A Framework to Implement a U-Learning Service based on Software-Defined Television

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***Abstract*—This paper aims to propose a framework to implement a ubiquitous learning service based on software - defined television (Sw-de TV) under the approach of software-defined everything and cloud computing. The lack of u-learning frameworks and the little convergence of infrastructure and flexibility in educational contexts are some challenges to overcome. Here, we present the general framework and an experimental test. The experimental results indicated a satisfactory performance of the video display for different screens, and a very high relevance to be applied in an educational context. One of the test conclusions is that video processing platforms defined by software offer more scalability and flexibility than a conventional television (TV) infrastructure. Such platforms make possible to adapt content to different screens, favoring the implementation of a ubiquitous learning service in which users can choose the moment, place and device in order to perform a learning activity, having video as its main content.**

Keywords—U-learning; cloud computing; framework; software –defined TV; multi-screen

I. Introduction

The possibility of doing a learning activity at any time, place and with the support of any device (PC, smartphone, TV, video console, among others) is the paradigm known as ubiquitous learning or u-learning. As Richardus Eko [1] indicates, u-learning is supported by information and communication technologies (ICT), where the learners can easily move from one place to another, across space and time.

Television, as well as other technologies, has been applied in educational contexts. Traditional TV systems have been characterized by implementing an exclusive infrastructure for a medium, broadcast by air, cable, satellite, or IPTV, limited to a device (TV set), and with problems of convergence with other systems or to deploy to other screens, such as mobiles. Nowadays this can limit the applicability in the educational context to respond to flexibility and performance challenges, and considering the new apprentices known as millennial generation [2], generation Y or Z, among others.

Technological advances have searched for convergence between broadband and Internet, in cases such as Smart TV, the hybrid broadcast broadband (HbbTV) [3], or Over the Top (OTT) TV services [4] which are deployed directly to a connected device. Thanks to cloud computing [5], software-defined TV became a reality.

The term Software-defined television (Sw-De TV) is coined within the Software-defined everything concept [6], in which many components are configured by software, or in which all the infrastructure can be programmable. An important part of software-defined everything is that computing technology, storage and networks are virtualized, so that they provide many benefits for supplying, management, maintenance, among others [7].

According to Sathaye [8] several factors are driving changes in the architecture of technology which are creating an environment of software-defined TV: changes in consumer behavior, online video proliferation and consumer expectations for service consistency across all devices. Ultimately, the user is the one deciding where, when and how to watch the content. Another aspect is that it is no longer necessary to change the hardware constantly for processing updates since this is now possible through a software. In addition, users also want to see live, real-time video.

Users are increasingly more connected to Internet and they use several screens that go from computer, to tablets, to smartphones, to connected TV, etc. Video is the most consumed content from internet [9]. This opens a great possibility for traditional TV operators to update their infrastructure, to reach to more users, and to offer more services and contents or other business models, by migrating to platforms that allow displaying videos to any screen, taking advantage of Internet connectivity. This scenario provides the opportunity for software-defined TV to be applied in the educational context, where it can contribute to improve flexibility, coverage, motivation, media convergence, among other aspects, which would be limited by a system of traditional TV. Table 1 shows a general comparison between these platforms.

TABLE I. TRADITIONAL TV PLATFORMS VS SW-DE TV

	DTT	Satellite	Cable	IPTV	Sw-De TV
TX Medium	Air	Satellite	Cable		Various/ internet network
Coverage	National	World/ national	Regional / local		Wide
Interactivity	Limited	regular	Higher		Wide
For reception	DTT Antenna Decoder TV set	Satellite antennal STB TV set	Modem or STB TV set		Internet Network Connected Devices
Network	Owner / Open Sign	Owner/ sign closed	Owner/sign closed		Internet/ Open
Portability / Mobility	It's possible		Very limited		Wide
Watch anywhere / any time	Limited				Wide
Multi-screen	Generally a screen (TV set)				Several
Implementation Time	Delayed		A bit delayed		Faster

Other terms related to Sw-De TV are TV everywhere, TV OTT, multiscreen TV, Software-defined video processing, cloud TV, or what we propose as ubiquitous TV, a television which can be seen everywhere, at any time and in any screen, supported by a convergence of technologies and connectivity.

The purpose of this work is to project the potential of software-defined TV, especially for educational use, and to provide a framework that shows the implementation of a u-learning context. Also, we intend to contribute to the discussion on this topic.

The rest of the article is structured as follows: Section II, Materials, presents TV antecedents for educational purpose, u-learning aspects and related frameworks, and software-defined TV aspects. Section III, Method, explains how the research was carried out. Section IV presents the general framework proposal to implement a u-learning service based on software-defined television, the framework of architecture, and examples of suppliers. Section V is the experimental part and discussion. Finally we present the conclusions.

II. MATERIALS

A. *Antecedents of TV for Educational Purposes*

Just as many other technologies have had an impact on different sectors, TV has been projected in the educational sector, known as educational TV [10]. Another term that was known to many in the 2000's, mainly thanks to the digitalization of the terrestrial system, is t-learning. As defined by Bates [11], it is the interactive learning through television, or the interactive access to educational contents rich in video through a television set.

From broadcast TV, cable TV, satellite TV, IPTV and TV in convergence with Internet, different proposals for educational use have been explored. Some examples date from the years 50's and 60's, such as Kraus [12] with the proposal of Television Systems for In-School Teaching; Noble et al. [13] with Application of Airborne Television to Public Education; and Francis E. [14] who presents a design for using closed-circuit television in education. In more recent years, we can find some other examples, such as Dos Santos et al. [15], with a Remote Experimentation Model Based on Digital TV; or Pires and Miranda [16], who comment on the production of digital educational resources in a study of digital TV.

Regarding satellite systems, Kirstein [17] presents Experiences with the University of London interactive video education network, in which direct broadcast satellite is used; Rajashekhar et al. [18], present Satellite-based distance education in digital paradigm: ISRO perspective; and Xiang-yu et al. [19] present DTN-based interactive communication mechanism for satellite distance education systems.

On systems by cable and IPTV, we find works by Jiangxm et al. [20]: Exploration in developing modern distant education base in digital video broadcast cable network; Zhu Xiao Liang et al. [21]: Education IPTV for E-learning in Rural Area; and Duran [22]: an Architecture for the support of the video on demand service for virtual academic communities on IPTV.

In terms of terrestrial digital television, authors like Dos Santos et al. [23] present Digital TV and distance learning in Brazil; Lopez-Nores [24] introduces an Architecting multimedia-rich collaborative learning services over Interactive Digital TV; Moreno and Jimenez [25] present a model that describes the t-learning process applied to DVB-T in Colombia.

As for hybrid systems with Internet, some examples are Acosta et al. [26], with a proposal of educational hybrid TV for a regional channel; and Montoya et al. [27], with a multi-platform learning system.

B. *U-learning*

U-learning is the paradigm or concept arising from ubiquitous computing, defined by Weiser [28], who indicated that computing would be immersed in many parts and integrated with daily life.

Ubiquitous learning involves learning in an environment where "all students have access to a variety of digital devices and services, including computers connected to the Internet and mobile computing devices, whenever and wherever they need them" [29]. As pointed out by [30], and [31], it is a learning environment that anyone can access anywhere, any time or through any device.

U-learning can be implemented in a formal, non-formal or informal learning context, and can complement or substitute, totally or partially, what is taught in a classroom [32].

Some authors have proposed frameworks applied in u-learning, but they are little related to the trends of software-defined TV, offer insufficient description or do not indicate implementation alternatives.

In [33], authors presents a theoretical framework for using context awareness, M-learning in the podcast form. In [1], author proposes an architectural framework of the u-learning ecosystem implementation through courseware development and management. In [34], author provides a framework for mobile learning, where there is a classification according to the transactional distance theory, and according to individual or social activities. In [30] the design of a Sensor framework for Ubiquitous Learning in Nigeria is presented. [35] proposes a methodology for developing u-learning models, a task-based u-learning model, incorporating well-bounded learning content; and describes the implementation of this architecture through the development and deployment of the Walkabout u-Learning Environment. [36] presents a Unified Framework for u-Edutainment Development of Using e-Learning and Ubiquitous Technologies. The main characteristic of the Unified Framework is to bolster basic e-learning systems with game theory in ubiquitous computing environments. [31] presents a Hadoop-framework based ubiquitous learning, which is an android-based U-learning system that provides personalized recommendations and is implemented on Hadoop platform. [37] aims to develop the pedagogical communication model of u-learning, Youubi. The ubiquitous learning environment that will be our object of study is the YUUBI. [38] addresses a standardization progress on service framework and a scenario for establishing self-directed u-learning (Y.fsul) applications in accordance with ubiquitous ICT. [39] provides a framework (CEP) of processing learning portfolios (e-portfolios, eP) based on ubiquitous learning activities.

C. Software-defined Everything & Software-defined TV

According to Virmani [6], the phrase Software-defined everything has to do with the grouping of a variety of software-defined computing technologies into one over-arching framework and architecture. Within the software-defined everything technologies, we can find software-defined networking (SDN), software-defined computing, software-defined data centers (SDDC), software-defined storage (SDS), and software-defined storage networks, among others. With software-defined everything, the computing infrastructure is virtualized and delivered as a service. In a software-defined everything environment, the management and control of the networking, storage, and data center infrastructure is automated by intelligent software rather than by the hardware components of the infrastructure.

For example, SDN refers to a network architecture where the forwarding state in the data plane is managed by a remotely controlled plane decoupled from the former [40]. The control and data planes are decoupled, as shown in Fig. 1.

Another case of Software-defined everything is Software-defined radio (SDR), where different components are implemented for the reception and transmission of radio-communication signals through software. For example, [41] presents a platform equipped with a reconfigurable processor and common hardware, where different receiver algorithms are implemented in software. It was tested in DVB-T2 broadcasting environment.

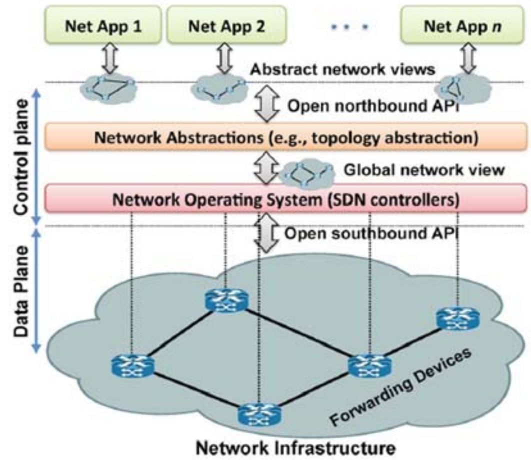

Fig. 1. Example of planes of control and data decoupled in SDN.

A software-defined view of IT virtualization has several advantages [6]:

1) It is more workload-aware and provides a top down view.

2) It uses server, storage, and network integration (sdi) for responsiveness.

3) It uses heterogeneous compute federation.

4) It manages pools of systems as a single system.

5) It truly uses virtualization to manage it.

6) It is managed by advanced programmed automation.

Software-defined TV

How say *Keith Wymbs* [42], it is an infrastructure-agnostic approach to implementing flexible, scalable and easily upgradable video architectures. Unlike legacy solutions, this advancement allows video providers to deploy software across an optimal combination of dedicated and virtualized resources in both private and public data centers. The days of proprietary broadcast hardware are over. Standardized software running on commodity IT equipment, virtual machines or the cloud is how it is done [43].

Software-defined TV takes as reference the cloud computing service models to be implemented [5]: software as a service (SaaS), Platforma as a Service (PaaS), and Infraestructure as a Service (IaaS). Cloud computing comprises essential characteristics [5]: such as: On-demand self-service , broad network access, resource pooling, rapid elasticity, and measured service. The cloud can help organizations handle variable video processing demand with great flexibility and agility, while improving customer service [44]. The following figure illustrates the Software-defined TV approach with cloud computing (Fig. 2).

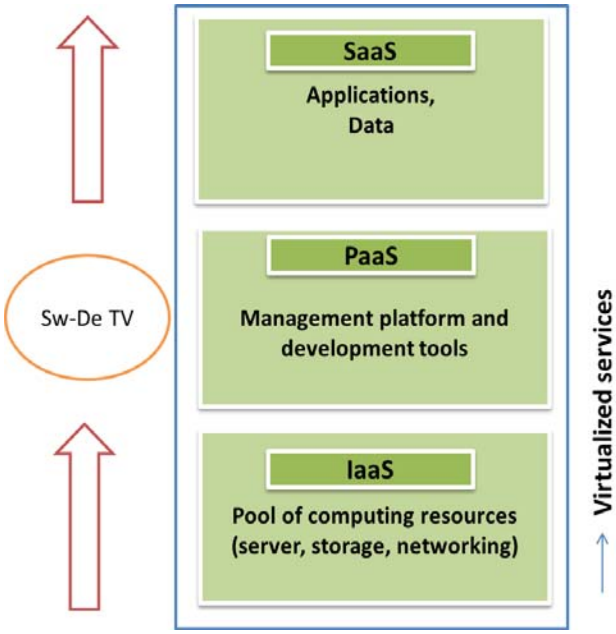

Fig. 2. Software-defined TV viewing with cloud computing.

Some changes in the architecture of technology that stand out in a software-defined TV environment are [8]:

- Network and device virtualization, including software-based transcoding and content processing, virtualization of network transport and routers, and virtualized applications execution environments.
- Dynamic media adaptation, including content ingest, transcoding and delivery, as well as metadata management and cloud-based DRM.
- Migration to all-IP networks from QAM or IPTV delivery, creating a common architecture for cable, IPTV and mobile video delivery.

Among other benefits of Sw-De TV are: flexibility, reliability, adequate levels of performance, scalability, ensuring high-quality video for all platforms, increase in return on investment, integration of workflow components, elasticity, high availability, distribution of secure content across platforms with confidence, and short time to market [40], [44]. Software defined video minimizes technology risk, while maximizing innovation speed; for instance, the continued expansion of services like 4K and UHD services. Support for new services and video formats can be integrated seamlessly through simple software upgrades and API integration of third-party software, enabling video providers to immediately respond to changes in consumer demand [42].

III. Method

In general this study is a design-based research [45]. To carry out this research, we started from a literature review, we took television and convergence trends into account, as well as possible platforms to define TV/video through software. Afterwards, we carried out a projection and design of the framework for the implementation of a u-learning service based on software-defined TV. Then, we designed an experimental test that allowed us to check the time of implementation and the performance of a software-defined video platform for educational use.

To carry out this experiment, we previously defined aspects of the framework to be applied in the educational context. Afterwards, we made a video to be embedded and configured with different resolutions in a video platform. We published the video and a focal group (students) verified the display on different devices in order to measure the success of this test. We considered the display on different screens (Smartphone, Tablet, PC, Connected TV). We evaluated whether the video pixelates or freezes, whether it works with wireless and cable networks or 3G/4G networks, and eventually, the assessment of the test by the focal group by means of a survey.

To review the performance, we take into account the standards of ISO/IEC 25010:2011 [46], which refer to the performance relative to the amount of resources used under stated conditions, and those resources can include other software products, the software and hardware configuration of the system, and materials. In addition, the standards indicate that performance efficiency has three sub-characteristics, which are time behavior, resource utilization, and capacity.

IV. Framework of U-Learning based on Sw-De Tv

In this section, we introduce the general framework, some examples of suppliers or platforms alternatives for code programming to implement a solution based on Sw-De TV, and a framework of its general architecture.

The framework intends to be a support when implementing a u-learning service based on software-defined TV platforms. Technology is a means but the ultimate aim is to favor the teaching/learning process. That is why we must take many other aspects into account, such as learning objectives, activities, pedagogical aspects, personal aspects, among others. In Fig. 3, we present our proposal for the general framework, which includes several moments: 1) status and initial preparation; 2) planning & requirements; 3) design & development; 4) test & deployment service; and 5) confronting service and learning outcome. All these moments have a cyclic nature to feedback the process.

Video as main content is very versatile since class sessions can be recorded live, allowing a higher interaction, and it can also be displayed on different screens. In Table 2, we can find the elements to be considered in every framework moment.

Fig. 4 illustrates some examples of alternatives for implementing software-defined TV. It can be done through a cloud TV solution or OTT TV offered by a provider, or by code programming a new service/application with the cloud computing platform.

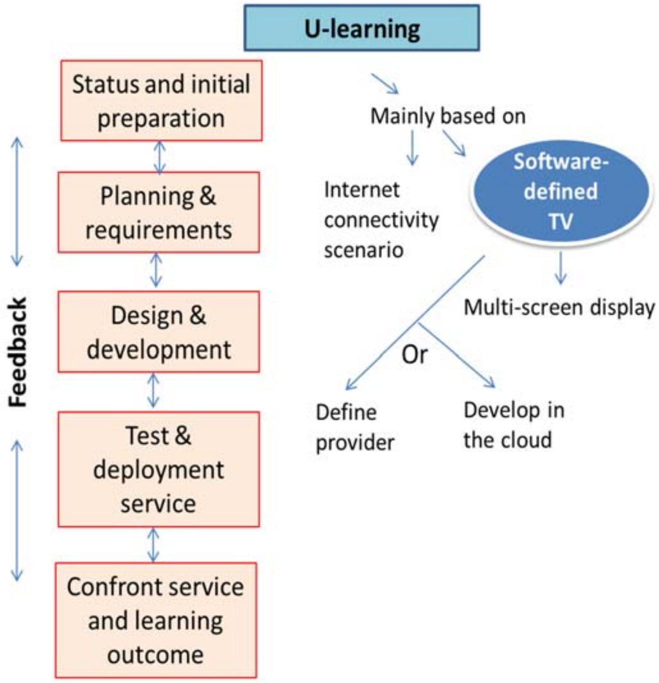

Fig. 3. General u-learning framework based on Sw-De TV.

TABLE II. MOMENTS OF THE FRAMEWORK

Moment	Description
Status and initial preparation	Understanding the idea of u-learning, looking for online solutions of video processing, identifying the application context, the participants, among others.
Planning & requirements	Planning the u-learning service and the technological, pedagogical, personal, workteam, and management requirements, etc. Defining the platform to be used.
Design & development	Designing the u-learning solution, contents, activities as well as configuring the platform and/or developing resources, services, contents, among others.
Test & deployment service	checking the platform's performance, the display of the u-learning service on different screens, monitoring, etc.
Confront service and learning outcome	Reviewing the experience, its impact and favoring of the teaching/ learning process.

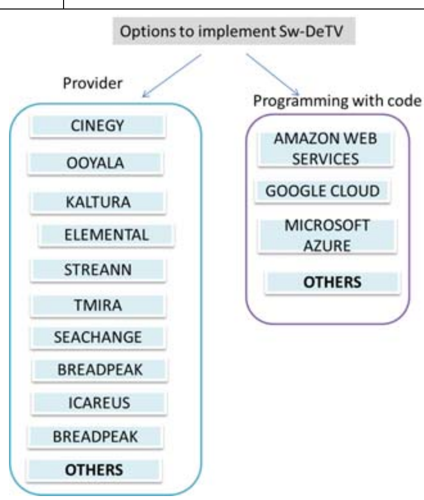

Fig. 4. Options to implementing Sw-De TV.

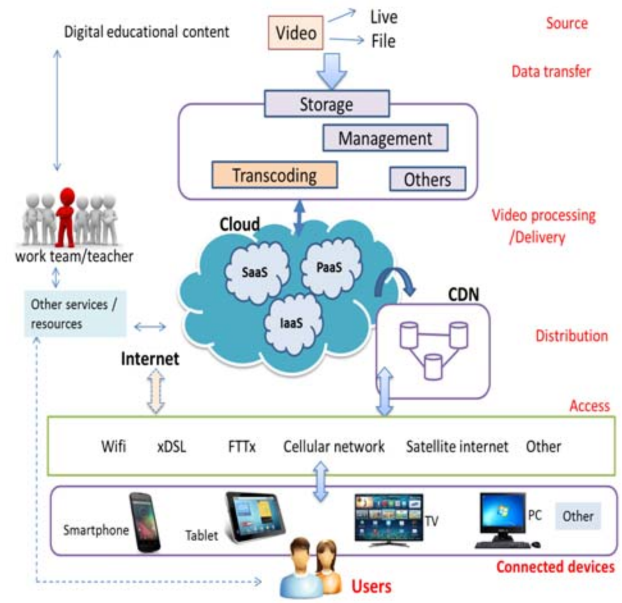

Fig. 5. General u-learning framework architecture based on Sw-De TV.

In Fig. 5, we present the general architecture framework for u-learning service based on Sw-De TV. This solution considers a video processing platform based on cloud computing. This platform involves storage components, transcoding to adapt content in different bit rates, management, among others. Other elements are the CDN (content distribution networks) [47] to facilitate the delivery of content to the users accessing the Internet via different means such as Wifi, 4G/5G, xDSL, or optical fiber, and using different ubiquitous devices (PC, smartphone, Tablet, Connected TV, smartwatch). The service can consist of an educational website, linked to social networks, LMS, among others.

V. EXPERIMENTAL TEST AND DISCUSSION

A. Experimental Test

When applying the proposed framework of u-leaning based on Software-defined television and putting it into practice in an educational context, various aspects must be taken into account. These aspects, and others defined by the framework and summarized in Table 3, have specific scope and limit for the purpose of this experiment. The scope is limited to test a convergent platform to display video on different devices. We checked the time needed to implement the video service and its performance to be displayed on different screens. A focal group of users took part of the tests by assessing the applicability of the service in supporting the learning process. Among the limitations, we found the fact that it uses a video platform in test mode, without having all the functionalities and it is limited in capacity and operating time; content is about telecommunication and it was tested with a focal group of 24 people from Politécnico Colombiano Jaime Isaza Cadavid institute; it did not have an impact on students' grades; learning results were not confronted: content was not articulated to an LMS: it depended on Internet connectivity (Wi fi, cellphone network), and on equipment conditions; there was not an interdisciplinary team.

TABLE III. SUMMARY OF DEFINED ASPECTS

Moment	Description
Status and initial preparation	U-learning, university context, teacher, students, video in the cloud
Planning & requirements	Test Platform of Kaltura, complementary service, telecommunication-themed video, focal group, students in normal conditions, learning objective (origin and meaning of telecommunications), quiz and homework activity, authentication, interactivity with QR and quiz, using devices such as PC, smartphones, tablet and TV
Design & development	Script, video making, video upload and configuration on Kaltura platform
Test & deployment service	Checking video's URL website on multiple connected devices
Confront service and learning outcome	Perception, survey, future feedback

Table 4 illustrates the different bit rates configured in the system so that the content can be adapted to different devices (transcoding).

TABLE IV. DIFFERENT BIT RATES DEFINED

Transcoding	Format	Codec	Bitrate (kbps)	Dimension	Size (KB)
Source	mp4	Avc1	328	1020 x 754	18534
HD/720 - web	mp4	Avc1	436	976 x 720	24678
HD/1080 - web	mp4	Avc1	436	1008 x 752	24678
WebM	webm	v_vp8	303	480 x 352	17100
SD/small - web	mp4	Avc1	380	640 x 480	21504
Basic/small - web	mp4	Avc1	360	640 x 480	20172
Mobile (3GP)	3gp	Mpeg-4 visu	308	320 x 240	17408

The focal group performs tests in different devices to verify performance. Fig. 6 illustrates the tests per device. All the tests were satisfactory. Fig. 7 shows an example of the video display on a Tablet.

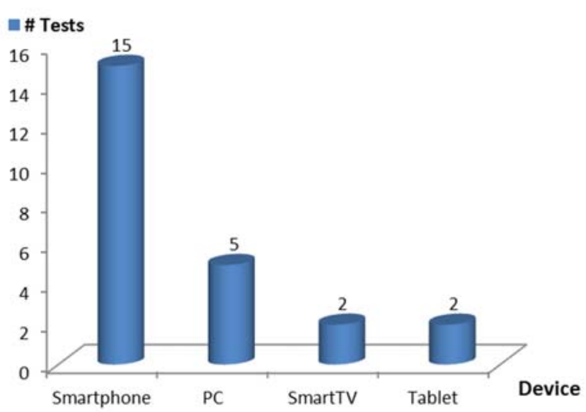

Fig. 6. # test by device.

Fig. 7. Example deployment in tablet.

B. Discussion

When performing the experimental tests of the u-learning service based on Sw-De TV, the result showed that implementation takes only a few hours (knowing and configuring the tool, preparing the videos) and/or can depend on whether or not it is programmed with code, on other services or activities, among others. When defining different video bit rates as it was indicated in Table 4, it is possible to have different profiles or resolutions that can be adapted according to the device and the Internet capacity, which allowed verifying the performance on different types of screen, as indicated in Fig. 6. When we asked the focal group of 24 people what relevance degree they gave to the use of video to complement or to replace a class topic and be able to watch it from any device, at any time and place, 96% of them answered very high, as it is shown in Fig. 8.

These results illustrate the applicability of using convergent video platforms for educational use, because they contribute to flexibility since the video can be seen in any screen, at any time and place, and taking into account that students increasingly use connected devices nowadays. It is possible to implement a u-learning service based on software-defined platforms since they can adapt the video to any screen connected to Internet (TV, Smartphone, Tablet, and PC) to be seen at any moment and from any place.

With a traditional TV system, implementing a u-learning service would be more difficult. The following table presents a comparison of the limitations of a traditional TV system versus Sw-De TV, to implement a ubiquitous learning service (Table 5).

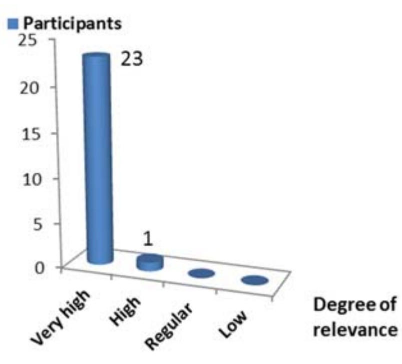

Fig. 8. Example deployment in tablet.

TABLE V. LIMITATIONS FOR U-LEARNING, TRADITIONAL TV VS SW-DE TV

Traditional TV	*Sw-DeTV*
• Private/public infrastructure that cannot be easily used or altered for testing or implementing educational service. • Not everyone can deploy a TV system. • Updating the HW • Implementation time is much longer or costs more. • limited interactivity (case DTT) • Devices that depend on a standard (DVB-T, or IPTV, or DVB-S, or HbbTV, etc) • By a single medium and for a single device (TV set) • Low coverage • Low flexibility of schedules, or integration with other services, etc. • Limited storage • Maintenance of infrastructure • Low mobility • Low or no analytics • It is more difficult to involve more teachers	• Few specific solutions for educational context • For some people, the programming of a proprietary solution • For some people, the price • Ignorance or paradigm change • If there is no internet connection.

TABLE VI. ADVANTAGE FOR U-LEARNING, TRADITIONAL TV VS SW-DE TV

Traditional TV	*Sw-DeTV*
• A particular audience • Traditional service. • For use in training and as comparison	• Do not have to worry about HW. • Software upgrade • Infrastructure convergence • Affordable solution for any institution or person • Faster implementation • Greater coverage • Having a unified video platform • Broad coverage and mobility • Greater flexibility for VOD, live services, integration with other solutions or applications, among others. • More interactivity • Multi-screen, for any device • Devices connected to the network • Scalable • More resistant to failures • Analytics

A Software-defined television system provides more advantages to implement a u-learning service. The table above presents a comparison of the advantages of a traditional TV system versus Sw-De TV when implementing a u-learning service (Table 6).

When comparing the platforms of Sw-De TV to the youtube channel, which is used by many companies or independent users to implement videos, we realize that Youtube is more an open social network accessible to any kind of public. It can easily lead to distraction since there are other contents popping up. It does not have an authentication requirement for users; it is not possible to personalize the platform; it does not allow advanced analyses of the service and of each user. However, it is also possible to use Youtube to complement the Sw-De TV platform.

VI. CONCLUSIONS

In this paper, we presented a proposal of framework to implement a u-learning service based on Software-defined television, as a referent or guideline to analyze, discuss, design and evaluate the viability of its application in an educational context. We used convergent platforms to display video on multiple screens, at any tie and from any place, in a scenario of connectivity, which can favor more flexibility and benefits for students. We presented options for its implementation and a comparison with a traditional TV system.

The results of the experimental test show the easiness to implement a software-defined TV system. It is faster and its performance and display to multiple screens are satisfactory (PC, Smartphone, Tablet, connected TV) as compared with traditional TV systems. The survey respondents emphasize the appropriateness of being able to watch a video related to the learning topic at any time and from any place, on any device. This projects a greater versatility to be applied on education and to enrich u-learning, making it more flexible, providing a convergent system for different devices, and a higher level of participation by students.

The platforms of Software-defined television have a high resources optimization potential. They offer new services and applications, making an impact on users, with content diversity, new business models; and they can be applied in different sectors (businesses, industry, government, entertainment and education), among others. Based on cloud computing, it allows the access under demand to computing resources and infrastructure, and provides mechanisms to measure the service, availability, scalability, fast supplying, the use of networks and ubiquitous devices, among others. Regarding its applicability in an educational context (school, university, etc.), it can contribute to solve aspects of inclusion, coverage, flexibility, and involvement; improve learning results and take advantage of increased connectivity scenarios surrounded by ubiquitous devices. As future work, we plan to continue reviewing and adjusting the different elements to be considered in an educational teaching/learning process that uses technology, in this case, with software defined TV platforms. We also intend to prepare and have more video content available and apply it widely to more students, and to explore the development of a platform specifically for educational context, and its integration to systems such as LMS, Apps, among others.

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REFERENCES

[1] Ri. E. Indrajit, THE ECOSYSTEM FRAMEWORK FOR U-LEARNING IMPLEMENTATION THROUGH COURSEWARE DEVELOPMENT AND MANAGEMENT. Universitas Negeri Jakarta, 2016.

[2] K. McKeown et al., “Re-Energize Entertainment Engineering: How to Blend the Experience of Yesterday with Millennials´s Vision of Tomorrow,” in SMPTE 2016 Annual Technical Conference and Exhibition, 2016, pp. 1–21.

[3] ETSI, “Hybrid Broadcast Broadband TV.” Jun-2010.

[4] M. Hooper, A. Moyler, and R. Nicoll, “Over The Top TV (OTT TV) Delivery Platforms Review,” BCI, Sep-2010.

[5] P. Mell and T. Grance, “The NIST Definition of Cloud Computing.” Sep-2011.

[6] M. Virmani, “Understanding DevOps & bridging the gap from continuous integration to continuous delivery,” in Innovative Computing Technology (INTECH), 2015 Fifth International Conference on, 2015, pp. 78–82.

[7] R. Bawa and R. Clark, “Software-defined everything.” Deloitte, 2015.

[8] S. Sathaye, “Cloud Tech and the Software Defined TV Paradigm,” 22-Apr-2015. [Online]. Available: http://www.btreport.net/articles/2015/04/cloud-tech-and-the-software-defined-tv-paradigm.html. [Accessed: 09-Apr-2017].

[9] Cisco, “The Zettabyte Era—Trends and Analysis,” Cisco - White Papers, May-2015. [Online]. Available: http://www.cisco.com/. [Accessed: 31-Mar-2016].

[10] G. G. Broderick, “Educational Television: Are we Educating by Television,” J. SMPTE, vol. 65, no. 1, pp. 20–22, Jan. 1956.

[11] P. J. Bates, “t-learning Final Report,” Reporte, May 2003.

[12] M. H. Kraus, “Television systems for in-school teaching,” Trans. Am. Inst. Electr. Eng. Part Commun. Electron., vol. 77, no. 4, pp. 406–411, Sep. 1958.

[13] C. E. Nobles, F. G. Mullins, J. L. Avagner, and R. Lee, “Application of Airborne Television to Public Education,” IRE Trans. Educ., vol. 4, no. 1, pp. 26–33, 1961.

[14] F. E. Almstead, “A design for using closed-circuit television in education,” Trans. Am. Inst. Electr. Eng. Part Commun. Electron., vol. 78, no. 4, pp. 439–444, 1959.

[15] R. A. dos Santos, E. Pozzebon, L. B. Frigo, and R. Marcelino, “Remote experimentation model based on digital TV,” in Experiment@ International Conference (exp. at’15), 2015 3rd, 2015, pp. 321–324.

[16] T. Pires and G. L. Miranda, “Digital educational resources production in a Digital Tv studio: Training course for teachers,” in Information Systems and Technologies (CISTI), 2016 11th Iberian Conference on, 2016, pp. 1–7.

[17] P. T. Kirstein and R. Beckwith, “Experiences with the University of London interactive video education network,” Electron. Commun. Eng. J., vol. 3, no. 1, pp. 4–12, 1991.

[18] S. L. Rajashekhar, G. V. Ayyangar, and R. Sharma, “Satellite-based distance education in digital paradigm: ISRO perspective,” in 6th International Conference on Digital Content, Multimedia Technology and its Applications, 2010, pp. 366–371.

[19] Xiang-yu, L. Gang-xiao, and L. Jun, “DTN-based interactive communication mechanism for satellite distance education systems,” in Computer Science and Network Technology (ICCSNT), 2013 3rd International Conference on, 2013, pp. 783–787.

[20] J. Chen, Z. Qin, and H. Zhang, “Exploration in developing modern distant education base in digital video broadcast cable network,” in 2001 International Conferences on Info-Tech and Info-Net. Proceedings (Cat. No.01EX479), 2001, vol. 6, pp. 72–77 vol.6.

[21] Zhu Xiao Liang, Liu Quan, Yin Jie, and Song Xiao Juan, “Education IPTV for E-learning in Rural Area,” 2008, pp. 268–271.

[22] F. Duran, M. R. A. Cerón, and H. J. L. Arciniegas, “Architecture for the support of the video on demand service for virtual academic communities on IPTV,” in Computing Congress (CCC), 2011 6th Colombian, 2011, pp. 1–7.

[23] T. Dos Santos, D. T. Do Vale, and L. G. P. Meloni, “Digital tv and distance learning: Potentials and limitations,” in Frontiers in Education Conference, 36th Annual, 2006, pp. 1–6.

[24] M. López-Nores, Y. Blanco-Fernández, J. J. Pazos-Arias, and J. García-Duque, “T-learning in Telecommunication Engineering: The Value of Interactive Digital TV in the European Higher Education Area,” 2010, pp. 624–626.

[25] G. A. Moreno López and J. A. Jimenez Builes, “CYCLE OF PDCA T-LEARING MODEL AND ITS APPLICATION ON INTERACTIVE DIGITAL TV,” Dyna, vol. 79, no. 173, pp. 61–70, 2012.

[26] S. Acosta, G. Moreno, H. Recaman, and A. Reyes, “Proposal to develop educational content destined to hybrid tv of a regional channel,” Revista Politécnica, vol. 12, no. 22, pp. 57–64, Jun-2016.

[27] M. Edwin, M. Juan Carlos, T. Juan, R. J. Cesar, V. M. Johan, and I. T. Oscar, “Multiplatform learning system based on interactive digital television technologies, IDTV,” presented at the 2012 XXXVIII Conferencia Latinoamericana En Informatica (CLEI), 2012, pp. 1–10.

[28] M. Weiser, “The computer for the 21st century,” Sci. Am., vol. 265, no. 3, pp. 94–104, 1991.

[29] M. van’t Hooft, K. Swan, D. Cook, and Y. Lin, “What is ubiquitous computing?,” in Ubiquitous computing in education, Mahwah, New Jersey: Lawrence Erlbaum Associates, 2007.

[30] O. K. Boyinbode and K. G. Akintola, “A Sensor-based framework for ubiquitous learning in Nigeria,” Int. J. Comput. Sci. Netw. Secur., vol. 8, no. 11, pp. 401–405, 2008.

[31] C. Valliyammai, S. E. Thendral, V. Muthuvalliammai, S. Anandhavalli, and K. M. Madhumathi, “Hadoop framework based ubiquitous learning,” in Advanced Computing (ICoAC), 2015 Seventh International Conference on, 2015, pp. 1–5.

[32] G. A. Moreno Lopez, J. A. Jimenez Builes, and S. C. Bernal Villamil, “Overview of u-learning. Concepts, characteristics, uses, application scenarios and topics for research,” IEEE Lat. Am. Trans., vol. 14, no. 12, pp. 4792–4798, Dec. 2016.

[33] M. A. Amasha and E. E. AbdElrazek, “An M-Learning Framework in the Podcast Form (MPF) using Context-Aware Technology,” IJACSA Int. J. Adv. Comput. Sci. Appl., vol. 7, no. 12, p. 9, 2016.

[34] Y. Park, “A pedagogical framework for mobile learning: Categorizing educational applications of mobile technologies into four types,” Int. Rev. Res. Open Distrib. Learn., vol. 12, no. 2, pp. 78–102, Feb. 2011.

[35] Casey and J. Fraser, “A Framework for Developing and Implementing u-Learning Models,” in Handbook of Research on Human Performance and Instructional Technology, United States of America: Information Science Reference, 2010, pp. 310–323.

[36] S. Jang, B. Kye, and Y. Kang, “A Unified Framework for u-Edutainment Development of Using e-Learning and Ubiquitous Technologies,” in Lecture Notes in Artificial Intelligence 4251, Verlag Berlin Heidelberg: Springer, 2006, pp. 1163 – 1170.

[37] J. A. Brito, R. Amorim, and A. S. Gomes, “Effectiveness of educational practices through the extension of a framework ubiquitous learning environment,” in Information Systems and Technologies (CISTI), 2015 10th Iberian Conference on, 2015, pp. 1–5.

[38] Y. J. Kim, S. Cho, and I. Chong, “Standardization on framework and scenarios for self-directed ubiquitous learning (Y. fsul),” in Advanced Communication Technology (ICACT), 2014 16th International Conference on, 2014, pp. 425–430.

[39] T.-C. Yang, T. H. C. Chiang, and S. J.-H. Yang, “Creating e-portfolio in U-learning Environment: A Framework of Could-based e-portfolio Service,” 2012, pp. 292–295.

[40] D. Kreutz, F. M. V. Ramos, P. Esteves Verissimo, C. Esteve Rothenberg, S. Azodolmolky, and S. Uhlig, “Software-Defined Networking: A Comprehensive Survey,” Proc. IEEE, vol. 103, no. 1, pp. 14–76, Jan. 2015.

[41] J. Yu, H.-Y. Lee, C. H. Choi, and J. Chung, “Software-defined DTV platform,” in Consumer Electronics (ICCE), 2013 IEEE International Conference on, 2013, pp. 492–493.

[42] TVtechnology, “Software-Defined Video: A Conversation with Elemental’s Keith Wymbs,” 15-May-2015. [Online]. Available: http://www.tvtechnology.com/news/0086/software-defined-video-a-conversation-with-elementals-keith-wymbs/275942. [Accessed: 09-Apr-2017].

[43] Cinegy, “Cinegy - Software Defined Television,” 2017. [Online]. Available: https://home.cinegy.com/index.php/products/software-defined-television. [Accessed: 09-Apr-2017].

[44] Elemental, “Software-Defined Video Processing Solutions | Elemental,” 2017. [Online]. Available: http://www.elemental.com/. [Accessed: 09-Apr-2017].

[45] S. Kennedy-Clark, “Reflection: Research by design: Design-based research and the higher degree research student,” J. Learn. Des., vol. 8, no. 3, 2015.

[46] ISO, “ISO/IEC 25010:2011 - Systems and software engineering -- Systems and software Quality Requirements and Evaluation (SQuaRE) -- System and software quality models,” Mar-2011. [Online]. Available: https://www.iso.org/standard/35733.html. [Accessed: 01-Jul-2017].

[47] Elemental Technologies, “CDNs DEMYSTIFIED.” 2012.