DOCSIS® ACCESS NETWORK CONSIDERATIONS FOR CONVERGED IP SERVICES

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Abstract

This paper explores DOCSIS parameters that should be managed when offering multiple services over the access IP network, DOCSIS being defined as the connection between a CM and CMTS. When offering multiple services on a DOCSIS connection, there will be resource contention that needs to be accounted for.

INTRODUCTION

Business Case

The cable industry is migrating from proprietary technologies to standard technologies based on the Internet Protocol (IP). DOCSIS is the method for moving IP packets over a Hybrid-Fiber Coax (HFC) network and within DOCSIS, the Cable Modem Termination System (CMTS) arbitrates bandwidth allocation.

The IP infrastructure has proven to be both general purpose (supporting many different applications from web and email to VoIP and streaming media) and low cost. IP has stood up in the face of competition from other networking technologies such as AppleTalk and Novell Netware. IP technology just works, is widely deployed and available from multiple suppliers.

The first service over DOCSIS was High Speed Internet (HSI). In 2003, several operators began offering telephone service over DOCSIS as well. Trials for a third service over DOCSIS, the DOCSIS STB Gateway (DSG) are planned for 2004.

With DSG, the migration of the video business to the common IP platform is underway. Not only will cost savings be realized by making use of the existing infrastructure, there is more innovation and less operational expense associated with the existing IP infrastructure.

These three services (and others that will be offered in the future) have different traffic characteristics and system resource needs that place unique demands on the Cable Modem Termination System (CMTS). Any single service is easily accommodated because the specific demand on the system is more easily monitored. But when multiple services are offered simultaneously, the demands on the system develop more complex interactions.

Said simply, Cable is getting to the point where the DOCSIS connection (CM-to-CMTS) should be engineered. This paper will describe several DOCSIS system parameters and resources that could be observed and managed as multiple services are deployed.

Specifically with HSI, a system generally ran out of DOCSIS bandwidth before other DOCSIS system resources were exhausted. But when offering multiple services on a single DOCSIS connection, other DOCSIS resources may be exhausted before the total bandwidth of the system. If the DOCSIS network is not managed properly, services

offered over that network may not get the needed service assurance guarantees.

Areas of Discussion

This paper will address several types of CMTS resources that may exhaust before the available bandwidth on the system is fully utilized. These are:

1. Bandwidth Resources, specifically just the raw amount of bandwidth needed to offer services in addition to HSI on the DOCSIS connection.
2. How DOCSIS Quality of Service (QoS) can be used to "carve up" bandwidth for individual services such that bandwidth for a particular service can be exhausted while there is still bandwidth available on the channel.
3. DOCSIS Protocol Resources that could possibly exhaust before bandwidth runs out.

As the DOCSIS connection is used to carry more and different types of services, operators will need to implement systems to better manage the bandwidth and the services delivered to customers over the IP connection.

OVERALL SYSTEM VIEW

A Cable IP network view is shown in Figure 1.

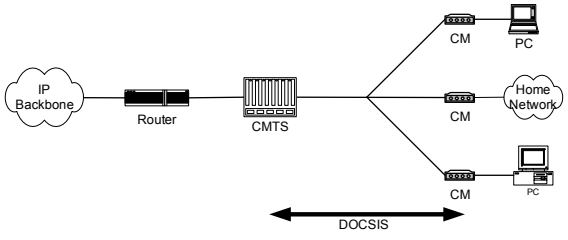

Figure 1 – DOCSIS System

Whereas the DOCSIS protocol by definition exists only between a CMTS and a group of Cable Modems (CMs), the entire Cable IP network extends well beyond the DOCSIS network and includes both the regional and backbone networks. This paper focuses on the DOCSIS connection only.

1. BANDWIDTH RESOURCES

Introduction

Bandwidth is a finite resource; the DOCSIS connection is no exception. As the number of subscribers and services increases they all have to share the available bandwidth.

Figure 2 shows how bandwidth is allocated in a typical DOCSIS system.

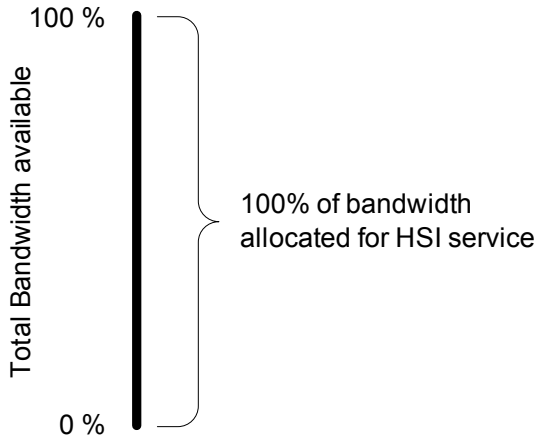

Figure 2

As shown, all of the bandwidth on the CMTS is allocated to HSI. As the number of HSI subscribers is still growing, an operator has to decide how to get additional bandwidth in order to support additional services because adding new services will take bandwidth away from the growing number of HSI subscribers.

Figure 3 shows a hypothetical allocation of bandwidth in a system where more than just HSI service is offered.

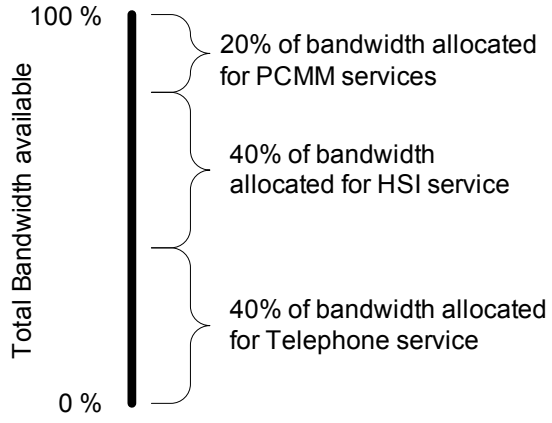

Figure 3

In this example, the 40% of available bandwidth is assigned to HSI service, another 40% to telephone service and the final 20% to new services managed with PacketCable Multimedia.

Looking back at Figure 2 where 100% of the bandwidth was available for HSI, either that amount of bandwidth is shrunk to 40% (having an impact on the HSI service) or the total amount of bandwidth available on the system is increased by 250% such that 40% of that new bandwidth is equal to the bandwidth assigned to HSI on the old system.

These figures illustrate that as additional services to the DOCSIS connection, it may be necessary to add additional bandwidth. Adding additional bandwidth can be done several ways, including:

- Splitting nodes
- Adding additional upstream and downstream channels to nodes
- Migrating to DOCSIS 2.0 for a higher speed return path
- Migration to 256 QAM for a higher speed forward channel.

The choice should be made to fit the business needs of the services.

2. DOCSIS QOS RESOURCES

Introduction

It is a fairly common experience to be on a network that is perceived to operate slowly. This is the result of having too much traffic and too little bandwidth which can happen on any network. There are technologies that allow premium services to receive premium service even when the network is congested. These technologies are broadly known as Quality of Service (QoS).

DOCSIS 1.0 provides tools to prioritize traffic from particular CMs; however, these tools are not widely used. These tools provide only prioritization, not a guarantee of a certain amount of bandwidth.

This is one reason why primary line voice deployment had to wait for DOCSIS 1.1 which included the tools necessary to offer a guaranteed experience for a service such as voice. DOCSIS 1.1 tools can guarantee a level of service for voice traffic (or any type of traffic) on the HFC connection.

But QoS is not a panacea. On any network connection there is a finite amount of bandwidth and it is not possible to guarantee service for all comers. This is similar to having too many cars in a High Occupancy Vehicle (HOV) lane of a highway. The HOV lane has a finite capacity but as more cars enter it, it too begins to slow down.

Much like an HOV lane can slow down, if DOCSIS QoS is overused the channel can still congest and the customer may no longer be receiving the service guarantee needed for a pleasing experience. QoS can be used to ensure certain services get a service guarantee on a congested channel, but that only means another service on that channel may get less bandwidth.

Figure 4 shows a DOCSIS connection that is allocated solely for HSI service. As is the business today, HSI subscribers are continually added to this channel until the available bandwidth on the channel no longer allows subscribers to receive their expected grade of service.

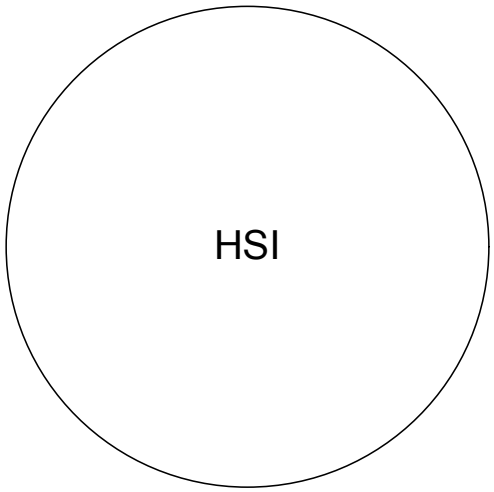

Figure 4

Similarly, Figure 5 show how QoS can be used to "carve up" the large pipe into a larger number of virtual pipes dedicated to individual services. The individual services can be constrained to the size of the virtual pipe even though there may still be available bandwidth on the channel. In this particular example, the HSI service is left to use whatever bandwidth is available on the connection.

The DOCSIS QoS rules are very flexible allowing the operator many configuration options. But QoS will not create bandwidth out of nothing; QoS only allocates bandwidth that already exists. The available DOCSIS bandwidth needs to be managed to ensure all services, from telephony to simple web surfing meet service guarantees. The availability of QoS technology in DOCSIS is necessary but not sufficient to ensure all services will receive service guarantees.

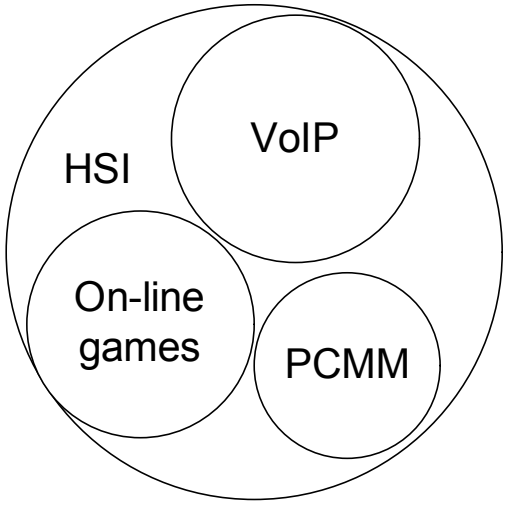

Figure 5

DOCSIS QoS Services

DOCSIS 1.0 is what started HSI and provides prioritized best-effort service with bandwidth limits. Bandwidth limits come into play when there is more available bandwidth on the system than traffic. When this occurs, a particular CM will be throttled to its bandwidth limits. As more and more users are added to a channel and the DOCSIS bandwidth becomes fully utilized, the CMTS will be fair to all users and it is possible that individual CMs will not be able to send and receive data at their limits. For DOCSIS, it is the CMTS that decides which CMs get to transmit and which will have to drop packets. There are many algorithms designed to drop

packets according to either fairness or business policy that can be implemented on a CMTS.

The DOCSIS connection gracefully tolerates overload. HSI services such as email and web are tolerant to packet loss, unlike digital video or voice. In the case of email and web, if a packet gets dropped there are "higher layer protocols," such as TCP, that cause the dropped packet to be retransmitted. So while there may be a delay of hundreds of milliseconds, the packet will eventually get through. Many Internet services are designed to be very forgiving and can recover gracefully from packet loss. However, as more services migrate from single purpose networks to IP networks, there may be challenges to meet service guarantees for all services.

DOCSIS 1.1 can provide QoS guarantees for bandwidth, latency, and jitter. However, if that DOCSIS connection is oversold, it may not be possible to guarantee the delivery of all services intended to be sent over it, even if those services are assigned QoS. If the DOCSIS 1.1 upstream channel is configured to be 5 Mbps, then only 5 Mbps can be carried. The services guaranteed for delivery over that connection simply cannot total more than 5 Mbps; it's not possible. There should be some "wiggle room" on the connection to allow best-effort services such as web and email a chance to get through. These best-effort services can be degraded at certain time in order to meet peak QoS loads; however, users of Best Effort services may notice service degradation.

PacketCable™ Multimedia

Whereas DOCSIS provides a QoS toolkit, PacketCable Multimedia (PCMM) provides the tools to manage QoS based on a set of business rules. As shown in Figure 6, PCMM exists as a layer that controls IP network QoS (including DOCSIS) based on information received from operator back-office systems.

PCMM supports the deployment of general Multimedia services, online gaming, video-conferencing, streaming media, etc., over DOCSIS. These services can be enhanced by assigning QoS to them as opposed to services such as web browsing, e-mail and instant messaging where customers may tolerate some slowness. Note, even services such as simple web surfing can be enhanced using PCMM; the possibilities are limited only by what the operator chooses to implement.

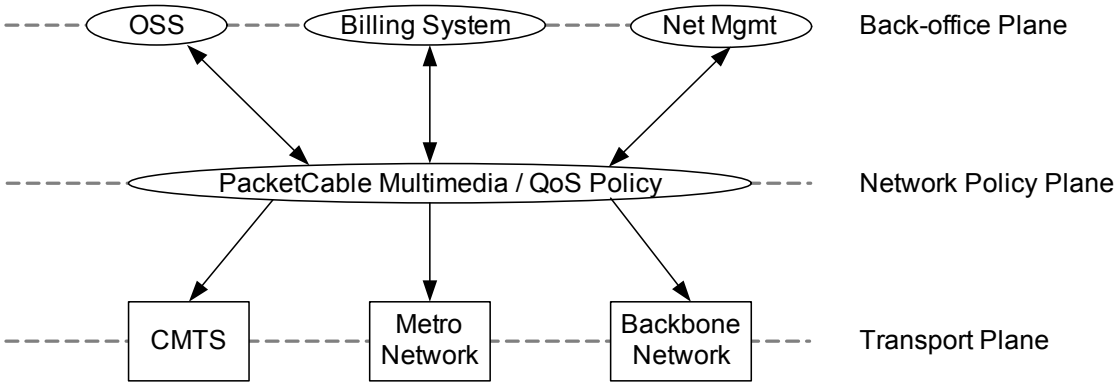

Figure 6

While telephony or voice-based services are not specifically excluded from PCMM, the PacketCable 1.x specifications provide specific QoS management methods to this type of service. Therefore, those specifications should be consulted as appropriate. PCMM could also be used for voice as the PCMM framework was founded upon the mechanisms defined in PacketCable 1.x.

Most importantly, PCMM provides the capabilities to manage the QoS tools available with DOCSIS 1.1 allowing operators to establish business rules for offering QoS on the DOCSIS network.

Impact on HSI Service

When services requiring service guarantees (QoS) are offered on the same DOCSIS channel as HSI, tools will be needed to ensure the QoS services do not starve the HSI service of bandwidth. A system such as PCMM can be used to effectively manage the overall bandwidth on the channel especially as operators are offering higher-speed HSI tiers.

3. PROTOCOL RESOURCES

Introduction

DOCSIS is a protocol which is a fancy way of saying DOCSIS uses defined formats and parameters to move IP packets across the HFC. Some DOCSIS parameters have finite amounts or ranges. It is possible that a particular parameter may exhaust before the available bandwidth on the system runs out. This situation is expected to be extremely rare if it could happen at all. With HSI service there has not yet been a case where a parameter other than bandwidth has been exhausted.

But DOCSIS is being used for more and more different types of services, with telephony being just one example. The DOCSIS Set-Top Gateway (DSG) effort allows DOCSIS to be used in STBs. PCMM will allow new uses for DOCSIS as well, including on-line games and video conferencing. As the cost of DOCSIS continues to drop, there is also more of a chance for lower bit rate applications such as monitoring and telemetry to come into play.

So while it is not clear if a DOCSIS protocol parameter may ever exhaust, it is clear that DOCSIS is being used for more and more applications so it is worth a look at one such parameter that has recently been under discussion by engineers.

Service Identifier (SID)

The parameter discussed in this section, the Service Identifier (SID), is an upstream resource that has a defined range; there are only so many SIDs that can be in use at one time. That number is just over 8,000 and is inclusive of all the upstream channels associated with a downstream channel. Therefore with a 1 x 4 CMTS card where there is one downstream and four upstream channels, there can be a combined 8,000 SIDs in use at one time across those four upstream channels.

SIDs are associated with a CM and a DOCSIS 1.1 CM can have one or more SIDs assigned to it. DOCSIS 1.0 CMs use only a single SID. The SID can be active regardless of if data is being sent through the CM or not.

. With HSI, typically between 2,500 and 4,000 SIDs will be consumed before the system becomes bandwidth limited and the subscriber experience degrades to the point where the operator would consider methods

to offer more bandwidth to those customers, such as splitting the node.

But with a combination of lower bandwidth services (such as iTV and telemetry) and high capacity return channels such as DOCSIS 2.0, there is an outside chance that SID depletion could occur before the available bandwidth is depleted. Several factors would play into the situation and while theoretically possible, further study is needed to understand if this situation might actually happen.

PCMM Example

PCMM, as well as PacketCable 1.x, contain methods to dynamically assign SIDs to services that need them. For instance when a PacketCable telephone call is placed over DOCSIS, an additional SID will be assigned for the duration of the call.

This dynamic mechanism provides a method to ensure that additional SIDs are only used when needed, however, every active CM is consuming at least one SID.

Telemetry Example

Telemetry in this usage assumes a persistent but low-bandwidth connection between a CM and CMTS. This connection could be used to signal the setting of a home thermostat or to poll a water meter. Such applications use only a small amount of bandwidth; however, as long as that CM is booted a SID is consumed even if there is no data being sent.

Even though these CMs send and receive minuscule amounts of data, they still consume SIDs.

SUMMARY

More and more services are being moved to the common IP infrastructure. Managing the DOCSIS bandwidth will require tools that were not needed when just HSI was being offered.

PacketCable Multimedia is a tool to manage that bandwidth based on operator business policies. But offering QoS-based services may require the addition of more overall DOCSIS bandwidth.

As counter intuitive as it sounds, as additional low bandwidth services are added to a DOCSIS connection, it is possible that DOCSIS resources other than bandwidth may exhaust before the available bandwidth is exhausted.

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