一种比较研究:宽带社区接入技术的多服务提供[*]

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A Comparative Study: Offering Multi-Service of the Generic Broadband Residential Access Techniques

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Abstract:　　Nowadays, the broadband residential access infrastructure remains one of the major research areas for NGN (next generation network). Apart from popular ADSL (asymmetrical digital subscriber loop), HFC (hybrid fiber-coax) and APON (ATM passive optical network), academic communities and industry are increasingly showing great concern about Ethernet technique in the subscriber access network. This paper investigates the substantial differences among the generic broadband residential access techniques and allows a comprehensive understanding of them. The authors survey the generic broadband residential access techniques and present a comparative study on the emerging residential Ethernet-based access solutions with the ADSL, HFC, and APON techniques based on multiplex methods and transport technologies in terms of network architecture, service and traffic models, and QoS (quality of service) provisioning. The comparative study is of benefit to research and implementation of the future broadband residential access infrastructure.

Key words:　　residential access network; ADSL; HFC; APON; ethernet; IP; ATM; multiplex method; architecture; service model; traffic model; QoS

摘　要:　　今天,宽带社区接入基础设施仍然是下一代网络的主要研究领域之一.除了流行的非对称数字用户环

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路、光纤同轴混合网和 ATM 无源光网络,学术界和工业界正日益表现出对于以太网技术应用于宽带社区接入网的巨大关注.试图调查通常的宽带社区接入技术的本质区别,给出全面的理解.综述了通常的宽带社区接入技术,基于复用方法和传输技术发布了新出现的基于以太网技术的社区接入网和非对称数字用户环路、光纤同轴混合网和 ATM 无源光网络的比较研究.这个比较研究深入地讨论了宽带社区接入技术网络结构、服务模型、通信量模型和服务质量提供.比较研究将有益于将来的宽带社区接入基础设施的研究与实现.

关键词: 社区接入网;非对称数字用户环路;光纤同轴混合网;ATM 无源光网络;以太网;网际协议;异步传输模式;复用方法;体系结构;服务模型;通信量模型;服务质量

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During the past several years, many access techniques have emerged. In the wireline access scenario, three main broadband access techniques are mastering the market of access network, i.e. ADSL, HFC and APON. On the other hand, a great deal of interest surrounds the deployment of Ethernet in the subscriber access network. In the past years, there are some carrier-grade residential multi-service access networks over Ethernet. Some standard organizations and institutes such as the IEEE study group on EFM (ethernet in the first mile), EFMA (ethernet in the first mile alliance), the MEF (metro ethernet forum), and so on, are studying the related issues.

Multiplex methods and transport technologies result in the different residential access solutions. Based on the two considerations, we present a comparative study on the residential Ethernet-based access techniques with ADSL, HFC and APON in many aspects, i.e., network architecture, service and traffic models, and QoS provisioning.

1 An Overview of the Residential Access Techniques

ITU-T issued the recommendations of V5 Interface in 1994, i.e., G.964, G.965 and G.967, and presented the concept of access network firstly. The residential access network mainly provides the services for the residents. The residential access network has already become one of the key components of telecommunication networks. There are also many access technologies emerged in the past decades, i.e., ADSL, HFC, PON and wireless access techniques. We mainly discuss wireline access techniques in this paper.

The residential access network can be decomposed into different portions, as shown in Fig.1. Every portion has its own functional requirements[1]. The first access portion, the feeder network (or primary distribution section), is usually realized with the aid of SONET/SDH (synchronous optical network/synchronous digital hierarchy) or DWDM (dense wavelength division multiplexing). The second distribution network (or local distribution section) connects the primary distribution points to the last drop. For the local distribution section, it is the consensus of
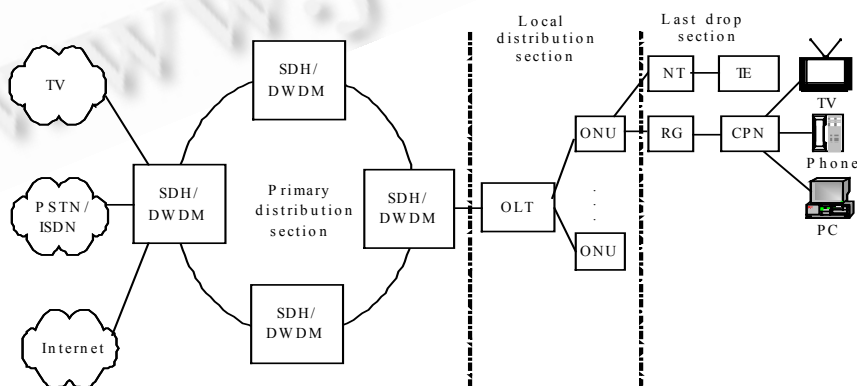

Fig.1　Architecture of residential access network

people using optical technology, the so-called ODN (optical distribution network). The "FTTx" terminology produces terms such as fiber to the cabinet/curb/building/home (and corresponding abbreviations FTTCab/FTTC/FTTB/FTTH) for representing implementations where the ONU (optical network unit) is gradually placed closer to the customer premises. FTTH is our final target, but it might still take a long time to be realized due to the high cost.

So far the residential access infrastructure remains one of the major obstacles to deploy a broadband network. The major obstacle locates at the last drop, because it represents a potential bottleneck in terms of bandwidth, and it is the most sensitive cost component of any upgrading of the local loop infrastructure. The last drop has to adopt different physical mediums such as the popular legacy Cat3 UTP cable, coaxial cable and fiber. Now, three main broadband access technologies are mastering the main market share of wireline access network, i.e. ADSL, HFC and APON, and they adopt different physical mediums respectively. The emerging residential Ethernet-based access solution using Cat5 UTP cable is popular in some countries, especially in China.

There are two kinds of access systems based on the different physical mediums. The first one is passband systems of multicarrier channelization such as HFC. The second one is baseband systems based on baseband binary coding schemes, such as ADSL, PON and Ethernet. The transport technologies are independent of the physical mediums, and all physical technologies of the last drop can freely select different transport technologies. IP and ATM are two main transport technology candidates. Previous broadband residential access solutions mainly adopt ATM technique. However, IEEE study group on "Ethernet in the First Mile" is now studying Ethernet, namely IP solution, in the subscriber access network, and mainly studying the support of existing copper plant of PSTN networks, point-to-point optical fiber and point-to-multipoint optical fiber. Indeed, combining different multiplex methods with IP or ATM transport technologies results in so many kinds of the residential access solutions.

2 Architecture of the Broadband Residential Access Network

This section describes the architecture of the local distribution section and the last drop in the broadband residential access network. In practice, the local distribution section may be omitted in the residential access networks if the distance from accessing point to the CPN (customer premises network) of the residents is covered by the loop length of the selected physical technologies. Employing different physical mediums results in different architectures. Typically, the residential access network is a star-structured topology network. Several main architectures of the residential access techniques are illustrated in Fig.2.
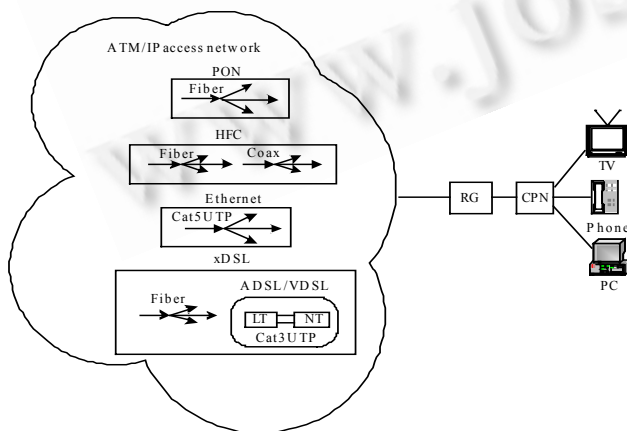
The architecture of the access networks can be divided into two dimensions based on traffic delivery and carrier utilization. First, the traffic delivery mode is either *broadcast* or *switched*. Second, a signal carrier may be either shared by all subscribers or dedicated to a single subscriber[2]. We restate some basic concepts. The broadcast mode inherently suits to the delivery of broadcast services, but the switched does not. In the upstream direction, however, the broadcast mode has some disadvantages, since there are complications of multiple access, network security, and diagnostic measurements. On the other hand, the switched networks may

Fig.2   Reference model of last drop

relieve many network functions required by the TE (terminal equipment) and allow the enhanced network control and reliability. We can say the advantages of the switched networks are the disadvantages of the broadcast mode. In addition, the switched networks are more expensive, since generally speaking, a switch requires more sophisticated technology than a broadcast network does. Advantages of the shared carriers are economies of transport and possibility of accessing the full capacity of a carrier on a burst basis. However, the improvement in throughput and administration of the excess original design becomes increasingly expensive.

Generally speaking, star PON and HFC can be topologically structured as point-to-multipoint and are broadcast. But ADSL is point-to-point and switched. HFC belongs to the shared carriers. Star PON also belongs to the shared carriers, but the WDM PON belongs to the dedicated carriers. The ADSL belongs to the dedicated carriers as well. With evolution, Ethernet may be switched mode. However, legacy bus technique of Ethernet is broadcast.

The reference model of protocol stack for different access solutions are illustrated in Fig.3. It only shows the protocol stacks of HFC, ADSL and PON networks using ATM technique, comparatively, and also gives the protocol stack of Ethernet technique. HFC technique mainly has two kinds of standards, i.e. DOCSIS (data over cable service interface specifications) and IEEE 802.14a. Both kinds of HFC MAC protocols may provide the capability to transport 802.2 LLC (logical link control) protocol data units over HFC networks. IEEE 802.4a provides a complete support of ATM. The ADSL solution gives the popular solution of PPP protocol using ATM technology for providing data service. IEEE G.983.1 defines APON's transmission convergence layer and MAC layer. In fact, different physical mediums result in different physical layer and data link layer implementations.

OSI reference mode	802.14	DOCSIS	xDSLdataservice	APON	Ethernet
Datalinklayer	ATM	802.2LLC	PPP	ATM	802.2LLC
		Linksecurity	AAL5		
Physicallayer	802.14aMAC	DOCSIS MAC	ATM	G.983.1MAC	802.3MAC
	TC		ADSL/VDSL	G.983.1TC	10Base-T/100Base-TX/1000Base-T...
	PMD			PMD	
Medium	Coax		LegacyCat3UTP	Fiber	CatxUTP

TC:TrasmitionConvergence

Fig.3   The reference model of protocol stack for different access solutions

In the residential access networks, in general, the upstream bandwidth is shared by a number of users, and the access protocol has to be implemented to control the upstream traffics. The protocols used to determine who goes next on a multipleaccess channel belong to a sublayer of the data link layer, called the MAC (medium access control) sublayer. Tanenbaum discussed many algorithms for allocating a multiple access channel thoroughly[3]. Both DOCSIS and IEEE 802.14a of HFC networks model an upstream channel as a stream of minislots, namely, DOCSIS MAC and IEEE 802.14a MAC, like slotted ALOHA systems. The headend must coordinate accesses to this shared bandwidth since stations cannot listen to the upstream channel[4]. Between these two MAC protocols,

DOCSIS can be considered as a simplified version of IEEE 802.14a. It imitates the concepts of minislot, bandwidth allocation map, piggybacking reservation, virtual queue, downstream MPEG-2 format and ranging in IEEE 802.14a. For collision resolution, in which they differ the most, IEEE 802.14a exercises a fairly sophisticated first transmission rule, which includes priority admission control and FIFO mechanisms, and a retransmission rule, which runs a *n*-ary tree walk algorithm. IEEE 802.14a also allows a headend to run multiple collision resolution engines in parallel. In contrast, DOCSIS uses a simple binary exponential backoff algorithm. APON networks are also using slot-based MAC protocol, defined by ITU-T G.983.1 MAC, to allocate a multiple access channel. The ADSL solutions belong to the point-to-point and switched mode, and generally using ATM for providing the switched access like POTS to end users. The CSMA/CD (carrier sense multiple access with collision detection) protocol used in Ethernet is a very popular protocol for the shared bus. However, the new emerging full-duplex switched Ethernet LAN doesn't need the CSMA/CD mechanism.

Network architecture of the new emerging broadband residential Ethernet-based access infrastructure is illustrated in Fig.4. It consists of four components, i.e. layer 2 domain, layer 3 domain, service domain and CPN (customer premises network). The layer 2 domain consists of multi-level LAN switches. The first level LAN switch is in charge of user accessing and the other level LAN switches are in charge of aggregating traffics in the large-scale broadband residential Ethernet-based access network. The layer 3 domain includes access router, edge router and core router with DiffServ-enable. These kinds of routers must offer EF PHB and AF PHB defined by IETF DiffServ Workgroup. Service domain includes local service domain and MAN/WAN service domain. The local service domain offers TV and VoD. On the other hand, MAN/WAN service domain offers Internet access and VoIP. The broadband residential Ethernet-based access network uses the Ethernet link, i.e. gigabit Ethernet, 100 Mbit/s Fast Ethernet or 10 Mbit/s Ethernet connecting between the different equipments. In addition, exploiting IEEE 802.3ad link aggregation or MPLA techniques in the BREAN (the broadband residential Ethernet-based access infrastructure) can improve network availability.

3   Service Model

The broadband residential access networks, so-called full-service networks, must provide generic legacy services, i.e. TV, PTOS (plain old telephone service), and data services and so on. On the other hand, they may also provide all kinds of emerging digital services, such as Web browsing, digital audio, digital video and HDTV (high definition television), etc.

Service model is an important component of network technology. Indeed, the service model is related to network mechanisms and also influences network architecture. ATM technique is celebrated for providing service guarantees, and ATM Forum's traffic management specification version 4.1 specially designs the service mode. A set of six service categories is specified. For each one, a set of parameters are given to describe both the traffic presented to the network and the QoS that is required of the network[5]. The architecture for services provided at the ATM layer consists of the six service categories, i.e. CBR (constant bit rate), rt-VBR (real-time variable bit rate), nrt-VBR (non-real-time variable bit rate), UBR (unspecified bit rate), ABR (available bit rate) and GFR (guaranteed frame rate).

At first, IP service model is simple, since it only provided best-effort service. In order to support multi-service, IETF presented integrated services architecture. IntServ is a QoS framework based per-flow with dynamic resource reservation. RFC 1633 discusses a proposed extension to the Internet architecture and protocols to provide integrated services, i.e., to support real-time as well as the current non-real-time services of IP. This extension is necessary to meet the growing need for real-time service for a variety of new applications, including teleconferencing, remote seminars, telescience, and distributed simulation[6]. As we all know, scalability is still a
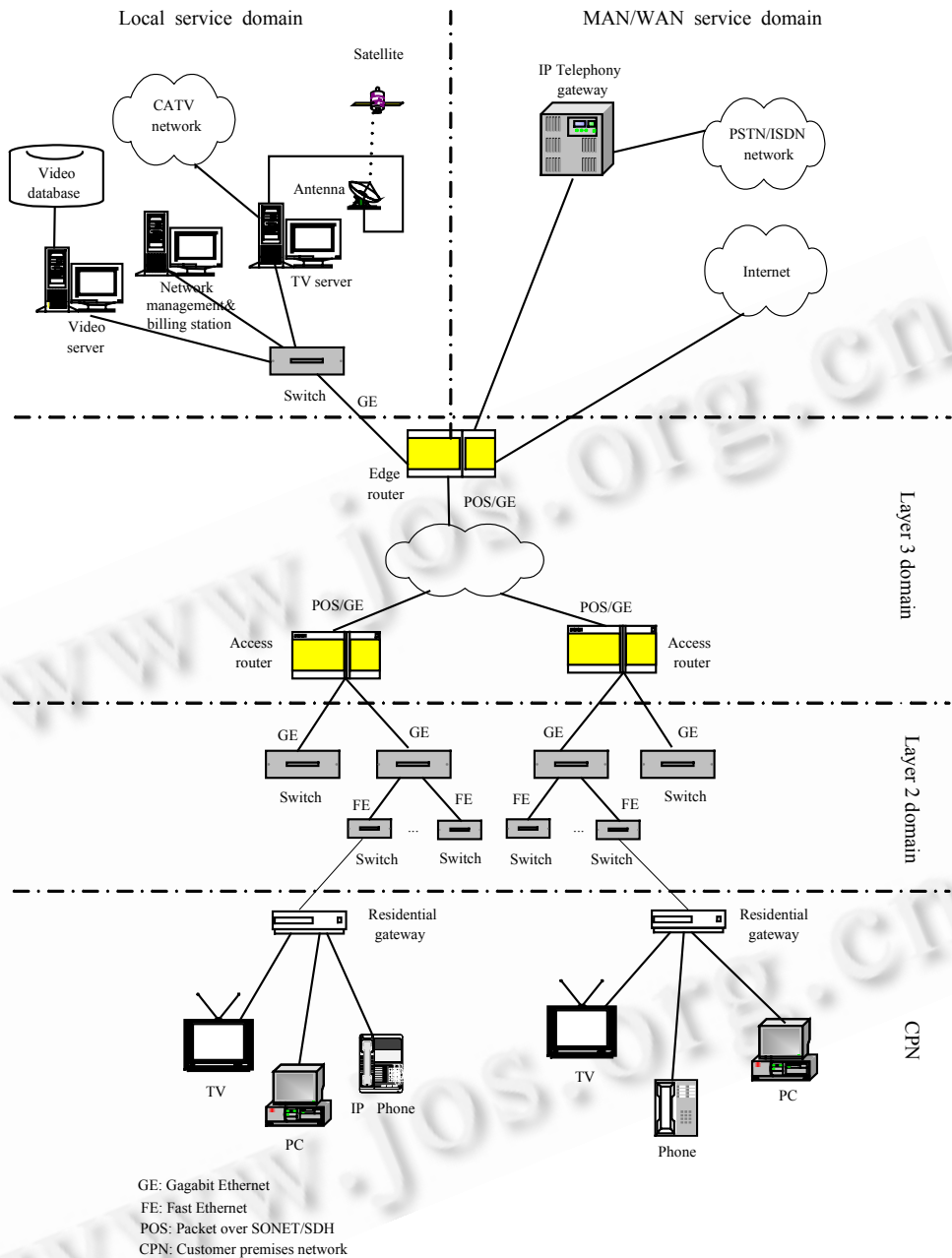
Fig.4   Architecture of the broadband residential Ethernet-based access network

problem of integrated service architecture, and end-to-end QoS provisioning is a vast challenge traversing backbone network. For the sake of resolving the problem of scalability in the IntServ network, an architecture for service differentiation is issued by IETF. RFC 2475 defined the architecture for implementing scalable service differentiation in the Internet. This architecture achieves scalability by aggregating traffic classification state that is conveyed by means of IP-layer packet marking using the DS field[7].

Scalability in the small-scale residential access networks isn't as difficult as in the backbone network. By using per-flow resource reservation, IntServ can deliver fine-grained QoS guarantees for these applications[8].

The IntServ model adds two service classes to the existing best-effort model, i.e., guaranteed service and controlled load service. Guaranteed service[9] provides an upper bound on end-to-end queuing delay. This service model is aimed to support applications with hard real-time requirements. Controlled-load service[10] provides a quality of service similar to best-effort service in an underutilized network, with almost no loss and delay. It is aimed to share the aggregate bandwidth among multiple traffic streams in a controlled way under overload condition[8].

In the large-scale carrier-grade broadband residential access networks, however, scalability is still an important problem to be solved. Thus, employing DiffServ model to offer QoS provisioning for multi-service is a good choice. The DiffServ model provides two kinds of services besides best-effort service. Premium service[11] is a guaranteed peak rate service, which is optimized for very regular traffic patterns and offers small or no queuing delay. This model can provide absolute QoS assurance. One example of using it is to create "virtual leased lines", with the purpose of saving the cost of building and maintaining a separate network. Assured service[12] is based on statistical provisioning. It tags packets as *In* or *Out* according to their service profiles. *In* packets are unlikely to be dropped, while *Out* packets are dropped first if needed. This service provides a relative QoS assurance. It can be used to build "Olympic Service" which has gold, silver and bronze service levels.

Matthias Grossglauser, *et al*. examined a number of service models, i.e., best effort, DiffServ, IntServ and CBR, and addressed that to each model corresponds a balance between application complexity, network complexity, and network efficiency[13]. We need to improve the service models to decrease the network complexity and increase the network efficiency in the residential access networks.

4 Traffic Model

The residential access networks are typical asymmetry networks. Upstream traffics mainly consisting of control message and interactive applications such as voice, game and videoconference are inappreciable for downstream traffics such as TV, VOD program, FTP, and Web contents. HFC and ADSL networks provide asymmetric network capacity based on the asymmetric feature. APON networks can provide symmetric network capacity or asymmetric network capacity. Ethernet with full-duplex mode is a symmetric network.

On the other hand, different multiplex methods greatly impact network traffics of the applications. HFC networks support a mix of analog and digital channels using a FDM (frequency-division multiplexing) scheme. TV doesn't interfere with data traffics in HFC networks. Similarly, PTOS doesn't also interfere with data traffics in ADSL networks. We can respectively model the traffics of these services mentioned above and capture their traffic characteristics.

Traffic modeling is fundamental for researching and planning of networks. Traffic models that accurately capture the salient characteristics of traffic are useful for analysis and simulation, and they further our understanding of network dynamics and so aid design and control. In the past, there are many traffic models for the telecommunication networks. Indeed, traffic model of the legacy services in the specific network is well studied and has some nearly perfect results. The traffic models can be stationary or nonstationary. We mainly discuss the stationary traffic models. Stationary traffic models can be classified in general into two classes: short-range and long-range dependent. Short-range dependent models such as Markov processes and Regression models have a correlation structure that is significant for relatively small lags[14]. Traffic measurements from communication networks have shown that network traffic is quite complex, exhibiting phenomena such as long-tail probability distributions, long-range dependence and self-similarity[15~19]. Long-range dependent traffic models such as F-ARIMA (fractional autoregressive integrated moving average) and Fractional Brownian motion have significant correlations even for large lags[14].

The source traffic modeling is a fundamental research issue in the area of the traffic modeling which is expected to behave as users of the network services. Statistical and deterministic properties of traffic sources strictly depend on the encoding techniques adopted to support multimedia services with different levels of priority and QoS satisfaction[20]. The applications are classified as the essential categories of elastic and streaming flows in the broadband residential access networks. Streaming flows are produced by audio and video applications. On the other hand, Elastic flows result from the transfer of digital documents (Web pages, files, MP3 tracks...) using a transport protocol like TCP.

Different video compression schemes, such as H.261, H.263, MPEG-1, MPEG-2, and MPEG-4, are designed to meet different objectives and therefore have different bit rates and stream characteristics. The video characteristics are also affected by the video encoding control scheme used. For a given content and a given compression scheme, CBR video maintains a streaming rate that varies little over time. By contrast, variable bit rate (VBR) video traffic has been shown to be self-similar and may have a peak rate which is many times the average. Encoding a TV or VoD program source by MPEG-2 (moving pictures experts group type 2) as CBR or VBR traffic is feasible.

Voice connections, in general, generate a stream of small packets of similar size (a few tens of bytes) at relatively low bit rates, and exhibit the low burstiness[21]. Typical stream rates range from 5 Kbps to 64 Kbps, depending on the encoding scheme, to which header overhead adds a few tens of Kbps. Each speech coding algorithm implements a different trade-off between output speech quality, algorithmic delay, bit rate, computational complexity and robustness to background noise. The optimal speech coder for VoIP depends on the specific scenario. No speech-coding standard has been yet developed with VoIP as primary application. Usually, fixed-rate speech coders are employed. Such coders generate a constant output bit rate, independently of network conditions[22].

The ON-OFF source model is the most popular source model for voice. In this model, packets are only generated during talk spurts (ON state) with fixed inter-arrival time. The ON-OFF assumption is due to the typical behavior of a voice source with silence suppression: it is active or inactive depending on whether the talker is speaking or silent. Moreover, in-depth analyses of this traffic source available in the literature[23] have emphasized that the distribution of active and inactive periods lengths can be approximated by an exponential function. The time spent in ON and OFF states is exponentially distributed with mean α^{-1} and β^{-1}, respectively[14]. An exponential variable X has the following density function:

$$f_X(\chi) = \begin{cases} \alpha e^{-\alpha\chi}, & \chi > 0; \alpha > 0 \\ 0, & \text{otherwise} \end{cases}$$

where $E[X] = 1/\alpha$ and $Var[X] = 1/\alpha^2$. The fraction of time that the voice source is "ON" is $\dfrac{\alpha}{\alpha + \beta}$. The cumulative distribution function of talk-spurt durations is approximated by an exponential function and that of pause durations is approximated by a constant-plus-exponential. In general, we may consider an average talk spurt rate of 38.53% and an average silence period of 61.47% recommended by the ITU-T specification, and set $1/\alpha = 1.004$ and $1/\beta = 1.587$ [24].

Headers corresponding to the various layers of the protocol stack are appended to voice packets before they can be transmitted on the network. For an Ethernet LAN with IEEE 802.1q, a 12 byte RTP header, an 8 byte UDP header, a 20 byte IP header, and a 30 byte 802.3 MAC header are appended to voice packets, namely, a total header size $H = 70$ bytes. Karam *et al.* investigated the effects of packet size on voice delay and bandwidth utilization and showed that in most cases, choosing a packetization dynamically on a per-connection basis only provides a modest benefit as compared to using a fixed packet size for all connections[21]. They noted that G.729A, using 30 ms formation time leads to a negligible waste in resources, and constitutes a good compromise in terms of delay and

bandwidth utilization. The recommended formation time for G.711 encoder is 10 ms (that is, the recommended packet size is 80 bytes) and 30 ms for G.723.1 encoder (that is, the recommended packet size is 20 bytes).

Data applications in the residential access networks mainly include WWW browser, FTP, e-mail, etc. We can use Web traffic to represent the general applications for simplifying. Web traffic, carried by HTTP over TCP, is closely tied to the contents of web pages and to the dynamics of TCP. Trace studies of web traffic have shown that the majority of HTTP requests for web pages are smaller than 500 bytes. HTTP responses are typically smaller than 50 KB, but may also be very large when HTTP is used to download large files off web pages[25]. Crovella and Bestavros carried out an analysis of World Wide Web traffic and attributed the heavy tailed distribution of document lengths to the self-similar features in the traffic[17]. Crovella *et al.* found the sizes of both the retrieved documents by clients and available documents on servers follow a Pareto distribution, which has probability density function (pdf)

$$p(x) = \alpha k^{\alpha} x^{-\alpha-1},$$

where k is the minimal value of the random variable x and the exponent α determines the shape of distribution.

Deng *et al.* performed their own analysis on the actual WWW traffic to characterize the document inter-arrival times and suggested that a Weibull distribution may be a more reasonable model than the Pareto distribution for WWW document inter-arrivals[26]. Weibull distribution has probability density function (pdf)

$$p(x) = \frac{k}{\theta} \left(\frac{x}{\theta} \right)^{k-1} e^{-(x/\theta)^k} .$$

Furthermore, some theorems have shown that aggregating traffic sources with heavy-tailed distributions leads directly to (asymptotic) self-similarity. Distributions with infinite variance lead to self-similarity. Leland *et al.* analyzed the Ethernet traffic on a LAN connecting workstations, file servers and personal computers, proposed a self-similar process as a possible traffic model[15] and stated that the aggregation of a large number of WWW sessions may cause self-similarity[16]. For the wide-area networks, Paxson and Floyd analyzed the connection and packet arrivals in wide-area TCP traffic and concluded that wide-area traffic, particularly at the packet level is much more bursty than that predicted by Poisson models[18]. Most traffic analysis and modeling studies to date have attempted to understand aggregate traffic, but these studies mainly focus on ATM technique. There are many traffic models for Ethernet in the past. However, previous traffic studies have primarily concentrated on LAN's data applications in business or academic environments, not a residential multi-service access network. Deng's study was undertaken to measure the suitability of various LAN protocols for the residential network[26]. It gave a traffic measurement and modeling including LAN data traffic, WAN data traffic, and video traffic. However, Deng's study focuses on the home networking and doesn't in total suit for the needs in a residential multi-service access network.

Indeed, the complexity of traffic in a multimedia network like a broadband residential access network is a natural consequence of integrating, over a single communication channel, a diverse range of traffic sources such as video, voice, and data that significantly differ in their traffic patterns as well as their performance requirements[27]. A traffic model must be very flexible and capable of capturing the realistic traffic characteristics of video, audio and data application mixes.

Note that traffic modeling must consider the impact of QoS mechanisms such as different service strategies. For example, the insight into the impact of strategies of service differentiation on the performance behavior of the network nodes' queue is in particular important for an evaluation of QoS oriented protocol mechanisms[28]. We need to investigate the properties of the aggregating traffic data combining QoS mechanisms in the residential access networks.

5 QoS Provisioning

Up to now, QoS provisioning is still a great challenge for providing multi-service in the packet networks.

Nowadays, in a popular view, a network consists of backbone network and access network. There is an agreement that backbone network and access network can deploy the different design methods of QoS provisioning respectively. So, we can solely consider the QoS provisioning in the residential access networks. In addition, there is still a need to cooperate in handing traffic between access network and backbone network to offer end-to-end QoS guarantee for the applications. Note that for some accessing solutions adopt multiplex methods mentioned above, their services don't interfere each other, and they are provided with a dedicated bandwidth. For example, TV and data in HFC networks, or PTOS and data in ADSL networks, don't interfere with each other.

To support QoS, DOCSIS defines six QoS services: UGS (unsolicited grant service); UGS-AD (unsolicited grant service with activity detection); rtPS (real-time polling service); nrtPS (non-real-time polling service); BE (best effort) service; and CIR (committed information rate) service[4]. DOCSIS also defines various access modes in implementing the six QoS services, i.e., isochronous access, periodic request polling and immediate access, and also different resource reservation methods, i.e., normal reservation and piggybacking reservation. To meet the QoS requirements, the headend must employ an admission control mechanism and a scheduling algorithm among difference services to reduce QoS violation probability.

IEEE 802.14a provides QoS support at the ATM layer through MAA (media access arbitration)[4]. Having global knowledge of all stations, the MAA at the headend is able to schedule upstream transmissions such that the ATM layer of the HFC access network can meet the traffic contract for all VC (virtual channel) and VP (virtual path) connections. QoS support of ATM is deeply discussed in ATM Traffic Management Specification[5]. Similarly, both APON and popular ADSL technologies use QoS support of ATM. For more technical details, refer to the new ATM traffic management specification version 4.1.

However, every kind of traffics in the residential Ethernet-based access networks share all the bandwidths. How to guarantee quality of multi-service, such as TV, POTS, Internet access, etc., is obviously a more difficult question. The best effort service doesn't suit for multi-service, but IntServ and DiffServ are two kinds of main QoS frameworks for providing quality services guaranteeing in IP packet networks. Most often, industry players talk in terms of IntServ being deployed at the edge of a network, while DiffServ is used in the core network. There are many study efforts about IntServ framework at the edge of a network, i.e. access network in the past years. The ISSLL Working Group of IETF, working group of integrated services over specific link layers, defines specifications and techniques needed to implement Internet Integrated Services capabilities within specific network technologies. The IntServ is known to be unable to scale. In the carrier-grade residential access networks, however, there are thousands of residential users, and these users produce thousands of flows of the applications. Scalability is still an important design target in the residential access networks. DiffServ is an appropriate choice in carrier-grade residential access infrastructure, but it introduces inaccuracy and incompleteness into service guarantee. While it is relatively clear how to build a predictable application by using protocols and mechanisms of RSVP and IntServ, the way to establish DiffServ-aware application in fine-granularity is still an open issue[29]. Since the DiffServ specifies only local forwarding behaviors, the biggest challenge is to identify the way to best utilize the DiffServ for emerging applications. However, designing elaborately the relating components of QoS provisioning can eliminate the limitations of DiffServ in the residential access networks.

Ethernet technique was firstly standardized by the IEEE in 1985, and designed for traditional data applications. However, there is a great interest in supporting multimedia applications over existing network infrastructure, such as Ethernet, etc., since changing to new technologies would be costly and would most likely delay the introduction of these applications[30]. Indeed, there are many protocols devised to transmit real-time applications in bus based multiple access networks. Norden *et al.* gave a good survey for past real-time protocol over multiple access networks[31]. Note that the past studies mainly focused on Ethernet-based shared bus.

Traditional Ethernet technique didn't provide bounded delay and distinguish between different traffic types. However, Ethernet technique has evolved from shared bus to switched mode in the past couple of years. In the early 90's a new class of multi-port bridge, i.e. LAN switch, appeared on the scene supporting a large number of network nodes on multiple segments and offering full Ethernet line speed. They were increasingly used for dedicated connections (a single node on a segment) when high performance was required. A dedicated segment is no longer a shared medium, there are no collisions and the full bandwidth is available to a single node. The segment becomes a point-to-point link, which can support full duplex operation instead of the original half duplex. In addition, the distance limitations of CSMA/CD are removed. Full duplex operation of Ethernet was standardized in 1997 along with using flow control frames. These new emerging mechanisms have effectively improved the performance of Ethernet. These mechanisms indirectly contributed more for implementing differential services, and these mechanisms are even indispensable for multi-service over Ethernet.

On the other hand, queuing mechanism directly contributes for implementing differential services. IEEE standard 802.1P and 802.1Q are presented to provide services differentiation of Layer 2, and IEEE 802.1Q adds a 16-bit tag to the Layer 2 header, including three bits that can be used to classify priority. The standard specifies eight different priorities. The way the different queues are filled and serviced determines the details of the QoS offered. LAN switches typically implement multiple queues in their input port interfaces or output port interfaces.

Some researchers have investigated the QoS provisioning over Ethernet embodying new features mentioned above. Tobagi *et al.* evaluated the use of expedited traffic classes to prioritize multimedia and other time-critical information in a switched LAN, and addressed buffer sharing and contention on the Ethernet are the two basic effects that lead to performance degradation when real-time video and non-real-time data traffic are mixed[32]. The contention is to be eliminated completely, by means of switching hubs, dedicated ports for individual stations, and full duplex links connecting stations to their respective ports. Queuing mechanism can effectively solve buffer sharing problem. Tobagi *et al.* noted that, given a certain end-to-end delay requirement, there are a maximum number of hops that the path from source to destination could have. In the other paper, Tobagi *et al.* also studied the performance of GARP/GMRP in terms of response time, traffic overhead created by the protocol's control messages, and other artifacts that arise from the particular operation of the protocol[33]. Norden *et al.* proposed real-time protocols for the switched LAN. The proposed protocols are based on CSMA/CD with deterministic collision resolution and belong to the dynamic planning based category[31].

Nowadays, cost of Ethernet equipments with new features is cheaper with large installed base. Thus, employing switched Ethernet technique can eliminate completely contention in the residential Ethernet-based access networks. We presented a broadband residential Ethernet-based access infrastructure in the past paper, and also noted that combing network dimensioning and DiffServ infrastructure can offer QoS provisioning for multi-service in the residential multi-service access networks[34].

Note that scalable QoS provisioning with high bandwidth-utilization is indispensable for any large-scale broadband residential access networks.

6 Conclusions

Our comparative study discusses technical details of the broadband residential access infrastructure, such as network architecture, service and traffic models, and QoS provisioning. A broadband residential IP-based access infrastructure over Ethernet is our future research focus.

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第 4 届中国信息和通信安全学术会议(CCICS 2005)

征 文 通 知

中国信息和通信安全学术会议(CCICS)是国际信息和通信安全学术会议(International Conference on Information and Communications Security，简称 ICICS)的地方版，已成功举办了 3 届，第 1 届由中国科学院信息安全技术工程研究中心主办，于 1999 年 12 月召开；第 2 届由上海交通大学计算机学院主办，于 2001 年 5 月召开；第 3 届由武汉大学计算机学院主办，于 2003 年 3 月召开。该会的规模和影响逐届扩大。第 4 届中国信息和通信安全学术会议(CCICS 2005)拟定于 2005 年 5 月在陕西西安举行。热忱欢迎所有涉及信息安全、通信安全理论和技术方面的研究论文提交本次会议进行交流。会议论文集将由科学出版社出版，会议的优秀论文将被推荐到《软件学报》。

一．征文要求

论文须为未公开发表并且未向学术刊物和其他学术会议投稿的最新研究成果。文稿使用中文或英文书写，字数一般不超过 6000 字。请将论文(word 文档)全文(注明作者的联系电话和 E-mail 地址)发送到 yangbo@mail.xidian.edu.cn。

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