Triple Play – A survey

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Abstract

Service providers are competing to take advantage of the rapidly-developing market for *Triple Play* services, a service that aims at achieving integration of voice, video and data communication, over both fiber and copper, with scalability at an optimal cost. In addition, technology providers are aiming at providing these services over wireless media, commonly referred to as *Quadruple Play*. IPTV, VoIP and high-speed Internet access are some of the key services provided by key technology-providers like Alcatel, Juniper and Nortel Networks.

In this article, we study the basics of triple play and quadruple play services and a few common applications. Then, we study a popular triple play architecture. The research also includes study on the pricing model adapted to support triple play services followed by a simulation study on OPNET 11.5 to analyze and understand QoS parameters, i.e. end-to-end delay and jitter experienced by voice, video and data traffic as they traverse routers configured with various scheduling policies.

1. Introduction

Triple Play is a combined offer which includes voice, video and data. However, the emphasis is on delivering video through a digital broadband network as part of a bundled offering. Delivering TV is the basic challenge of telecommunication operators interested in deploying and enhancing their networks to offer Triple Play services. In this survey, we will concentrate on the video service of the Triple Play and especially video delivered with different DSL technologies. This service is called Internet Protocol TV (IPTV) and the last few years it is a very popular term in the telecommunications industry.

In our days, it is obvious that traditional tele-communication companies that have been providing voice and/or data services are being interested in provisioning TV entertainment too. This is something essential to them since the antagonism with cable companies would probably take them out of the market. As a result, the turn to IPTV is not only a matter of profit; it has to do with their maintenance in the telecommunication arena. Therefore, offering this combination of services can convince costumers not to be lured away by other providers.

2. Triple Play – Overview

The Triple Play service is a marketing term for the provisioning of three services; high speed Internet, television (Video on Demand or regular broadcasts) and telephone service over a single broadband connection. Today, Triple Play services are offered by cable television operators as well as by telecommunication operators. These two kinds of operators are competing each other.

Telephone local exchange carriers (LEC) deliver Triple Play using a combination of optical fiber and digital subscriber line (DSL) technologies, called fiber in the loop (FITL). This means that carriers use optical communications to connect distant locations and use DSL over the existing Plain Old Telephony System (POTS) twisted pair technology to achieve the last mile access to the subscriber's home. On the other hand, cable companies use an architecture called hybrid fibre coaxial (HFC) to reach the subscriber's home. This technology uses coaxial cables instead of twisted pair cables for the last mile transmission standard to the subscriber [1].

Delivering video using DSL over twisted pair is a booming technology called IPTV. Here, video is streamed to the subscriber using the MPEG-2 (and soon MPEG-4) format. On the contrary, on an HFC network, television may be a mixture of analog and digital television signals. A device called Set-Top-Box is used by the subscriber to control and order video services, like video on demand. Internet data can be delivered using ATM or DOCSIS (Data Over Cable Service Interface Specification). Voice can be distributed in two ways; using the traditional POTS interface or using Voice over IP (VoIP).

Some service providers are considering new architectures using Ethernet and fiber to the home (FTTH). Supporting Triple Play Services in such way has the advantage of bypassing the need of broadband transmission using the legacy network. Upgrading the legacy network to provision broadband transmission is not considered a wise idea due to the tremendous cost required for such activity.

Triple play has generated a closely related term called Quadruple play. In Quadruple play voice, data and video are delivered using the wireless medium. Next generation networks like UMTS allow operators to distribute the aforementioned services efficiently. A new term named multi-play is used to describe both triple and quadruple services.

In addition, we should also have in mind the Quality of Service requirements of Triple Play services. Using a shared network like DSL or cable, QoS mechanisms are inevitable. It is well known that voice, video and data have different characteristics that operators have to have in mind in order to deliver the desired services complying to the Service Level Agreements (SLAs) and the requirements that subscribers pay.

3. Types of 3P Services

In this section we will give a description for each service of the triple play. However, our attention will be focused in delivering the TV service. As a result, we focus our analysis in IPTV; we believe that effectively transmitting video is the greatest challenge. Later, we continue with a brief review of the other two services, i.e. VoIP and Data. Finally, an introductory section to Quadruple Play services is discussed.

3.1 Data services

Data services refer to activities familiar to all of us like web browsing, file downloading, e-mail, electronic purchases, electronic games and other applications using high-speed Internet.

3.2 Voice over Internet Protocol

Voice over Internet Protocol (VoIP), is a technology that allows us to make telephone calls using a broadband Internet connection instead of a regular (or analog) phone line. VoIP enables telephone calls through a data network like the Internet. It converts the voice signal from the telephone into a digital signal that travels over the Internet and then converts it back at the other end so we can speak to anyone with a regular phone number. Some signaling protocols used for internet telephony are the Session Initiation Protocol (SIP) and the H-323 protocol.

3.3 IPTV

Traditional telecommunication providers need to protect and increase their market share. The more serious reason that phone companies are considering video over the phone lines is to ensure their own survival. This is why the idea for Internet Protocol TV was born. Voice providers have to compete with the cable providers. Cable companies are considering providing communication to their customers besides entertainment. They intend to capture millions of voice subscribers who are interested in long distance and international voice calls. Cable providers entice their customers with voice over Internet Protocol (VOIP) so as to achieve that target. Cable operators' ambition is based on the fact that the customers are willing to take the bundle of services they provide (video, voice, data) because it is more convenient and more valuable. As a result, traditional telecommunication operators had to find the antidote for that movement. Thus, their response is to try to provide entertainment beside communication to their customers.

Different access methods like fiber, copper and soon wireless are being considered to deliver video. IPTV can be delivered using digital broadband networks like ADSL (Asymmetric Digital Subscriber Line), VDSL (Very High Bit-Rate Digital Subscriber Line), fiber and wireless LMDS (Local Multipoint Distribution Service). As we see, it has nothing to do with the traditional cable or broadcast and satellite TV that we are familiar. Deploying video-over-DSL (i.e. video over phone lines) is the usual way for telecommunication providers to fend off the triple play choice from cable operators and thus we will concentrate with DSL in our discussion.

3.4 Quadruple Play

A Quadruple play service is the little brother of the Triple play. It combines the triple services (high speed internet, voice and video) with wireless services. When we say wireless services we do not only mean having a cellular-like service; rather it is the ability to have wireless access to all the aforementioned services. Given the advancements in WiMax (Worldwide Interoperability for Microwave Access) the ability to transfer information over a wireless link at combinations of speeds, distances and non line of sight conditions is rapidly improving. WiMax is a wireless technology that has the ability to provide broadband connections over long distances. Moreover, advances in both CDMA and GSM standards, utilizing 3G, 4G or UMTS allow the service operators to enter into Quadruple Play and gain competitive advantage against other providers. A scenario of Nortel's Passport Solution to achieve the quadruple play is shown in Figure 1[13].

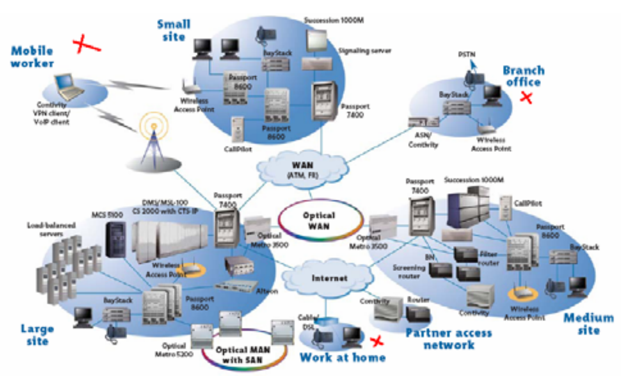

Figure 1: Nortel's Passport Solution

3.5 Network Transformation

Triple play faces some new network challenges. Deploying the aforementioned services requires some significant changes in today's network architecture. Triple play services are not like traditional Internet services. Traditional Internet is "best-effort" service. This means that due to the fact that users are not online the same time, aggregating traffic from multiple users increases network efficiency. However, triple play includes real-time services, like voice and video. These kinds of services have strict and-to-end delay, jitter and bandwidth requirements. Therefore, we cannot treat triple play services as "best-effort" services. If a real-time service confronts packet delay or packet loss the connection is instantly dropped.

From the above discussion it is obvious that a network transformation is required for triple play services. The solution for voice is trivial though; since voice has small bandwidth requirements we can alleviate all the problems by just reserving some network capacity for it. However, with the video service – which includes IPTV, Video on Demand and HDTV - things are not so apparent. Users may now need up to 20Mbps to satisfy their needs. A study from Alcatel (see Fig.2) has indicated a huge bandwidth increase in different portions of the network compared to today's requirements. Ideas like multicasting the video with a protocol called IGMP (Internet Group Management Protocol) have emerged. As a result, we realize that triple play postulates a new kind of network architecture.

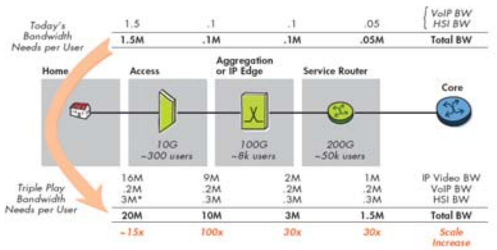

Figure 2: Triple Play bandwidth requirements

4. Technical details

At this section we get into more technical details. We believe that it is important to begin our technical part with a comparison between IPTV and cable TV. We will concentrate on video services, leaving aside voice and data for a while, because we believe that video is the main challenge operators on both sides are facing. Delivering video efficiently and with the lowest possible cost are two very important parameters taken under consideration when designing a network's architecture. We first start our discussion with a brief technical juxtaposition of DSL against cable technology. In order to make a comparison between IPTV and cable TV we should have an idea about how DSL and cable work. However, we shall not be misleaded that DSL is the only way to provide IPTV. We are doing this comparison because the possible optical access methods (Fiber to the home – FTTH, Fiber to the curb – FTTC) have not become so popular yet due to their cost. In the second part of this section we proceed with a more detailed view of triple play, with emphasis on IPTV.

4.1 DSL vs. Cable

4.1.1 DSL overview

DSL is a very high-speed connection that uses the same wires as a regular telephone line. DSL allows us to make regular phone calls and surf the Internet simultaneously. It is a point-to-point medium that manages to squeeze more information through a standard copper wire. However, the capacity and moreover the availability of DSL depends on the length of the local loop. DSL is distance sensitive technology and a user's distance from the closest Central Office should be less than 18000ft.

The bandwidth of copper wires is capable of carrying more than the phone conversations. DSL exploits this property. In particular, asymmetric DSL (ADSL) divides up the available frequencies in a line such that upstream and downstream data as well as voice can travel together in the same copper wire. A particular standard used with ADSL is the discrete multitone (DMT) system. This system divides the spectrum into 256 independent channels of 4000 Hz each. The first channel is used for voice, 250 channels are used for data and the remaining 5 channels are not used to avoid interferences. So, using DMT is like having 250 regular dial-up 56Kbps modems working in parallel [3]. ADSL allows speeds of as much as 8Mbps downstream and 1Mbps upstream.

4.1.2 Cable Overview

Whereas in the telephone system every house has its own private local loop, in the cable technology every cable is shared by many subscribers. Typical cables nowadays have 500-2000 houses to serve. Cable providers do not claim any guaranteed bandwidth; the bandwidth depends on how many people are currently active on each cable. A single coaxial cable can fit 100 cable TV channels and Internet data. This is due to the tremendous bandwidth that a cable wire can transfer [3].

Cable television channels occupy the frequencies between 54-550MHz [4]. Each television signal from various TV stations is given a 6MHz slice of bandwidth on the cable. Upstream data use the 5-42 MHz band and downstream data use the 550-750 MHz band. Internet downstream data are sent from the cable provider to the user into a 6MHz channel. Thus, on the cable data look like a TV channel. Upstream data require just 2MHz of bandwidth since most people download much more information than they upload.

4.1.3 Comparison DSL-Cable - Advantages of IPTV

The most important advantage of triple play services through DSL, as opposed to cable, is the effective use of bandwidth. To get an idea of what we are talking about we will briefly compare IPTV bandwidth usage with Cable TV bandwidth usage. In the Cable TV network, a huge amount of bandwidth is dedicated to a number of multicast streams that they will eventually enter our homes. These streams are our TV channels. Even though this multicast scheme works excellent and has a low cost, it suffers from a major drawback; that is the huge waste of bandwidth. This is because multicast means that the streaming is sent to all the subscribers in the Cable network. However, we do not need all these channels since we can only watch one channel at a time. As a result, a huge fraction of the bandwidth is wasted. On the flipside, the amount of bandwidth required for an IPTV system is more moderate since the operators unicast the desired TV programs to the subscribers [5].

Another advantage of using IPTV over DSL is that we do

not have to worry about the performance of our network as the users increase since each user has its own connection. On the other hand, with cable, as more subscribers join a provider the performance gets worse because users share the same medium, i.e. cable speeds vary depending on the number of users in the network. Nevertheless, cable speeds are usually two times faster than DSL 1.5Mbps.
What is more, DSL is more secure than cable due to its point to point functionality. Using a shared medium like a cable is vulnerable to eavesdropping and privacy violations. Moreover, the telephone system is more reliable than cable. It can work constantly even after a power failure because it has backup mechanisms. With cable, if the power goes down all users are cut off instantly.

But the advantages are not over yet. New types of services and levels of interactivity between the user and the network can be implemented. Here, we can mention as an example Alcatel's IPTV solution. Alcatel describes its services as “user-centric broadband”. They state that they can provide a new and better way to watch TV that it is simple, personalized and predictable. It is simple because now users are not limited by the number of tuners in the box; they can have picture-in-picture (PIP) navigation capability of other channels. Users are also given the capability of browsing channels while watching another show. It is personalized because subscribers can get live TV notifications such as caller ID, SMS and email notification while their watching their favorite show. Using picture in picture streams users can view multiple angles of a game or an event and receive information about the program they are watching. They can view picture or photos on their TV and personalize parental control, television and account settings. Finally, it is predictable because users can formulate the TV program as they like, make advance searches by title, actors etc, schedule recordings of programs taking advantage the DVR functionality and choose video programs categorized like a video store. All these new services are complex to be accomplished in Cable TV since there we have the separation of IP packets and MPEG stream. Moreover, Cable TV does not have a return path, as IPTV does, something that hinders advanced services as the ones described above [6].

Nevertheless, DSL faces some disadvantage too. The most important limitation of triple play is that it is a distance sensitive technology. As we have already said, a user should be in a distance no more than 18000ft from the Central Office so as to be able to get DSL. As a result, not all users are able to have triple play. This could be the reason that in the United States triple play is not so popular yet; it is not easy to implement it in thinly populated areas.

4.2 Details of 3P

A basic triple play system (see Figure 3) consists of the digital head-end equipment, the core network, the access network and the equipments at the subscriber's home (i.e. middleware, DSL modem , the IP set-top box and so on). A triple play solution can distribute 50 to 150 TV channels over an IP network, voice over IP and high-speed Internet. A simple description of the architecture is being described here (a more thorough description of different architectures will be described in a later section). Services (video, voice, data) are sent from the operator's IP head-end - using an ATM or IP core network over an optical backbone network – to the central office (CO) in the subscriber's region. The CO relies the data to the access network (AN) which consists of digital subscriber line access multiplexers (DSLAMs) and broadband digital loop carriers (DLCs). There we have the so-called last mile distribution of the service (i.e. video or voice) which afterwards enters the subscriber’s home through the modem. For the video service in particular, an IP set-top-box (STB) is also used to unscramble the signal and display our movies on the TV set [5].

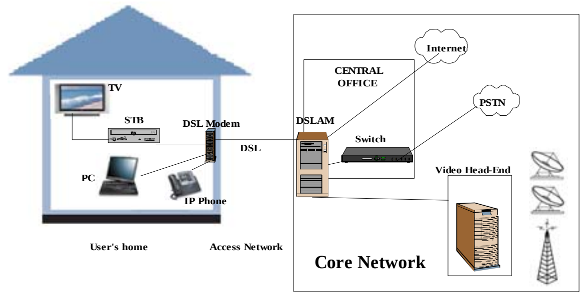

Figure 3: A Basic Triple Play architecture

In the following paragraphs we briefly describe the basic components of a triple play network.
The head-end – The head-end is the source for all video content. It includes all the video streams that come from broadcast stations, Video-On-Demand servers, and so on. Depending on the QoS level required, the amount of delay and jitter in picture, as seen on the TV screen, is determined. Then, the stream is put into IP packets. Special encoders are converting the stream into an MPEG signal at a rate of 3-5Mbps. After that, once the MPEG packets have been encoded, they are assigned a channel identifier and passed on to the Internet Group Management Protocol (IGMP) multicast router for broadcast to the channel groups subscribing to each video stream. At that instance the video stream can access the STB.
The core network – Core networks are consisted of switching offices and transmission lines that connect central offices. The core network, which is a high capacity fiber backbone network, uses ATM or IP/Ethernet over SONET. ATM is a transport protocol that uses 53-byte cells to transmit voice, video, and data simultaneously. Telecommunication operators have been using ATM for their data and voice services. The basic characteristic of ATM is that it has build-in QoS mechanisms. However, it is more expensive and less flexible than IP/Ethernet which has started gaining ground. No matter the method of delivery, these backbones enable large quantities of bandwidth to be delivered to the regional central offices. From the COs, the packets reach the access network after passing through the DSLAMs.

The DSLAM – The digital subscriber line access multiplexer lies between the core network and the access network and generally resides at the central office. Its purpose is to multiplex all the DSL data traffic into a single high-speed signal and to pass that signal to the core network. When the IP packets leave the CO are forwarded to DSLAM. From the DSLAM the virtual channel is terminated to a DSL modem at the subscriber's home. The modem splits the data into three categories: voice goes to the telephone device, video data (MPEG in IP packets) go the set-top box and Internet data go to the PC. The set-top box "delivers" the MPEG video to our TV monitors.

The Access Network – The Access Network is the "last mile" of the network between the CO and the subscriber's home. It consists of twisted pair copper wire or fiber. As we already said, the DSLAM combines voice, video and data and distributes them to the access network. Asymmetrical Digital Subscriber Line (ADSL), Very high-speed Digital Subscriber Line (VDSL) and Passive Optical Network (PON) are some of the technologies used in the access network.

Now we will examine the equipments that reside to subscribers homes. We first start with devices related to the video service and then we will proceed with a voice over IP related device.

Video related equipment

Set-top boxes – The main functionality of the set-top box (STB) is to unscramble the signal and present it on the TV. After the IP packet arrives to the STB it is stripped and the MPEG2 stream inside the IP packet is now delivered to the decoder. The decoder decompresses the signal and delivers it to the TV set. When a subscriber requests an IPTV program, one of two things can happen. If the signal is multicast (i.e. it sent to more than one subscriber simultaneously), the STB requests a copy of the multicast stream, which must be found in the network and supplied to this STB. In the case where the signal is unicast the stream is requested directly from the head-end.

Middleware – Middleware is the command-and-control center of the interactive TV environment. The role of middleware is to define and manage the overall TV environment, manage subscribers and service bundles and to create interactive television services and features. It forms the link between the head-end and the consumer. It behaves like a client-server application, where the client software resides in the set-top box and the server is located in the head-end facility. Middleware's graphical interface would allow the subscriber to select and customize channels, select video or pay-per-view services, set up local preferences and parental controls, view their current bill and others. On the other hand, the server not only manages all the customers but also manages service activation, billing, service termination as well as other applications [7].

Voice over IP related equipments

IP phones – These are specialized phones that look like our intimate normal phones. However, instead of having the standard RJ-11 phone connectors, IP phones have an RJ-45 Ethernet connector. IP phones connect directly to our router and have all the hardware and software necessary to handle the VOIP calls.

5. 3P Network Architectures

After presenting the basic overview of Triple Play, it is worth analyzing architectures proposed in the market. It will be useful to get an idea of how technology providers try to address the challenges of multiservices. Triple Play is considered to become a "killer application" as soon as its requirements are satisfied and market matures enough to provide it in low cost. Increasing revenues lead many big companies to enter to field of IPTV and Triple Play in general. There have been a number of different architectural approaches which claim to be able to integrate all the types of services in a flexible and scalable manner. They also attempt to satisfy all the requirements of Triple Play services and keep the CapEx(Capital Expenditure) and OpEx(Operational Expenditure) as low as possible. Below we present the architecture proposed by Alcatel.

5.1 Alcatel

The French Company that has now become one of the dominant companies worldwide in the area of communications has developed a Triple Play Service Delivery Architecture (TPSDA) that aims to be widely used, scalable and useful for many years to come. What Alcatel pursues for its architecture is to distribute functionality to three different nodes to avoid bottlenecks and inefficiencies.

Lately, it partnered with Microsoft to jointly conduct end-user research to be able to define what consumers would be willing to pay for and what they would expect from next-generation multi-service delivery architectures. The conclusions were that users would want more enriching and personalized service mix that would integrate seamlessly with their communications. They would also want to control their viewing choices, shift programming, quick channel response and differentiated service according to their taste. So, the company tried to integrate all the users' needs with the Triple Play services requirements to provide a robust architecture that would remain scalable, support service innovation for providers and in that way would ensure revenue maintenance and growth.

5.1.1 Architecture

Alcatel realized from the beginning that approaches like having one Broadband Remote Access Server (BRAS) for the services wouldn't be suitable for Triple Play because of its stringent requirements. Instead, they believed in a distributed and scalable approach that would make sure that their architecture would survive the competition and will be able to include new services in the future without affecting the architecture functionality. Traffic load in Triple Play is sensitive on transport delay, jitter, packet loss and bandwidth. The large number of aggregated users will make us need routers of hundreds of Gbps and even the transition from pure multicast to hybrid multicast or pure unicast traffic(Video on Demand) will increase our bandwidth needs even more. Moreover, all-IP philosophy lays in all kinds of network approaches nowadays since IP technologies are widely used and implemented.

Thus, Alcatel has developed its TPSDA bearing in mind all the above. The main nodes participating in the architecture are the Broadband Service Access Node (BSAN), Broadband Service Aggregator (BSA), Broadband Service Router (BSR). What is more, it includes a routing element at the user side that would bind all the home devices to a single IP. The nodes in the architecture can be seen in Figure 4.

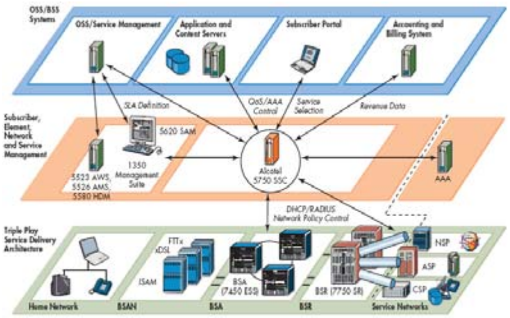

Figure 4: Alcatel's architecture

The functionality of each node according to Alcatel has as follows:

- Homes follow a routed model which is more convenient in address management, since there is a single IP connection per home and multiple devices bound to this IP. In that way any device can have access to any service provided. Thus a kind of a router at the home would be appropriate.
- The BSAN is the first aggregator of the network. It supports many different kinds of technologies like FTTC, FTTH, ADSL, vDSL or other types of DSL access. It also supports IP multicast, filtering, subscriber and user device authentication. So, we could claim that optimizes the cost-effectiveness of the overall architecture by pushing IP functionality closer to the home.
- The BSA is a Layer 2 switch that that has subscriber management functionality. It can support proxy multicasting, filtering, accounting and queueing and works as the intermediate node between the access network and the network edge. It also ensures that the QoS burden doesn't fall on to the services edge by taking care of the per-subscriber QoS. It can take up to hundreds of thousands of different policies, tens of thousands of queues and hundreds of GE ports.
- The BSR works like an IP service edge. It terminates Layer 2 and also supports GE ports. The QoS it provides is per service or per content which means that it simply classifies traffic to content based classes for a given BSA to ensure that each traffic type receives the appropriate treatment towards the BSA, i.e. it is possible to have the BSR give preferential treatment to content or services from a specific Internet Service Provider (ISP) or Application Service Provider (ASP) partners.

It is worth mentioning that the BSA along with the BSR form a "virtual node" that provides subscriber services and also IP edge functionality, equivalent to BRAS (Broadband Remote Access Server). In addition, the subscriber QoS and the service QoS provided by different nodes ensure the scalability and flexibility that avoid having to take care of thousands of subscribers in a single node and thus having bottlenecks in the system. Eventually, Alcatel has already hit the market with the devices that form its architecture. Models like 7450 ESS(BSA), 7750 SR(BSR), 5750 SCC (subscriber services controller which has accounting functionality and interacts with BSR and BSA) can actually be used to deploy the proposed architecture.

5.1.2 Protocol Stack

In this subsection we describe some of the protocols used by Alcatel in each node:

- BSAN is a Layer 2 aggregator of the network that supports IP multicast, filtering, subscriber and user device authentication.
- As we mentioned above, BSA is a Layer 2 switch that that has subscriber management functionality. It supports MultiProtocol Label Switching (MPLS), Internet Group Management Protocol (IGMP), proxy multicasting and wirespeading per-subscriber, per-service We can say that it is a high-capacity Ethernet-centric with tens of thousands of filter policies, and tens of thousands of queues. Note that the BSA can support class based queueing upload to the BSR in order for example for video control messages to pass on to the BSR with high priority. What's more there is a VLAN per subscriber for the aggregation and access network. H-QoS ensures that the right service differentiation is performed on each underlying service component of the VLAN.
- As for BSR, instead of Point-to Point Protocol (PPP) ituses DHCP relay to obtain IP for the subscriber devices. It also terminates Layer 2 access and routes over IP with support for a full set of MPLS and IP routing protocols including multicast routing (PIM-SM, PIM-SSM, IGMP), non-stop routing, nonstop services, VPLS, control processor module queuing (CPMQ) (for DoS containment), per-service hierarchical QoS (H-QoS) and much more BSR2BSA if congestion data traffic is compromised instead of video and voice.

5.1.3 Functionality Issues

Alcatel also pays attention to a number of different issues that need attention and should be satisfied to ensure the overall viability of the architecture. These would be:

- Always-on services: Video and audio services are "always-on" services that cannot accept unpredictable network recovery timeouts and best-effort QoS implementations. They solve the problem with fast-reroute techniques that make restoration as quick as 50ms.
- Security: They want to avoid cases like theft of services or content, Denial of Service and illegal broadcast. Such incidents are avoided by using application level security implemented on set-top boxes, video servers and

content stores and include encryption and scrambling and network level security that is implemented in the underlying infrastructure and guarantee authenticity, integrity and confidentiality. Such responsibilities are begins the moment content is received from the owner and continues until it is delivered to the end user.

- Flexibility and versatility which are achieved, as we have shown before, by the distributed services and subscriber management in different parts of the network.

5.1.4 Cost efficiency

Traditional BRAS-based architectures do not scale economically to support triple play service delivery. As subscribership and bandwidth demands grow over time, additional, complex equipment must be deployed which in turn would drive up OPEX, leading to an exponential cost structure. Though, Alcatel claims that increased demand can be accommodated with a much lower, linear cost curve. This gives TPSDA a three to five times advantage in total cost of ownership over a traditional BRAS-based triple play service delivery network approach over time.

6. Simulation – Case study

In our simulation, we simulate a part of the Triple Play service network. The platform we chose to implement it is OPNET 11.5. We decided that the different QoS for the various services is an important issue that can be implemented in a simulation. So, trying to see the different treatment each service flow would receive and compare it with the case where no QoS is taken into consideration was chosen as our goal.

We constructed a simple topology as shown in Figure 5. We created a voice client, a video client and two Internet (FTP) clients. We also created a voice, Video and FTP servers for the clients to communicate. The intermediate nodes between the clients and the servers are two routers. We also use two multiplexers that interconnect the clients and servers together in order to multiplex the traffic from the clients and servers respectively. The following figure shows the basic topology we used for our simulation.

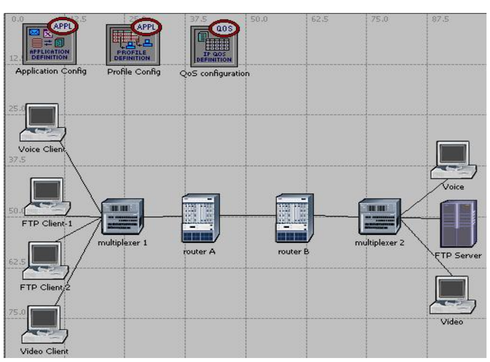

Figure 5: The simulation topology

The idea behind the scheme is that the *voice* client communicates with the *voice* server, the *video* client with the *video* server and the FTP clients with the FTP server. All these connections share the same path through the routers. So, the QoS routers can be configured to provide different QoS to various applications. We built two basic router configurations. The first one is having the routers support their default routing scheme which is FIFO and the second is having them support WFQ (Weighted Fair Queuing). Then we created a number of scenarios to examine the network reaction to certain occasions. More analytically all the scenarios are described below.

<u>The scenarios</u>

- **Basic1**

There is only voice client active. All the others are deactivated.

- **Basic2**

The voice and the video client are active. The bit rate of the video is low, that is 15 frames/sec.

- **Basic3**

Voice traffic and video traffic of 30frames/sec is active.

- **Basic4**

The active clients are the voice, video (30frames/sec) and one FTP.

- **Basic5**

All clients are active. The video rate is high again (30frames/sec).

- **WFQ1-5**

We also have 5 scenarios for WFQ. They are named WFQ1, WFQ2, WFQ3, WFQ4 and WFQ5. The traffic is exactly the same as in the Basic corresponding ones. The only thing that changes is that the routerA and routerB support WFQ this time. The weights for FTP, Video and Voice are 1, 30 and 60 respectively. The buffer size is set in OPNET to be 3000. Since the Voice, Video and FTP traffic are set up in OPNET to be of different Type of Service (ToS) then we expect that the treatment they will get from WFQ routers will be following their ToS requirements according to the WFQ weights.

The execution process lasts for 30 minutes for each scenario. OPNET needs quite much time to finish each scenario because of its complicated simulating process of all the underlying layers, so 30mins was a reasonable amount of time to be able to make conclusions. The statistics we decided to collect had to do with the QoS per service and the queueing on the routers. Thus, we studied the jitter, end-to-end delay and delay variation for Voice, end-to-end delay and delay variation for Video. We didn't pay much attention to FTP because it is the less important traffic since it is best effort. Besides, we examined the different queues and queueing delay of the routers in the WFQ scenarios. In order to be able to make secure observations and have an overall idea, first we looked into how the FIFO scheme reacts when we add different kinds of traffic gradually, then we wanted to compare the same scenarios of FIFO and WFQ and finally see the queueing delay of WFQ scenarios.

The simulation results verified what we expected. That is the QoS requirements of Voice and Video are better satisfied with WFQ. The end-to-end delay, jitter and delay variation are much lower and thus the QoS provided with WFQ is much more sufficient than with FIFO queueing. The complete analysis of our simulation can be obtained from the separate simulation report because presenting it here would be outside the scope of this survey presentation.

7. Market Outlook – Case study

In that section we conducted a case study on the services offered by Homechoice in United Kingdom to understand the pricing model.

Services

The services provided by Homechoice:

(a) **Digital TV on your television**

Special features include:

- Up to 80 digital channels
- Replay after a week they are aired.
- Over 20 digital radio stations to listen to through your TV.
- 'Real on-demand' because on-demand programmes really are ready to watch at your say-so. There's no waiting around for 15 minutes for your chosen show to start because as soon as you've selected an on-demand TV programme, music video or movie on Homechoice, you can watch it immediately.

(b) **Movies on-demand**

Special features include:

Over 1,000 movies to choose from that you can pause, rewind, fast-forward or stop - just like a DVD!

(c) **High-speed broadband on PC**

Special features include:

- Choice of up to 2Mb, up to 4Mb or Max Speed (up to 8Mb) broadband
- High-speed internet connection
- No hanging around for files to download
- Unlimited downloads with Max SpeedFast upload speeds, up to 512Kbps with Max Speed
- Use the phone whilst online because you're always hooked-up to the net
- Great features included like 100MB webspace and a spam filter

(d) **Free calls on your telephone**

Pricing

Homechoice UK offers 3 pricing models (PM indicates per month basis) that are presented in the tables below

Packs	**TV Channels**			**Video On-demand**	**Calls**		**Price (PM)**
	Digital	**Kids(PM)**	**V:MX Music (PM)**		**Freetime (optional)**	**Anytime (PM)**	
Max Speed	35 channels	£6	£6	Taster	✓	£5	£27.99
4 Mb	35 channels	£6	£6	Taster	✓	£5	£22.99
2 Mb	35 channels	£6	£6	Taster	✓	£7	£17.99

Figure 6: Homechoice UK base pack

Packs	TV Channels			Video On-demand	Calls		Price (PM)
	Digital	Kids (PM)	V:MX Music (PM)		Freetime (optional)	Anytime (PM)	
Max Speed	60 channels	£4	£6	✓	✓	£5	£37.99
4 Mb	60 channels	£4	£6	✓	✓	£5	£32.99
2 Mb	60 channels	£4	£6	✓	✓	£7	£27.99

Figure 7: Homechoice UK big pack

Packs	TV Channels			Video On-demand	Calls		Price (PM)
	Digital	Kids	V:MX Music		Free-time (optional)	Anytime(PM)	
Max Speed	85 channels	✓	✓	✓	✓	£5	£47.99
4 Mb	85 channels	✓	✓	✓	✓	£5	£42.99
2 Mb	85 channels	✓	✓	✓	✓	£7	£37.99

Figure 8: Homechoice UK max pack

8. Conclusions and future work

In this report we have analyzed Triple Play from different views. In order to fully understand it we have first made a “journalistic” research regarding triple play services. Then, we moved to further details and we have investigated and analyzed some recent architectures of triple play. Our next step, was to verify some network characteristics of a triple play scenario. We created our simulations using the OPNET environment. Despite the fact that our simulation was done in a high level, we extracted some important and interesting results.

Triple play services are rapidly deployed all over the world. Regarding Europe, triple play is becoming the dominant way to deliver voice, data and video services. Triple play is following the trend of deploying every service over an all-IP network infrastructure. This ultimate goal has brought up new ideas like quadruple play. However, moving towards that direction requires a significant increase of bandwidth in different portions of the network. Nevertheless, building a new network from scratch is not a wise idea. Therefore, solutions like upgrading the existing network with cheap and efficient technologies like Fast Ethernet are well considered.

Our next step would be to study and simulate more thoroughly particular architectures. One example of those architectures could be Alcatel's architecture. Alcatel is now one of the main market players of triple play. Being able to analyze in detail such architecture would really convince us about the perspectives of triple play.

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