeneous networks", *IEEE Journal of Lightwave Technology*, *vol.34, pp.3859-3866*, 2016.

[15] J.Varga, A.Hilt, Cs.Rotter, G.Járó, "Providing ultra-reliable low latency services for 5G with unattended datacenters", *11th IEEE/IET International Symposium on Communication Systems, Networks & Digital Signal Processing, CSNDSP'2018,* pp.1-5, Budapest, Hungary, July 2018.

[16] Cisco, "Cisco visual networking index: Global mobile data traffic forecast update, 2017–2022", February 2019. [Online]. Available: https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paper-c11-738429.pdf. [Accessed: Feb. 14, 2020].

[17] GSM Association, "Migration from physical to virtual network functions – Best practices and lessons learned", October 2018. [Online]. Available: https://www.gsma.com/futurenetworks/wp-content/uploads/2018/10/Network-Virtualisation-Best-Practices-and-Lessons-Learned-Migration.pdf. [Accessed: Feb. 14, 2020].

[18] R.Roseboro, "Telco transformation journey – Achieve value at every step", October 2018. [Online]. Available: https://www.oracle.com/a/ocom/docs/dc/hr-oracle-vnf-maturity-wp.pdf. [Accessed: Feb. 14, 2020].

[19] ONAP, "VNF/PNF guidelines", August 2019. [Online]. Available: https://docs.onap.org/en/dublin/submodules/vnfrqts/guidelines.git/docs/vnf_guidelines.html. [Accessed: Feb. 14, 2020].

[20] G.Járó, A.Hilt, L.Nagy, M.Á.Tündik, J.Varga: "Evolution towards Telco-Cloud: Reflections on Dimensioning, Availability and Operability", *invited paper, 42nd Conference on Telecommunications and Signal Processing, TSP'2019,* Budapest, Hungary, July 2019.

[21] Lanner Electronics, "Cloud computing in the network data center", [Online]. Available: http://www.lannerinc.com/applications/telecommunication/cloud-computing-in-the-network-data-center, [Accessed Feb. 14, 2020].

[22] ETSI, "Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; IP Multimedia Subsystem (IMS) centralized services; Stage 2", ETSI TS 123 292 V15.0.0, July 2018.

[23] GSM Association, "Official Document IR.92 - IMS Profile for Voice and SMS, Version 12.0, Permanent Reference Document of the GSMA", 2 May 2018.

[24] GSM Association, "Official Document IR.94 - IMS Profile for Conversational Video Service, Version 12.0, Permanent Reference Document of the GSMA", 12 June 2017.

[25] GSM Association, "Official Document IR.64 - IMS Service Centralization and Continuity Guidelines, Version 8.0, Permanent Reference Document of the GSMA", 28 November 2013.

[26] Nokia, "Open Telecom Application Server 18.5 MP3, Open Telecom Application Server", Product Description, DN09226505, 2019.

[27] 3GPP, "IP Multimedia Subsystem (IMS) service continuity", 3GPP TS 24.237, V16.3.0, 2019. [Online]. Available: http://www.3gpp.org/ftp/specs/archive/24_series/24.237/. [Accessed: Feb. 14, 2020].

[28] 3GPP, "Support of SMS over IP networks", 3GPP TS 24.341 V16.0.0, 2019. [Online]. Available: http://www.3gpp.org/ftp/specs/archive/24_series/24.341/. [Accessed: Feb. 14, 2020].

[29] A.Hilt, G.Járó, "Licensing options for virtual network functions in telecommunications cloud environment", *11th IEEE/IET International Symposium on Communication Systems, Networks & Digital Signal Processing, CSNDSP'2018,* Budapest, Hungary, July 2018.

[30] UEFI Forum, "Advanced Configuration and Power Interface (ACPI) Specification", version 6.3, January 2019. [Online]. Available: https://uefi.org/sites/default/files/resources/ACPI_6_3_final_Jan30.pdf. [Accessed: Feb. 14, 2020].

[31] Nokia, "Open TAS Hardware Description, Open Telecom Application Server 18.5 MP3", Operating Documentation, DN09122488, 2019.

[32] A.Hilt, G.Járó, I.Bakos, "Availability prediction of telecommunication application servers deployed on cloud", *Periodica Polytechnica, Electrical Engineering and Computer Science, Vol.60, No.1, pp.72-81*, Budapest, Hungary, January 2016.

[33] Nokia, "Site Connectivity Configuration for Open TAS, Open Telecom Application Server 18.5 MP3", Operating Documentation, DN09179985, Issue 6-0-0, 2019.

[34] L.Nagy, A.Hilt, L.Jánosi, G.Járó: "Analysing Efficiency of New Load Distribution Algorithm with Horizontal Scaling", *HTE Infokom conference*, Tapolca, Hungary, Oct. 2016.

[35] Nokia, "Dynamic Virtual Unit Configuration in Open TAS, Open Telecom Application Server 18.5 MP3", Operating Documentation, DN09176531, Issue 2-0-0, 2019.

[36] Nokia, "TS-TAS-SW-0116, Preparing GPLUs in Open TAS for SW upgrade on ATCA HW, IP Multimedia Products, Open Telecom Application Server, Open TAS 16.5 and 18.5", Technical Support Note, Feb. 2019.

[37] Nokia, "Migration of Native Units to Virtual Units, Open Telecom Application Server 18.5 MP3", Operating Documentation, DN09182549, Issue 6-0-0, 2019.

[38] Nokia, "Communication Matrix for Open TAS, Open Telecom Application Server 18.5 MP3", Operating Documentation, DN09172005, 2019.

[39] X.An, W.Kiess, J.Varga, J.Prade, H.Morper, K.Hoffmann, "SDN-based vs. software-only EPC gateways: A cost analysis", *IEEE NetSoft'2016,* Seoul, Korea, June 2016.