TECHNOLOGY WHITE PAPER

Alcatel-Lucent Triple Play Service Delivery Architecture

Operators are making strategic business and network transformation decisions that will allow them to become fully engaged in the triple play business. To benefit from triple play opportunities, operators must ensure that their networks can accommodate new demands for content-rich applications and bandwidth-intensive services over the next five to ten years. In that context, the Alcatel-Lucent Triple Play Service Delivery Architecture (TPSDA) has become a tangible blueprint for operators and vendors alike to enable and accelerate large scale triple play network transformations around the world. It is today by far the most widely deployed end-to-end architecture for triple play networks, with over 40 deployments to date. This paper describes how the TPSDA helps operators transform their networks to realize mass-market delivery of profitable blended voice, video and data services — providing a superior user experience anytime, anywhere.

Introduction

Operators around the world are already commercializing triple play services. Fierce competition to retain current and attract new customers, as well as the need to increase average revenue per user (ARPU), has led operators to embark on plans to combine comprehensive IP television (IPTV) and streaming multimedia services with voice over IP (VoIP) and high-speed Internet (HSI) access. They will then be able to provide a convenient one-stop shopping experience for end users.

Adding new triple play services to the service bundle have compelled many operators to rethink their network infrastructures. To support triple play, operators need to factor in stringent requirements for high availability, service flexibility and richness, scale, and service reach, as well as network and service manageability. The existing high-speed Internet infrastructure based on ATM aggregation and centralized broadband remote access servers (BRAS) is unable to meet the cost, reliability, scalability and quality of service (QoS) requirements needed to deliver triple play services.

The most demanding requirements are those introduced by the addition of the video component. Video is a fundamental change with far reaching implications for the underlying IP-based network infrastructure.

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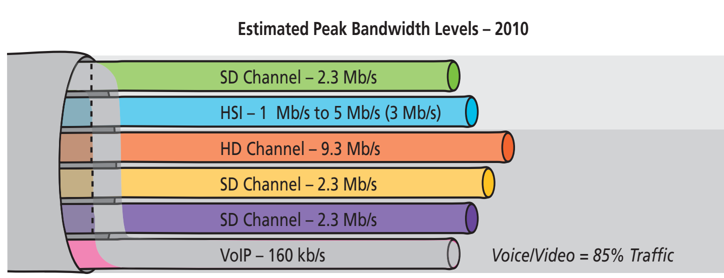
Triple Play Services and Network Transformation

Over the last ten years the Internet has emerged as a key infrastructure for service innovation, enabling IP to become the wide area network communication protocol of choice. The natural result of this selection is that operators are looking for ways to optimize costs by migrating existing services and applications onto IP as well. The ultimate goal of triple play is to move all current and future services onto IP: data, voice and video. However, to reach that goal, operators must overcome the limitations of traditional IP networks and communication services, which were designed to support basic Internet services and applications, notably web browsing, e-mail and file transfer. These applications generally have modest transport service requirements, known as "best-effort" service. Best-effort service means that the network is allowed to discard or delay data packets when congestion occurs due to heavy traffic on the network. A specific characteristic of traditional best-effort IP applications is that a high degree of bandwidth oversubscription is possible when aggregating traffic from multiple users because not all users are online at the same time. Oversubscription is both technology acceptable and financially necessary. Thus, the average bandwidth demand placed on the network is much lower than its peak bandwidth.

While best-effort service works very well for non-real-time data transfers, problems can occur with real-time applications. Streaming video and voice services have strict requirements for transport delay, jitter and packet loss, bandwidth availability and connection reliability. Packet delay or loss can impair voice service quality to the point that voice connections are dropped or generally become unusable, while packet loss on video is instantly recognized by the user. Because the bandwidth required for voice is relatively low and irregular, problems can be avoided by reserving some network capacity exclusively for voice applications and ensuring that this capacity is not exhausted. However, the introduction of video services causes a dramatic shift in networking requirements towards high capacity bandwidth with stringent QoS and availability requirements.

A global study conducted by Alcatel-Lucent among operators found that the packet loss sensitive traffic (IPTV and voice traffic) is expected to drive 82 percent of total revenues on average while consuming up to 85 percent of network capacity by the year 2010 (see Figure 1).

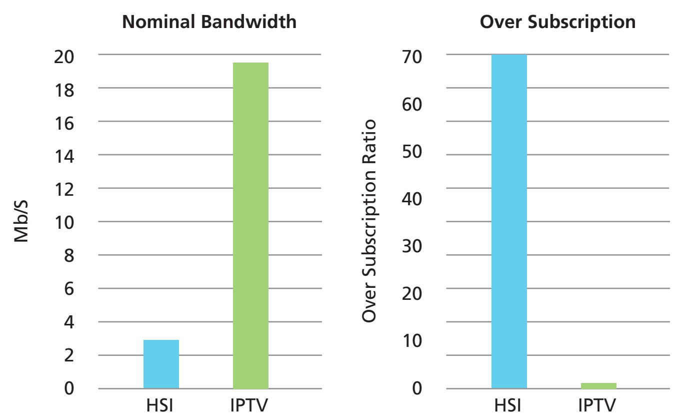
Figure 1. Estimated Peak Bandwidth per User



Source: Alcatel-Lucent Global Study

Unlike best-effort services, which can benefit from a significant level of oversubscription in the network, IPTV-based services cannot. The almost constant bandwidth demands of video simply do not accommodate statistical multiplexing. As a consequence, IPTV not only requires a significant increase in access capacity, it also has a dramatic impact in the average bandwidth consumption per user deeper in the network. Bandwidth of a traditional 3 Mb/s HSI access service is typically oversubscribed by a factor of up to 70, consuming as little as 48 kb/s on average per user (see Figure 2). In contrast, one high definition and two standard definition video streams will consume up to 15 Mb/s access capacity. Bandwidth consumption is particularly high for video on demand (VoD), where the use of statistical multiplexing gains in the aggregation network would inevitably result in dropped packets. In most cases, this would be instantly noticeable on the television screen (pixelization, screen freeze, audio quality distortion). As a result, IPTV bandwidth consumption in the aggregation part of the network can be 50-200 times higher than what is required today for basic Internet access.

Figure 2. Peak Bandwidth per User and Oversubscription Ratio for HSI and IPTV



Source: Alcatel-Lucent Global Study

While IPTV, including BTV and VoD, is the principal driver for new revenue and network investments, the growing popularity of YouTube and Google video, and new interactive TV applications like Joost are starting to cause a video-driven inflection point for Internet applications and traffic patterns as well. Video streaming through Web browsing is growing quickly to consume more bandwidth than all other traditional Internet voice and data traffic combined, impacting the core networks as much as the metro and regional networks. With this new requirement, HSI can no longer be considered a best-effort service as end users are now expecting high quality streaming video on their personal computers. Therefore, operators must deliver more bandwidth to consumers and cannot continue to engage in heavy oversubscription as previously done with best effort HSI services at the risk of increasing customer churn.

The Video Inflection Point – Driving Network Technology Shifts

As we have shown, video is causing a major inflection point that calls for an architectural change from a traditional best-effort IP infrastructure to a new purpose-built and future-proof network foundation. This new foundation must be able to meet the flexibility, scalability, high availability and QoS needs of video, voice and rich multimedia services, accommodating both IP unicast and multicast traffic delivery.

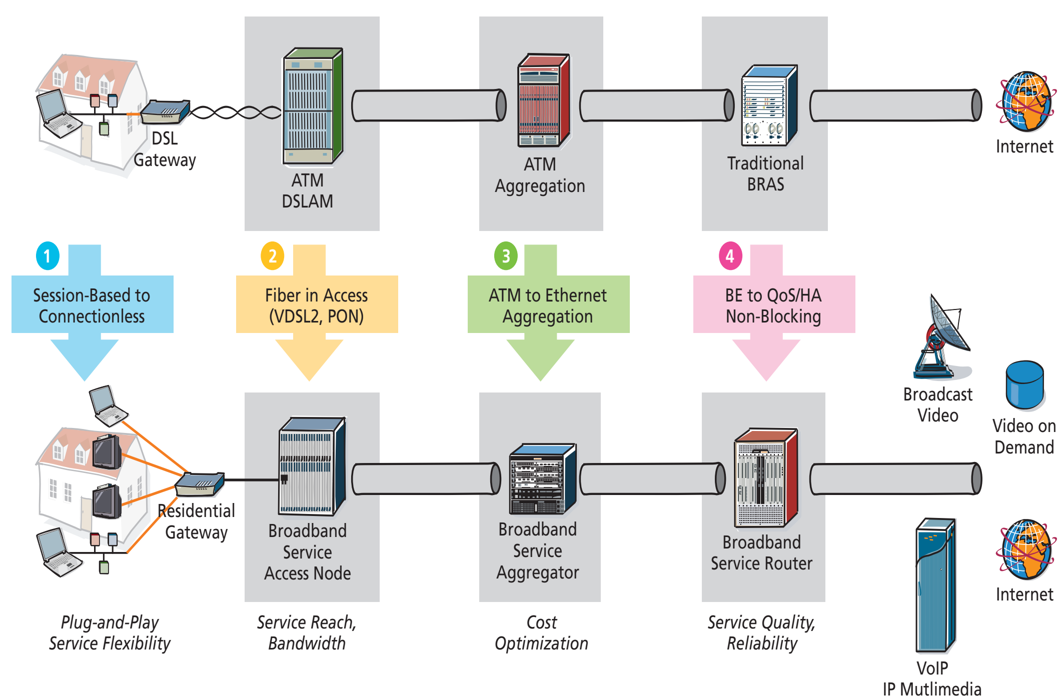
The video inflection point triggers significant technology shifts towards a next generation IP network foundation:

1. A strategic shift from session-oriented to clientless connectivity models better suited for delivering broadcast video and media rich services over a broad range of "plug-and-play" appliances in the household. Such models use proven technologies, such as dynamic host configuration protocol (DHCP) and offer added flexibility for implementing services and service policies across the service delivery architecture.

2. A transformation of the access network, by extending the service reach to deliver rich, always-on broadband video services in an economical way to various geographies using copper, fiber, and wireless access. This will deliver triple play services with at least 20 Mb/s per user regardless of subscriber location, using passive optical networking (PON) or digital subscriber line (DSL) technologies such as ADSL2plus, VDSL and VDSL2. High capacity switching fabrics supporting IP multicast, IP QoS and IP/Ethernet filtering have been added to support the delivery of triple play services.
3. A shift from ATM to Ethernet for broadband service aggregation to leverage the lower cost per bit provided by Ethernet for delivering services to millions of subscribers who average 10 Mb/s, 20 Mb/s, and some day, 100 Mb/s per household.
4. A transition from best-effort IP connectivity to a highly available, QoS-enabled IP network to assure a premium quality of experience (QoE) for applications such as IPTV. Beyond bandwidth, this requires rich service policies and control capabilities in the service delivery network, such as multicast, security and QoS.

Figure 3 depicts the required technology shifts.

Figure 3. The Four Technology Shifts Leading to Network Transformation

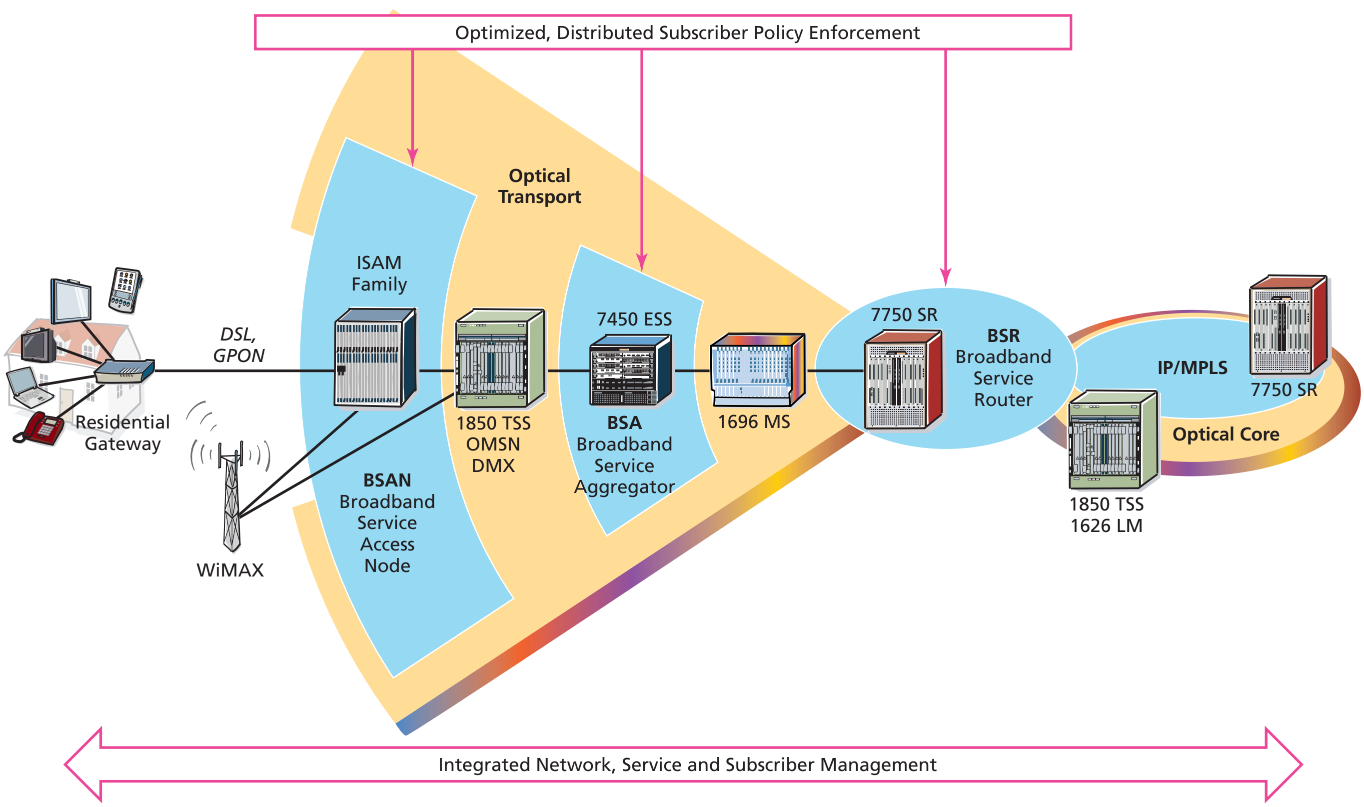


The Alcatel-Lucent Triple Play Service Delivery Architecture

The TPSDA is a network reference architecture that describes access, aggregation, edge and subscriber service delivery as an integrated solution and addresses requirements for triple play (see Figure 4). It enables operators to engage strategically in the triple play transformation process with a purpose-built, next generation network foundation. To reap the full benefits from the opportunities presented by triple play, operators must ensure their networks can accommodate the demands for content-rich applications and bandwidth-intensive services over the next five to ten years.

The TPSDA was introduced in late 2004 with the landmark contract award of project Lightspeed by former SBC (now AT&T). Lightspeed aimed to deliver triple play services to more than 18 million subscribers. Since then, the TPSDA has been adopted by more than 40 operators worldwide to support their goal of building a triple play service infrastructure able to accommodate high-performance BTV and VoD services, real-time voice/multimedia, and new HSI access services, including the evolution toward Internet video.

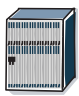
Figure 4. The Alcatel- Lucent Triple Play Service Delivery Architecture



The TPSDA is designed to address the fundamental challenges of optimizing scalability, performance and cost. To be scalable, it is necessary to distribute functionality and allow each device to optimize its particular role in the network. This functional distribution is balanced by centralized administration and control capabilities to retain consistent service control end to end, in a cost-effective manner.

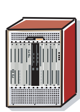
In designing the TPSDA, Alcatel-Lucent has capitalized on its operational experience as a service and solution integrator to develop a proven triple play service infrastructure. Two of the key design goals for the TPSDA are scalability and flexibility. This is why the TPSDA applies distributed service intelligence throughout the network in a way that better leverages the capabilities of individual nodes in the end-to-end service delivery path, than what can be accomplished through purely centralized or decentralized approaches. Splitting per-subscriber functionality between the access and aggregation nodes, and per-service functionality between aggregation and edge nodes alleviates scaling issues for bandwidth-intensive services and allows operators to optimize the network for future services. The TPSDA encompasses the network components described below.

RESIDENTIAL GATEWAY (RG). RGs are the demarcation devices between the home network and the operator network. They typically combine a broadband access termination function with an integrated router and firewall, VoIP gateway and wireless LAN access capabilities. They enable the connecting of home computers, TV set-top boxes (STBs), and existing POTS/ISDN "black phones," as well as IP "hard phones" and IP "soft phones."

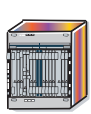


BROADBAND SERVICE ACCESS NODE (BSAN). The BSAN is a new generation of access devices that leverages the economies and versatility of IP/Ethernet switching and employs DSL technologies (such as ADSL, ADSL2plus, SHDSL, VDSL and VDSL2) and FTTx technologies (e.g., GPON and Ethernet) to create deep fiber access networks (fiber-to-the-node and fiber-to-the-premises). Rather than deploying access nodes that act as Layer 2 aggregation elements, the TPSDA enables the use of IP layer functions such as IP multicast, IP QoS, filtering, IP address anti-spoofing, routing, and subscriber and user device authentication in the BSAN, to optimize the cost-effectiveness of the overall architecture. The Alcatel-Lucent Intelligent Services Access Manager (ISAM) portfolio was designed to support the role of the BSAN.

BROADBAND SERVICE AGGREGATOR (BSA). The BSA is a new type of network element that combines the strengths of Ethernet and MPLS technologies to enable virtual private LAN services (VPLS). VPLS is an Ethernet multipoint service that uses multiprotocol label switching (MPLS) to efficiently aggregate traffic. The BSA supports subscriber access control functions and optimizes quality and efficiency in IP service transport over Ethernet for both IP unicast and multicast traffic. It supports both ring and tree topologies in the aggregation network. The BSA has IP service awareness and support functions. For example, it maps DiffServ CodePoint (DSCP) QoS marking at the IP layer to IEEE 802.1p marking at the Ethernet layer and grooms multicast forwarding at the Ethernet layer to eligible IP multicast destinations by snooping Internet group management protocol (IGMP) membership reports exchanged at the IP layer. The Alcatel-Lucent 7450 Ethernet Service Switch (ESS) was designed to support the role of the BSA.



BROADBAND SERVICE ROUTER (BSR). The BSR acts as the converged IP service edge and performs IP routing functions. The BSR uses a unified mode of operation based on IP over Ethernet (IPoE) and DHCP to deliver services and obtain IP addresses on behalf of the subscriber or user device. The BSA and BSR work together as a virtual node that functionally replaces the BRAS and associated ATM-based aggregation nodes in legacy IP service infrastructures. The Alcatel-Lucent 7750 Service Router (SR) was designed to support the role of the BSR.



OPTICAL TRANSPORT. Multiservice optical platforms provide simple Ethernet aggregation to cost-effectively connect the BSA with the BSAN. The connection can also be done in a more transparent way with wavelength division multiplexing (WDM) systems to reach the distance and increase the usage of the optical fiber infrastructure in metropolitan areas. The Alcatel-Lucent OMSN, DMX and 1850 TSS are multiservice optical transport platforms. The Alcatel-Lucent 1696 MS and 1626 LM are WDM transport platforms.

The TPSDA is complemented by the Alcatel-Lucent 5750 Subscriber Services Controller (SSC) which provides integrated and centralized subscriber and service management for the entire range of triple play services end to end.

The TPSDA introduces an innovative architecture that leverages distributed intelligence in the access, aggregation and edge networks for a more flexible and optimized deployment of services, guaranteeing high quality and reliable delivery of all services to the end user, regardless of service mix, traffic patterns, or network loads and conditions.

Building a Future-Proof Network Foundation

To deliver premium triple play services cost effectively, the network must be able to meet a new set of requirements for service capacity, availability, flexibility and QoS control. Operators are adopting service delivery architectures that will be the foundation for their consumer and business service rollouts for many years to come. The service infrastructure needs to be a highly flexible, service-rich and dependable resource pool that will allow operators to engage in rapid service innovation and rollout, without requiring a complete redesign of their service delivery network or deployment of new equipment.

Enabling Non-Stop Service Delivery

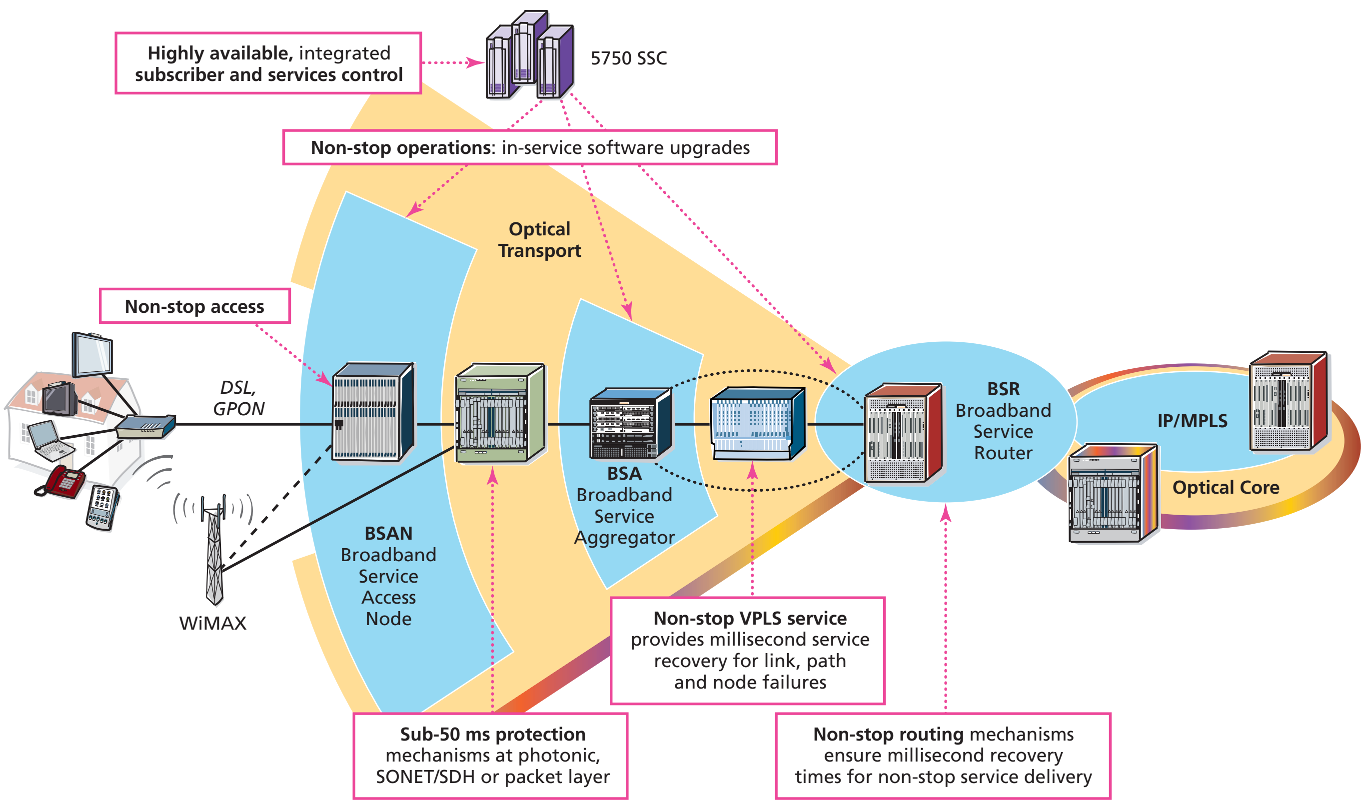
Streaming video and multimedia services are “always-on” services. They cannot tolerate unpredictable network recovery timeouts or best-effort QoS implementations, which would result in a user perception of poor video quality and eventually increase customer churn. The triple play service delivery network must therefore be capable of delivering always-on service.

The Alcatel-Lucent TPSDA provides a highly available infrastructure for delivering video and other premium triple play services (see Figure 5). Because all system platforms in the TPSDA are fully redundant, with no single point of failure, the TPSDA can deliver non-stop routing and non-stop services. To reach 99.999 percent reliability, all nodes in the TPSDA come with redundant controller and network interface cards, delivering non-stop service routing and forwarding with in-service software upgrades for maintenance releases.

The TPSDA enables rapid network protection and restoration mechanisms which provide sub-50 ms recovery times in the event of node or link failures. The TPSDA uses fast reroute to defend against node or link failures in the BSA-BSR aggregation rings. Protection mechanisms are implemented within the optical network at the photonic layer, at the SONET/SDH layer and/or at the packet layer.

The Alcatel-Lucent Service Router Operating System 5.0 (the 7x50 Service Routing Operating System) uses multi-chassis link aggregation groups (MC-LAG) to offer network level redundancy with persistent subscriber state failover though dual homing of BSANs to redundant pair of BSAs and BSRs. Subscriber Routing Redundancy Protocol (SRRP) is also used on top of MC-LAG when the BSAN is connected to a pair of BSRs.This industry-leading innovation provides synchronized and stateful redundancy in the event of the access link or aggregation node failing, with zero impact to end users and their services, and is a key differentiator for the TPSDA.

Figure 5. Enabling Non-Stop Service Delivery with the TPSDA

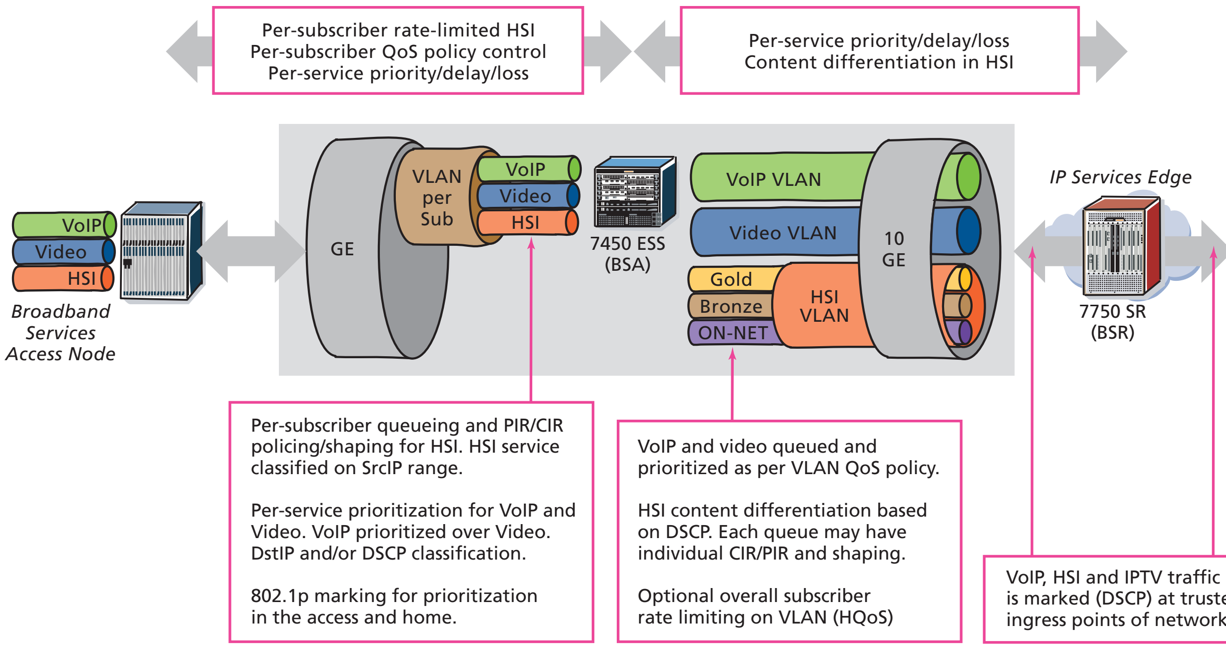


End-to-End QoS Policy Enforcement

In the Alcatel-Lucent TPSDA, all elements in the end-to-end service delivery path contribute to reaching the goal of assuring a premium QoE for end users. A chain is as strong as its weakest link and this principle is applied in the TPSDA by distributing policy enforcement functions in the end-to-end service path to achieve the goal of supporting reliable, secure, premium quality services to subscribers in a cost-optimized way. Applying a flexible distribution of the traffic management, filtering and accounting functions end to end enables the network to support different needs for multiple applications in a scalable manner. The application of hierarchical QoS (HQoS) policy enforcement allows the operator to implement meaningful per-subscriber and per-service level controls. Per-subscriber and per-service QoS policies are enforced by the BSAN and BSA, while the BSA and BSR together enforce per-service and per-node policies. Figure 6 shows how multilevel QoS is supported in the reference solution of the TPSDA with one virtual local area network (VLAN) per subscriber on the BSAN (some other models are supported, as explained in the section "Ultimate Triple Play Service Deployment Flexibility" later in this paper).

VoIP, BTV, VoD and HSI traffic have different QoS and bandwidth demands and must be treated accordingly. HQoS enables the operator to allocate a bandwidth budget and/or priority to each subscriber and each service category. VoIP has the highest priority, then video services, followed by the various quality grades of HSI traffic. HQoS ensures that unused bandwidth dedicated to a higher order service class will automatically become available for lower classes of service, thus optimizing resource utilization. Where a higher priority service class needs more bandwidth than budgeted, it may pre-empt bandwidth of lower priority services to optimize revenue. This is controlled by means of committed, peak and sustained information rates for each service class.

Figure 6. End-to-End Per-Subscriber and Per-Service QoS Control in the TPSDA Reference Model



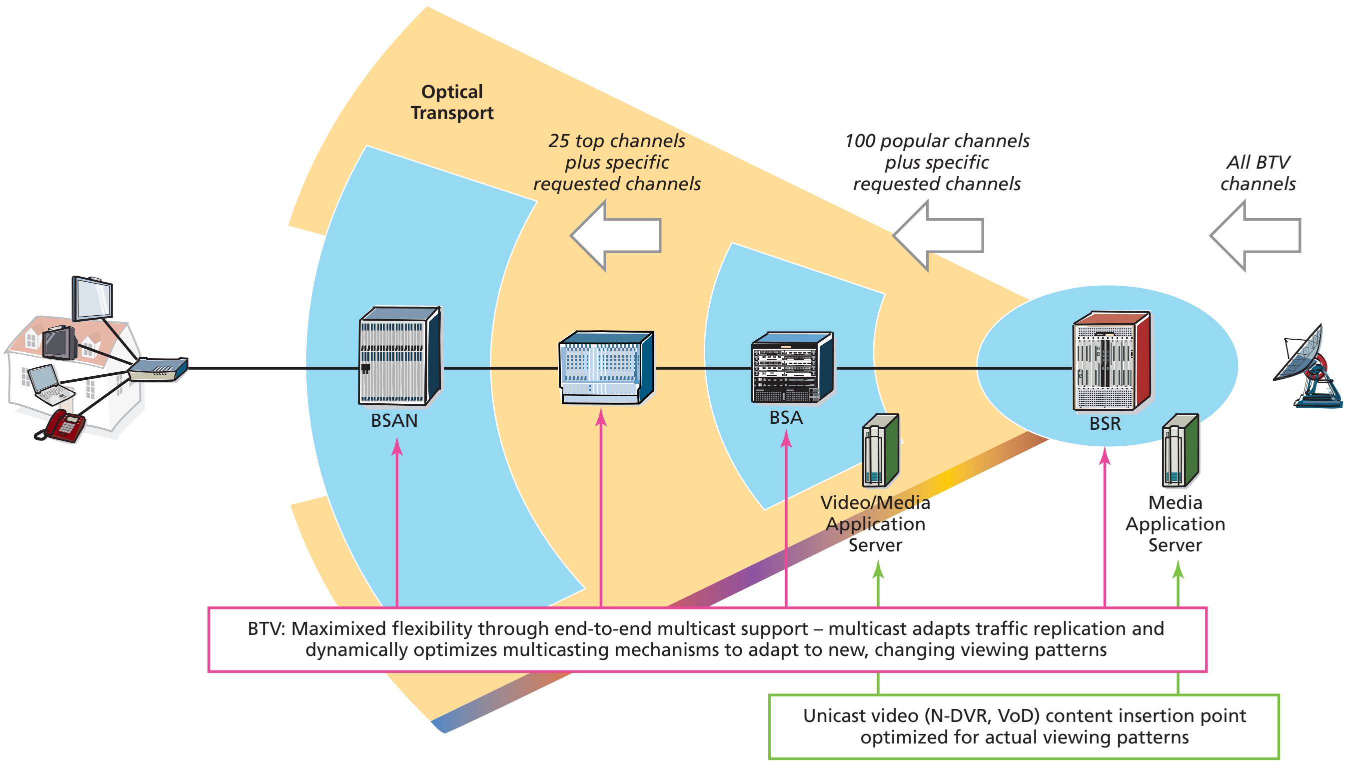
QoS, bandwidth and security policies are enforced by all the nodes in the end-to-end service path and are centrally administered by the Alcatel-Lucent 5750 SSC broadband policy server and provisioned based on the services to which a user subscribes. Since there are a number of technology transitions, QoS needs to be preserved end-to-end by consistently mapping IP ToS/DSCP on Ethernet 802.1p bits and MPLS EXP bits. When a subscriber signs up for VoIP services, proper QoS, bandwidth and filtering policies are configured based on the amount of VoIP lines he or she wants to connect.

Optimizing Bandwidth Efficiency for IPTV

Today's predominant mode of video service is BTV. As video services are introduced, it makes sense to optimize investment by matching resources to the service model relevant at the time. Therefore, the objective of the triple play service delivery network should be to incorporate sufficient flexibility to optimize for BTV service now, and still scale bandwidth levels to support a full unicast model.

Optimizing for BTV now means implementing multicast packet replication throughout the network. Multicasting increases the efficiency of the network by reducing the bandwidth and fiber requirements for delivering broadcast channels to the subscriber. A multicasting node can receive a single copy of a broadcast channel and replicate it to any downstream nodes that require it, thus substantially reducing the necessary network resources. This efficiency becomes increasingly important closer to the subscriber. Multicasting should therefore be performed at each of the access node, aggregation node, and video edge points (i.e., BSAN, BSA, BSR) as well as the optical transport layer, as shown in Figure 7.

Figure 7 . Optimized IPTV Content Delivery with the TPSDA



The Alcatel-Lucent TPSDA leverages a distributed architecture to optimize service cost, scalability and performance of BTV content delivery. These aspects are implemented, controlled and assured for each element of the end-to-end infrastructure using:

- Distributed multicast in access, aggregation, optical and edge nodes in combination with IGMP snooping and proxy to ensure that only the channels that are being requested by subscribers are forwarded. It maximizes bandwidth efficiency while automatically adapting network capacity allocation to actual traffic patterns.
- IGMP snooping and proxy functions in conjunction with multicast service admission control (SAC) to set bandwidth policies on second and third mile links to prioritize available link capacity for mandatory and popular channels.
- Distributed policy enforcement capabilities to enable video content insertion at the most economical point in the network. National broadcast channels and infrequently watched VoD can be inserted at central locations while popular VoD titles can be streamed from regional offices closer to end users. This conserves bandwidth by shortening the service delivery path.

The use of multicast capabilities in the network must not preclude support for video service models that are more unicast-oriented. Unicast video service uptake such as VoD, network-based personal video recording and Internet video are growing over time, and their impact on the bandwidth demand should not be underestimated as they are more resource intensive than BTV. Internet video, for instance, is not something operators detect and monitor directly. It is lumped in with Web browsing, peer-to-peer file sharing and email exchange, and it is already using a lot of bandwidth today. This places a great demand on network resources that is also highly unpredictable and volatile. A lack of bandwidth resources inside the network would result in a poor quality for these services and could lead to customer churn.

The Alcatel-Lucent TPSDA includes an underlying optical infrastructure that increases the transportable capacity over the fiber infrastructure and reduces the cost per transported bit. WDM capabilities, whether deployed in a stand-alone system (Alcatel-Lucent 1696 MS or 1626 LM) or integrated inside multiservice optical platforms (Alcatel-Lucent OMSN, DMX or 1850 TSS) provide up to Terabit/s capacity per optical fiber. The optical infrastructure is data-aware to allow the control of the bandwidth allocation according to the priority assigned to transported packets by the BSAN/BSA/BSR service-aware functionality. This optical infrastructure also answers the need for minimizing the initial investment and for supporting ever-growing traffic volumes by allowing incremental growth of the network capacity whenever the need arises. Automated features and reconfigurable optical add/drop multiplexers (ROADM) ease and speed up the implementation and provisioning of the required capacity. This helps operators manage unexpected bandwidth growth and shortens the service delivery lead time, thus allowing rapid and efficient responses to end users' demand for more bandwidth.

Policy-Based Service Admission Control

Assuring quality of experience for video is not just a matter of bandwidth capacity. Proper network dimensioning is essential, but not sufficient. A comprehensive approach to congestion avoidance is needed to meet the service quality and availability objectives. In particular, SAC can be a useful complement to other quality assurance mechanisms to preserve service sessions in progress against the risk of quality degradation due to a network overload (e.g., extreme demand peaks or multiple link failures). SAC is a mechanism that verifies that adequate capacity exists in the network to allow the user request (e.g. start of a VoD movie) to proceed. In general, admission control only applies to session-oriented services requiring deterministic QoS and bandwidth guarantees to function properly. Thus, both streaming video and real-time communications over IP would be session-oriented services for which admission control applies, but Internet access services are not.

As every session denied is a lost revenue opportunity, and an unpleasant customer experience, there should be no sessions denied under normal operating conditions. In some particular situations however (e.g., VoD), it may be more cost effective and therefore profitable if not all demand peaks are met, and in this unusual case, admission control might deny session requests during normal operational conditions. Also operators may wish to differentiate their VoD service offering by offering content in various price ranges from free to premium VoD content, with availability in Standard or High Definition format. Differentiated payment models such as pre-paid subscriptions and pay-per-view may be introduced and prices may vary based on time of day and network utilization. As a result, different priority levels may be associated with content to allow making policy-based SAC decisions.

The Alcatel-Lucent TPSDA supports both multicast and unicast SAC. Multicast SAC is a capability of the TPSDA that works in conjunction with the IGMP snooping function. It maximizes available second and third mile bandwidth for mandatory and the most popular broadcast content, allowing operators to enlarge their channel line up while controlling potential resource contention issues. Multicast SAC is enforced by the network control plane to cater for the extremely low latency requirements for instant channel changes. Unicast SAC, for example to control VoD session requests, is enforced by a centralized policy control mechanism to perform arbitration between services and guarantee service delivery when multiple services compete for bandwidth. The Alcatel-Lucent 5750 SSC policy-based authentication, authorization and accounting (AAA) and SAC functions are tightly integrated and centrally administered to close the loop on service authorization based on the subscriber service profile and network resource availability.

Through integration with the network management layer, topology and link capacity is learned and congestion notifications are used to exchange bandwidth updates and verify congestion-free performance. For example, the BSAN has an actual view on the training rate of the DSL loop. Should the training rate drop below the provisioned capacity as known by the broadband policy server, an update notification is sent by the BSAN through the access network control protocol (ANCP). When the BSA receives this notification, it can automatically adjust its subscriber scheduling policies. (ANCP is introduced in SR_OS 5.0.) This further ensures a consistent end-to-end QoS implementation. This mechanism is subject to threshold and latency mechanisms to avoid "ping-pong effects". If a subscriber wants to upgrade his or her services or attach additional devices, the BSAN can be triggered by the policy server to increase the configured capacity (where the configured capacity is less than the DSL training rate).

The admission control and HQoS policies implemented will largely depend on the operator's service offering and commercial strategy. Through the Alcatel-Lucent 8920 Service Quality Manager (SQM), accurate usage and QoE measurements can be made. The operator can then better engineer network capacity, tune bandwidth allocation policies for SAC functions, and take corrective measures if subscribers are not receiving premium quality for their IPTV, VoIP or HSI services.

Network Security and Content Protection

Security is one of the principle concerns of content owners as it provides protection from piracy and unauthorized replication, which can cause a significant loss of revenue to the owner. Generally, the operator is liable for securing the content. Responsibility begins the moment content is received from the owner and continues until it is delivered to the end user (and beyond if the user is allowed to store and reuse the content). Providing a security solution requires an understanding of possible threat scenarios and their related requirements. Four main types of threats must be considered:

- Theft of services: illegally benefiting from services provided by an operator
- Theft of content: illegally obtaining a usable digital copy of copyrighted material
- Disruption or denial of service: malicious action designed to alter the normal behavior of the IPTV infrastructure
- Illegal broadcast: illegally using the IPTV infrastructure to broadcast arbitrary content

To deal with these threats, operators must address two related, but independent, layers of security:

- Application-level security, encompassing all protection mechanisms deployed on the STB video client, video servers and content store. These are often referred to as digital rights management (DRM) systems, and may include conditional access, encryption and scrambling.
- Network level security, including all protection mechanisms deployed on the content delivery infrastructure (underlying network). These guarantee authenticity, confidentiality, integrity and availability of the data flows by implementing attack prevention, detection or reaction.

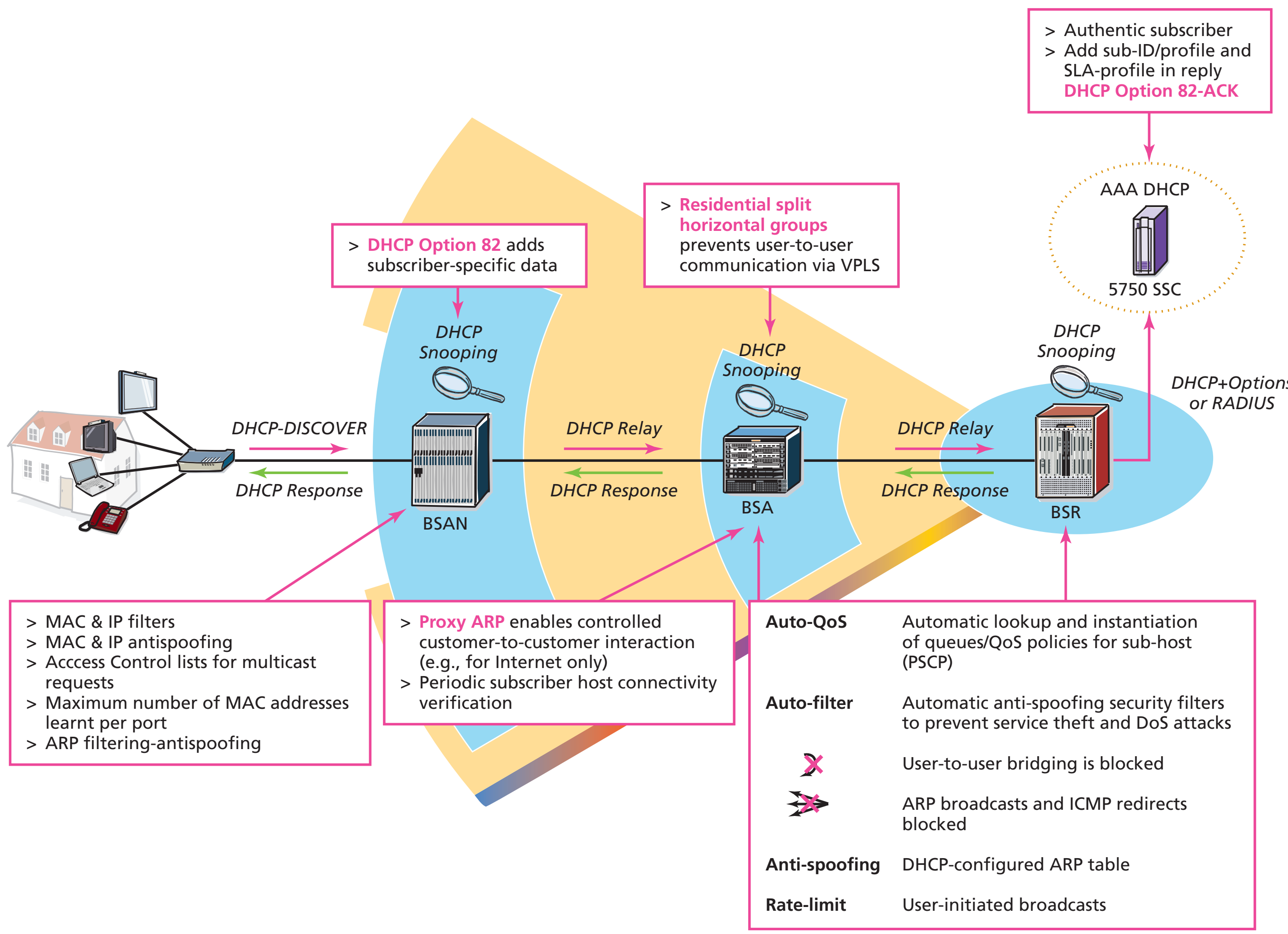
Security policies must be enabled across the infrastructure to address the challenges of triple play service delivery. Security is yet another example of a function that must be distributed / optimized across the infrastructure to enable a superior user experience. The Alcatel-Lucent TPSDA accomplishes this optimization and incorporates internal and external security solutions to ensure content and network security for a safe and high-quality user experience.

Security features in the TPSDA include:

- Guaranteeing the privacy and logical separation of user communication
- Authentication of the residential gateway upon service activation
- Enforcement of user policies to prevent both theft and denial of service (DoS)

These features require that both the IP and Ethernet layers be secured. Security and authentication in the Alcatel-Lucent TPSDA are accomplished through key functions in the residential gateway, BSAN, BSA and BSR (see Figure 8).

Figure 8. Content and Network Security in the TPSDA



The BSAN provides the physical port access to the user and is therefore the appropriate location to do port authentication via the 802.1x protocol. The BSAN can perform local authentication or use extensible authentication protocol (EAP) over a remote authentication dial-in user service (RADIUS) to connect to an AAA server. The BSAN also signals which port DHCP messages are received on (using option 82) to ensure that DHCP requests are properly authenticated. The BSAN can ensure media access control (MAC) address uniqueness among the attached subscribers and prevent user-to-user bridging locally on the access node. In addition, the BSAN provides IP address antispoofing, essential for IPTV subscribers to ensure the correct user is requesting and paying for the service.

The BSAN, BSA and BSR provide per-subscriber security policy enforcement and block DoS or theft of service attacks. They do this by tracking the IP and MAC addresses assigned to a customer through DHCP. With this knowledge, access to the network can be restricted to allow only valid and authenticated customers to use specific ports. This strict anti-spoofing ensures that there is no unauthenticated access to the network and also that there is no anonymous access to the network. In addition to anti-spoofing, the IP-MAC association is used to secure the Ethernet infrastructure.

The Alcatel-Lucent 5750 SSC supports integrated AAA to control access to network-based services and content for user devices and subscribers. It enables this for both DHCP and/or RADIUS depending on deployment preferences of the network operator. The Alcatel-Lucent TPSDA provides a reliable and secure service delivery infrastructure to protect subscribers, operators and valuable content.

Streamlining Management and Operations

It is clear from the preceding sections that there are many factors in play when delivering personalized triple play service bundles to the mass market. Indeed, many operators are concerned about the multi-dimensional operational challenges they face when setting up triple play services.

Effective control of operating expenditures (OPEX) is equally important as capital expenditures (CAPEX) in a triple play service delivery network. In order to quickly and cost-effectively deliver new triple play services, tools are necessary to orchestrate the interaction of all elements of the service delivery network and control operations end to end across multiple layers.

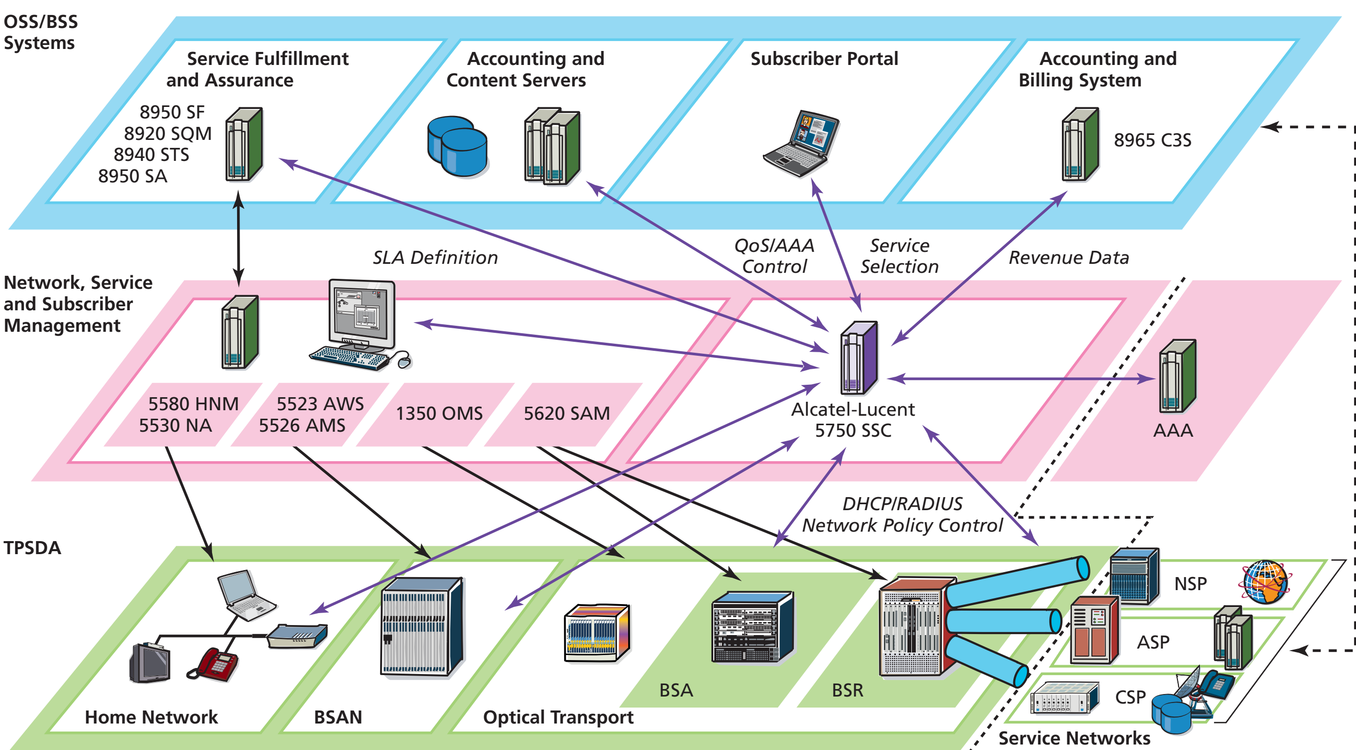
- *End-to-end network management:* Operators need to plan and manage the network infrastructure over which triple play services are delivered. This includes commissioning devices, building topologies, provisioning capacity, and checking that the network is operating properly. This requires intuitive and graphical element, network and service management tools that provide a full network topology perspective. The management systems should also include operations, administration and maintenance (OAM) techniques that provide end-to-end service-specific OAM rather than hop-by-hop network debugging. In the TPSDA, this is supported by specific management systems for each technology, as depicted in Figure 9, and the Alcatel-Lucent 8950 Service Fulfillment product, which provides an end-to-end service fulfillment solution for the provisioning and monitoring of triple play services.

- *Integrated subscriber and service control:* Operators need to control subscriber access to network services and content. The operator must be able to effectively enforce control over network resources to enable subscriber access to the network and to ensure users receive the appropriate QoS, based on the applications they are using. The Alcatel-Lucent 5750 SSC supports unified subscriber management, service creation and policy administration as part of its role as the AAA broadband policy server. Unified subscriber management entails the ability to maintain a single user account and billing entity to which all subscriber services are attached. Unified subscriber management offers the subscriber and operator an integral view of all services provided to an account. With single sign-on to access account information through the customer self-care web portal, unified subscriber management effectively creates a one-stop shopping experience.

  As shown on Figure 9, the control flows of the Alcatel-Lucent 5750 SSC extend to the OSS layer where it interacts with OSS service activation systems, application middleware and content servers, as well as billing systems. Given its role in AAA, the Alcatel-Lucent

5750 SSC is also able to interface with AAA servers from wholesale partners that use the triple play service delivery infrastructure for distributing their services to subscribers. In addition, the Alcatel-Lucent 5750 SSC is in direct contact with end users through subscriber self-serve portals that can be used to sign up for services, make modifications to services, or receive directions for specific usage events.

Figure 9. Orchestrating Operational Tasks for Triple Play Service Delivery



- *Service monitoring:* Front office operators need to monitor service quality to make sure they are delivering the quality of experience end users are expecting. The Alcatel-Lucent 8920 SQM collects usage and performance data coming from the entire service delivery path to help assure quality of experience and diagnose potential problems. It organizes this data into reports and performance metrics so that operators can respond to increased demand and remedy potential quality issues in time. It also alerts them if any viewers are not receiving a top quality experience. The Alcatel-Lucent 8920 SQM is complemented with troubleshooting tools (like the Alcatel-Lucent 8940 Service Troubleshooting Solution) that help front office operators to detect potential service degradation before end users notice the service impact, and diagnose and isolate the source of the problem in the end-to-end network. The troubleshooting operation can also be done by the end user him- or herself, through a dedicated self-care application that will guide the end user through the different steps required to resolve the problems.

- *Digital home management and subscriber self-care:* With triple play, service providers enter customers' homes with devices and applications that create a more complex home environment. The limited technical knowledge of end users, and the real-time and sensitive nature of voice and video services is a matter of great concern for service providers. If not managed properly, the home network and the last portion of the access loop could be the source of many problems, resulting in service disruption or poor service quality, which will frustrate users and result in an increase in help-desk calls, costly repair operations, and subscriber churn. To address these challenges, Alcatel-Lucent TPSDA includes the Digital Home Care (DHC) solution, which facilitates and automates various operational processes including device installation, service activation, customer support and troubleshooting operations. The DHC solution is based on several modules that manage home devices, the access loop quality and customer support interactions. The Alcatel-Lucent DHC solution includes the Alcatel-Lucent 5580 Home Network Manager, which provides remote device management based on the DSL Forum TR-069 standard. This includes zero-touch provisioning, configuration, software management and troubleshooting, all performed in a granular or mass/automated mode. Customer access line quality is managed with Alcatel-Lucent 5530 Network Analyzer, which provides service-aware line qualification, quality optimization and assists in trouble-shooting operations through advanced line diagnosis. The Alcatel-Lucent DHC can also be extended with customer support tools for customer self-care (for device installation, service activation and troubleshooting) and assisted care with customer service representatives.

Ultimate Triple Play Service Deployment Flexibility

While automation of operational processes is a key requirement, it is also important to retain the operational freedom and flexibility to make customer-specific deployment choices. The Alcatel-Lucent TPSDA has been adopted as a blueprint for many of the largest triple play service roll-outs worldwide. With over 40 deployments during the past two years, Alcatel-Lucent acquired critical operational expertise as a network and service integrator. Based on operational lessons learned, the TPSDA has been augmented and enhanced to provide the ultimate deployment flexibility, allowing operators to optimize their service delivery infra-structures in anticipation of the mass adoption of triple play services.

The Alcatel-Lucent TPSDA enables optimized triple play service delivery for any mode of operation — i.e., for any combination of access technology, home gateway, authentication protocol, and connectivity mode, as well as subscriber management, policy enforcement and content insertion choices. The Alcatel-Lucent TPSDA caters to a multitude of network and deployment environments with different characteristics like legacy infrastructure and network assets, region- or geography-specific characteristics, strategy and customer base. This ultimate flexibility allows the TPSDA to be adopted as the network foundation by any operator for triple play rollout, whatever the requirements.

Home Gateway Choices

There are vast disparities today across regions for home gateway choices, with no predominant mode of operation across operators globally. Some operators favor a routed home gateway mode of operation, while others favor the continuity from the traditional HSI mode of operation and use of bridged home gateways.

In cases such as in the United States, where there is a large average number of home appliances per household (STBs, VoIP phones, etc.), routed gateways ensure any service on any device, which greatly simplifies subscriber and host/appliance management challenges. Routed gateways typically also provide:

- Additional security with no in-home traffic entering the network (maximized security, minimized risk of theft of service/address spoofing)
- Simplified address resolution protocol (ARP) and MAC address management
- Simplified troubleshooting with granular fault isolation

The Alcatel-Lucent TPSDA supports any type of home gateway within a service delivery framework.

Access Technology Choices – Extending Fiber to the Most Economical Point

The success of triple play and rich media services depends on the operator's ability to provide a dramatically enhanced user experience. Operators must deliver user-centric broadband services — that is, any content, to any user at any time — in the most efficient and cost-effective way. This need for flexibility and delivery of services to the most economical point dictates that operators must use a variety of access types and technologies to reach all subscribers cost-effectively, over both fixed and mobile access methods.

- For operators, this typically results in a mix of access technologies including:
- Central office based DSL
- Multiservice access nodes (MSAN), which combine next generation DSL access with voice access for PSTN migration to a next generation network/IP multimedia subsystem (NGN/IMS)
- Fiber to the node (FTTN) based on ADSL2plus or VDSL2
- Fiber to the user (FTTU) based on a PON
- WiMAX

The key challenge for operators when they introduce these technologies is to minimize the operational impact by maintaining a unified mode of operation across all access networks. Ideally, therefore, access nodes should share the same equipment practice, provide interchangeable blades, typically run the same software, and present unified interfaces and modes of operations toward the aggregation network. In this way, operators can rationalize their networks and simplify their operations in the aggregation and edge networks. This is achieved by the Alcatel-Lucent the TPSDA, leveraging the full breadth of Alcatel-Lucent's market-leading ISAM portfolio and the Alcatel-Lucent WiMAX solution, providing for maximum flexibility in the first mile.

Aggregation Network

Transport between BSAN locations and the BSA can take a number of forms that include point-to-point fiber, WDM or optical Ethernet aggregation. The option to be used could depend on the subscriber density, the services supported, the existing infrastructure, the distance to cover, etc.

Where optical Ethernet aggregation is used between the BSAN and BSA, this layer is not aware of the subscriber and service policies however it guarantees that the overall committed bandwidth is preserved and ensures that the subscriber's QoS (as enforced at the BSA) is not impacted. Optical Ethernet aggregation can be achieved with multiservice optical platforms that help operators leverage their TDM installed based and smoothly manage the transition to pure packet environment. This solution may be particularly appropriate where:

- A single infrastructure can be used to support multiple services on top of triple play (TDM, mobile backhauling, business services, etc.)
- An existing transport network can be extended to include simple Ethernet aggregation, e.g., to use the physical fiber infrastructure in the access network and overcome fiber exhaustion when adding new BSANs.

Many of the benefits of the TPSDA (support for multicast, high availability, and platform reliability, for example) are inherent in this building block.

Authentication Protocol Choices

Although a majority of legacy HSI deployments are based on point-to-point protocol (PPP)/ RADIUS technologies for telco companies, the results of an Alcatel-Lucent research study indicated that most operators worldwide have made the strategic decision to leverage DHCP as the predominant mode of operation for their triple play infrastructures. DHCP provides proven, robust and efficient authentication mechanisms that enable multi-appliance plug-and-play connectivity; maximize flexibility for policy enforcement, content insertion and subscriber management; and facilitate and accelerate the migration from legacy infrastructures through native support for HSI, voice, video and managed enterprise services.

A key concern for operators is to facilitate and accelerate the migration from a strategic PPP/RADIUS-based HSI installed base to a unified, DHCP-based mode of operation for all services. The Alcatel-Lucent TPSDA provides a comprehensive set of legacy AAA support functions, including AAA/RADIUS proxy and PPP offload capabilities, together with the most comprehensive and complete set of subscriber management, AAA and DHCP capabilities to support native retail and wholesale HSI service (in addition to voice and video). Alcatel-Lucent has also innovated and pioneered unique capabilities, such as enhanced subscriber management using programmable subscriber configuration policy (PSCP) to facilitate and accelerate the seamless migration to a unified DHCP-based network operation for all services, while enabling both DHCP and RADIUS-based AAA integration (the latter is enabled by a DHCP-RADIUS proxy function in SR OS).

Connectivity Mode Choice

The Alcatel-Lucent TPSDA reference solution uses a VLAN-per-subscriber connectivity model in the second mile (see Figure 6). This model mimics modes of operations that were used for previous ATM-based virtual path identifier/virtual channel identifier connectivity models, which are the norm for HSI deployments. A VLAN-per-subscriber model brings the following benefits:

- Consistency with present mode of operation (one logical connection per subscriber).
- VLANs can be mass-provisioned through single-click provisioning and provide a consistent and scalable context per subscriber across all access methods (FTTx/xDSL) regardless of authentication state.
- Per-subscriber traffic compartmentalization facilitates security, troubleshooting and accounting.
- Extensive granular and simplified troubleshooting and traffic interception/mirroring are available for law enforcement compliance.

The TPSDA also supports alternative connectivity models including:

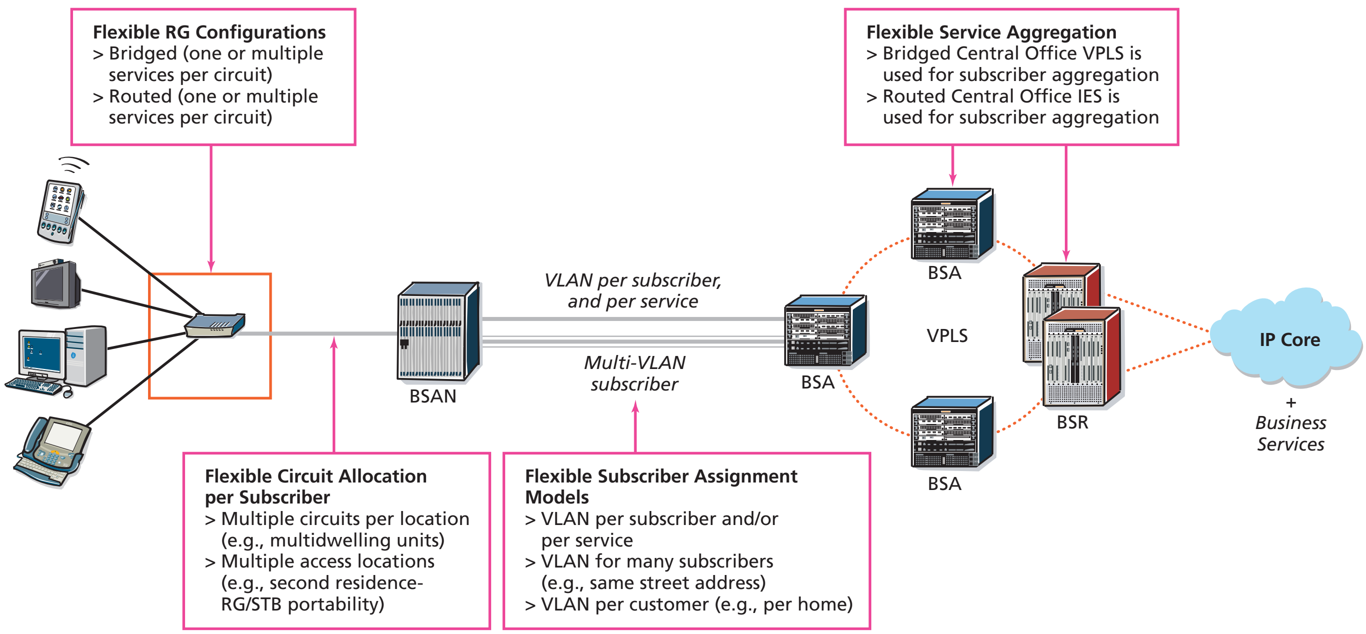
- VLAN per service
- VLAN per service, per subscriber
- VLAN per IP DSLAM.

The Alcatel-Lucent TPSDA provides a comprehensive set of subscriber management and policy enforcement capabilities that allow operators to deploy optimized triple play services over any combination of BSAN to BSA connectivity modes across the second and third miles.

Any Mode of Operation

The TPSDA enables operators to choose the deployment model that best suits their operational needs. Any mode of operation describes the capability to support various access methods, home gateway configurations and connectivity models in a manner that is transparent to the AAA infrastructure. A comprehensive feature set called enhanced subscriber management enables the operator to deploy and optimize triple play service delivery in any mode of operation using DHCP or RADIUS based AAA approaches (see Figure 10).

Figure 10. Supporting Any Mode of Operation



Legacy Migration and Service Innovation

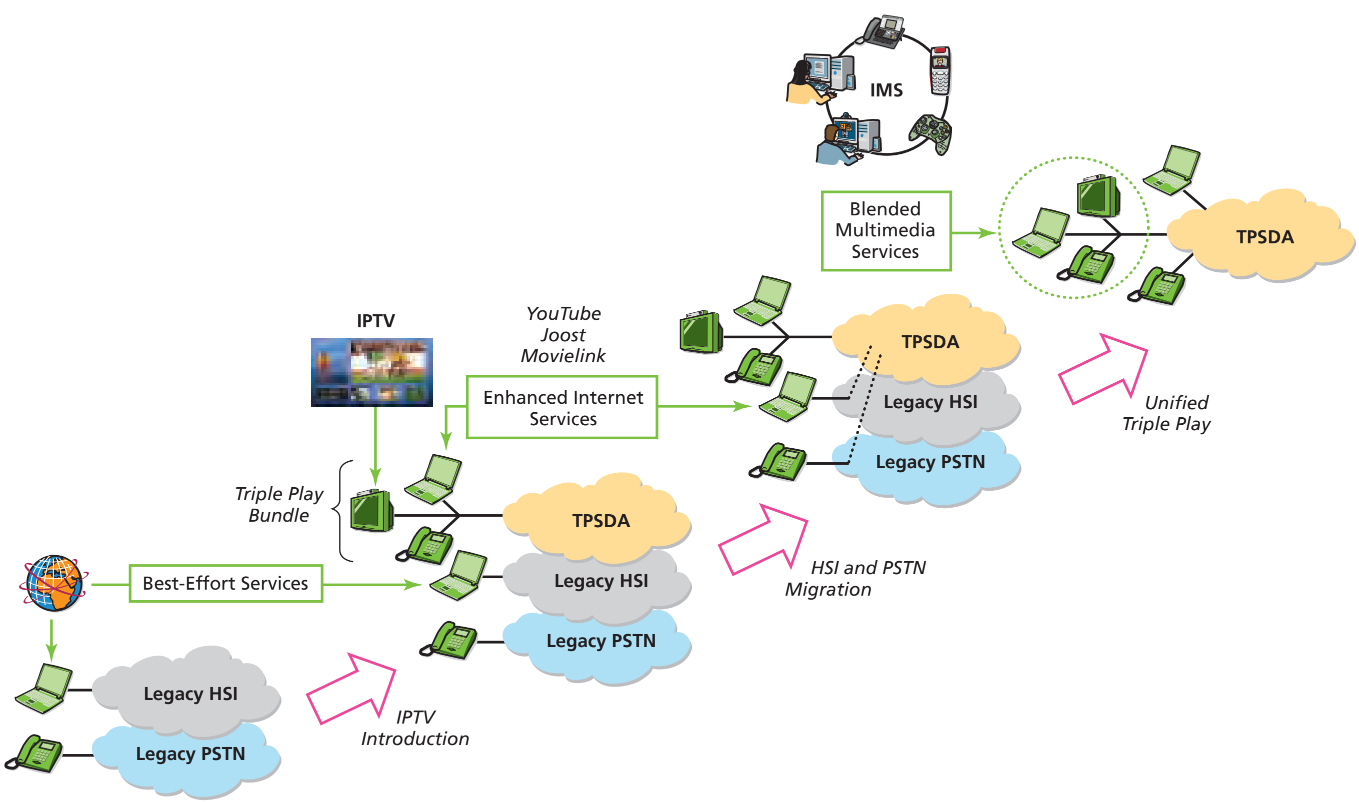
As operators are building a converged, next generation IP infrastructure to deliver triple play services, a key requirement is the non-disruptive migration of legacy voice and HSI infrastructures:

- Non-disruptive in terms of controlling OPEX and CAPEX investments by leveraging investments made in legacy infrastructure
- Non-disruptive in terms of providing a seamless migration of existing subscribers and services on legacy infrastructures to a service bundle provided through the next generation target infrastructure.

The existing PSTN voice and HSI subscriber base is a key strategic asset that needs to be leveraged. Operators will typically take an approach in which the TPSDA is initially deployed to coexist with the legacy infrastructure to support IPTV service introduction; cap investments in legacy voice and HSI service infrastructures; and support the evolution to NGN/IMS and enhanced Internet services, as shown in Figure 11. Legacy voice and HSI service offerings are typically migrated to the TPSDA at the time a subscriber signs up for an IPTV/triple play service bundle. In addition to that, there are various ways in which interworking between the TPSDA and legacy infrastructures can be realized to support a cost-effective “horizontal migration” of legacy subscribers and services to the TPSDA (refer to the “HSI & PSTN Migration” step in Figure 11).

From a cost and investment perspective, the goal is to balance the cost of rolling out a new infrastructure that is able to address the introduction of IPTV, while avoiding the need to make substantial upgrades and extensions of the installed base to cater for continuing growth in HSI and additional capacity required for NGN voice. In other words operators want to implement an effective cap-and-grow strategy that leverages installed base assets while reaching the end-goal of unified triple play. In this context, the TPSDA can efficiently leverage the TDM transmission network and enable a smooth transition to a pure optical packet transport environment, providing an optimal service transformation strategy.

Figure 11. Migration Steps from Legacy Infrastructure to the TPSDA

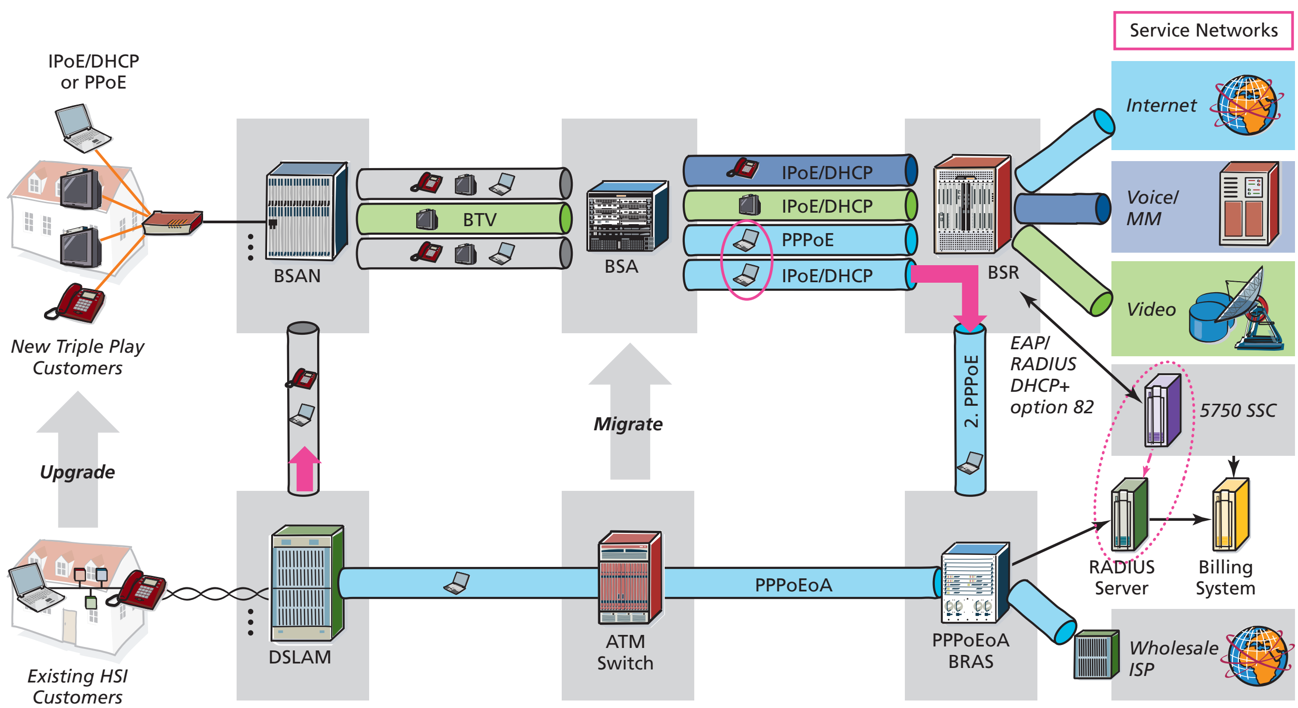


Migrating Legacy HSI Services and Infrastructure

The Alcatel-Lucent TPSDA facilitates the introduction of triple play service delivery and subsequent consolidation and migration of traditional HSI services and subscribers on a common infrastructure. The Alcatel-Lucent 5750 SSC provides a converged AAA solution for triple play that not only enables the support of converged triple play service delivery over an IPoE/DHCP-based environment, but supports the integration of legacy PPPoE-based HSI services and infrastructure components as well. By providing multi-vendor support integration for a variety of BRAS systems, operators can migrate and upgrade legacy HSI subscribers to triple play service offerings with minimal effort. This will enable them to avoid the operational expense of maintaining separate AAA infrastructures (see Figure 12).

The Alcatel-Lucent 5750 SSC can handle millions of subscribers in an operationally flexible, cost-effective and secure manner while enabling a smooth evolution of the legacy Internet infrastructure and subscriber base to triple play, helping operators preserve past investments. The Alcatel-Lucent 5750 SSC makes it transparent to the end user that individual services may use different access technologies and modes of operation. For example IPoE/DHCP-based triple play services can be combined with PPPoE/RADIUS-based legacy HSI services and 802.1x EAP/RADIUS-based wireless access service, all under the same user account. In addition to saving operational costs and hassle, this capability facilitates a smooth legacy service migration from PPPoE to IPoE by simply modifying the AAA policy, rather than creating a whole new user account in a different subscriber management system.

Figure 12. Migration from Legacy HSI to Triple Play Service Delivery



Migrating Legacy TDM Voice to Blended NGN/IMS Services

The combination of the TPSDA and a market leading NGN/IMS portfolio places Alcatel-Lucent in a unique position to help operators meet the real-world network transformation challenges of migrating legacy voice subscribers and PSTN infrastructures to an NGN/IMS infrastructure. The biggest challenge in offering VoIP services lies in assuring service quality and reliability. The bar has been set high by legacy PSTN-based services, leaving little or no room for trading off a lower service cost against lower quality or availability. Failing to meet these user expectations can lead to a rapid deterioration of brand equity and even litigation. Maintaining customer loyalty is critical since there are increasingly more alternative voice operators in the market. The TPSDA is ideally suited to meet these stringent requirements and supports a variety of PSTN-NGN interworking and support options.

In most cases, the legacy PSTN infrastructure will coexist with the NGN infrastructure for a number of years. This allows operators to get full coverage of the subscriber base during the rollout period while preparing for the introduction of NGN/IMS services in key markets. Operators may have different requirements for their networks. As a result, they may take different approaches to deploying voice over a next generation IP service infrastructure and, particularly in the case of incumbent operators, in the migration of existing PSTN subscribers and infrastructures. The TPSDA supports various migration scenarios:

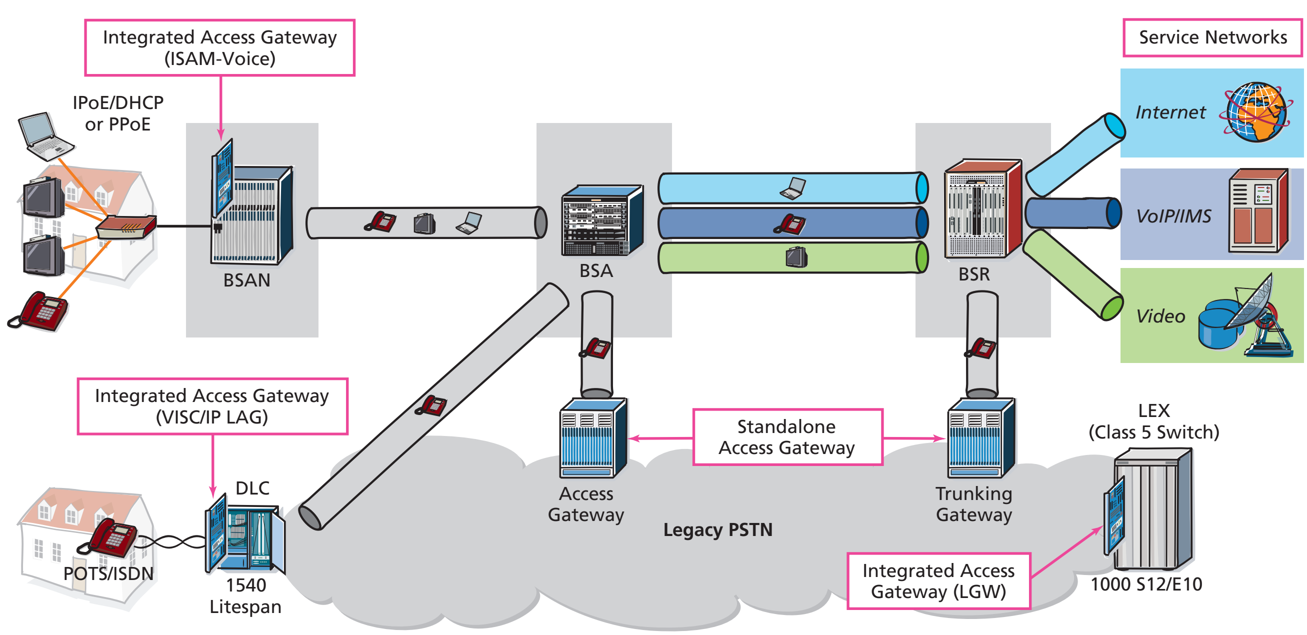
- *CPE-based PSTN migration:* client-side voice adaptation is done using a residential gateway with integrated VoIP gateway for regular VoIP services (e.g., second line) or PSTN migration of the primary line
- *Network-based PSTN migration:* the BSAN, the digital loop carrier or the PSTN switches (labeled LEX in Figure 13) are upgraded with VoIP access gateway capabilities. Stand alone access and trunk media gateways can also be deployed to adapt PSTN voice for VoIP.

For network-based PSTN migration, the Alcatel-Lucent ISAM family (the BSAN) has an integrated VoIP access gateway card (e.g., ISAM voice package) to convert POTS/ISDN traffic into VoIP for delivery to an NGN/IMS core. The ISAM voice solution combines Alcatel-Lucent's strength and leadership in DSL and NGN/IMS infrastructure to offer a compelling new generation multiservice access platform. ISAM voice is already the leading DSL/voice access platform with over one million voice access lines deployed so far.

For those markets where the moderate broadband penetration does not justify the deployment of VoIP access gateways based on IP DSLAMS, the Alcatel-Lucent 1540 Litespan Multi-service Access Gateway can be used for PSTN replacement. Access gateway functionality can be added to the already-installed Alcatel-Lucent 1540 Litespan whenever desired, by inserting a VoIP server card (VISC). Also the Alcatel-Lucent 1540 Litespan incorporates the leading triple play ISAM technology. This basically means that the Alcatel-Lucent 1540 Litespan fits perfectly in the Alcatel- Lucent TPSDA as a BSAN, not only because it provides voice services, but also because of its ability to deliver advanced broadband services like VoD or IPTV.

Figure 13 shows the TPSDA (top) and the various VoIP network components and interworking points to connect to an existing PSTN infrastructure (bottom).

Figure 13. Legacy PSTN Interworking and NGN Migration with the TPSDA



Conclusion

The Alcatel-Lucent Triple Play Service Delivery Architecture is a purpose-built network foundation to support the service and network transformation to triple play providing:

- *Ultimate flexibility and scalability:* The Alcatel-Lucent TPSDA enables right-sized deployments that can grow cost-effectively to support mass-market service rollouts. It also provides the key service capabilities across the network so that policies can be optimally activated across different nodes as traffic patterns and services evolve. This allows operators to cost-optimize their service infrastructures and optimize each service so that it can scale cost-effectively.
- *Non-stop service delivery for assured quality of experience:* The TPSDA guarantees the experience expected by users, who demand service continuity, image quality, and reliability as a matter of course.
- *Secure access to network infrastructure, services and content:* The TPSDA provides comprehensive and integrated security features.
- *Cost-optimization for improved profit potential:* The TPSDA enables operators to extend their service reach over any access method with consistent, predictable, rich capabilities. Moreover, the TPSDA can support both mass-market consumer services and demanding enterprise applications as well as retail and wholesale services.
- *Future-proof:* The TPSDA provides operators with the flexibility and headroom to introduce new services and scale existing services without compromising cost or performance. Operators can concentrate on attracting and retaining customers through their service offerings, leveraging the brand equity generated by their ability to deliver services flawlessly.
- *Non-disruptive legacy migration:* The TPSDA enables operators to capitalize on strategic installed base assets, and facilitates the integration and non-disruptive migration of legacy voice and HSI infrastructures on a converged next generation IP infrastructure.

The Alcatel-Lucent TPSDA is by far the most widely deployed end-to-end architecture for triple play networks with over 40 deployments to date. This solution is complemented by a rich portfolio of professional services that draws on lessons learned in the field to assist operators in accelerating the deployment of large scale triple play networks while minimizing risk and time-to-market.

Acronyms

AAA	authentication, authorization and accounting
ADSL	asymmetrical digital subscriber line
ANCP	access network control protocol
ARP	address resolution protocol
ARPU	average revenue per user
ASP	application service provider
ATM	asynchronous transfer mode
BRAS	broadband remote access server
BSA	broadband service aggregator
BSAN	broadband service access node
BSR	broadband service router
BTV	broadcast television
CAPEX	capital expenditures
CO	central office
CSP	content service provider
DHC	digital home care
DHCP	dynamic host configuration protocol
DLC	digital loop carrier
DoS	denial of service
DRM	digital rights management
DSCP	DiffServ CodePoint
DSL	digital subscriber line
DSLAM	digital subscriber line access multiplexer
EAP	extensible authentication protocol
ESM	enhanced subscriber management
FTTN	fiber-to-the-node
FTTU	fiber-to-the-user
GigE	Gigabit Ethernet
GPON	Gigabit passive optical network
HD	high definition
HQoS	hierarchical quality of service
HSI	high-speed Internet
IGMP	Internet group management protocol
IP	Internet protocol
IPoE	IP over Ethernet
IPTV	Internet protocol television
ISP	Internet service provider
LAG	link aggregation group
LEX	local exchange
MAC	media access control
MC-LAG	multi-chassis link aggregation group
MPLS	multiprotocol label switching
MSAN	multiservice access node
NGN/IMS	next generation network/IP multimedia system
NSP	network service provider
OAM	operations, administration and maintenance
OMSN	Optical Multiservice Node
OPEX	operating expenditures
PON	passive optical network
PPP	point-to-point protocol
PSCP	programmable subscriber configuration policy
QoE	quality of experience
QoS	quality of service
RADIUS	remote authentication dial-in user service
RG	residential gateway
RIP	routing information protocol
ROADM	reconfigurable optical add/drop multiplexer
SAC	service admission control
SRRP	subscriber routing redundancy protocol
STB	set-top box
TDM	time division multiplexing
ToS	type of service
TPSDA	triple play service delivery architecture
VLAN	virtual local area network
VoD	video on demand
VoIP	voice over IP
VPLS	virtual private LAN service
WDM	wavelength division multiplexing
WiMAX	worldwide interoperability for microwave access

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