Survey of Next-Generation Broadband Aggregation Networks

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Abstract

Broadband Aggregation Networks are becoming increasingly important as the internet evolves in a way that increases bandwidth requirements. This paper aims to provide an overview of various broadband aggregation applications, and how this technology can help to better provide broadband access to users. From this paper, the reader should develop an understanding of the motivation behind broadband aggregation, as well as learn specific knowledge about various architecture designs that aggregate different existing technologies.

Keywords: Broadband aggregation, aggregation networks, broadband access, Triple Play Services, WiMAX, OBS

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1. Introduction

With the Internet continuously growing and evolving, bandwidth usage has been increasing, forcing service providers to offer technologies that meet changing requirements [CiscoProposal]. One large source of bandwidth demand growth comes from service providers offering triple-play services (voice, video, and data) [UStar]. Other examples of bandwidth intensive activities that have taken off recently include Hi-definition video and video-on-demand applications. Various other sources of bandwidth growth will be introduced throughout the paper.

These changes motivate taking a closer look at broadband aggregation, a practice of taking different technologies and combining them into one connection in order to increase bandwidth. The combined technologies can be things like DSL (Digital Subscriber Line), cable, Ethernet, and wireless devices, to name a few [CiscoGuide].

This paper looks at various different applications of how broadband aggregation is used to deliver services that can accommodate growing internet demands. The sections in this paper show how many different technologies can be aggregated in order to achieve specific results. An important part of analyzing different broadband aggregation networks is to identify the strengths and weaknesses that the technologies offer. Throughout the paper, the architectures that are described are then evaluated, and possible improvements and solutions are examined.

2. D-Link DIR-605 Fuzion Broadband Aggregation Router

The D-Link DIR-605 Fuzion Broadband Aggregation Router [DLink] is Cloud-managed and meant to serve small and medium businesses that need increased Internet capacity. This service provides scalability and costs less than upgrading to T1 services. In addition, the connectivity is reliable, flexible, and fast. The improved connection enables Fuzion's customers to deploy services like VoIP (Voice over Internet Protocol), video conferencing, hosted applications, and off-site data backup.

The router functions by taking several low-cost broadband lines and combining them into one internet connection that is faster and more reliable. Different service types like DSL and Cable can be aggregated.

In the following subsections, the router's management system and reliability will be discussed, followed by a detailed explanation of the router's layout and installation.

2.1 Management

Fuzion makes it easy to manage the router through its online management system. Administrators can manage security and users online in a secure fashion. Any traffic that goes through the Fuzion portal is securely encrypted, and wireless LAN (Local Area Network) access is secured using WPA/WPA2 (Wi-Fi Protected Access). The online management system helps save costs by eliminating the need for on-site IT support.

2.2 Reliability

Multiple connection types from different providers help to improve reliability because if one line fails, other lines will still be available to provide service. The only impact of a line failure is slower speed until the failed line is fixed. Fuzion consistently monitors the different connections and adjusts the routing in the case of a failure.

2.3 Router Specifics

Figure 1 shows a Fuzion D-Link Router installation setup. Customers will have modems for each line from their ISP (Internet Service Provider). Fuzion installs one router for each line and then everything is sent to a Fuzion aggregation server which combines the traffic before sending it to the internet. At the customer's site, Fuzion routers are connected by Ethernet. Traffic is divided between the different lines and the default gateway and DNS (Domain Name System) for devices on the customer's LAN are represented by a Fuzion VRA (Virtual Router Address). A DHCP (Dynamic Host Configuration Protocol) server runs on the VRA router and copies any changes on this router to the other ones as backup for failures. If one of the routers fails, service is only interrupted for a few seconds during the router switching.

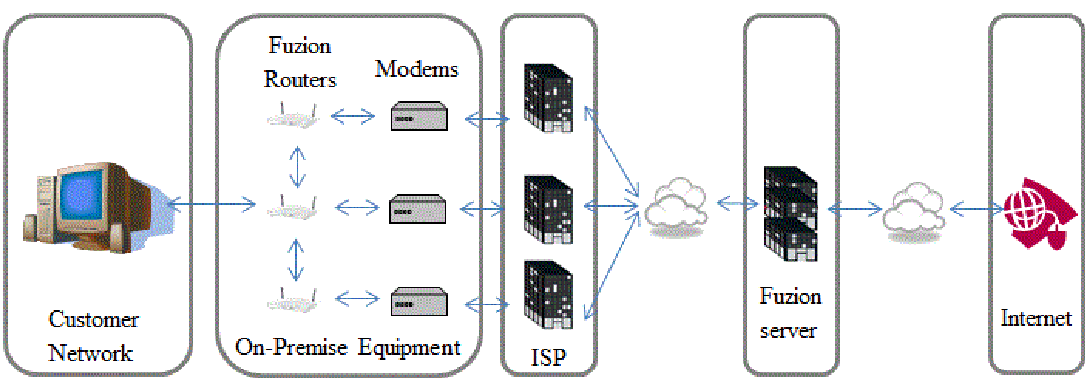

Figure 1: D-Link DIR-605 Fuzion Broadband Aggregation Router setup [DLink]

2.4 Summary

The Fuzion router is an option that can work with almost any ISP. As seen previously, the router offers easy management and user reliability. However, performance is largely dependent on connectivity between the ISPs and the Fuzion server, as well as connectivity between the ISPs. Overall though, the Fuzion router can reliably aggregate broadband lines.

In the next section, the integration of technologies to support the convergence of wired and wireless technologies is examined in detail.

3. WiMAX over OBS

More data and IP traffic continues to be generated as a result of new applications like e-science, e-business, e-learning, e-health, and e-government. In addition, business services (ex. IP VPN (Internet Protocol Virtual Private Network), VoIP, IP Videoconferencing) and residential services (ex. triple play and IPTV (Internet Protocol Television)) keep evolving. Traffic continues to grow as new services become more demanding in terms of network accessibility, functionality, capacity, and interoperability between different network segments and domains.

In the following subsections, the setup of an integrated WiMAX (Worldwide Interoperability for Microwave Access) over OBS (Optical Burst Switching) network is presented [Katrinis09]. Then, various issues of the architecture are discussed, along with possible alternatives and solutions.

3.1 General Overview

Several new wired and wireless network technologies are being deployed to meet new traffic requirements. While wired broadband access technologies like VDSL (Very High Speed Digital Subscriber Line) and PON (Passive Optical Networks) are able to satisfy the growing traffic requirements, wireless broadband access solutions can be more competitive with respect to capitalization and operational expenses. In addition, at high data rates, several things like nomadicity and mobility can only be achieved with wireless broadband.

There are two technologies that can be integrated to support the convergence of wired and wireless network segments. These are: wireless broadband access technology, and WiMAX integrated with an aggregation metro network solution that is based on OBS [Katrinis09]. Focus in the following sections will be placed on the WiMAX/OBS technology.

3.2 Integrated WiMAX/OBS Network Setup

In an integrated WiMAX/OBS network [Katrinis09], the WiMAX broadband is transported over OBS both to and from the core network. The setup, shown in Figure 2, places a WiMAX BS (Base Station) at the center of each cell. Each BS is connected to various SS (Subscriber Stations) through PMP (Point-to-Multipoint) wireless connections, and to one or more OBS Edge Routers through a wired physical connection (ex. Fast Ethernet).

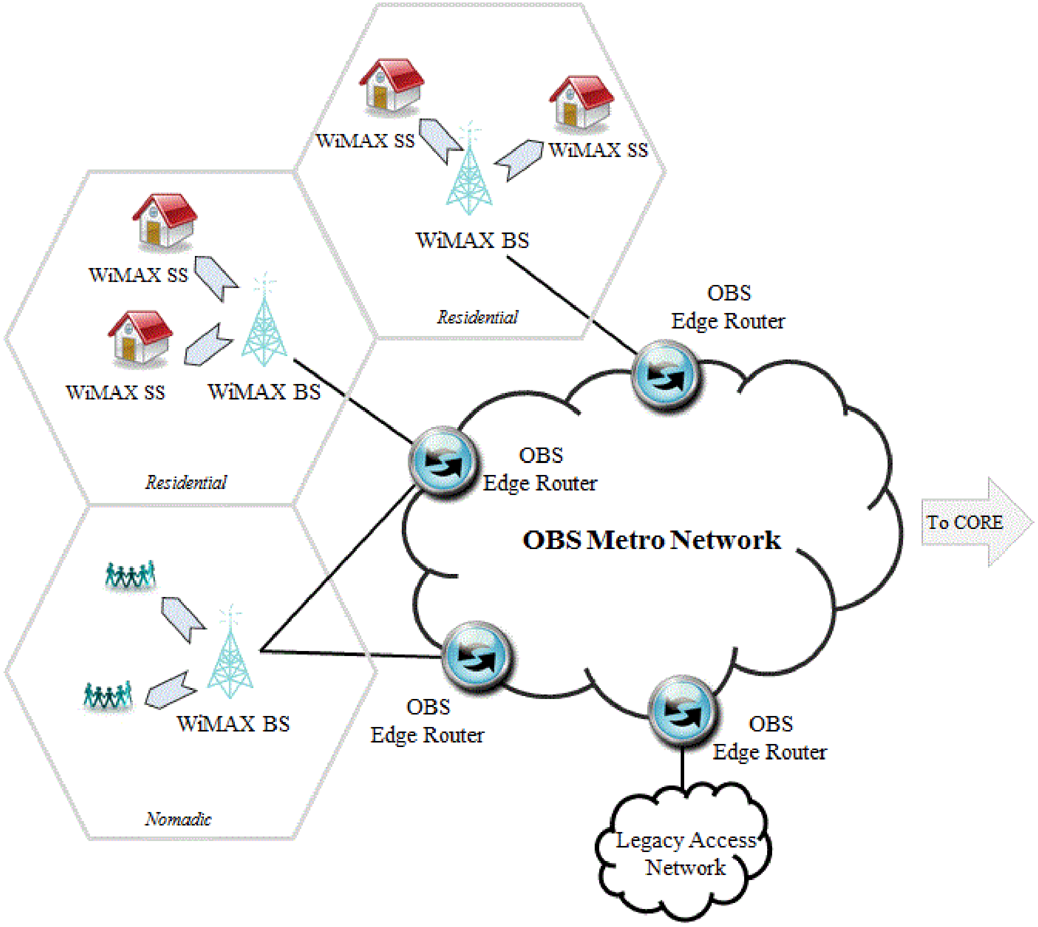

Figure 2: WiMAX/OBS Architectural Diagram [Katrinis09]

3.3 OBS Edge Routers

OBS Edge Routers [Katrinis09] first take incoming traffic through supported interfaces like PPP (Point-to-Point Protocol) or Ethernet. The OBS Edge Routers aggregate this traffic which comes from adjacent BSs and/or legacy access networks like xDSL (Digital Subscriber Lines). Afterwards, the router creates bursts which are made up of multiple IP packets. These bursts get forwarded through the OBS metro network towards the core using conventional OBS routing mechanisms. This same process is simply reversed for traffic incoming from the core towards WiMAX Subscriber Stations.

3.4 Issues

This proposed architecture contains various issues that need to be resolved before service requirements of WiMAX users can be met. The three issues discussed include issues with QoS (Quality of Service) requirements, service continuity, and servicing many users over a short period of time [Katrinis09].

- **QoS Requirements**

  Meeting QoS requirements requires matching QoS service-flow parameters from the CS (Convergence Sublayer) of the WiMAX MAC (Medium Access Control) with QoS classes' parameters from each OBS edge Router. WiMAX BS and OBS Edge Router differ in that a WiMAX BS can apply QoS on a per-service basis while an OBS Edge Router applies QoS to multiple services that share the same QoS class and destination.

  Because of the setup, class-based burst forwarding may not be enough to satisfy QoS Service provisioning requirements. To solve this problem, applying extensions to existing OBS schemes can result in reservation of resources on a per service basis that satisfy the QoS level requested by a service when it enters the WiMAX MAC CS. In addition, end-to-end QoS provisioning should be transparent to the user.

  Bandwidth reservation is an important part in the QoS matching process because service throughput has to be guaranteed in both the isolated network segments and across the boundaries of WiMAX and OBS. If the OBS part has service flows that receive available bandwidth without having reservation capability and guarantees, this may significantly limit benefits that come from MAC-level QoS differentiation applied in the WiMAX part. Alongside this, delay and delay variation guarantees need to be provided and enforced across segment boundaries.

- **Service Continuity**

The second issue with WiMAX and OBS is service continuity. A solution to this problem is to extend the WiMAX handover mechanism so that resources are automatically reserved and released at OBS Edge Routers and states are shifted between BSs whenever the services switch between edge routers.

Another possible solution is to reduce the need for switching between OBS Edge Routers through network and dimensioning planning. In this scenario [Katrinis09], there is a Base Station N and a set S that contains all of the BS's serving cells that are adjacent to the cell served by N. If all BSs in S ∪ N are served by the same OBS Edge Router, there is no need for handoff support. Because of this, OBS metro routers need to be properly dimensioned to sustain traffic from multiple cells. This setup is less dependable because if one OBS Edge Router fails, many cells will be disconnected.

- **Servicing Many Users in a Short Time**

  The third issue is that a WiMAX cell may need to service a large number of users over a short period of time. This occurs because nomadic access patterns can be bursty, for example when there is a large crowd at a concert. When this happens, having a properly dimensioned OBS Edge Router dedicated to their BSs is very inefficient because there is a low utilization ratio of the resource. A better option is to use ad-hoc load-balancing mechanisms between WiMAX and OBS.

3.5 Conclusion

Overall, it is important to look at the convergence of emerging wireless broadband technologies with hierarchically higher network segments from a service-level perspective. Several issues exist regarding service-level convergence of WiMAX over an optical aggregation network. A simulation study [Katrinis09] has shown that inter-segment cooperation at the service-layer and below is needed in order to fulfill end-to-end service requirements.

The following section discusses broadband aggregation in the context of how to bring broadband access to fast-moving users.

4. Broadband Access for Fast-Moving Users

The problem of bringing broadband access to fast moving users in places like trains and cars can be solved by combining a hierarchical Ethernet aggregation network with Ethernet-based access networks.

Broadband end-to-end mobile networking includes a combination of aggregation networks, access networks, and core networks. Access networks are wireless networks like 3G/4G cellular networks, 802.16 Wireless MAN (Metropolitan Area Network), and IEEE 802.11e Wireless LAN. On the other hand, broadband wired networks are generally classified as aggregation and core networks like IP/MPLS (Multiprotocol Label Switching) with WDM (Wavelength Division Multiplexing) optical networks, or Ethernet networks.

In order to maintain overall session mobility when bringing broadband access to fast moving users, the macro- and micro-mobility of the session are considered. Mobile IP addresses problems with macro-mobility while cellular IP handles problems with micro-mobility. Hierarchical IP uses regional registrations which can improve the efficiency of mobility management in mobile networks through reducing overall registration signaling overhead that is generated by mobile IP.

In the following subsections, the setup and specifics of the aggregation network architecture are covered. Then, the hierarchical Ethernet aggregation network is introduced and described. After an overview of how the network is setup, different tunnel management methods are presented and evaluated to identify their advantages and disadvantages.

4.1 Aggregation Network

When constructing an aggregation network [Quickenborne10] architecture, Ethernet is a strong option that offers ease-of-use, auto-configuration, and advanced QoS support. Telecom operators tend to use networks with standard QoS-aware Ethernet switches because of economical reasons. For trains in which there is a large group of users, an aggregated tunnel per train is more efficient and manageable than per user tunnel management. The aggregation network is structured, as shown in Figure 3, with a SGW (Service Gateway) installed at the top, which acts as an uplink towards the Internet. At the lower side, different ABS (Access Border Switches) are installed, which create the connection between the aggregation network and the various access networks.

4.2 Access Network

When Wi-Fi technology is used, each access network will have different antennas which allow multiple trains to be connected to one access network, creating a need for VLAN tunnels in the access networks. For WiMAX technology, each access network only has one antenna, eliminating the need for further tunneling in the access network.

4.3 End-to-End Tunnel Scenario

The aggregation network adopts a moving tunnel concept [Quickenborne10] where tunnels must move with the trains in order to preserve their connection between the train and the core network. In this scenario, the network does not assure seamless connectivity, but making on-time resource reservations in the aggregation network helps to assure service guarantees. The resource reservations help to prevent high congestion levels which can harm network performance during tunnel switching.

Since it is assumed that each train has one or more antennas on its roof, which each use a single associated tunnel, using multiple tunnels per train can achieve a continuous connection. Tunnels that map the data connection of fast moving users are VLAN based, and are responsible for delivery to the correct ABS.

As shown in Figure 4, the core router is placed in the service provider domain (Core Network), and the train router is placed on every train (Train Network). Between these two, a MIPv6 (Mobile Internet Protocol Version 6) tunnel establishes an IP-connection. IP-packets that go from the core router to the train router make the IP address of the user the destination IP address. The packets are encapsulated in Ethernet packets that use the MAC-addresses of the train antenna as the destination address.

Tunnels are automatically setup if the connection will be effectively used. If the train terminates its connection with the ABS, the tunnel is no longer required and gets released. This practice helps to guarantee that the current and the next hop tunnel maintain their service level, and also helps to prevent useless reservations.

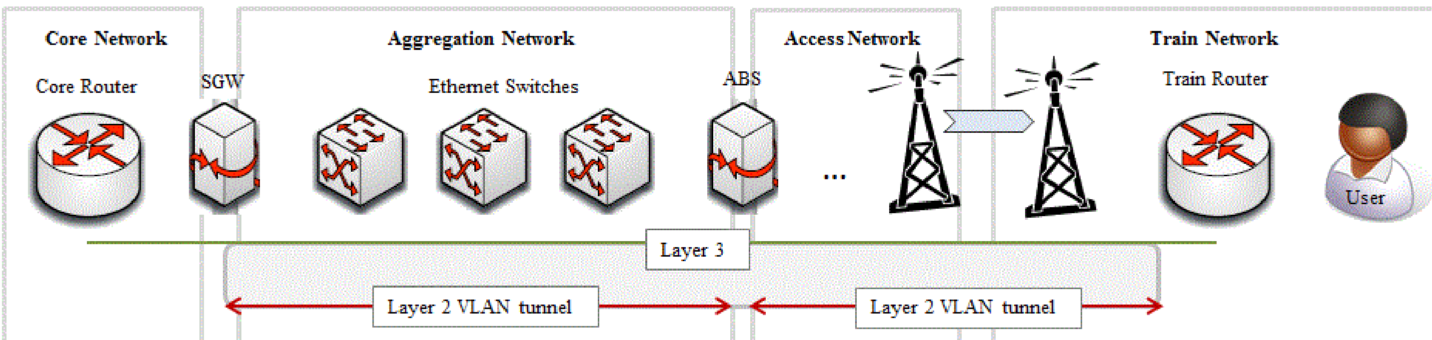

Figure 3: End-to-End Tunnel Scenario [Quickenborne10]

4.4 Hierarchical Ethernet Aggregation Network

When Ethernet is used in large aggregation networks, it comes across various scalability issues like spanning trees and non-scalable MAC learning and forwarding principles. The need to learn or use MAC addresses can be eliminated by using VLAN tunnels instead of MAC addresses to route packets in the aggregation network between the source and destination. Ethernet is not scalable enough for use in large aggregation networks because of spanning trees, but a hierarchical approach can be used to solve this problem. Besides bringing scalability, the hierarchical approach also offers support for multicasting [Quickenborne10].

4.5 Border Switches

This approach is setup by defining BSWn (Border Switches Level n) [Quickenborne10] in the aggregation networks, which help to distinguish different levels of the hierarchy. An example of a hierarchical Ethernet aggregation is referenced previously in Figure 3. The aggregation network is essentially made up of several smaller aggregation networks that have SGWs or BSWns at the upper side, and ABSs or BSWns at the lower edge. The BSWn nodes act as intermediate nodes between the aggregation networks. VLANs are separately installed in the smaller aggregation networks and are therefore only defined in a small area of the aggregation network. From this setup, the smaller aggregation networks each define their own MSTI (Multiple Spanning Tree Instance). Tunnels in the aggregation networks connect border switches between different levels, and the management platform manages continuation of a tunnel in an aggregation network to another tunnel.

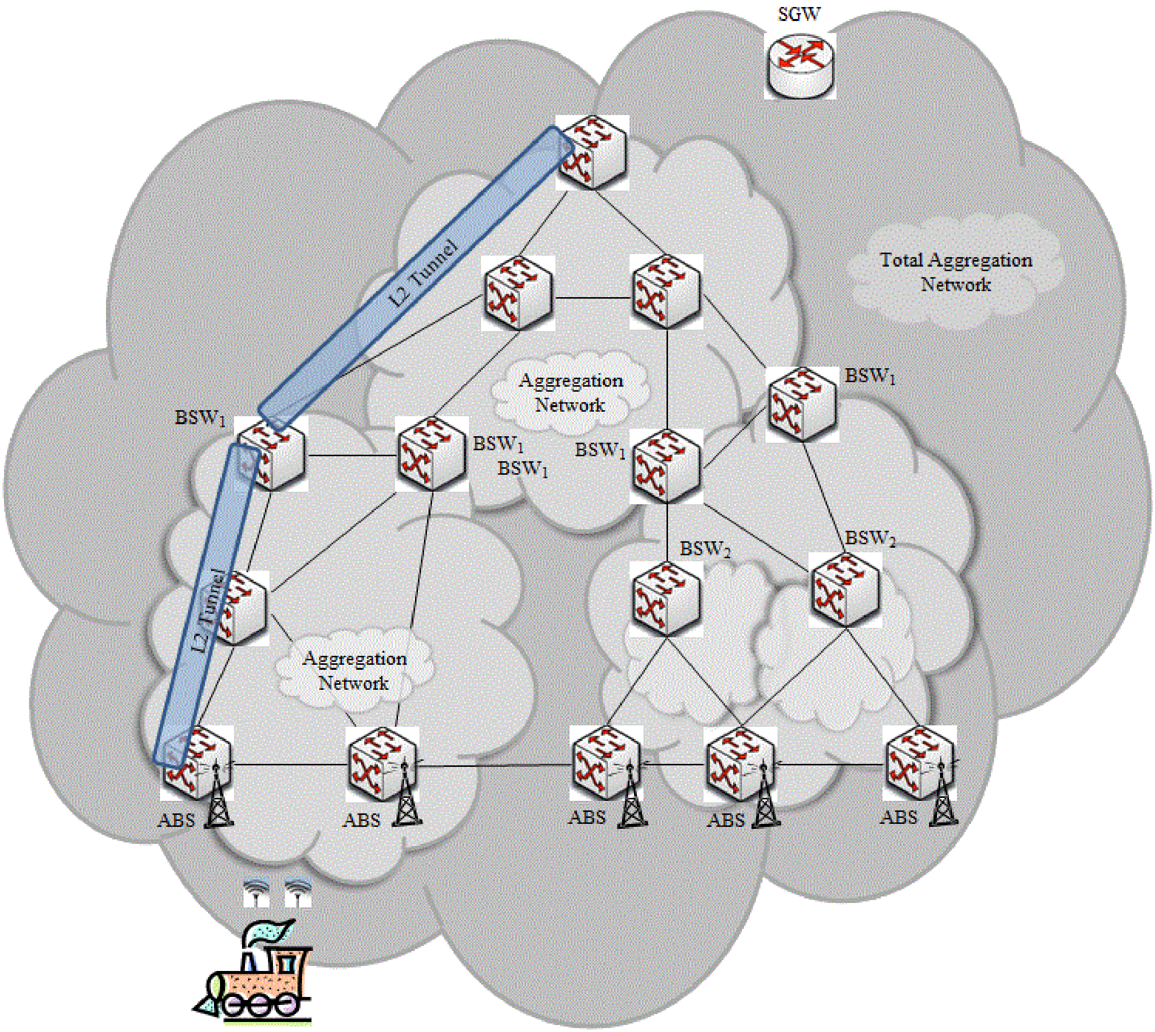

Figure 4: Hierarchical Ethernet Aggregation Example [Quickenborne10]

4.6 Tunnel Management

Tunnels are configured using an automatic tunnel configuration [Quickenborne10] that allows the tunnels to automatically follow the trains. There are two different types of moving tunnels: those in the aggregation networks, and those in the access networks. For both types, L2 (Layer 2) tunnels are preferred. Sending the IP packets through the tunnels eliminates the need to change the IP addresses of the packets. Following, the three different ways to handle tunnel management are discussed.

- **Management Based**

  This management-based [Quickenborne10] approach is based on the location information of trains. By using their GPS (Global Positioning System) information to determine the location of the train, the appropriate tunnel is used. SNMP (Simple Network Management Protocol) configures the VLANs on the Ethernet switches. An important fact is that the tunnels are set up by management before they need to be used, so that they are available when needed. This approach is more affordable when the time between tunnel switches is not very small, and is a good option for setting up and taking down tunnels that are located at the upper side of the aggregation network.

- **Signal Based**

  The next approach is signal-based [Quickenborne10], which offers better performance if the time between successive tunnel movements becomes too small. This approach installs GVRP (Generic VLAN Registration Protocol) -aware switches on the trains. The train sends a GVRP message to the antenna on the ground in order to signal when it is at a certain access network. This action automatically sets up the tunnels, as opposed to the management-based approach where the tunnels are installed before use.

  Tunnels in the management approach are static, resulting in complex traffic engineering. On the other hand, tunnels in the signal based method are dynamically managed and automatically set up and tore down by the signaling protocol. Half of the tunnel is set up when the train sends GVRP messages and the other half is set up when the upper BSWn send GVRP messages towards the trains.

- **Hybrid Approach**

  The third and last approach is the hybrid approach [Quickenborne10], which combines both the management and signal based approach.

4.7 Evaluation

An advantage of management-based solutions is that they offer fast setup times. On the other hand, a disadvantage is that it is necessary to know the positions of the trains. In the signal-based approach, the tunnel automatically follows the train, but the setup is done sequentially which results in higher setup times if the tunnel is longer than 2 hops.

The hybrid approach is an optimal solution for the hierarchical aggregation network architecture. This approach minimizes tunnel setup times while providing accurate tunnel set triggers.

Another thing to take into consideration is packet loss percentages, which are measured when the train is at a speed of 200 km/h and tunnels move following the train. It is found that for management-based tunnel setup, the times between position updates are important for packet loss ratios. In the signal-based setup, the length of the tunnel determines the packet loss ratio.

4.8 Conclusion

After evaluation of tunnel setup and packet loss measurements, the hierarchical Ethernet architecture combined with the hybrid tunnel setup approach offers flexible management of broadband aggregation for fast moving users.

Next, the discussion moves on to the topic of Triple Play Services and different architecture designs that seek to better accommodate these services.

5. Aggregating Networks Designed to Provide Triple Play Services

Increasing demand for multiplay services from Video on Demand, multicast, and P2P (Peer-to-Peer) traffic has drastically increased bandwidth requirements in broadband networks. Currently, about a quarter of all consumer internet traffic is video and studies have suggested that annual global IP traffic will double in value every two years. Because of more HD (High Definition) Video Broadcasting and P2P IPTV, current architectures will have problems with efficiency, flexibility, and scalability.

Two architecture designs are described and then evaluated in the following sub-sections.

5.1 Architecture Designs

The first architecture is the Centralized Edge Design [Papapanagiotou10], shown in Figure 5, which takes traffic from multiple access points. This traffic gets aggregated by the L2 Metro Ethernet before going to the IP Edge network. All traffic types are backhauled to a BNG (Broadband Network Gateway) before going to a PoP (Point of Presence) or P-Router location that is connected to the ISP backbone. The BNG, which is deeper in the network, executes multicast replication, subscriber termination functionality, and IP QoS policies. For Broadcast video's IP Multicast, the traffic starts from the edge router and is transmitted to customer premises over L2 multicast VLANs.

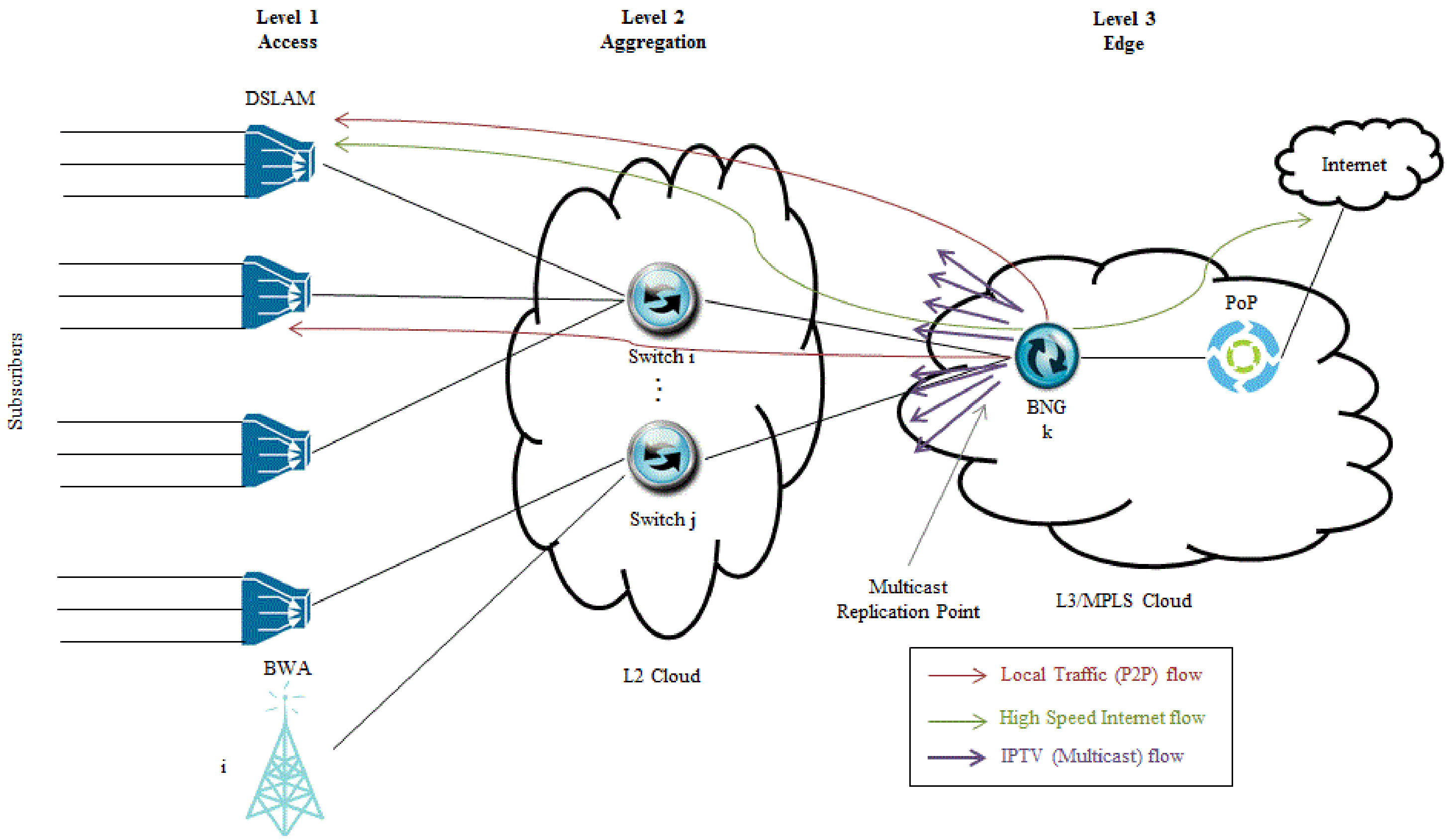

Figure 5: Centralized Edge Design Architecture [Papapanagiotou10]

The second architecture is a Distributed IP Edge Design [Papapanagiotou10]. Many SPs are looking into this architecture as an alternative to satisfy bandwidth requirements for future applications. The setup of this design is shown in Figure 6. The edge network is made up of L2 and L3 (Layer 3) routers, and access and services to the IP network are controlled at the Edge Routers. HSI (High Speed Internet) and video get backhauled over VLANs to the Edge Routers. This architecture increases scalability because fewer subscribers are terminated per BNG which decreases the amount of state information in the BNG. In addition, IP QoS is enforced closer to the last mile. In this architecture, broadcast video services are delivered through IP multicast routing in the L2/L3 Carrier Ethernet Network.

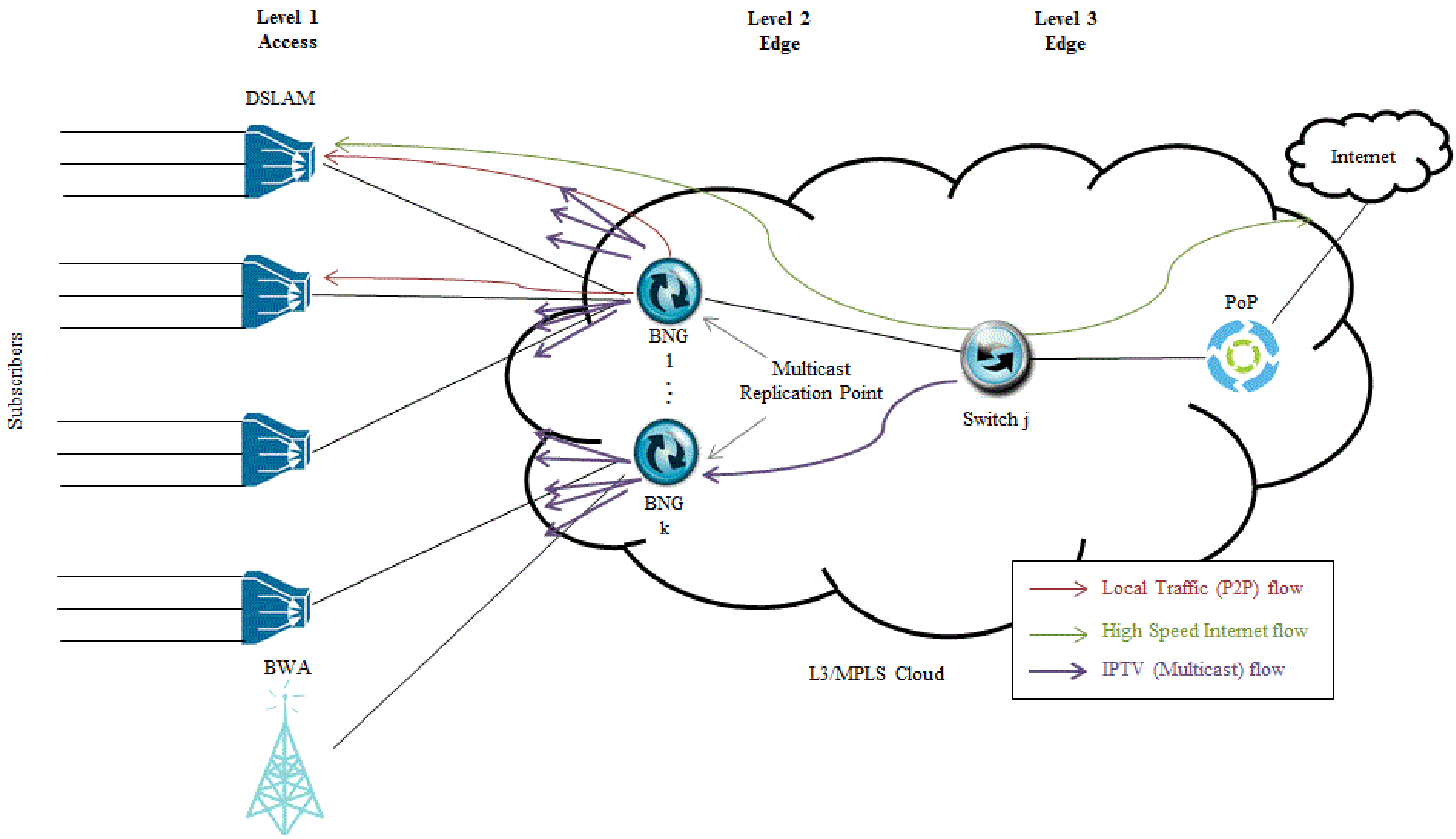

Figure 6: Distributed IP Edge Design Architecture [Papapanagiotou10]

5.2 Evaluation

Quantitative models [Papapanagiotou10] that analyze the two architectures show that the Centralized Edge Design is lower cost for low multicast traffic. On the other hand, for multicast IPTV with higher bandwidth, the Distributed IP Edge Design is a cheaper option. Distributed IP Edge Design is better for SPs who want to provide HD channels through C-VLANs. For both architectures, a combinatorial algorithm [Papapanagiotou10] proves that moving IP layer functionalities closer to the last mile decreases deployment costs.

6. Alcatel's Broadband Aggregation Network Architecture for Triple Play Services

With demand in voice, video, and high-speed internet services continually growing, aggregation networks have to be versatile and optimized in order to meet these demands. Service providers can realize economies of scope, scale, and skill by taking a comprehensive approach to triple play architecture design.

Alcatel proposes a Triple Play Service Delivery architecture [Alcatel] that lets network operators combine HSI, video, and voice services inside an Ethernet-based aggregation network environment. This infrastructure brings reduced risk, cost optimization, and faster delivery to market for new services.

In the following subsections, an overview of implementations within the architecture is first covered, followed by the basis of Alcatel's service delivery architecture. Then, multicasting is discussed, followed by PPPoE (Point-to-Point Protocol over Ethernet) and DHCP. PPPoE-based and DHCP-based services are compared to each other to highlight their differences. Finally, a brief overview is given of Alcatel's products that can be combined to deliver Triple Play Service solutions.

6.1 Implementations within the Architecture

The Triple Play Service Delivery architecture [Alcatel] implements five different parts that provide optimization:

1. Ethernet-based service architecture: Because Ethernet provides network efficiency, it solves bandwidth bottlenecks and allows SPs to cost-optimize their service infrastructures. This architecture helps to achieve economies of scope, scale, and skill.
2. Multiple distributed service edges: Lets SPs deliver new services to the market faster while still allowing them to keep their current BRAS (Broadband Remote Access Servers). In addition, network operators can make use of purpose-built platforms for their services in order to satisfy service requirements.
3. Distributed multicasting functions in access and aggregation networks: Helps SPs to optimize content delivery and bandwidth. Besides this, distributed

multicasting helps to optimize bandwidth requirements in aggregation networks and is very important for subscriber and service scaling.

4. Carrier video and VoIP services using DHCP: Helps SPs to bring in "plug-and-play" services that are used with DHCP. Also helps to increase bandwidth efficiency while scaling and simplifying multicast video services.
5. Flexible deployment models: VoIP, video, and data services can be easily deployed because SPs do not have to be locked-in to specific operation models. This lets SPs minimize technological and financial risks and maximize flexibility through allowing different modes of operation including: single or multiple last mile circuits, bridged or routed home gateway, single or multiple IP address deployment models, and fiber-based (FTTx (Fiber to the x)) and copper (DSL/DSLAM (Digital Subscriber Line Access Multiplexer)) deployments.

6.2 Distributed Service Edges

Alcatel's service delivery architecture [Alcatel] is based on the BSR (Broadband Service Router) and BSA (Broadband Service Aggregator), which are both optimized in different ways. BSRs provide cost-effective routing intelligence while BSAs take care of subscriber-specific functions that are scalable.

BSAs and BSRs are connected by a L2 forwarding model, for example a secure VPLS (Virtual Private LAN Structure) infrastructure. The layout of the architecture is shown below in Figure 7. This infrastructure creates a multipoint Ethernet network that offers security services and can support multiple modes or operations.

Another feature of Alcatel's service delivery architecture is that it allows SPs to provide service differentiation by providing per-subscriber bandwidth controls and content differentiation. SPs can implement per-subscriber service level controls because the QoS policy and enforcement is distributed to hundreds of interfaces that are on lower-cost Ethernet distribution ports.

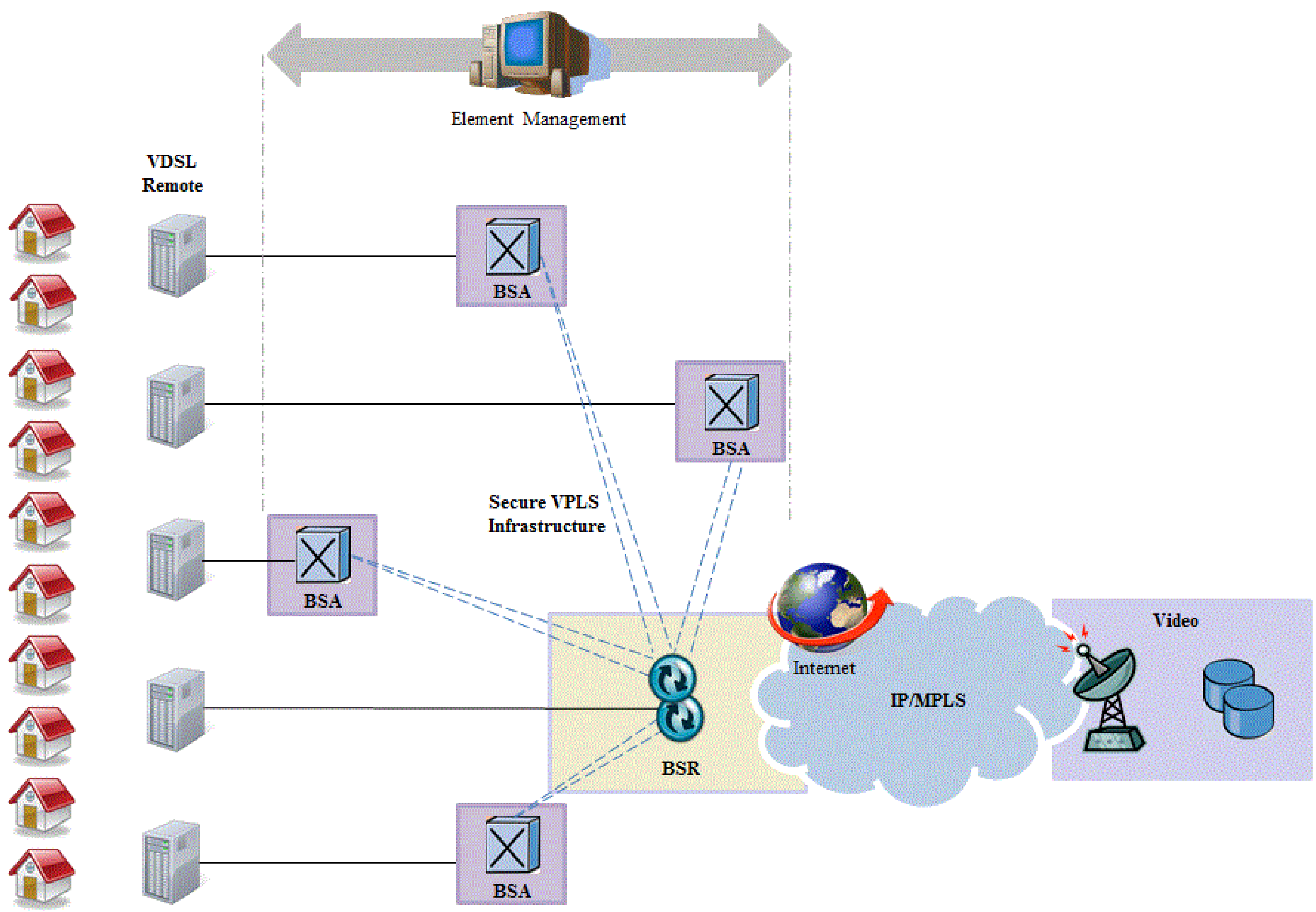

Figure 7: Service Delivery Architecture [Alcatel]

6.3 Multicasting

Alcatel's objective for service infrastructure [Alcatel] is to be able to optimize for broadcast TV video service for the near future, but also be able to evolve in order to support full unicast (video-on-demand) models as different types of video services are offered. In order to optimize for broadcast TV, it is better to implement multicast packet replication in the network. Multicasting improves efficiency because less bandwidth and fiber is needed when delivering broadcast channels to subscribers. One multicasting node can copy a broadcast channel it receives to any downstream nodes that require it, which reduces required network resources. As we move closer to the subscriber, efficiency becomes more important and as a result, multicasting should be done at the aggregation, access, and video edge nodes. Doing this also lets a large number of users view the content at the same time.

PPPoE can also be used for video services, but results in less efficient delivery of broadcast TV. When PPPoE is used, only the device that terminates the PPP session can implement multicasting, while the intermediate nodes cannot. Because of this, multicast replication has to take place in the BRAS which increases bandwidth requirements in both the access and aggregation networks. Another option is to distribute BRAS nodes across the access network but doing this creates operational complexity and cost issues.

In order to achieve efficient multicasting, functions have to be distributed across the aggregation and access network in order to prevent overloading the network capacity with unnecessary traffic. Alcatel's service delivery architecture is able to achieve efficient multicasting by using different IGMP (Internet Group Management Protocol) methods and multicast routing.

6.4 Evaluation of DHCP-Based Services vs. PPPoE-Based Services

Alcatel is able to offer "plug-and-play" services [Alcatel] through VoIP, and video using DHCP. DHCP improves bandwidth efficiency by scaling and simplifying multicast video services. Although it was seen before that using PPPoE for HSI creates issues, using this method in the short term can still help SPs deliver video services to market faster.

A special feature of DHCP that is different from PPPoE is that DHCP can handle failovers (that do not affect service) without the home network knowing of the failure. On the other hand, PPPoE sessions become lost and need to be re-established using the backup edge device if there is an edge failure or restart. This causes service to be disrupted and is made even worse when clients try to re-initiate their sessions. The clients end up placing a high load on the PPPoE edge platform which in turn requires processing capabilities to handle the events. This problem can greatly increase the cost of PPPoE solutions.

DHCP-based services differ because they are not session-based, so they do not have the issues that PPPoE-based solutions encounter. In the service delivery mode, dynamic restoration can be achieved through the VRRP (Virtual Router Redundancy Protocol). As seen before, DHCP can handle failures without the home network knowing about it. This works because the redundant node automatically takes over the failed node in a transparent fashion.

6.5 Alcatel's Products

Alcatel has a product range that can be combined to create a complete triple play solution:

- Alcatel 7450 ESS (Ethernet Service Switch): A carrier-class Ethernet switch that is service-oriented. It offers support that has better reliability and scalability, QoS for individual subscribers, multicast support, and logging and filtering. Provides BSA functionalities within Alcatel's service delivery architecture [Alcatel].
- Alcatel 7750 SR (Service Router): A service router that delivers carrier data, video, and voice services that have high-performance and are highly available. This router acts not only as a router, but also as a service delivery platform. It is useful for deploying triple play services because it provides scalability without sacrificing performance. Provides BSR functionalities in Alcatel's service delivery architecture [Alcatel].
- Alcatel 5260 SAM (Storage Area Management): Manages the 7450 ESES and 7750 SR as a virtual node. This interface provides streamlined service and policy activation throughout the architecture [Alcatel].

6.6 Summary

Alcatel recommends that providers should explore Ethernet-centric aggregation network architectures that can meet growing demands. The architectures should be scalable and adaptable to new technologies that develop over the years. For the Triple Play Service Delivery Architecture, key points are to: utilize architectures that can support multiple service edges, deliver VoIP and video services using DHCP while on the other hand, using PPPoE for HSI at least for the short term, and lastly, distribute multicasting functions across aggregation and access nodes to optimize and reduce bandwidth requirements.

7. Summary

As the internet continues to evolve and become increasingly demanding, broadband aggregation solutions are an important advancement in networking technology, which can deliver increased bandwidth. Broadband aggregation can combine several different existing technologies, each possessing their own positives and negatives.

In this paper, a commercial broadband aggregation router provided by D-Link was introduced. Following this, integrated WiMAX over OBS networks was discussed in detail, showing the setup and issues associated with this integration. The discussion then moved on to the question of how to deliver broadband access to fast-moving users. A hierarchical Ethernet aggregation network architecture was covered in detail, along with an evaluation of different ways to manage this system. Lastly, the paper discussed the issue of providing demanding Triple Play Services. We first looked at two general architecture designs before moving on to a specific solution proposed by Alcatel. In conclusion, broadband aggregation solutions can combine many existing technologies and products; however each has strengths and weaknesses that can offer unique services when combined.

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9. Acronyms

3G/4G	Third Generation/Fourth Generation
ABS	Access Border Switches
BNG	Third Generation/Fourth Generation
BRAS	Broadband Remote Access Servers
BS	Base Station
BSA	Broadband Service Aggregator
BSR	Broadband Service Router
BSWn	Border Switches Level n
C-VLAN	Customer-Virtual Local Area Network
CS	Convergence Sublayer
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name System
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexer
ESS	Ethernet Service Switch
FTTx	Fiber to the x
GPS	Global Positioning System
GVRP	Generic VLAN Registration Protocol
HD	High Definition
HSI	High Speed Internet
IGMP	Internet Group Management Protocol
IP	Internet Protocol
IPTV	Internal Protocol Television
IP VPN	Internal Protocol Virtual Private Network
ISP	Internet Service Provider
L2/L3	Layer 2/ Layer 3
LAN	Local Area Network
MAC	Medium Access Control
MAN	Metropolitan Area Network

MIPv6	Mobile Internet Protocol Version 6
MPLS	Multiprotocol Label Switching
MSTI	Multiple Spanning Tree Instance
OBS	Optical Burst Switching
P2P	Peer-to-Peer
PMP	Point-to-Multipoint
PON	Passive Optical Network
PoP	Point of Presence
PPP	Point-to-Point Protocol
PPPoE	Point-to-Point Protocol over Ethernet
QoS	Quality of Service
SAM	Storage Area Management
SGW	Service Gateway
SNMP	Simple Network Management Protocol
SP	Service Provider
SR	Service Router
SS	Subscriber Stations
VDSL	Very High Speed Digital Subscriber Line
VLAN	Virtual Local Area Network
VoIP	Voice over Internet Protocol
VPLS	Virtual Private LAN Service
VRA	Virtual Router Address
VRRP	Virtual Router Redundancy Protocol
WDM	Wavelength Division Multiplexing
WiMAX	Worldwide Interoperability for Microwave Access
WPA	Wi-Fi Protected Access
WPA2	Wi-Fi Protected Access 2
xDSL	(All types of) Digital Subscriber Lines

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