Scalability of Telecom Cloud Architectures for Live-TV Distribution

A. Asensio[1]*, L.M. Contreras[2], M. Ruiz[1], V. López[2], L. Velasco[1]

[1] *Optical Communications Group (GCO), Universitat Politècnica de Catalunya (UPC), Barcelona, Spain*
[2] *Telefónica Investigación y Desarrollo (TID), Madrid, Spain.*
**e-mail: aasensio@ac.upc.edu*

Abstract: A hierarchical distributed telecom cloud architecture for live-TV distribution exploiting flexgrid networking and SBVTs is proposed. Its scalability is compared to that of a centralized architecture. Cost savings as high as 32 % are shown.

OCIS codes: (060.4250) Networks; (060.4252) Networks, broadcast

1. Introduction

Video signal distribution is one of the stringent and more popular services that a telecom network needs to support. The bandwidth needed to convey a video stream is actually determined by its quality. In the live-TV broadcasting industry, uncompressed video streaming formats are used before video production. In a recent demonstration, the authors in [1] reported 4K Ultra-High Definition (UHD) TV video streaming over an IP network, thus enabling the migration from traditional Serial Digital Interfaces (SDI) -based transmission to all-IP environments. Notwithstanding, stringent quality of service is required since uncompressed video streaming in the 4K UHD TV format ranges from 6 to 48 Gb/s, according to ST 2036-1 [2]. In addition, 4K UHD digital cinema has been standardized and commercialized in the movie industry, while 8K quality is in the roadmap of some operators [3]; uncompressed real time 8K transmission needs 72 Gb/s connections.

Once the video has been produced, distribution to end-users is based on compressed video, which quality is adapted to the one that fits better the user's device. Compressed streams for video distribution require up to hundreds Mb/s, depending on its quality, i.e., standard definition (SD), high definition (HD) or UHD. Digital TV and online video are expected to show the higher penetration percentages among the residential services; in fact forecasts show that 79% of the global IP traffic will be related to video traffic by 2018 [4].

Video signal processing is needed to adapt a full-quality signal to players' quality. Taking advantage from the cloud infrastructure that many telecom operators have recently deployed, video signal processing can be performed in commodity hardware inside datacenters (DC) and distributed directly towards the end-users. When the telecom cloud consists of one single large DC, a large number of small flows need to be conveyed to the metro networks, which are commonly used to aggregate users' traffic. On the contrary, if several small DCs performing signal processing are placed closer to end-users, uncompressed UHD video signals need to be conveyed from the signal source to each of the small DCs over the core network.

In this paper, we study the scalability of telecom cloud architectures for video signal processing and live-TV distribution. To that end, we assume that the core network is based on the flexgrid technology and that sliceable bandwidth-variable transponders (SBVT) as well as fixed transponders (FT) can be installed.

2. Telecom cloud -based architectures for live-TV distribution

Fig. 1 illustrates the centralized and distributed architectures for live-TV distribution. In the centralized architecture, depicted in Fig. 1a, one single large DC receives an uncompressed video stream from the production facilities. Video processing and distribution in the required quality for each end-user is performed in that DC. Each compressed video stream is conveyed over the core network to the metro switch where the end-user is connected to. That fact derives in a large number of aggregated flows to be transported from the DC location to different metro segments (represented by a Layer 2 (L2) switch in this paper). To that end, a large switch needs to be deployed connecting the DC to the flexgrid core network.

In the distributed architecture (Fig. 1b), the uncompressed video stream is received in a primary large DC and is forwarded to secondary DCs placed closer to the end-users, where video processing and distribution to the end-user is performed. Compressed video streams are then aggregated into a single flow and conveyed to the corresponding metro L2 switch.

Fig. 2 depicts the configuration of the primary DC (a), metro locations (b), and secondary DCs (c). A core L2 switch needs to be installed close to each DC to perform flow switching and aggregation, adapting input flows to the core flexgrid interconnection network. We consider that SBVTs can be installed in those switches to interface optical cross-connects (OXCs) in the core network. On the contrary, FTs need to be installed to interface DCs and metro switches. It is worth noting that to properly dimension a switch, two parameters need to

The research leading to these results has received funding from the European Community's Seventh Framework Programme FP7/2007-2013 under grant agreement n° 317999 IDEALIST project.

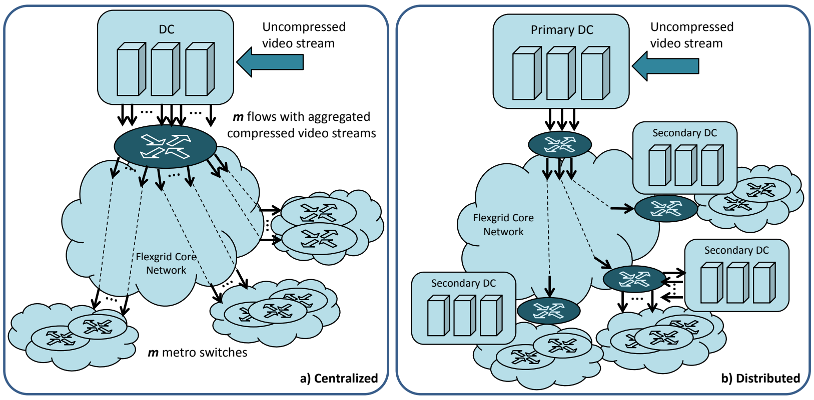

Fig. 1. Centralized (a) and distributed (b) architectures.

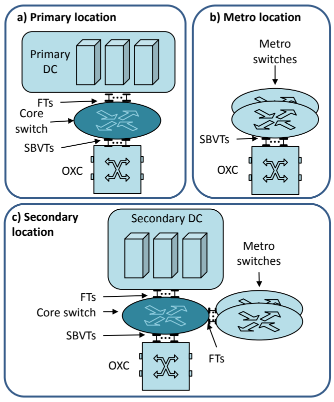

Fig. 2. Architecture details.

be considered: a) switching capacity, and b) number of card slots, each with a number of transponders. It is clear that both core L2 switch dimensioning and number of SBVTs and FTs are different in the two considered architectures. This fact motivates the study in this paper.

3. Proposed planning procedure

To compare the scalability and network capital expenditures (CAPEX) of both architectures, we propose an optimization problem for the distributed architecture targeting at finding the most cost efficient architecture, given a number *n* of secondary DCs. The problem can be stated as follows:

Given: *i*) a primary location *p; ii*) a set *M* of metro locations each containing a set of metro switches, *iii*) a subset $D \subseteq M$ of locations that can host a secondary DC; *iv*) the topology *G* of the optical network interconnecting locations in *D*; *v*) the cost structure for core switches, FTs, and SBVTs; and *vi*) an uncompressed video stream to be distributed from *p* to every secondary DC (*n*) and a set of aggregated video streams to be distributed from every secondary DC to the corresponding metro switches.

Output: *i*) the set $D^* \subseteq D$ of locations, where secondary DCs are placed, *ii*) the configuration of every core switch in terms of capacity, number of card slots and number and type of transponders to be installed, *iii*) the set of optical connections to be set up in the optical network.

Objective: minimize CAPEX when *n* secondary DCs are installed.

Aiming at solving this problem, we developed an iterative procedure, which randomly generates secondary DCs placement (set *D'*) and computes the associated solution by using the constructive algorithm in Table 1. Several iterations are performed until some stopping criteria is met (e.g. maximum number of iterations or total time).

Table 1. Constructive algorithm.

INPUT: *M, D', G, cost structure*
OUTPUT: *cost*

1: **for each** $d \in D'$ **do**
2: Find a connection from *p* to *d* on *G*
3: **for each** $m \in M$ **do**
4: **if** $m \in D'$ **then** assign all metro switches in *m* to the local secondary DC
5: **else** Find a connection from *m* to the nearest $d \in D'$ on *G*
6: **for each** $d \in D'$ **do**
7: Compute # FTs and SBVTs
8: Find the cheapest feasible switch
9: **return** Compute network CAPEX using cost structure

The cost computation algorithm firstly finds the optical connections to distribute the uncompressed video signal and the aggregated video streams (lines 1-5). Next, core switches are dimensioned according to the above connections, i.e. the sets of required FTs and SBVTs are computed and a switch with enough switching capacity and number of card slots is installed (lines 6-8). Finally, the total CAPEX is returned.

4. Illustrative numerical results

The scalability and network CAPEX of both architectures have been evaluated using a network topology based on the Telefonica's national network, consisting of 5 regional 30-node optical networks connected through a 21-node core optical network (271 nodes in total) and assuming a realistic number of users (7-8 millions). Adoption scenarios for video-technologies are based on the traffic share percentages for SD, HD and UHD forecasted in [4]. Table 2 summarizes representative values of those scenarios per year and considering connection speeds recommended by Netflix for each technology.

We assume a scenario where 8 TV channels are distributed, i.e. 8x 12 Gb/s uncompressed 4K UHD TV video streams are conveyed using 100 Gb/s optical connections. In addition, 100 Gb/s connections aggregating SD, HD and 4K UHD compressed video streams have been considered. Metro switches are connected to OXCs at regional level; the number of switches increases with the video technology adoption scenarios. 4x100 Gb/s and 1x400 Gb/s line-cards and 100 Gb/s FTs and 400 Gb/s SBVTs, capable of sourcing 4x 100 Gb/s optical connections, are considered to be installed in the core switches; the cost model in [5] for switches and FTs was used, and a SBVT cost 2.5 times that of the 100 Gb/s FTs was assumed, in line with [6].

Results for the centralized architecture are shown in Table 3, where the values of four parameters for the single core L2 switch to be equipped are presented. Both, L2 switch's capacity and number of transponders

Table 2. Technology adoption scenarios for different years.

		2015	2016	2017	2018
Traffic share	SD (3 Mb/s)	28.6%	22.0%	13.6%	7.0%
	HD (5 Mb/s)	65.7%	72.0%	70.5%	71.0%
	4K (25 Mb/s)	5.7%	6.0%	15.9%	22.0%
# users per metro switch		22,900	21,900	19,300	17,400
# Metro switches		336	357	399	441

Table 3. Representative values for the centralized architecture.

Parameter	2015	2016	2017	2018
Capacity (Tb/s)	70.4	76.8	83.2	89.6
Used cap %	47.7%	46.5%	48.0%	49.2%
# SBVTs	84	90	100	111
# FTs	336	357	399	441

Table 4. Representative values for the distributed architecture.

n	Parameter	2015	2016	2017	2018
5	Capacity (Tb/s)	12.8	12.8	19.2	19.2
	Used cap %	53.3%	56.6%	42.1%	46.5%
	# SBVTs	13	14	16	17
	# FTs	68	72	80	89
10	Capacity (Tb/s)	6.4	6.4	6.4	12.8
	Used cap %	54.1%	57.3%	63.9%	35.2%
	# SBVTs	5	5	6	6
	# FTs	34	36	40	45
15	Capacity (Tb/s)	6.4	6.4	6.4	6.4
	Used cap %	36.6%	38.8%	43.1%	47.5%
	# SBVTs	2	2	2	3
	# FTs	23	24	27	30

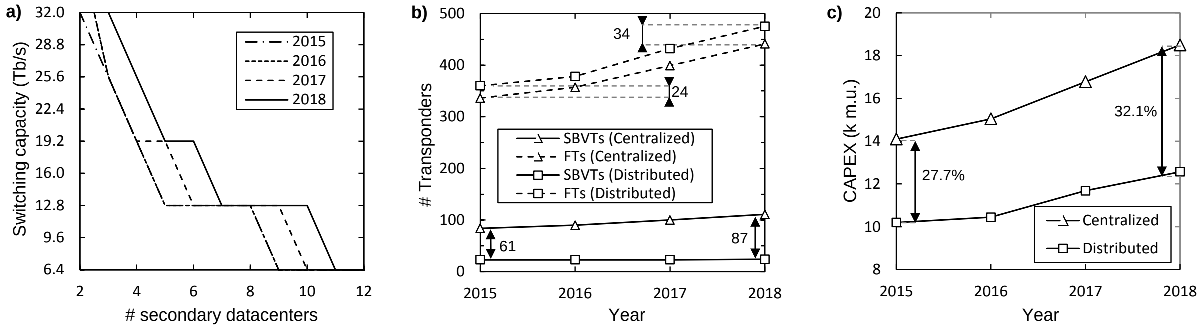

Fig. 3. Average switching capacity (a), total number of FTs and SBVTs installed (b) and total network CAPEX (c).

increase with the increasing number of metro switches required, being the capacity that needs to be installed in the stringent scenario as huge as 89.6 Tb/s.

Table 4 details the configuration of each secondary DC for the distributed architecture, for different number of secondary DCs (*n*) ranging from 5 to 15. As expected, the capacity of every core L2 switch to be installed in each secondary DC location is much lower than in the centralized architecture, being as low as 6.4 Tb/s. Fig. 3a plots the required capacity of individual switches vs. the number of secondary DCs. It is clear that the capacity of every L2 switch in each secondary DC decreases with *n*.

Regarding transponders, those to be equipped in the switches in the secondary DCs and in the primary location need to be accounted. For instance, 13*5+ceil(5/4) = 67 SBVTs are needed for *n*=5, whereas 2*15+ceil(15/4) = 34 SBVTs are needed for *n*=15 in 2015. Hence, noticeable reductions in the number of SBVTs are observed, whereas the number of FTs increases when *n* increases. To fairly compare the centralized and the distributed architectures, we got the solution minimizing the total CAPEX in the distributed architecture; these solutions where for *n* = 18, 18, 18, and 19, from 2015 to 2018, respectively. Fig. 3b plots the total number of transponders to be equipped in the centralized and the distributed architectures. The amount of FTs is slightly higher in the distributed architecture; the difference ranges from 24 to 34. However, the number of SBVTs to be installed in the centralized architecture is always higher than in the distributed, being the difference as high as 87.

Finally, Fig. 3c plots the total network CAPEX for both architectures in monetary units (m.u.). Network CAPEX is lower for the distributed architecture under the evaluated scenarios. As soon as HD and 4K UHD streams to be distributed start representing a significant portion of the total traffic, and thus, more metro switches are required, savings increase up to 32% in the most stringent scenario. This is as a result of the combined effect of the increasing switching capacity of the single L2 switch and from the ever increasing number of SBVTs to be installed in the centralized architecture.

5. Conclusions

Two different telecom cloud architectures for live-TV distribution have been studied: the centralized and the distributed architecture. From the results, the distributed architecture scales the best. Moreover, the number of SBVTs to be installed is noticeable lower, which results in a lower total network CAPEX for the distributed architecture.

References

[1] F. Poulin et al., “Ultra High Definition TV Over IP Networks,” EBU Technical Review, 2014.
[2] ST 2036-1 "Ultra High Definition Television — Image Parameter Values for Program Production," SMPTE, 2009.
[3] S. Namiki et al., “UHD video transmission and extremely Green Optical Networks for Future”, IEEE Sel. Top. in Q. Elect. 2011.
[4] Cisco, “Cisco Visual Networking Index,” 2014.
[5] F. Rambach et al., “A multilayer cost model for metro/core networks,” OSA JOCN, 2013.
[6] L. Velasco et al., “Finding an Objective Cost for Sliceable Flexgrid Transponders,” OFC, 2014.