Cloud Browser Business Opportunities

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1 Executive Summary

This white paper presents the Cloud Browser technology that simplifies application deployment and maintenance by shifting their execution into the Cloud. Operators are concerned about services when deploying applications onto a fragmented device base, including Set-Top Boxes (STBs), smartphones, tablets and Connected TVs. The Cloud Browser technology addresses business and technology constraints and can reduce the overall Total Cost of Ownership (TCO) of a Quad-Play service.

Advancements in GSM standards, utilising 3G, 4G, and even 5G technology in the near future, can enable many telco operators to enter into a Quad-Play era which introduces wireless communications as another medium to deliver operator services, including HD (High Definition) and UHD (Ultra High Definition) video. As markets are becoming globalised, the most important differentiating factor for operators that currently emerge, is the quality of delivered service. More importantly, it is the Quality of Service at application level that plays a great role as users want a better application experience on multiple devices.

To achieve this and address users' demands, operators struggle with operational difficulties in providing qualitative user experience with high-value User Interface (UI) across multiple devices. Operators suffer from the inability to develop the UI once and deploy it on all end user devices as they have to provide different UI versions for every device, rendering engine and operating system. One solution for the described issue could be Cloud Browser technology.

The Cloud Browser approach does not attempt to treat the symptoms of the UI development problem caused by device fragmentation. Instead, this approach deals with the cause of the problem by shifting the complete UI application execution into the Cloud. This requires the UI to be developed just once and afterwards managed remotely out of the Cloud environment. The entire UI is delivered to users as a video stream therefore does not require the replacement of existing devices. The UI updates, carried out in the Cloud, immediately addresses all platforms and the latest UI techniques can be made available even on legacy devices. This has implications also on reduced efforts for testing and deployments of necessary security patches, resulting into a lower TCO.

Cloud Browser enables operators with multiple innovative applications and use cases that bring real business values and benefits. This paper also demonstrates performance data of Cloud Browser applications, based on user friendly trials. The data highlights, (irrespective of the application) the overall system latency of the Cloud Browser, it never exceeds the 400ms threshold, defined by Doherty and Thadhani [Ref:9], which makes the system highly responsive and desirable for users. Finally, it addresses various Cloud Browser deployment schemes that can help operators achieve faster innovation and great service flexibility.

2 Introduction

2.1 Scope

With the Quad-Play service, all household communications are provided by one operator. This results in growth of multi-screen services that will be available on multiple multi-screen devices such as televisions, STBs, mobile devices, tablet PCs and computers, in a seamless manner.

Telco operators or service providers are willing to provide seamless UX (User Experience) and UI through multi-screen services, however they are not able to implement it due to the fragmentation within multi-screen devices. The problem arises due to major differences in hardware performance depending on the combination of various SoC (System on a Chip) processors and graphics cores. The seamless UX/UI experience also cannot be achieved due to manifold software runtime environments including multiple operating systems and middleware. Moreover, there are several legacy CPE (Customer Premises Equipment) existing, usually owned by service providers that do not support future technologies such as browser implementations.

All multi-screen devices have taken their own technology evolution paths creating a variety of models and specifications which depends on the type of business environment and service requirements. For example, mobile devices which are sold in a higher price range with the largest annual volume can quickly improve their hardware performance and software features. STB devices are not easy to upgrade or improve specifications since they are sold in a very low price range with a smaller volume in contrast to mobile devices.

Cloud Browser addresses the problem of device fragmentation utilising the power of the Cloud to enable the latest browser technologies for any hardware and software platforms. Cloud Browser runs applications in the Cloud and delivers them as a video stream to the end user devices. The delivery of the UI as a video stream enables unified UX and constant service quality as a client only needs to decode an H.264 video stream that is currently supported on all devices.

The purpose of this document is to provide high-level information in Cloud Browsers technology for quad play operators that provide multimedia services over fixed-line networks. With this intention, this whitepaper describes the Cloud Browser technology options, its various applications and use cases. Importantly, the main focus is to emphasize business values, benefits and opportunities that Cloud Browser can bring to operators.

2.2 Cloud Browser Technology Pitch

Today's browsers need a vast amount of hardware resources to process modern web sites or simply unable to support modern web technologies such as HTML5. The Cloud Browser concept addresses these issues by putting the browser into a more powerful, easier and manageable server or Cloud. The service execution is shifted to the Cloud, where the user interface is rendered and streamed down as a video stream to the client. The main functionality of the client is decoding and presenting the video stream to the end user. In this approach the user interacts with a Cloud environment, as all user requests are forwarded by the end user device to the Cloud, where the UI gets adjusted.

Using this design, it is possible to provide a uniform UI for a large range of devices. Furthermore, this concept reduces the need for processing power of the client and helps in deploying new browser technologies faster.

2.3 Connection with W3C: On the Way to Standard Approach

The Cloud Browser technology is currently under development at W3C (World Wide Web Consortium) Web and TV Working Group as part of a dedicated Cloud Browser Task Force [2]. The work of this group is based upon real network deployments that already exist in the market. The group aims to unify and standardise this technology which would enable a wide range of Cloud browsing.

The W3C Cloud Browser Task Force has been actively focusing on the development of a Cloud Browser based technical specification and API (Application Programming Interface) design. This includes identifying use cases, developing technical architecture and defining service APIs for developers.

2.4 Definitions of Terms

Term	Description
Quad-Play	Quad play or quadruple play is a combination of the triple play service of telephone, broadband Internet access and television with wireless telephone services.
UX (User experience)	User experience is an entire experience of an end user while using a particular service.
HTML5	HTML5 is the fifth and current version of the HTML standard that is a markup language for structuring and presenting content on the Internet.
Cloud Browser	Browser instance originated in the Cloud that executes and renders the TV UI and delivers it to the client as a video stream. Also known as “network based browser”.
TV middleware	TV middleware is an execution environment for a TV User Interface (UI). It is an abstraction layer between the Set-Top Box (STB) operation system/hardware and TV related applications. Also known as “STB middleware”.

2.5 Abbreviations

Term	Description
API	Application Programming Interface
CA	Conditional Access
CB	Cloud Browser
CCU	Concurrent User
CPE	Customer Premise Equipment
CPU	Central Processing Unit
CSS	Cascading Style Sheets
DRM	Digital Rights Management
EPG	Electronic Program Guide
GPU	Graphics Processing Unit
HDMI	High Definition Multimedia Interface
HTML	Hyper Text Markup Language
IP	Internet Protocol
IPG	Interactive Program Guides
Kbps	Kilobits per second

Term	Description
Mbps	Megabits per second
NFV	Network Function Virtualization
OS	Operating System
OTT	Over-The-Top
QoS	Quality of Service
ROI	Return on Investment
SDN	Software-defined Networking
SoC	System on a Chip
STB	Set-top Box
SVOD	Subscription Video-On-Demand
TCO	Total Cost of Ownership
TTM	Time-to-Market
TVOD	Transactional Video-On-Demand
UHD	Ultra High Definition
UI	User Interface
URL	Uniform Resource Locator
UX	User Experience
VOD	Video On-Demand Service
VR/AR	Virtual and Augmented Reality
W3C	World Wide Web Consortium

2.6 References

Ref	Doc Number	Title
[1]	RFC 2119	“Key words for use in RFCs to Indicate Requirement Levels”, S. Bradner, March 1997. Available at: http://www.ietf.org/rfc/rfc2119.txt
[2]	W3C Cloud Browser	W3C Cloud Browser Task Force Main Page https://www.w3.org/2011/webtv/wiki/Main_Page/Cloud_Browser_TF
[3]	Netflix on Comcast	Netflix on Comcast’s X1 News Release http://www.recode.net/2016/7/5/12096380/comcast-to-let-netflix-onto-its-x1-platform-which-is-a-very-big-deal
[4]	Charter	Charter Expands Rollout of Cloud-Powered Spectrum Guide http://www.multichannel.com/news/content/charter-expands-rollout-cloud-powered-spectrum-guide/404531
[5]	UPC Hungary	UPC Hungary (now Liberty Global) Launches Apps Including YouTube Using Cloud http://www.multichannel.com/news/tv-apps/upc-hungary-nets-cable-europe-innovation-honor/388800
[6]	Cablevision launches Hulu using Cloud	Cablevision (now Altice) Launches Hulu Using Cloud http://www.multichannel.com/news/content/cablevision-offers-hulu-set-top-boxes/403930

Ref	Doc Number	Title
[7]	ACG Research	ACG Research: Business Case for CloudTV http://www.activevideo.com/fl-2580/ACG_Research_%20ActiveVideoCloudTV.pdf
[8]	Cloud UI Latency	Cloud UIs: Managing Latency without Compromise http://www.activevideo.com/fl-2578/CloudTV%20Latency%20White%20Paper_111113.pdf
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[10]	O'Reilly Media	Hurff, Scott. Designing Products People Love: How Great Designers Create Successful Products. " O'Reilly Media, Inc.", 2015.
[11]	AppFlinger	AppFlinger - a Cloud Browser from TVersity http://www.appflinger.com/

3 Operators Motivation

Several operators are already delivering triple play services with voice, data and video as a pay-TV service. Rolling out gigabit speeds to the home, operators are looking for innovative services that can make use of all available bandwidth.

For operators, service innovation needs to go beyond pay-TV such as:

- On boarding online video, Over the Top (OTT), gaming and other popular applications with the greatest appeal.
- Extending services on both fixed line and wireless networks, and to devices such as connected TVs, mobile tablets owned by the subscriber.
- Enabling quad play for future innovation and services.

With myriad device hardware and software complexities, and a large installed base of existing managed devices, operators need to find ways to decouple services and applications from device dependencies.

3.1 Service Motivation

Operators are motivated to develop and deploy new services by trends and behaviours driven by their own subscribers. Subscribers are enticed by services such as below:

- **Modern Pay-TV Experience**: Operators are expected to bring modern interactive or electronic program guides (IPG or EPG) with mosaic/animation features, video on-demand (VOD) services – replacing old devices with the new ones that can bring these experience to the subscriber is a significant challenge.
- **Online Video or OTT**: Many young potential customers are willing to subscribe for services with unlimited free or premium online videos content.
- **Gaming**: Subscribers have to use other devices that are not usually provided by an operator to access gaming applications and services.

- **Web Based Applications**: Connected IP (Internet Protocol) devices such as smart TVs, mobile tablets and smartphones provide access to lot of attractive applications which are not available on the managed operator's services.

Operators have deployed millions of devices however, many of these managed devices do not have the graphics capability required for gaming applications or rendering advanced UI/UX. If the operator decides to develop applications, it will involve significant time and resources with native device code, dealing with browser or plugin issues. These significantly impact the TTM (Time-to-Market) for bringing these services and experiences that subscriber's demand.

Operators require service agility rather than limitations by device capabilities. They should take advantage of developments in Cloud & virtualisation, web services and tools, application ecosystems and online partnerships.

3.2 High-level Business Constraints

Operators encounter several market and ecosystem issues that have an impact on their CapEx and OpEx, when onboarding new services or embracing quad play:

- **Operators need an alternative while they replace older managed devices** with new ones – not only does replacement involve significant CapEx, but what is deployed today may become legacy in a few years.
- **It is expected that more operators will partner with OTT providers.** The Comcast and Netflix recent announcement is an example [3]. However, a device-centric approach can limit these business models to certain high-end devices or premium subscribers.
- **Online content market is fragmented resulting in a myriad of media formats**. Devices such as STBs are fragmented due to multiple vendors and models launched in many years. Regardless, subscribers will expect a consistent experience from an operator.
- **Longer time and significant costs to replace multi-screen devices.** A totally new and innovative service requires more powerful hardware performance which in turn requires replacement of the end users devices. Televisions and STB devices have longer product life-cycles and are more price-sensitive than mobile devices or those devices which can be largely distributed with a higher retail price. Therefore, the burden of device replacement needs to be considered as a key factor for the constraints in service innovation.
- **Significant burden of costs to develop and maintain multi-screen applications.** When developing seamless multi-screen services covering mobile devices, computers, televisions, and STBs, it is inevitable to develop each application in accordance with various OSs (Operating Systems)/middleware/runtime environments of each device. Even if an application is able to run on the same OS/middleware/runtime environment, continuous efforts are necessary to correspond to upgrade releases of different OS versions. Application maintenance costs will increase when any necessary upgrade is required in due time.
- **TTM in on-boarding of new services.** Fragmentation in multi-screen devices becomes a great obstacle when it comes to trying to quickly on-board new services or products. It basically requires not only more resources to meet the requirements of

different environments, but also requires an adequate amount of time and costs to undergo the quality assurance process.

Online content is protected by a variety of DRM (Digital Rights Management) systems, while pay-TV boxes use conditional access systems. Operator’s devices may only support specific CA (Conditional Access)/DRM systems. However, they need a way to manage security that can target a wide variety of popular and premium online content.

3.3 High-level Technology Constraints

- STBs deployed over the years have varying CPU (Central Processing Unit), memory and graphics profiles. Even in the future, there will be mix of devices, to bring next generation features and form factors to the market. e.g., HDMI (High-Definition Multimedia Interface) dongles, 4K ready STB, VP9 format support etc. Devices should focus on latest codecs and content related value rather than computing and graphics improvements.
- Operators have to address low-end or legacy devices to achieve consistency in delivering experiences across their service area. Streaming models will depend on device types in the operator’s footprint. If the end user device has more capability such as better graphics or it can run a browser, techniques such as pass through mode to offload work to the device is viable however, this is not the case with many devices.
- Operators should try to leverage third party application ecosystems and web development to bring the applications available to subscribers. Development resources with native software on each device model involves significant OpEx and not viable as a strategy for onboarding new applications. It also involves dealing with constant browser and plugin updates. Applications are typically in web format other than native device code. Furthermore, premium online applications are updated every year to support new formats such as resolutions, DRMs, policies, etc. New yearly certification may also be required, and keeping them up to date may require using an external service.
- Big gaps in available application ecosystems amongst multi-screen devices. Televisions and STBs show lower hardware performance compared to mobile devices or computers in terms of computing power and graphics core, which results in poor usability and lack of a mature application ecosystem. This gap creates a problem for telco operators and service providers to achieve technological innovation.

Online content uses many DRMs, therefore a multi-DRM approach is needed. However, implementing every single DRM solution on the device is not always possible. A better solution would be to handle the security in a way that it can map to the conditional access or DRM already supported by the device.

4 Cloud Browser Solution

Over the last decade web browsers have made significant improvements in developments from HTML code interpreters towards ecosystems for high end applications. The ubiquity of web technologies has hit the TV domain and heavily disrupted classical video delivery services. The convergence of web and TV has introduced the browser as a TV middleware technology. The execution of the UI in the TV domain has undergone major changes and evolved to the so-called browser based UI. More and more new STB deployments make use of web browser technology as their core runtime environment for portals and applications.

However, with regards to the browser as the TV middleware technology, the STB market is becoming very fragmented. A lot of legacy STBs do not have enough hardware power to support the browser. This also applies to the new coming low-cost STBs like HDMI Dongles and low-end STBs. Moreover, high-end legacy STBs often run proprietary media frameworks which are still unable to execute the latest HTML5 features.

These challenges, described in detail in Section 3 Operators Motivation, could be addressed by the Cloud Browser solution, also presented in Figure 1. The Cloud Browser solution enables the shift of the browser into the Cloud environment. Therefore, all data to be delivered to the end customer, such as UI applications, e.g. electronic program guide (EPG) and corresponding meta data, linear TV, VoD assets, web video, gaming applications and other operator services, are fed into the Cloud Browser instance. The Cloud Browser instance performs media processing and application execution. Cloud Browser combines video, user interface, applications and services, captures it into a video and streams it to the user. The user receives the entire service as a video stream and nothing is being executed on their local device. The Cloud Browser instance also performs media adaptation and DRM bridging by conversion and re-encryption of the media to the streaming format and content protection systems supported by the devices.

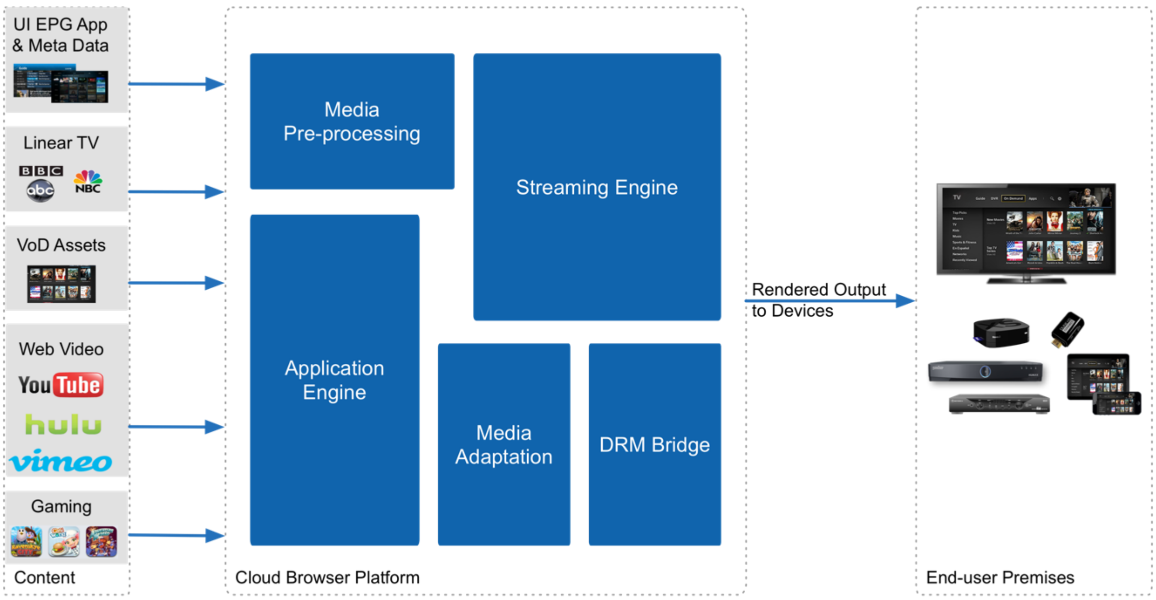

Figure 1: Cloud Browser Platform

In this approach the middleware is decoupled from the hardware due to the shift of the browser into the Cloud which resolves hardware dependencies and makes the system highly adaptive and flexible, providing a variety of the application environments. This approach also solves the STB capability limitations and thus enables the operator to deliver new rich multimedia services to legacy STBs and in general to any device owned by the end user.

The benefits of shifting most of the STB processing functionality to a virtualised Cloud environment with the Cloud Browser solution can be explained from two perspectives. First, from the operator's perspective, device fragmentation issues can be solved, pursue a better manageability of the customer devices and simplification of the service and application delivery. Second, the consumption of content, services and applications through potentially less complex hardware at the end user's domain is a good attraction for customers as it enables energy saving

However, both the network load and degree of service composition complexity in the Cloud increase when moving to the Cloud Browser solution. Taking this into account, the Cloud Browser solution can be divided into two different approaches with respect to the UI and video delivery to the client. These approaches are explained below.

4.1 Single Stream Cloud Browser

The maximum number of functionalities that can be shifted into the Cloud environment is referred to as a single stream approach of a Cloud Browser, presented in Figure 2.
In this approach the end-device for example a STB, receives only a media stream, which represents the whole user experience. The Cloud Browser is acting like a conventional (or locale) browser. Only resource termination is done in the cloud and rendered as a media stream. Therefore the end-device is only responsible for displaying the stream and providing essential information like key presses. The end-device does not have any notion of the resource content.

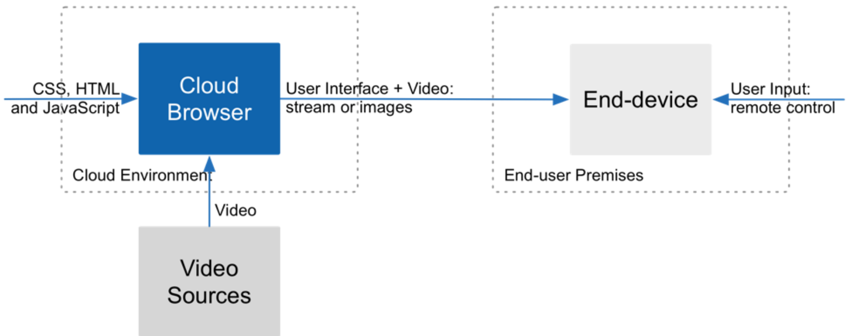

Figure 2: Cloud Browser Single Stream

4.2 Double Stream Cloud Browser

With regards to the double stream approach of a Cloud Browser presented in Figure 3 below, the Cloud Browser renders the UI with applications only, while the media is delivered from another server. Thus, the UI/Apps and media streams are delivered separately to the client, which then has to combine both of these streams and present them to the end user in a unified form.

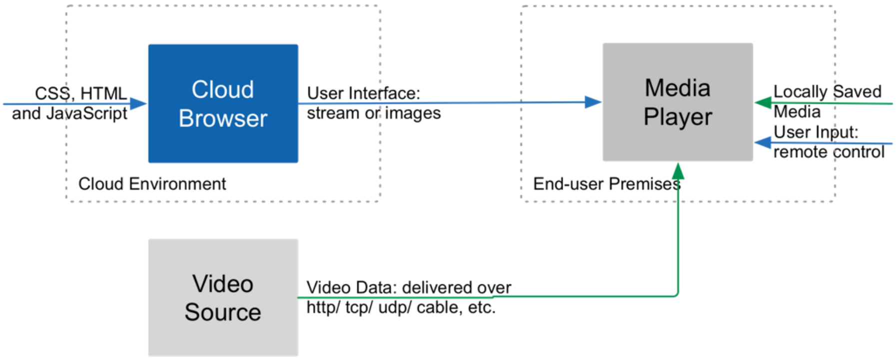

Figure 3: Cloud Browser Double Stream

The double stream approach of a Cloud Browser implements a separate delivery of the video stream and the UI stream to the client STB. This approach therefore enables reuse of the legacy video delivery infrastructures, e.g. multicast networks, cable networks, etc., thereby cutting down the unicast traffic that will be used only in certain cases where the UI stream is delivered.

5 Cloud Browser Applications & Use Cases

Cloud Browser is the answer to quickly onboard applications and scale to large footprint. The browser runs in the Cloud, executes the applications in HTML5 or other browser compatible formats, and the rendered content is streamed to the end-user device. It accelerates service agility and delivery for an operator, and there is no longer a need to wait for the next device upgrade cycle to bring new experience to subscribers.

5.1 Advanced UI Streaming

A linear TV program guide is a prime application for Cloud rendering. The preferred method is to develop an HTML5 application of the UI for the EPG or interactive program guide (IPG), though other browser executable formats and native UI development environments can also be considered. Other UI-centric applications such as transactional video-on-demand (TVOD), subscription video-on-demand (SVOD), and web content UI can be also delivered as a stream from the Cloud. The Cloud Browser can render the UI, and stream the output to the device in one of the following ways:

- **Image UI streaming:** Graphics images of the UI as a JPEG or PNG file are transferred to the device. The device capabilities can supplement for complex features such as animations.
- **Video UI Streaming:** The browser rendered UI output is streamed as an MPEG2/H.264 video. Video streaming can be used to deliver complex user interfaces with advanced animations, video mosaics or tiles, independent of device capability.

For legacy or low-end devices with limited graphics capability, UI streaming is the only way to deliver the UI. Therefore, subscribers can get state of the art user interfaces delivered from the Cloud.

Two examples are shown below:

"*Charter Communications, a leading North American cable operator has successfully rolled out its modern Spectrum EPG using the Cloud rendering technology [4]. Charter has used ActiveVideo's CloudTV platform to deliver it to older QAM-locked set-tops as well as its newer IP-capable devices."*

"SK Telecom along with SK Broadband, the largest quad play operator in Korea, has successfully launched Advanced UI service based on Entrix Cloud rendering technology. The Cloud-rendered advanced UI services include standard HTML5 based Home, VOD, EPG service, UI with higher resolution, clear image quality and smooth animation effects. The target STB models are high end HD STB running Android OS and older low-profile STB running conventional middleware."

Using Cloud based UI streaming, operators can deliver a consistent, superior user experience to all subscribers, regardless of whether they have legacy devices or new devices. New UI designs can be rolled out overnight, enhancing the subscriber satisfaction.

5.2 OTT Video Application Streaming

Online video or OTT applications are being increasingly integrated with pay TV as a service enhancements. Cloud Browser is an excellent option for this strategy. The seemingly infinite media content from various web providers poses two main problems for device support:

1. It requires devices to support multiple media formats – more than the typical MPEG2 or H.264 profiles used for pay TV.
2. It requires devices to support multiple DRMs – beyond just the pay TV operator's conditional access system.

This seemingly infinite media content makes it unrealistic to onboard a wide variety of online video applications directly onto the end-user devices. However, using the Cloud rendering approach, media adaptation can be done in the Cloud. The web media content can be converted, rendered and streamed in the format and resolution supported by the device.

The content security can also be bridged in the Cloud, the original source content can be decrypted and re-encrypted in the Cloud to the CA or DRM system supported by the device. This way, the Cloud rendering approach also enables a multi-DRM strategy. The subscriber experience is however seamless.

Two examples are shown below:

"Liberty Global in Hungary, along with ActiveVideo and Metrological as partners, launched a Cloud based platform to offer a wide range of applications including YouTube [5]. The service has been deployed to over half a million devices, with any format conversions for web content done in the Cloud."

"Cablevision, now part of Altice, launched Hulu as a channel on its Optimum TV pay-TV service [6]. Optimum TV Subscribers could just tune to channel 605 and watch Hulu content, or enrol directly to the Hulu service if they don't already have a Hulu account."

Media adaptation and DRM bridging allows devices to focus on their core capabilities as next-generation video decoding and processing capabilities such as 4K/HEVC or VP9 codec functionality.

5.3 Casual TV Games Streaming

A variety of web applications can be onboarded using Cloud rendering, examples include social media apps, personalized shopping, educational, music, exercise, interactive TV ads and even gaming applications. Regarding gaming applications, providers of gaming apps often have to deal with poor user experience due to insufficient memory and limited colour palates in STBs or Connected TVs. They also have to deal with a defragmented device market, where multiple device platforms must be addressed. For example, one of the growing and profitable segments of the entertainment market for operators are casual games, they can be provided on a special gaming channel by operators.

One example is shown below:

"CJ Hellovision and D'Live, the largest cable operators in Korea, also launched a Cloud-rendered TV application services such as casual game services in addition to the advanced UI streaming. Based on Entrix Cloud rendering technology, Cloud-rendered TV Applications are delivered with both single stream and double stream Cloud Browser technology, either over QAM channel and DOCSIS or IP delivery, depending on the use case scenarios."

The delivery of casual games to a variety of end user devices with limited capabilities can be addressed by Cloud Browser. If the games applications are executed in the Cloud, the operator has more control over the changes, and can time the feature updates. It is also faster to develop and deploy the games, providing a significant TTM advantage, since there is no need to develop for multiple device models in native software environments, but only for web based Cloud Browser environment. In other words, the operator has full control over the service execution environment, providing excellent gaming experience to its users. Delivery of casual games to STBs from the Cloud can leverage new revenue streams for operators.

5.4 Interactive TV Ads

Similarly to the delivery of casual games from the Cloud, web based interactive TV advertising for STBs and connected devices is also one important application for Cloud Browser. The Cloud Browser technology resolves device dependencies for TV advertisement applications and provides developed and deployed once which could be delivered to multiple devices as a premium and unified user experience. Legacy devices that do not support web technologies could be enabled with real-time web based advertisements that are fully independent from an operator platform.

Cloud Browser can also enable content-rich advertisements that could reach more customers and help to establish strong relationships with brands. The advertisers, in turn, could achieve large scale for their campaigns with Cloud Browser based delivery of their advertisements. Currently, a lot of advertisers simply ignore the interactive TV advertising market as any campaign could be very costly and limited with regard to device reach. Cloud Browser-enabled advertisement can also help to address poor processing power on legacy STBs and some of the other connected devices.

In summary, Cloud Browser or Cloud rendering approach can be used for delivering almost any application, UI, gaming, video etc. Cloud based video streaming can bring service innovation to low-end or legacy devices.

5.5 Scalability & Performance of Applications

The Cloud platform can perform well and be scaled to large footprints, with careful planning to meet latency, bandwidth and peak concurrency requirements and with the right selection of Cloud server architecture for UI, gaming and video applications, and by working with a reliable Cloud rendering vendor.

Standard applications, without high-end gaming ones typically involve a roundtrip session latency of less than 500ms, that is considered acceptable to the human eye [8], and operator deployments highlight that the Cloud rendering approach is highly scalable, addressing latency, bandwidth and other performance metrics as well. Moreover, with regard to the overall system response, Doherty and Thadhani identify in their work [9][10] that a computer response under 400ms is perceived by a user as rapid response time, which makes the system highly desirable for customers.

Regarding the Cloud Browser technology, image streaming is a low bandwidth option, in the few hundred Kbps (kilobits per second) range. Video streaming can deliver the experience in the low 1.0 to 3.0 Mbps (megabits per second) range depending on the UI and network characteristics. Most applications can be expected to be delivered in a 2.0 to 4.0 Mbps network bandwidth. Streaming of certain casual games may require higher bandwidth and server performance if it involves features such as 3D animation or if it requires full OpenGL support for rendering complex objects. Online video streaming would use typical bandwidths associated with video delivery over broadband influenced by factors such as standard or high-definition. As an example, the scalability and performance data of Cloud Browser applications, based on a friendly user trial in Deutsche Telekom Laboratories, is summarised in Figure 4.

	Advanced UI Streaming	OTT Video Application Streaming	Casual TV Games Streaming	Interactive TV Ads
Description	Streaming of UI elements (main menu, EPG, VoD menu) as image (.png/.jpg) or video stream (H.264)	Streaming of applications: HTML5, Android, native apps like Netflix (only UI)	Streaming of casual games with higher performance requirements (3D animated, OpenGL support)	Streaming of interactive TV advertisement ads to any kind of devices
Bandwidth	Image stream: 100-300 kbps Video stream: 1-3 Mbps	2-4 Mbps	4-8 Mbps	Image stream: 100-300 kbps Video stream: 1-3 Mbps
Scalability	High	Middle	Low	High
Latency	150-400 ms	300-400 ms	<300 ms	<300 ms

Figure 4: Scalability and Performance of Cloud Browser Applications (based on a friendly user trial in Deutsche Telekom Laboratories)

Studies by industry analysts such as ACG Research [7] have shown that the Cloud rendering approach delivers significant CapEx and OpEx savings for operators. Operators do not have to replace existing devices to bring new experience, they can leverage existing devices without upgrades and can shift functions to the Cloud for better control and manageability that saves operating expenses.

In the future, operators can focus on more savings through soft client models to support devices such as smart TVs, and reduce the need for operator provided hardware.

6 Business Benefits and Deployments

6.1 Benefits for Operators

Along with broadband, Cloud based virtualisation technologies have been developed in parallel. Starting with SDN (Software-Defined Networking)/NFV (Network Function Virtualisation) and virtual machines, now it is now getting less complicated automate allocation of Cloud resources and optimally manage them.

Cloud Browser and virtualisation liberates the UI/UX, gaming and online apps experience from device dependencies. The CPU or browser performance on a device, memory or GPU (Graphics Processing Unit) features are no longer limiting the delivered UI. Cloud Browser enables devices to leverage their core capabilities such as supporting future codecs and video resolution.

Recently, the Cloud Browser and the virtualisation technology, derived from the rapid evolution of Cloud computing, gained popularity amongst telco operators and service providers. It is being renowned as a successful alternative to resolve fragmentation issues.

The following two aspects can enable faster market penetration for the Cloud Browser technology:

1. All-IP based network costs are continuously declining, while network bandwidth with acceptable QoS has been increased enough to provide video services even under the network environment. Simply, Cloud rendered services based on Cloud Browser technology consumes equal or less network bandwidth than OTT video services. This can imply that any Cloud rendered service, whether it includes TV UI, OTT VOD, or game services, can be available in the existing network environment without degrading the overall quality or performance.
2. Server platform hardware has been upgraded evolutionary in recent years. CPU and GPU processor manufacturers have released new architectures that can achieve better CCU (Con-Current User) capacity and meet ROI (Return on Investment) requirements in terms of business aspect. Furthermore, proliferation of public Cloud computing environments can help telco operators and service providers to lower the costs in order to build and maintain Cloud server platforms, as it is cheaper than the total costs of replacing and upgrading multi-screen devices to pursue service evolution.

Consequently, the main benefits of Cloud Browser for operators can be categorized in the following four classes:

1. **Enriched consumer experience.** With Cloud Browser technology operators have full control of service execution environment and can provide a superior end-user experience with uniform UI providing constant and performant UI/application experience on all devices. Operators become device independent and can deploy services without custom device implementations, the UI can be consistently and rapidly updated. Operators can quickly adapt the UI/UX corresponding to consumer demands, which significantly increases the speed of innovation.
2. **Removing technical constraints.** With Cloud Browser operators can develop device independent UIs and applications because any device and platform constraints are

eliminated. This significantly speeds up the overall process of UI/UX development, in particular, the implementation, testing and deployment phases. Therefore, the expensive adaptation of the UI/UX to different types of devices regarding their hardware restrictions disappears.

3. **Open up new business opportunities.** Cloud Browser technology makes operators more agile in competition with OTT VOD/SVOD OTT providers. Operators can concentrate on their customers to develop new, compelling services and user interfaces without any hardware restrictions. Fast and dynamic adaptations and updates of UI/UX and applications become feasible, which leads to faster TTM and helps to keep up with the innovation pace of the web industry.
4. **Significant CAPEX/OPEX savings.** The deployment of Cloud Browser technology leads to lower costs for development, deployment, maintenance and troubleshooting with respect to services, UIs and hardware:

    a) **Cloud Browser enables scale and lower CapEx**. Cloud models can be in-house, or hybrid public/private and can leverage innovations in virtualisation, elasticity, open source etc., depending on the operator's need, size and budget.

    b) **Shifting to Cloud results in lower OpEx.** Applications for Cloud Browser can be developed quicker using web tools vs. native device middleware/software. Application driven models (Light Client integration) are possible for devices that can run a browser, such as mobile tablets or smartphones.

Briefly summarising the benefits of the Cloud Browser technology for operators, a current state-of-the-art STB could be compared with a Cloud Browser enabled STB as it is presented in Figure 5.

	STB	Cloud Browser	Comments
Unit cost	High	Low	
Performance	Moderate	Very high	W.r.t. games and powerful applications
Lifespan	Short	Very long	Fast hardware upgrade cycle
Fragmentation	High	No fragmentation	
Time to deploy	Long	Instant deployment	Average legacy STB upgrade cycle = 5+ years
Maintenance	Moderate	Low	
App ecosystem	STB dependent	STB agnostic	Any application can run on Cloud Browser

Figure 5: Benefits for Operators: STB vs. Cloud Browser

6.2 Cloud Browser Deployments

The following business cases presented in Figure 6 can be addressed by the Cloud Browser technology:

- **Migration of legacy STBs.** Operators have various STB generations with different performance capabilities deployed in the field. It's impossible to upgrade all hardware device capabilities or to exchange the whole STB population at a single rollout due to very high costs required. A viable option to extend the lifetime of these devices could be to deploy Cloud Browser solution and updating legacy STBs with a Cloud UI client.

- **Performance upgrade of low powerful STBs.** Operators do not have premium devices in the market only. To address different market segments, they also run devices with limited hardware performance that offer only a small subset of services to the end users. The Cloud Browser technology can be used to bring new service capabilities (VOD, SVOD, Apps) and UI features to these devices offering new attractive business opportunities for operators.
- **Operator services on smart TVs.** Another market segment to be addressed is the smart TV market, as smart TVs are already deployed in most households. Deploying a Cloud client on a smart TV leads to a great user experience which means no additional devices, cables or remote controls are necessary to consume video services. With this option operators can provide their services directly to smart TVs without the need for a STB, which could significantly reduce CapEx costs. This model can leverage a lot of new revenue streams for operators**.** However, this option would strongly depend on the willingness of TV manufacturers for such a collaboration.
- **Revive low cost STBs with high-end services**. The Cloud Browser technology opens up a great possibility to develop and deploy low cost devices capable of providing high-end entertainment services including 3D, games and 360 degree videos. Herewith, the CapEx expenditures could be also significantly reduced. The devices will be equipped with minimal hardware that is required to just run the Cloud Browser and its basic functionalities.

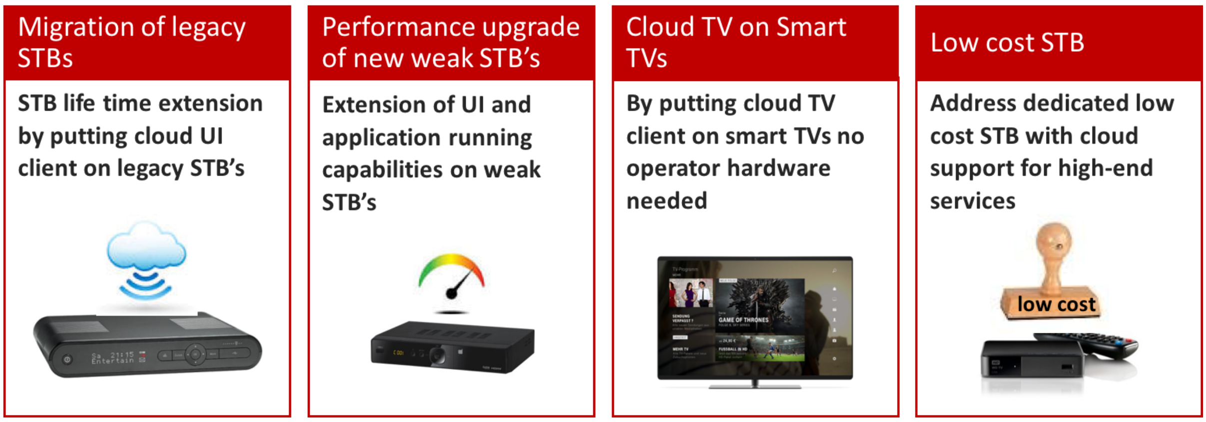

Figure 6: Cloud Browser: Possible Deployments

6.3 Costs Saving Potential

A deep dive analysis of costs and savings is needed to calculate a business case for a designated Cloud Browser use case. Figure 7 shows an exemplary overview about the different elements that should be considered for a delta cost analysis. The major impacts for Cloud Browser deployment are license costs, server investments and expenditures for client and backend integrations. In contrast, there are significant savings for hardware and client software implementations that also include the browser integration. Operators need a lightweight client that requires relatively low hardware performance. Moreover, STB maintenance costs can be considerably reduced due to its lower complexity, which leads to lower fault ratio and customer care expenses. Finally, service updates can be done in the Cloud, which will not require any testing on different STB types.

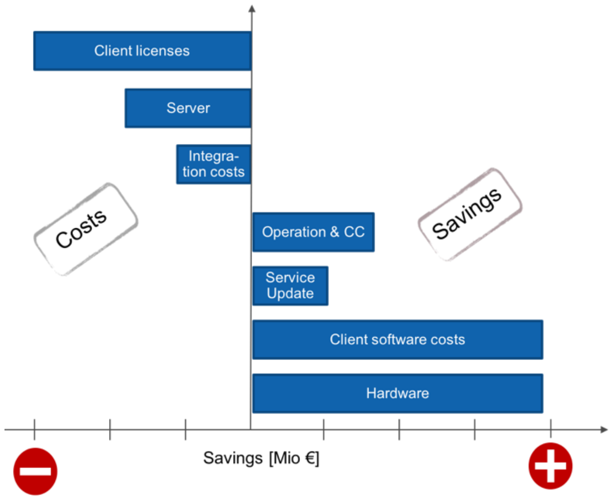

Figure 7: Cloud Browser Approach: Savings and Costs

7 Outlook

Cloud Browsers offer substantial benefits and with web technologies evolving towards HTML6, 360 videos, and VR/AR (Virtual and Augmented Reality), it is clear that the gap between device capabilities and the positive experience for users will grow. While edge devices are improving, history suggests that the web evolves faster and the gap is posed to widen further, leading those edge devices to continue and offer a sub-par web experience. This is the gap that Cloud Browsers aim to bridge and by doing so will offer a competitive edge to those that use them to deliver superior user-experience.

Trends in Cloud technology continue to improve the economics of deploying Cloud Browsers at scale. Elastic Clouds improve load management through automation and dynamic allocation of server resources with little or no upfront investment. Virtualisation, containerisation and open Cloud initiatives eliminate the traditional complexity of scaling Cloud services, such that resources can be quickly and cost-effectively allocated and managed across public and private Clouds.

8 Conclusion

Operators should consider Cloud Browser as a key part of their strategy for service innovation. Cloud Browser provides the service agility and scale to go beyond pay-TV and onboard new services such as modern UI/UX, online or OTT content, gaming and web applications on subscriber devices. Cloud and virtualisation technologies continue to make strides into the future, enabling highly flexible, efficient and cost-effective deployments. Using Cloud Browser technology, operators can grow into quad-play wired and wireless services as they expand using 5G technology, as well as satisfy current subscribers on legacy devices with new and improved experiences.

Annex A Document Management

A.1 Document History

Version	Date	Brief Description of Change	Approval Authority	Editor / Company
1.0	03/11/2016	New Position Paper	WWG/ PSMC	Alexandra Mikityuk (Deutsche Telekom)

A.2 Other Information

Type	Description
Document Owner	Web Working Group
Editor / Company	Alexandra Mikityuk (Deutsche Telekom)

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