Evaluation of Technological Solutions and Requirements for Cloud TV Services based on Decision Support System

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Abstract—Cloud TV will play an important role in future pay TV services and is quickly becoming the next arena for TV content providers. This emphasizes the need for a technology roadmap in order to address several key issues that may affect the deployment of future Cloud TV services. Three alternative technologies, namely Internet Protocol TV (IPTV), Over the Top (OTT) and Smart TV have been investigated and ranked using the Analytical Hierarchy Process (AHP). The results indicate that OTT service via cloud infrastructure seems to be the most efficient and valuable choice and also reveal an important blend of social, economic and technological requirements that have to be taken into account when deploying and/or adopting Cloud TV services from a pay TV operator. Finally, a sensitivity analysis is performed in order to investigate the stability of the obtained results and the accuracy of the approach. The findings of the current paper will be an important guide for the development of Cloud TV solutions and the improvement of the already deployed.

***Index Terms*—Decision making, Cloud TV, Technology Roadmap, Requirements, OTT, IPTV, Smart TV, Sensitivity Analysis**

Introduction

Cloud computing has already gained ground across the business market, as an innovative, agile and elastic provisioning model for Information and Telecommunications (IT) resources. Enjoying their second decade of existence, maturing cloud technologies have reformed the expectations and capabilities of the IT industry expected to play a crucial role in the new era of the Internet of Things (IoT) (Gubbi, Buyya, Marusic, & Palaniswami, 2013). In a IoT world with billion connected devices, the classic distribution networks are migrating in a broadband environment through the cloud computing services. The broadcasters and the communication operators who want to offer video services are faced with a daunting task: ensuring the live and on-demand video on any device. The operators that want to capitalize this change need a complete television platform based on cloud computing (CTV), that drastically reduces the time to market and increases the revenues.

Cloud TV (CTV) is a software platform that virtually depicts the functionality of a STB (Set-Top-Box) (Dawi, Jusoh, Nor, & Qureshi, 2016), allowing pay TV (Xiao, Du, Zhang, Hu, & Guizani, 2007) operators and other video service providers to bring advanced user features for online videos, such as YouTube and Hulu. CTV is implemented on existing cable TV, next generation of cable TV sets, Internet Protocol Television (IPTV) decoders (Nielsen & Fletcher, 2020) and any other connected consumer electronics.

TV service providers already have the experience of modern television content, but flexibility, cost reduction and high-quality services are crucial needs that have to be captured in future TV services. Flexibility is an issue of paramount importance for modern television content providers in order to be able to convert the TV content to Live TV, Video On Demand (VOD), Catch-up, or Social Networking, offering the best possible quality (Noam, 2014). CTV is the technology that offers cloud-based TV products and facilities in any client equipment that is connected to Internet even this is a legacy STB or an Over the top (OTT) TV device. OTT is a media distribution practice that allows a streaming content provider to distribute TV content, and other media services directly to the consumer over the internet via streaming media as a standalone product based on unmanaged (public) network without a dedicate Set Top Box but only a media player box (e.g android box).

CTV is the place where content is ingested, transcoded, encrypted, and delivered. Operators can manage subscriber settings, acquire knowledge about specific customer segments and provide users specific content offerings. In the context of technological evolution from content ingestion to delivering end-user content and service enrichment, CTV offers an effective transition for pay TV operators who want to invest in the TV industry without much risk.

The main objective of this paper is to investigate the cloud based TV services, offered by cloud vendors, explore the key requirements that may affect the deployment/adoption of CTV services from a Pay TV operator and evaluate three alternative technological solutions for CTV, namely IPTV, OTT and smart TV (Gerdsri & Kocaoglu, 2007). Smart TV is a technological convergence between computers and flat screen television sets and STB. Besides the traditional functions of television sets and STB provided through traditional broadcasting media, new smart TV models can also provide Internet TV, online interactive media, OTT, as well as on-demand streaming media, and home networking access. Legacy TV is being replaced by IP connected Smart TV that offers more advanced computing ability and connectivity and allows users to install and run applications. Smart TV is called the fourth screen coming up with PC, Pad and smartphone. With high market penetration, good configuration and network features, smart TV provides a broader platform for VOD applications without the need of using STB and is based on unmanaged (public) network. IPTV is a service that provides television programming and other video content using the TCP/IP protocol suite as opposed to traditional cable or satellite signals. An IPTV service, typically distributed by a service provider, delivers live TV programs or on-demand video content through managed (private) network. An IPTV system with a dedicate STB is used to provide video content over a private network in an enterprise, although such implementations are far less common than subscriber-based models due to complexity and scaling issues. Except from IPTV, the other two technologies give the opportunity to clients to select any telecom provider for Internet connection.

In this paper, the aforementioned three alternative technologies that can offer TV content to clients, using the cloud architecture are evaluated and crucial requirements that may affect the deployment as well as the adoption of VTV services are highlighted. Towards this end, the framework of the analytical hierarchy process (AHP) is used as a fundamental part of an effective technology roadmapping (Saaty, 2008) (Staneket, 2015). Technology roadmapping is widely adopted in industry, government, and academia for providing a way to develop a technology strategy, identify gaps and opportunities in research development, and plan for resource allocation (Staneket, 2015). The three alternative deployment scenarios of CTV are identified and ranked based on AHP, which has been used around the world in a wide variety of decision and roadmapping situations, in fields such as government, business, industry, healthcare and education (Song & Pang, 2014). The importance of the various requirements involved is evaluated and discussed revealing an important blend of economic, social and performance related aspects that may influence the deployment of CTV platforms. The obtained results form a key part of future CTV solutions and implementations as well as a useful guide for pay TV operators in order to invest in CTV services. These findings will also be very helpful for pay TV operators that have already deployed CTV services, as a useful guide of improvement.

The current paper implements and verifies an open and transparent roadmapping model for CTV solutions, emphasizing on crucial interdisciplinary aspects of cloud operation. There are previous relevant studies using the Business-Model-for-Information-Security (BMIS) method in order to capture the risk analysis of using Cloud technology in multimedia streaming (Song & Pang, 2014) but there is no previous work aiming at the development of an effective CTV roadmap highlighting the crucial requirements. A sensitivity analysis is also performed in order to investigate the stability of the results and the accuracy of the approach.

The rest of the paper is organized as follows. In Section II, the motivation behind the roadmapping effort for CTV is analyzed. Section III deals with the methodology description, whereas the obtained results are discussed and analyzed in Section IV. Sensitivity analysis is performed in Section V and some concluding remarks are given in Section VI.

Motivation for a CTV roadmap

Today’s industries of pay TV services are based on legacy technologies providing services through satellite networks. In recent years, legacy TVs have been replaced by IP-connected smart TVs that offer advanced features and especially the ability to install applications for a particular TV content platform. During the last years, new hybrid solutions that take advantages of the network capabilities, can support new innovative features. These features are replay TV, time shifting, VOD, recommendation engines and social media interaction (Abreu, Nogueira, Becker, & Cardoso, 2017). Before this hybrid solution, consumers had a passive experience and there was no possibility to customize the content according to their needs (Research, 2020).

The television and media industries are an ever-changing and rapidly evolving landscape. Consumer behavior imposes this swift evolution, with users no longer wanting a passive experience but the ability to interact with content on their own terms. Ubiquitous access – "anywhere, anytime, any platform" and a demand for a personalized experience has a huge effect on established broadcasters and operators.

The last few years a new innovated technology has been adopted from many pay TV operators, this of CTV. This technology seems to be the appropriate solution optimizing the user experience. The deployment of CTV can ensure fast time-to-market plan for a new pay TV operator with low cost entry and especially low Capital expenditure (CAPEX). This is due to the reduction of hardware equipment on operator's premises. Consolidation and centralization into a single modular platform is another new feature compared to the legacy platforms. Some other significant benefits of CTV are scalability, portability and security.

There are also crucial aspects that have to be considered when investing in CTV solutions. The problem of the equipment location in case of troubleshooting has to be considered, but the Service Level Agreement (SLA) between vendors and pay TV operators may overcome this disadvantage. Management of customer database is another crucial issue of high concern, since it has to be migrated to the systems of the vendor. One more issue is the integration of the provisioning systems managing the billing and subscription operations. In addition, the latency of the signal and the high transmission capacity are crucial technical factors, especially for live events that could affect the customer experience and form undesirable Key Performance Indicators (KPIs).

An overview of CTV infrastructure is presented in Figure 1 (Cabała, 2010). The incoming signal of live TV content and VOD assets are encoded or transcoded using the appropriate equipment and are ingested in order to be delivered through Content Distribution Networks (CDNs) to reach end-user devices. These devices can be STBs, tablets, smartphones or smart TVs.

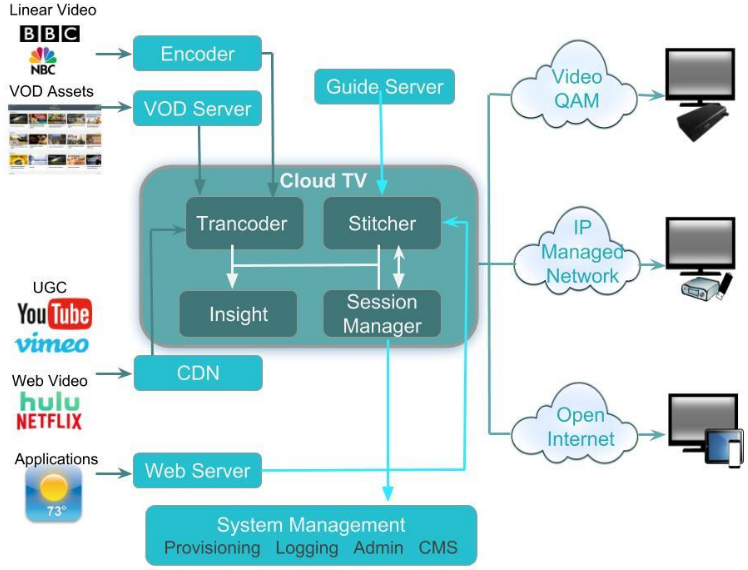

Figure 1 CTV infrastructure overview

Cloud Technology for TV solution can support a multitude of devices, platforms and networks. In general, CTV provides new features and business models. Regarding the content distribution there is a need to include infrastructure as Multi-CDN, real time CDN selection for best user video experience content protection. The aim is to meet content providers' requirements (watermarking, output control), Confront piracy Video and User Analytics, OTT QoE-Quality of Service. In addition, some important features are Reco Engines, Deep learning driven efficient content personalization. A fully Cloudified architecture comprises automation, Orchestration, Scaling in and out on demand deployable everywhere on standard hardware and clouds.

An overview of services and systems regarding the CTV infrastructure is presented in Figure 2:

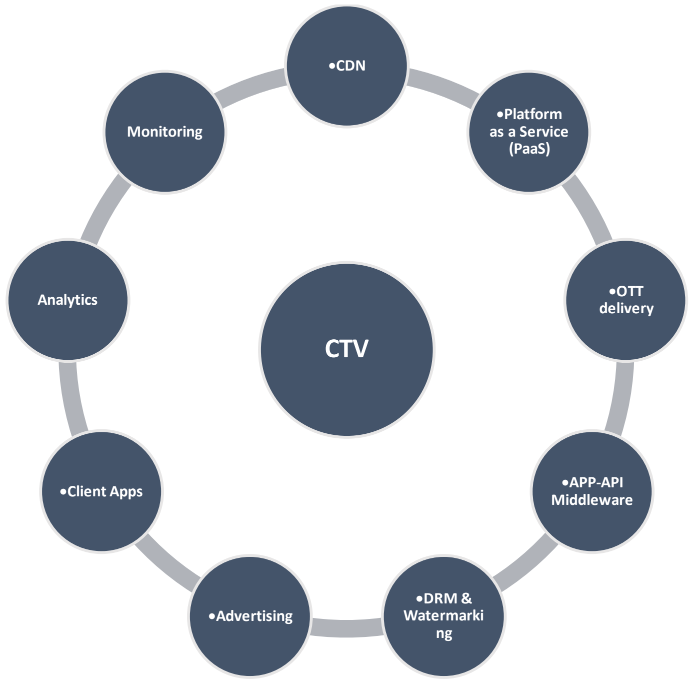

Figure 2 CTV Services

CTV technology enhance business strategies with getting instant and comprehensive visibility into the business performance. It also provides easy identification of the products and content according to the preferences of the viewers. Using these insights, operators can optimize their marketing strategies in order to increase their revenues. CTV can measure and optimize the effectiveness of the different sources of content discovery with searching, recommendations, promotions and catalog exploration. Based on the above, providers will be able to improve their viewers' experience and increase engagement levels. Moreover, the end users may use best-in-class content discovery to personalize recommendations for VOD and Live content. Outstanding TV experiences on mobile devices, PCs, connected TVs can also be delivered. Pay TV operators can maximize their revenues by leveraging a rich set of business models. From the common SVOD (Subscription Video On Demand) and Live packages, to sophisticated seasonal passes and advanced service bundles, they will be able to engage specific audiences. They could also utilize ad-supported business models like AVOD (Advertising Video On Demand) to expand their user base and diversify revenue sources.

CTV is a technology capable of dealing with all of the above challenges and even more, offering flexibility in order to expand user experience. It also promises enhanced security, thus allowing the fight against the weakness of card-based encryption technologies. Every commercial and technical director on a television content provider services should take seriously the CTV technology and all the offered benefits. For example, Deutsche Telekom **Error! Reference source not found.** has invested considerable amounts in analyzing the technical and commercial capabilities of CTV and concluded that the cloud will become one of the key elements of its future network and service strategy.

The vastly distributed nature of IoT applications will require additional investments in computational and communication infrastructure. In this context, pay TV operators are expected to invest in CTV, will is expected to play an important role in future smart home networks.

In this paper, three alternative CTV technologies, as discussed in session II, have to be evaluated and rated according to the opinion of experts and the key requirement for the deployment and adoption of CTV services from Pay TV operators are explored.

Methodology description

In order to evaluate the three alternative scenarios for CTV technologies, namely IPTV, OTT, Smart TV and explore the key requirements for CTV services, one may consider the problem from a decision making point of view and apply the AHP framework. The hierarchy levels of AHP are presented in Figure 3. The first level deals with the definition of the objective for evaluating the technologies. In this paper, the main objective is to develop a roadmap for CTV, rating three alternative scenarios and understand the relative importance of various critical requirements related.

In the second level, a number of requirements' categories $C_k(1 \leq k \leq N)$ on which the evaluation will be based, is identified. Each category may be an important aspect of the decision making problem. Performance and Economic issues may be representative requirements' categories of CTV. The specific requirements F_{jk} $(1 \leq j \leq J_k)$ that identify each category are defined in the third level of the hierarchy. Latency and hardware may be indicative requirements under the performance category. Finally, the alternative scenarios Ai $(1 \leq i \leq R)$ are presented in the fourth level of AHP hierarchy $(1 \leq i \leq R)$ are presented in the fourth level of AHP hierarchy.

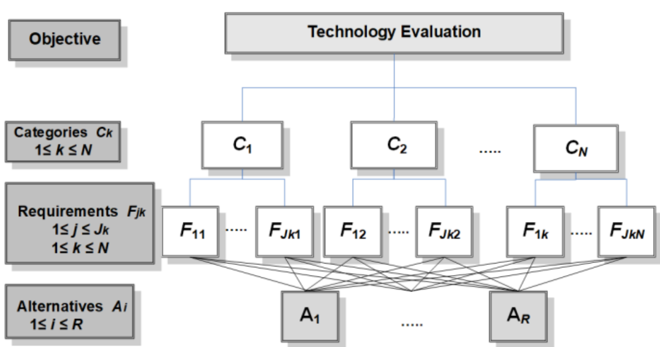

Figure 3 AHP hierarchical model

In order to rate the alternative technologies, one must first evaluate the weights of the categories and requirements. Each expert m $(1 \leq m \leq M)$ compares all possible combinations of C_k by filling out the pairwise comparison matrix (PWC) containing the upper triangular elements P_{ij} of an N x N matrix $\mathbf{P}^{(m)} = [P_{ij}^{(m)}]$, which signify the importance of C_i compared to C_j. The expert needs to complete only the upper triangular elements $(i<j)$ of $\mathbf{P}^{(m)}$ since PWC is a reciprocal matrix and hence $P_{ij}^{(m)}=1/P_{ij}^{(m)}$ and $P_{ii}^{(m)}=1$. The weights $w_k^{(m)}$ of category C_k according to expert m can be calculated with

various ways [i]. The most widely adopted approach is to solve the eigenvalue problem $\mathbf{P}^{(m)}\mathbf{x}_q^{(m)}=\lambda_q\mathbf{x}_q$, where λ_q are the eigenvalues of $\mathbf{P}^{(m)}$ and $\mathbf{x}_q^{(m)}=[x_{pq}^{(m)}]$ are the corresponding eigenvectors. Assuming that the eigenvalues are ordered so that λ_1 is the largest eigenvalue, then the weight of category C_i is estimated by normalizing the elements of the principal eigenvector $\mathbf{x}_1^{(m)}$ as $wk^{(m)}=x_{1k}^{(m)}[\sum_{m=1}^{M} x_{1k}^{(m)}x_{1l}]^{-1}$. In order to further simplify the comparisons, (Saaty, 2008)introduced the nine-level scale shown in Table 1. After all the comparisons have been completed, the average weight w_k for each category C_k is calculated by averaging out the weights $w_k^{(m)}$ obtained by the M experts, $w_k^{(m)} =1/M\, \Sigma w_k^{(m)}$. Care should be taken so that the pairwise comparison matrices produced by the experts are as consistent as possible. The PWC matrix $\mathbf{P}^{(m)}$ is said to be perfectly consistent if all its elements are of the form $P_{ij}^{(m)}=q_i^{(m)}/q_j^{(m)}$, where $q_i^{(m)},q_j^{(m)}$ are positive real numbers. The consistency ratio (C.R.) is one measure for consistency can be readily obtained from the pairwise. The comparison matrices as described in (Mu & Pereyra-Rojas, 2017). In our case, the C.R. values were less than 0.1 which is considered acceptable (Commision).

Intensity	Definition	Explanation
1	Equal importance	Two elements contribute equally objective
3	Moderate importance	Slightly favor one element over another
5	Strong importance	Strongly favor one element over another
7	Very important	Very strongly favor one element over another
9	Extreme importance	Extremely favor one element over another
2,4,6,8	Intermediate values	Intermediate values of the above

Table 1 Scale 1-9

A similar procedure is followed for the estimation of the weights of the requirements f_{jk} of each category. Finally, the alternatives are pairwise compared according to each requirement and for each alternative A_i one obtains the relative scores S_{ijk} under requirement F_{jk}. The final ranking priorities A_i of each alternative are evaluated by multiplying the relative scores S_{ijk} by the overall weight $f_{jk} \times w_k$ of the corresponding requirement as follows:

$$A_i = \sum_{k=1}^{N} \sum_{j=1}^{J_k} S_{ijk} f_{ijk} w_k \qquad (1)$$

Results and Discussion

In this section the crucial requirements that may affect the deployment and adoption of CTV services from a pay TV operator are examined and analyzed. For the needs of the present paper a survey platform was developed in order to perform the surveys.

Survey design

The survey design including the definition of categories and requirements was based on a thorough inspection of previous literature, the market needs and was extensively discussed among representatives of several telecommunication providers in Europe (such as OTE, France telecom, Deutsche telecom). The feedback from the telecom operators was interesting enough and very useful for the final survey design as they emphasized on the definition of criteria and factors taking into account the user perspective in both the performance-related issues and the socio-economic aspects. Eighteen experts have participated in structured PWC surveys.

Development of decision support platform

The survey was conducted by a web-based decision support platform incorporating all elements of the AHP framework where experts log on to the platform and fill out the questionnaires, as presented in. The web platform has been developed by the authors and maintained in the Harokopio University of Athens, as presented in Figure 4. The data supplied by the users are saved in a database and the survey designer can perform the AHP algorithm in order to estimate the weights and the priorities according to the equations that signify the importance of criteria and factors according to the methodology.

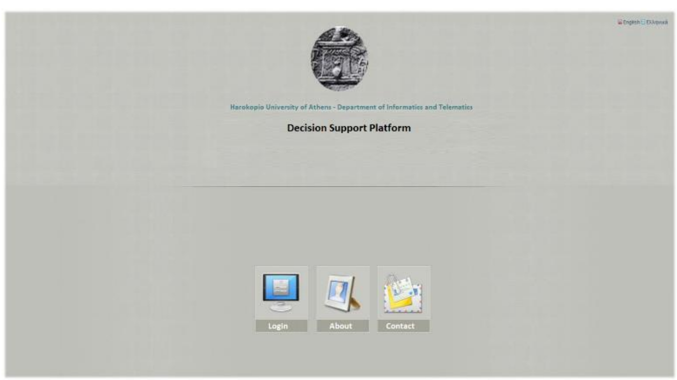

Figure 4 Decision Support Platform

Requirements for CTV Services

The results are based on the outcomes of PWCs for the evaluation of the importance of the categories and requirements, as presented in Table I. The weights of requirements' categories are depicted clearly in Figure 5. According to the opinion of the experts, all the categories, except from Security and Reliability, seem to have more or less the same weight of importance (ranging between 8% to 16%), suggesting that all corresponding issues have equal bearing.

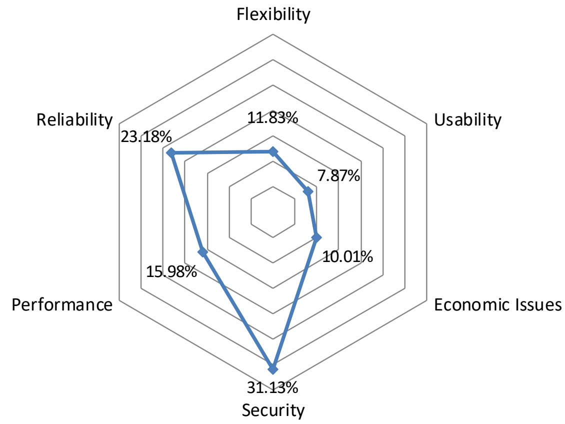

Figure 5 Requirements' Categories Weights

Security seems to take the precedence over the other categories, emphasizing the need of end users for reliable products since they want to request unceasing services from anywhere and anytime without any kind of malfunction. Security is at the top of expert's concern, taking into account that confidentiality, integrity and authentication are requirements that have to be very well considered, by pay TV operators. This is also very important for the end-users, because personal data are required for the provisioning system that handles and process these data in order to give them access to the content. According to GDPR regulation (Gupta & Kumar, 2014) all these personal and private data must be carefully under processing with encrypted methods such as hashing (Reddy & Saida, 2014)and anonymity **Error! Reference source not found.**. Regarding the system trustworthiness/confidence of CTV, it is clear that security issues are the most important aspects to consider reflecting the high customers concern on this subject. Security category is significant for Pay TV operators to prevent the incensement of piracy which leads to loss of profits.

The Reliability category has the second highest weight, emphasizing the need for providing reliable, uninterruptible services and also high availability to customers. Experts seem to believe that this category is very important for an existing or new Pay TV operator, who wants to choose a CTV vendor. The Reliability of cloud providers builds strong ties between the company and the customer as the uninterruptible service delivery is crucial for the customer experience. In case of unreliability, the impact on the company and its reputation will be negative. Live TV and VOD services must always be available to the customers with all the add-on features. Even though the other requirements' categories have minor severity, performance is the third most important category (~16%) as it affects the user experience.

Finally, the Usability category has the less importance impact for the decision of choosing a CTV vendor, since it depends not only on the provided services, but also on the end user device. As devices like tablets or smartphones are rapidly change, the usability is kind of a requirement that has to be relied to manufacturers with the respective hardware capabilities and software as well. The results are presented in Table 2.

Requirements		**Description**	**Weight**
C1 Flexibility (11,83%)			
F_{11}	Interoperability	Interoperability between the different platforms (IPTV / OTT/ Smart TV).	53,70%
F_{12}	Portability	Portability of services that offers in order to cover a wide range from different mobile devices.	21,06%
F_{13}	Scalability	Supports a wide range of TV channels.	25,24%
C2 Usability (7,87%)			
F_{21}	Accessibility	Supports highest degree of access to their clients.	42,97%
F_{22}	Content Control	Controls the TV content to the customer.	25,52%
F_{23}	TV Software App	The usability of the application that end-users experience.	31,50%

C3 Economic Issues (10,01%)			
F_{31}	Pricing Model	The pricing model followed by each cloud TV provider.	34,47%
F_{32}	Costs saving	The cloud providers should clearly state in the contract the resources that they use and what are the requirements from the client's side. (Capex/ Opex).	36,45%
F_{33}	Time-to-market	The time-to-market plan that cloud vendors promise.	29,08%
C4 Security (31,13%)			
F_{41}	Protection	The security offered by the cloud TV vendors in relation to their infrastructure.	41,11%
F_{42}	IT Compliance	Customer must consider the security policies of Cloud TV providers and how the internal compliance of the vendors meeting the standard's client.	17,85%
F_{43}	Data Security	Applicant cloud providers should explicitly state the encryption method to be used.	41,03%

C5 Performance (15,98%)			
F_{51}	Latency	Cloud TV providers accurately determine the latency to be present in the broadcast of live TV programs.[1]	50,91%
F_{52}	Software	Performance of the software tools that provide for Transcoding, Encoding/Decoding, Ingestion of TV assets and linear TV Channels.	28,01
F_{53}	Hardware	Technical characteristics of equipment.	21,09%
C6 Reliability (23,18%)			
F_{61}	Service Level Agreements (SLAs)	The SLAs that indicate the availability of vendors and the response time in the event of problems occurs.	36,21%
F_{62}	Availability	The availability of TV channels, VOD content, availability of Smart TV applications and the extra features such as social networks.	41,77%
F_{63}	Service Management	Providers should be trustworthy when, by their own means, supervise and control the television services.	22,02%

Table 2 Requirement's Result

It is also interesting to examine the weights of the specific requirements under each category. Regarding Flexibility category, experts seem to be more concerned about the interoperability, as its weight reaches 53.7%. They probably believe that complete interoperability between the different platforms (IPTV / OTT/ Smart TV) and devices (Ios/Android), offering the same TV services with the same features to the end users, is a very important requirement which may affect company's smooth operation and provide great customer's experience. The other two requirements, namely portability and scalability seem to be very close (21,06% - 25,24%) having the same significance (half of the interoperability weight). The big goal is to allow content to be consumed on TV and multiple screens using new multimedia dongles and connected devices.

Concerning the weights of the requirements under usability category, accessibility seems to take the precedence over the other issues, with a weight of 42,97%. This is an indication that the experts tend to think that CTV providers shall guarantee the highest degree of access to their clients (television service providers) so that they are able to draw as much information for all the different TV platforms. The CTV vendors should also be able to predict future increase of accessibility due to increased business activities of their clients. This is of paramount importance for the pay TV operators in order to implement their business plan in line with market requirements. TV Software App seems to be another important requirement, since usable applications of end-devices (STBs IPTV, OTT with smart phones / tablets and smart TV's), determine the user-friendliness of application features. TV Apps provide customizable mobile apps for TV Everywhere and Video multi-screen services. Using CTV one can get up and running swiftly, with minimal costs. Personalization of the product using customizable applications, reflecting the company's brand, is easily aligned with the service provider's offering.

Regarding the Economic category, the Cost saving has the highest importance related to the other two requirements, emphasizing its role as a motivation for potential investment. This requirement, according to experts' opinion, is considered of high priority, if we tend to think that cloud providers should clearly define the resources to be used (Hardware, software, infrastructure in general) and the requirements from pay TV operator's side (CapEx/ OpEx) in the contract. There must be a definition and a clear statement according to the required equipment to be installed in operator's premises and the kind of services that CTV vendor is going to implement and support. There is also another concern on the operational part including the monitoring systems and technical staff that will support and guarantee the functionality of services. This is something that will determine the financial planning and budget estimation. In addition, time-to-market has the lowest rating among the three requirements of Economic category, because all providers can guarantee that products and services will be available to the customer in a short time without large deviation. The economic issues seem to be very significant from any point of view and should be carefully examined.

Regarding the Security category, experts consider that datacenter protection and data security have equal importance (41,11% - 41,03%). The datacenter has to be privately owned or rented and provide physical security to the highest degree. Concerning data security, cloud providers should explicitly determine the encryption method in television services and predict a potential loss of profits in case of future upgrading of encryption systems and tracking tools for locating pirate sites. The providers should offer a great variety of high quality products and services; content services need to support a wide variety of business models. Towards a trust relation between the providers and the content owners, there is a crucial need for intricate rights management and content protection from distribution among every type of device.

According to the above, the vendors have to optimize and enforce complex right schemes based on device type, number of streams, views, geographical and other aspects. It is also very important to prevent content theft during content delivery through managed and especially unmanaged networks as well as during consumption, using off-the-shelf consumer devices. It is rather crucial the content owners and service providers to recover their premium content investment, in case of damage due to online piracy. Finally, interoperability with 3rd party DRM (Digital Rights Management) solutions is critical for success if a new model of client device is launched to the market.

Regarding the Performance category, the experts seem to be more concerned about the latency rather than hardware or software requirements. What experts think is that providers shall accurately determine the latency to be present in the broadcast of live TV programs. Additionally, specific development by engineering department is necessary in order to reduce the delay time to the lowest possible value, since customer experience is greatly influenced. An important consideration is how much delay time will affect the end user, when a live soccer match is ongoing and there is a delay of about 8 seconds. Therefore, network quality is the most important value that has to be examined from network analytics engineers, so as to design the topology and any media delivery network infrastructure to optimize and guarantee the best streaming usage.

Software has been rated higher than hardware (28,01% vs 21,09%), being more considerable according to the performance of software tools that used to provide Transcoding, Encoding/Decoding, Ingestion of TV assets and linear TV Channels. A good software at the client side can also expose assets, through a friendly catalog, that proactively displays relevant content to the customer base, increasing revenues and satisfaction.

Regarding the last category, Reliability, experts consider that availability is the most important requirement (41,77%) because it is the great goal of every vendor to provide any kind of variable content from anywhere and anytime that customer asks for. Vendors have to optimize content acquisition because clients should be able to watch the content that interests their viewers. CTV can provide rich delivery and management capabilities, including content remodeling, content protection and delivery. TV applications must be available for mobile devices, computers, and any streaming devices. The high quality hosting includes high availability and a fully secure infrastructure is necessary for providing auto scaling capability allowing content availability. Service Level Agreement (SLAs), rated second, is an important requirement for CTV, because vendors shall provide to pay TV operators continuous and effective technical support, through global technical platform, without fail, every time, which ensures smart home network stability and long-term service development to the utmost level. Moreover, vendors are committed to high-level SLA of service restoration and problem rectification, providing services such as high-level preventive maintenance initiatively, and promoting customer care to further enhance customer satisfaction.

Relative Scores of Requirements for each Technology

Table 3 illustrates the results of the surveys regarding the relative scores for each architecture (OTT, SmartTV, IPTV). Eighteen additional surveys were carried out in order to evaluate the technological architecture and the desirability applications, required for the estimation of the technology values for the various alternative technologies.

Relative Score for each Requirement			Weight
C1 Flexibility			
RS11	OTT	Interoperability	40,28%
RS21	SmartTV		19,23%
RS31	IPTV		40,49%
RS12	OTT	Portability	66,52%
RS22	SmartTV		20,68%
RS32	IPTV		12,80%
RS13	OTT	Scalability	43,56%
RS23	SmartTV		21,90%
RS33	IPTV		34,54%
C2 Usability			
RS11	OTT	Accessibility	50,72%
RS21	SmartTV		23,24%
RS31	IPTV		26,04%
RS12	OTT	Content Control	41,92%
RS22	SmartTV		26,29%
RS32	IPTV		31,79%
RS13	OTT	TV Software App	44,92%
RS23	SmartTV		35,11%
RS33	IPTV		19,97%
C3 Economic Issues			
RS11	OTT	Pricing Model	48,44%
RS21	SmartTV		23,36%
RS31	IPTV		28,20%
RS12	OTT	Costs saving	53,86%
RS22	SmartTV		22,49%
RS32	IPTV		23,65%
RS13	OTT	Time-to-market	57,88%
RS23	SmartTV		22,65%
RS33	IPTV		19,47%
C4 Security			
RS11	OTT	Protection	45,80%
RS21	SmartTV		21,00%
RS31	IPTV		33,20%
RS12	OTT	IT Compliance	43,16%
RS22	SmartTV		24,05%
RS32	IPTV		32,79%
RS13	OTT	Data Security	54,09%
RS23	SmartTV		21,87%
RS33	IPTV		24,03%

C5 Performance			
RS11	OTT	Latency	39,80%
RS21	SmartTV		22,58%
RS31	IPTV		37,62%
RS12	OTT	Software	44,38%
RS22	SmartTV		21,66%
RS32	IPTV		33,96%
RS13	OTT	Hardware	34,47%
RS23	SmartTV		23,01%
RS33	IPTV		42,53%
C6 Reliability			
RS11	OTT	Service Level Agreements (SLAs)	33,15%
RS21	SmartTV		21,78%
RS31	IPTV		45,08%
RS12	OTT	Availability	32,88%
RS22	SmartTV		20,50%
RS32	IPTV		46,62%
RS13	OTT	Service Management	32,28%
RS23	SmartTV		20,99%
RS33	IPTV		46,73%

Table 3 Relative scores of alternatives

With respect to the first category, Flexibility, experts believe that for interoperability requirement, OTT and IPTV technologies take the precedence and this is reasonable if we tend to think that there are several supported models on the market while market televisions have not yet all the possibilities to support pay TV. Regarding portability requirement, OTT technology has the highest rate, and it is the one that can clearly support it without problem. Considering scalability, OTT has the highest relative score while Smart TV comes third.

As far as Usability category is concerned, OTT technology is rated higher than the other alternatives for the accessibility requirement. According to the market trend and the functionalities of mobile phones and tablets that are evolving rapidly, these are the devices that can more easily support access to pay TV and its services. This stands for Content Control and TV Software App. Especially, regarding the TV Software App, IPTV technology has the lowest rating since it is considered the most outdated and all applications can now be supported without the need for a device next to our TV.

Concerning the economic issues, experts believe that for all requirements, OTT takes the overall precedence, reaching 57.88% for time-to-market requirement. In fact, OTT is widely adopted in the market and it is a technology that pay TV operators can join in a very fast time. There is also no special need and no major changes and significant difficulties in placing the product in the market if you are targeting the OTT service. On the other hand, IPTV technology seems to have the lowest relative score for Economic issues.

As far as the Security category is concerned, the OTT scenario is also at the forefront of the comparison, reaching its maximum value for the data security requirement of 54.09%. IPTV comes second for all security requirements. This is reasonable if we consider that OTT technology can more easily hijack and cause the illegal distribution of content to many users through Internet. In other words, piracy from malicious users is more often for OTT accounts and can easily implemented to distribute illegal content to the market.

Regarding performance category, the experts believe that both OTT and IPTV scenarios have the highest relative score for latency, the most important requirement of this category. Experts seem not to pay much attention to the smart TV scenario since, on the one hand, there is very little market penetration for this technology and on the other hand the home network is considered more stable in terms of speed and more reliable without great fluctuations affecting the performance of the content. In contrast to OTT devices, access to content, either for live or VOD, can be made from many different networks that may not be on the client's premises such as external Wi-Fi (Wireless Fidelity), 3G, 4G, sensitive and vulnerable to delay, which affects the quality of the service.

As far as Reliability category is concerned, IPTV technology scenario is rated higher than the other two for all the requirements. In fact, for SLAs, availability and service management, the percentage is almost the same and reaches 45%. OTT is the second highly rated technology for this category with a score of almost 33% for all the requirements. It is rather reasonable that the most traditional technology already been tested for a long time seems to provide more reliable customer service.

Figure 6 presents the relative scores of the three technologies for all the requirements.

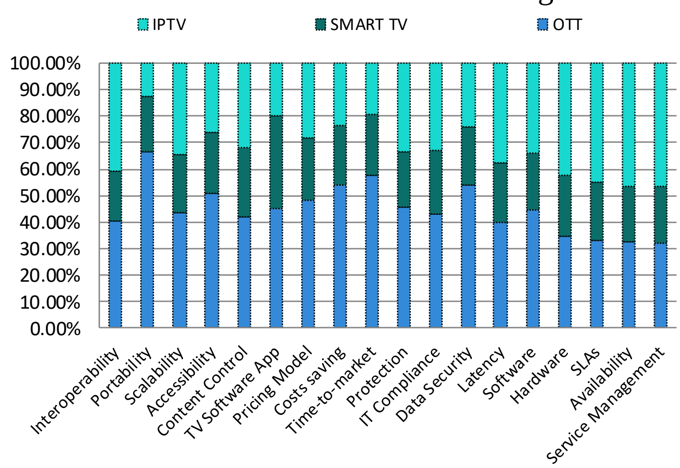

Figure 6 Analysis for relative scores for the alternative technologies

According to the opinion of the experts, portability and service management have the highest and the lowest relative score, respectively, for the OTT technology. Considering Smart TV, TV Software App rates highest and interoperability comes last. Interoperability, however, should be considered as an important requirement because there are many manufacturers of smart TV industry and for this reason has to be examined furthermore for the development of CTV using Smart TV technology. Regarding IPTV, experts believe that service management has the highest ranking and portability the lowest. This estimation seems to be reasonable, since portability issues are not so relative to the IPTV android boxes. Availability has also a high relative score as IPTV technology depends on the good functionality of android box, based on hardware functionalities.

Technology Evaluation

Figure 7 shows the ranking priorities of the five alternatives calculated based on the weights of the categories and requirements estimated in the previous section. The experts have judged that OTT scenario rates with the highest priority over the other two. According to the nowadays trend, the usage by population groups and the market movement in the particular telecommunications industry, OTT devices have the greatest penetration for the general public. OTT devices support flexibility, portability, functionality, rapid upgrading and adaptability to new trends and applications. OTT technology also offers low latency, content and personal data security, great usability and high performance by having 4K Ultra High Definition players installed. In addition, in terms of financial issues for the investment of a cloud provider, OTT is considered to be the most affordable solution by helping the pay TV company to save money and increase revenue by improving cash flows. Consequently, OTT technology is the one that fits into the implementation of CTV, since in almost all the requirements examined, has been highly rated.

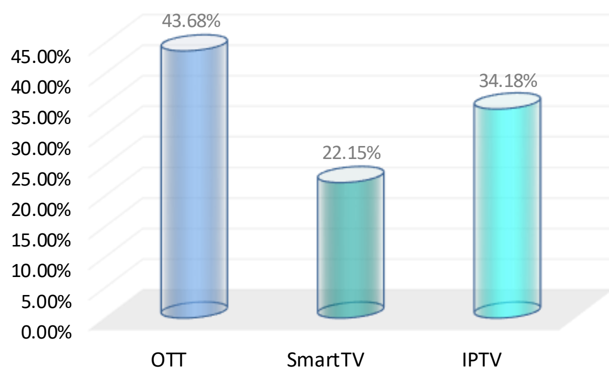

Figure 7 Technology evaluation

IPTV scenario is not expected to have any more penetration to the market because it is assumed as a legacy technology and probably its usability will decrease. Although Smart TV technology is ranked third, it is considered as a technology of the future, since the factories of major television manufacturers have spent plenty of time to research and development (R&D) activities for internet connectivity and optimization of the TV processors in order to provide as many applications as possible, including pay TV software Apps. The market trend in the upcoming years indicates a significant decrease of new smart models capable of supporting video streaming with high quality (Venkateswarlu & Renuka, 2017).

In addition, the wide expansion of fiber optic networks in the households will optimize the network quality and latency, which are very important for live TV or VOD content and hence the number of subscribers will be increased. Nowadays, Fiber-to-the-home (FTTH) (Saaty & Vargas, 1984) seems to the dominant technology for broadband access networks and thus the ultimate solution for providing various communications and multimedia services, including carrier-class telephony, high speed Internet access, digital cable television (CATV), and interactive two-way video-based services to the end users.

SENSITIVITY ANALYSIS

Simultaneous Changes of Parameters

In this section, we discuss the reliability of the results given the level of uncertainties involved by carrying out a sensitivity analysis. In order to further validate the reliability of the final ranking of the alternatives, Monte Carlo simulations are performed by simultaneously changing more than one parameters. The weights of all categories, requirements and alternatives are perturbed from w_k, f_{jk}, R_{ijk} to $w_k(1+\Delta W_k)$, $f_{jk}(1+\Delta f_{jk})$, $R_{ijk}(1+\Delta R_{ijk})$, respectively, where the perturbations ΔW_k, Δf_{jk}, ΔR_{ijk} are assumed zero mean, identically distributed, independent random variables uniformly distributed inside [$-s$ s] **Error! Reference source not found.**. Such random perturbation may be due to inconsistencies of the PWC matrices (G Dede, Kamalakis, & Varoutas, 2011). In an attempt to investigate the stability of the results the probability of rank reversal, a commonly used reliability measurement in AHP, between the two highest ranked CTV technologies OTT and IPTV is estimated.

In this context, we examine if A_1 and A_3 are correlated, since in that case the probability of rank reversal would be very small. In order to determine the degree of correlation, we compare the combined PDF $f_{A1,\,A3}\,(x,y)$ of A_1 and A_3 against the product of the individual PDFs $f_{A1}(x)\,f_{A3}(y)$ in Figure 8 (a) and (b) respectively. We assume 10^5 MC simulation and s=0.4 (corresponding to ±20% variations in all perturbations). The figure illustrates that A_1 and A_3 are indeed correlated since $f_{A1,\,A3}\,(x,y)$ is quite different than $f_{A1}(x)\,f_{A3}(y)$. In fact, Figure 8 suggests that A_1 and A_3 move on the same direction, i.e. when A_1 increases then it is more likely for A_3 to increase and vice-versa. Given this correlated displacement we expect a small probability of rank reversal.

Figure 9 also shows the probability of rank reversal $P(A_1>A_3)$ for various values of s calculated by Monte Carlo simulation (10^5 iterations). The figure confirms the aforementioned results since $P(A_1>A_3)$ remains sufficiently low (less than 4%) for $s\leq0.4$. We also calculate the probability of rank reversal for s=0.2 (maximum of ±10% variations) which turned out to be negligible < 10^{-3}.

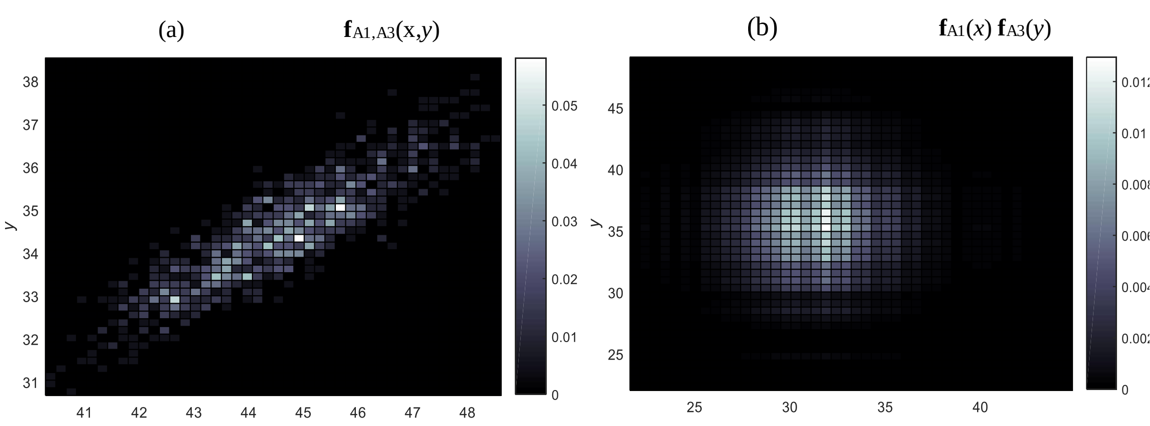

Figure 8 a) combined PDF of A1 and A3 and (b) the product of the individual PDFs of A1 and A3

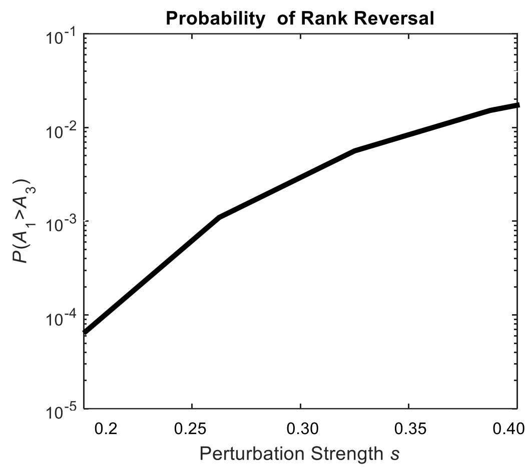

Figure 9 Probability of rank reversal P(A1 >A2) as a function of the perturbation strength

The sensitivity analysis presented in this section provide an indication of the reliability of the AHP results against uncertainties in the pairwise comparisons carried out by the experts.

The aforementioned sensitivity analysis procedure was also incorporated in the web based platform developed and maintained by the Harokopio University of Athens.

Changes of Experts Group Size

The AHP decision process involves pairwise comparisons commonly used in evaluation problems with a limited number of participants, since by augmenting the size of the participants beyond 15 there is no significant change in the final outcome (Georgia Dede, Kamalakis, & Sphicopoulos, 2015). As in our case there are 18 experts participating in the surveys and hence it is very interesting to investigate the impact of modifying their group size, from 18 to 15, on the outcome.

In this context, we perform MC simulations of $N_{MC}=10^5$ iterations. For each iteration z ($z \leq N_{MC}$) we randomly ignore a group of 3 participants and estimate the average priorities of the technologies $A_i'^{(z)}$ for the new group of M=15 participants. Finally, we estimate the average priorities from all iterations:

$$A_i'{}_{\_avg} = \frac{1}{N_{MC}} \sum_{z=1}^{N_{MC}} A_i'^{(z)}$$

The results are presented in Figure 10 in comparison with the initial ones for each of the alternative technologies. Inspection of the results reveals that there was no dramatic change in the final priorities. Interestingly enough, the ranking is reserved and OTT seems to retain its precedence. It is therefore deduced that the approach leads to accurate results even if we randomly reduce the experts' group size to 15.

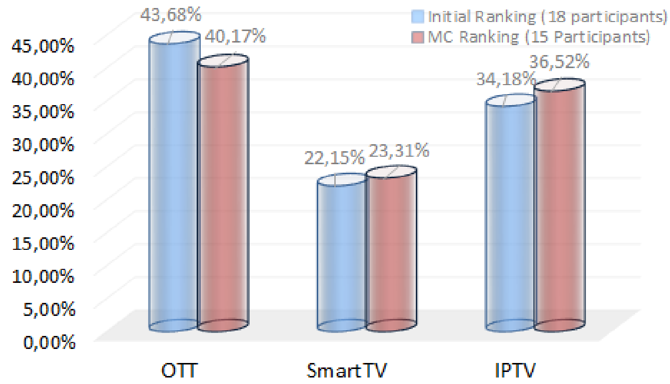

Figure 10 Technology evaluation with M=15 experts compared to the initial evaluation of the three alternative technologies

Conclusion

Since CTV will play a key role in the IoT era, in this paper the evaluation of the potential of three technological alternatives namely OTT, Smart TV and IPTV for CTV implementation in the context of pay TV business strategy, has been carried out. Moreover, the key requirements that may affect the deployment and adoption of CTV services from pay TV operators are examined. The analysis is based on the AHP framework. A number of important findings were obtained which should form a part of any type of carefully designed roadmap for CTV services. The results reveal that security, data protection, accessibility, costs saving and time-to-market are requirements of paramount importance. In any case, the advantages of OTT have been indicated, which seems to take some precedence over the rest alternatives, while IPTV is ranked second. Smart TV is considered as a longer term alternative, given that there are still issues to be addressed and improved by the TV developers such as flexibility, protection, performance and reliability. Taking into account the market trend indicating an increment of pay TV penetration, OTT seems to be the technology that will probably follow this trend and further dominate. Smart TV is under an optimization level being very promising for the future. OTT may offer fully integration with SaaS functionalities, new and engaging user & brand experience, improved time-to-market, provision of a more personalized-customer orientented UX, cost-efficiency and agility as well as monetization of exclusive content.

The growing penetration of portable devices in addition with the predictions and estimation of high video traffic through internet can motivate the OTT application in pay TV market. Furthermore, R&D activities will improve all these functionalities and optimize new features and applications that can be supported from OTT technology providing greater customer experience. There will be a wide range of services for all clients with different kind of subscriptions according to their interests at any time and from anywhere creating and ensuring ubiquitous video content.

Furthermore, sensitivity analysis was performed in order to investigate the stability of the results. It was found that under uncertainty the priorities of the alternatives are correlated and this correlation reduces the probability of rank reversal. The OTT solution is never surpassed by the IPTV alternative, even if all parameters are randomly perturbed by ±20%. A sensitivity analysis was also performed to examine the accuracy of the approach by randomly reducing the group size of the experts involved in the surveys. The results revealed that despite the reduction of the group size to 15 experts, there is no significant impact on the final outcome, which ensures the stability of the method.

The current paper implements and verifies an open and transparent roadmapping model for CTV investment, emphasizing on crucial interdisciplinary requirements of cloud operation. The obtained results form a key part of future CTV solutions and the current work can be further extended in order to capture the users' needs based on the IoT upcoming services for CTV. The findings of this paper will be very helpful for CTV implementations for countries that have not yet deployed CTV solutions. They constitute a great guide for newcomer pay TV operators and already established operators willing to invest on CTV services. On the other hand, they will be very beneficial for pay TV operators that have already invested on CTV, as a useful guide of further improvement of provided CTV services, taking into account the importance of crucial requirements that have been highlighted, such as latency aspects for live events and security issues.

COMPLIANCE WITH ETHICAL STANDARDS

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Conflict of Interest: The authors declare that they have no conflict of interest.

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