Community Network with Integrated Services

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Abstract. This paper first introduces the general problems met when building Broadband Community Access Network which supports Integrated Services, and then presents some solutions and achievements on multicast service, QoS provision, security, network accounting and billing. In the third section, this paper gives the architecture of a community network, which is a broadband access network based on high-speed switching Ethernet, and provides integrated services, such as digital TV, IP telephone, WWW, Email, and so on. This paper also gives an implementation of this broadband access system, which can afford the special requests of classified transfer, QoS and security, and at the same time provides the accounting and billing function. Lastly, this paper indicates the unfinished part of this broadband access system, and describes the future development.

Keywords: Broadband Access, Community Network, Integrated Services, QoS, Multicast, Security

1   Introduction

With the rapid improvement in communication and computer technology, broadband community network access to Internet and enterprise network has been the consequent request, which can give home users voice service and more video services. In the earlier of Internet, the data exchange is the main service provided by business based on TCP/IP architecture. The Internet of 1990s has not only a great improvement in scale and range, but also a extension to audio and video. During this period, researchers have tried every method to improve the quality of service of transferring audio and video streams in Internet, and also tried to provide the security for data transfer and some reasonable accounting policies. Lately, people have got great achievement in the transfer quality of audio and video in IP network. These improvements expand the application range of IP Network, and now pure IP telephone is quite popular, and TV service on IP is at the beginning. Except the traditional data service and the replacement with telephone and TV service, the broadband IP network[1] can provide some new-style applications, such as interactive TV, video conference, E-commerce[4], e-learning and so on. "All is on in IP" is the future of network development.

2   Issues in Broadband Access Network

2.1   Broadband Access Technologies

There are several typical technologies used for community broadband access network, which are xDSL, Cabel Modem, FTTx+LAN and Wireless access.

DSL stands for "Digital Subscriber Line", a broadband technology that uses telephone lines and digital coding to create a connection to the internet from computer. That link can carry vast amounts of voice, video and data information at very high speeds. The Asynchronous Digital Subscriber Line(ADSL) can provide 6~8Mbps data rates in the downstream direction while the upstream is relatively slow, 144~384Kbps. The Very-High-Bit-Rate Digital Subscriber Line(VDSL)[2] can reach speeds up to 52Mbps downstream, and up to 13Mbps upstream, but it operates only under distances not longer than 1.5 kilometers while ADSL can operate over 3.5 Kilometers. It is xDSL's main advantage that it can utilize the user's existed telephone line, and its disadvantage is too expensive device. If using xDSL, the telecommunication office must keep the same number of xDSL device with the users'. So xDSL is only suitable for the residential area with low density.

Cable Modem is another broadband technology used for community access network. Cable systems were originally designed to deliver broadcast television signals efficiently to subscribers' homes. To deliver data services over a cable network, one television channel (in the 50-750MHz) is typically allocated for downstream traffic to homes and another channel (5-42MHz) is used to carry upstream signals. It have a very high-speed downstream bandwidth (frequency can reach 1GHz), and is a very good access technology if only single-direction access. But there are several big problems when it is been reconstructed to accept two-way streams, they are the expensive reconstruction price, very limited upstream bandwidth, and the amplified noise by upstream amplifiers.

FTTx+LAN is the extension of Internet, which is widely used in Enterprise network and office network[5][6]. It carries several benefits for residential users: very cheap access, easily to upgrade more advanced system, great extensibility. It will need to solve more technology problems such as QoS, security and network accounting, if FTTx+LAN are provided for internet access, IP telephone, LAN TV of residential users. Its disadvantage is that this solution has very high technical threshold to be crossed.

Wireless access is also an interesting broadband technology, especially in the area which can't be easily wired. Bluetooth and 802.11b are the main standard of wireless access. They are not generally used because their short distance and slow bandwidth.

2.2   QoS Provision

Our object is to implement an IP network which can carry many services. In this network, the traditional burst-out traffic can share the same network device (router, switch and links) with the traffic which request more strict delay, delay jitter, bandwidth and lost-packet rate. So it can be named a QoS network, in which there are many kinds of service, every of which have many traffic. The QoS means that in the network it must be sure to provide the corresponding, expectable bandwidth for the special class of service traffic without the knowledge of other traffics. IP packets travel from source to one link, then across switch and router, at the last reach to another link of destination. For QoS, these packets' delay and jitter must be in a restrict range defined by service. In broadband access network, main influence came from the IP packet's transfer policy of switch and the allocated bandwidth of links for the service.

We setup a rate shaping and a rate control policy which based on dual leaky bucket algorithm[3] for the service provider, especially for the video service provider which have very high-speed output, to prevent the overflow of data link's bandwidth. We also add the guarantee for quality of service by an access control algorithm in network device for the classes of service by the current available bandwidth.

In switches, we add classify, queue and scheduler policy for traffics. The classify policy is admitted to specify a class for a destination address, which class is allocate a single transmit queue. A packet is dispatched to a specified class of queue by switch after it is accepted. The packets in high priority of queue are sent prior to lower priority of queue. Switch can provide classified services by classifying, queue and scheduler function. For example, switch can transmit the data by the defined priority of control packets, key service packets, voice packets, video packets and general packets.

2.3   Security of Home Network

The home network's security includes computer's security and network's security. In this paper, we just only concentrate on the network security, which existed in anywhere have network applications. The typical network security is the security of business data by transfer in E-commerce. The content of network security ranges from application layer to physics layer of OSI, and mainly is in network layer, data link layer and physics layer when talked about in broadband access network.

The content of security in physics layer is to prevent wire tapping. Traditional Ethernet have a basic idea of carrier detect, in which way signal is broadcast in a shared line from which every one can listen others' signal. This is not suitable to the request of physics security. In our broadband access system, we use the switched Ethernet as the basic transfer link, every user have and only have a separated line with one of switch port, the signals of which can't be listened by others.

To provide the security in data link layer, we must prevent the user's own information to be broadcast to other users. In general, VLAN can divide the whole network to several broadcast area, so as to separate the data communication form each other. But there are some problems in community network, in which many home of community share a video stream of one video server and they should be in one and the same VLAN with video server. And at the other times when they have a business or shopping by network, they hope to be separated with others. So we implemented an "asymmetric VLAN" technology to support the two requests.

PPPOE is a security technology of network layer on Ethernet. It basic idea is that by PPPOE, IP packet is put into a PPP frame, which is encapsulated by Ethernet frame. Every PPPOE user must login on PPPOE server, and establish a virtual PPPOE channel with PPPOE server on Ethernet before transferring data. When PPPOE user want to communicate with other user of a same LAN or outer network, PPPOE user must send or receive data to PPPOE server firstly, and then PPPOE server will transmit the data to their destination address or PPPOE user. Under PPPOE, everyone can't see others' IP packet directly and they must get admits to network by authentication, so user's security and data's security can be provided well.

2.4   Network Accounting

An accounting system should include both user authentication and billing. In a community network, user authentication can be based on PPPOE, or other connection properties like switch port number, MAC address of home gateway, or IP addresses; And the following price schemes can be used: (1) Flat fee pricing, this is probably the most simple and easy pricing scheme. That means subscribers pay each month certain fixed amount of money, independent of what services they received or how much traffic they used; (2) Usage-based pricing: The idea behind this scheme is that the costs should reflect the amount of usage. The switches will record the information of how much a user used the network, i.e. the amount of data a user has moved, or the quantity of service he has enjoyed. That way anybody who thinks he needs a bigger share of the resources of the network can have it by paying more. This pricing scheme is superior to the flat fee scheme, for it can utilize the information of how a user use the network; (3) Policy and content based pricing: This is a far more complicated pricing scheme, it takes more considerations into the pricing decision, such as the category of services, the traffic amount and time period of the services, even the discount policy for those big customers can be included. This is a more decent and integral scheme than the above twos.

3   Broadband Access System

3.1   Basic Ideas

Community broadband access network for integrated services is a very complicated system, which involves many software and hardware technologies (Figure 1), such as embedded real-time operating systems, multicast systems, QoS, network management, communication protocols and routing algorithms.
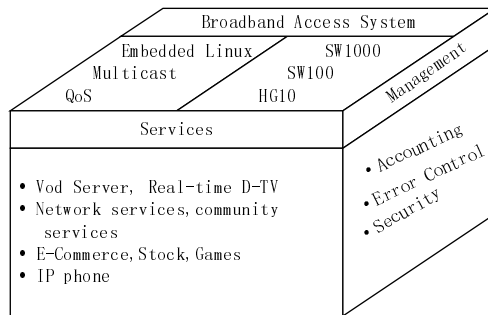
Fig. 1. Technologies of community broadband access system

3.1.1   Embedded Real-Time Operating Systems

Embedded Real-Time Linux is our choice of Embedded Real-Time operating system. Its kernel has all public source code, which made it easily to develop in the special hardware environment, and easily to improve the system's performance. Another

advantage is that its cost is very cheap than the business system with same performance. Now, Embedded Real-Time Linux has been used in switches and home gateway devices.

The software system of our Gbit access switch, named SW1000, is developed based on the Linux system. We have tailored the Linux kernel, TCP/IP protocol stack and some network application modules, such as ftp, telnet and so on, and add install/uninstall module, self-protective module, flow accounting module, VLAN-support module, IGMP Snooping module, interrupt and debug module to make up of a new kernel. In user's space, we add the system configure interface, VLAN management interface, network management interface and accounting proxy module.

3.1.2   Multicast Systems

The multicast source streams come from digital TV server, video server and other video provider of WAN, which are selected to decode and playback in home gateway by residential users. The multicast systems involve the server, switch and home gateway device. Server can control multicast streams' output rate by rate shaping and rate control algorithm, at the same time the receivers decrease the influence of delay jitter on the playback quality by pre-buffering video data. The IGMP modules in home gateway cooperate with IGMP Snooping modules in switch to implement the dynamic join and exit of a multicast group. This dynamic group management is the base of dynamic selection of channel. A demand of one channel is in fact that a user joins the multicast group corresponding to this channel, the exit of one channel is correspond to the exit of the multicast group, the switch from one channel to another channel is made up of the two operations.

3.1.3   QoS Provisioning Systems

The QoS system exists in the server, switch and home gateway. It is implemented based on the RSVP, by which switch reserve the bandwidth that server or home gateway requests. The switch has an access control policy, by which switch will deny the new streams if there are no enough bandwidth to satisfy their requests, so to avoid the network's congestion. Server and home gateway transfer and receive data streams only if their bandwidth request is satisfied. Switch also can classify, queue and scheduler the packets by the defined priority.
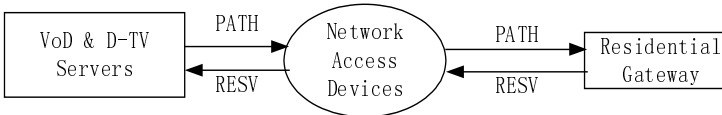

Fig. 2. The mechanism of RSVP

3.1.4 Network Management Systems

Network management system of a broadband community network consists of error management, configuration management, performance management, security management and account management. It bears the same design principle as the network management system in telephone networks, while they have very different focuses. The telephone network focuses on the management of network elements, while a community network puts more emphasis on the category of services and QoS management.

3.2 Implementation

The idea of our IP-based broadband community network is offering convergent services of Internet, IP phone and Digital TV through combined network of fiber and LAN. The system is composed of Digital TV receivers, video servers, TV conference servers, accounting servers, network management servers, broadband switches, home gateways, PCs, analog or digital TV sets, and IP phone(Fig. 3).
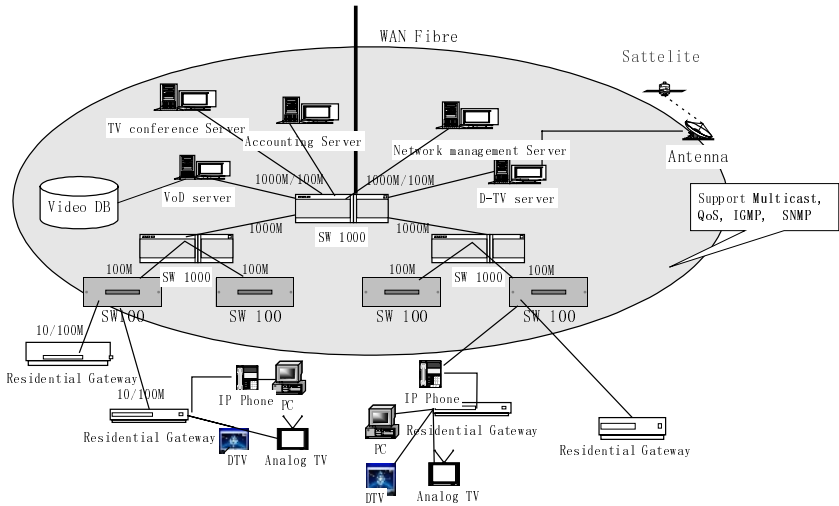
Fig. 3. IP-based broadband community network

Digital TV server's main function is to receive the signals from satellites, demodulate the DVB streams from them, demux the specified streams and put them into the IP packets, lastly send them to users by network or store them in the video database. This digital TV server consists of a high-performance computer, a receiving card for satellite TV, network card and the software system.

Video server's main function is to store, edit and send audio or video program. It mainly consists of a high-performance computer, a network card and a video database, which usually is a large scale disk-array.

3.2.1   Switches

The Gigabit switch SW1000 and the 100M switch SW100 are the main network access devices for community network. SW1000 supports 8~48 ports of 10/100Mbps or 1~6 Gigabit ports, each of them has the line-speed data switch capability. SW1000 consists of four modules: switch fabric modules, fast Ethernet modules, Gigabit Ethernet modules, supervisor modules. SW100 support 16~32 ports of 10/100Mbps, each of which has the line-speed data switch capability. SW100 consists of three modules: switch fabric modules, fast Ethernet modules, supervisor modules.

3.2.2   Home Gateway

Home gateway is the network access device for home network, and it is also a playback device for digital TV and other video programs. Its main function include: provide the playback of digital TV with SDTV quality, and provide IP telephone service, and provide internet data access such as www, email or other, and provide video-on-demand service, and provide the management automation for community. This device can decode and playback the DVB streams, and support the video output of RGB, S-Video, composite Video, and support the video output by PAL/NTSC, and support stereo audio output.

The home gateway device's interfaces consist of two ports of 10BaseT Ethernet, one S-Video port, one RGB port, one composite video port, and a pair of stereo audio ports. One of the Ethernet ports is connected to the ports of switch, and the other one is connected to PC or other network device of home user.

3.3   Future Development

3.3.1   Wireless Access

The coming down price of wireless devices and the rapid development of wireless technologies make the wireless home network design a reality. Now we are making enhancements to our home gateway devices, adding wireless modules to the device, so that the gateway can function as an access points for household wireless devices. (Figure 4).

3.3.2   Transition to IPv6

The community broadband network is the extension of Internet, which connects every home into a whole network. But the scale of this network is limited because the limited number of IP address. Today's IP address is based on IPv4, of which available address will exhaust in the very short future. The NAT technology can only slow down this process and can't radically solve the lacking-address problem because more and more applications are based on the bidirectional UDP communication. Another problem is the QoS and security which can't be taken great improvement by IPv4. IPv6 is designed to address these problems[7], so it becomes another focus of our

future research. The content of IPv6 project consists of how to transfer from IPv4 to IPv6 smoothly and the new feature of broadband access and integrated service under IPv6.
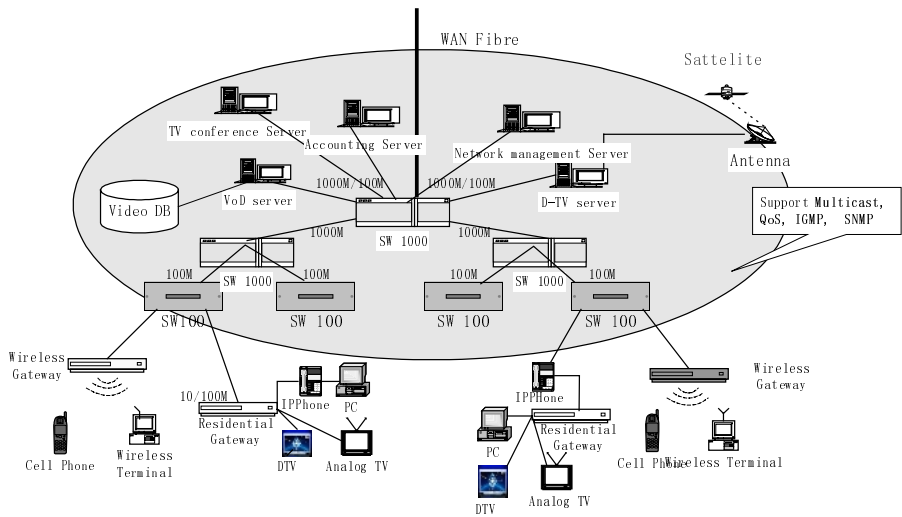
Fig. 4. Enhancement of Broadband Community Network

4 Conclusion

The broadband access network system for integrated services which this paper design and implement is based on IP, and is suitable to not only the community network with dense residential , but also the campus and enterprise network. This system's success will greatly drive the information process of community.

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