Reliable performance and QoS in the Home

Abstract

Priority-based Quality of Service (QoS) schemes for home IP networks are shown to be the most practical choice from a deployment and management point of view. Priority-based schemes can support a wide variety of simultaneous services without the management overhead required for parameter-based QoS schemes. The application of priority-based QoS media access and packet forwarding schemes is analyzed in the context of multimedia services distributed using wired (Ethernet, MoCA) and wireless (802.11) network technologies.

Introduction

Ensuring Quality of Service (QoS) on a home network requires different treatment than ensuring QoS in the enterprise or broadband access (e.g. DSL, Cable Modem) infrastructure. Enterprise infrastructure or broadband access infrastructure networks typically utilize professionally managed equipment and engineered cable plants using technologies that provide a constant underlying bandwidth. In contrast, home networking uses a wide variety of existing cabling or non-engineered placement of wireless access points using technologies that have varying underlying bandwidth. Users without much experience or knowledge of networking management often install home networking equipment themselves, and those users typically do not desire to actively manage their networks. Finally, the applications in the home tend to be multimedia intensive with a wide variety of bandwidth and packetization characteristics.

Once these types of characteristics of the home network environment have been identified, an evaluation of the techniques to provide an appropriate QoS scheme can begin. The resulting QoS system should answer the following design considerations:

- **Media Access:** How do individual devices on the network access the shared media?

- **Packet forwarding:** How are packets forwarded within in-home gateways, routers or bridges?

To provide QoS in a home network, the network interfaces on all devices must perform two basic functions: media access and packet forwarding.

QoS **Media Access** is the process of determining when a packet may be transmitted from one device into a network so as not to preclude the timely transmission of a packet on the media by another device. Specifically, it is the rules to indicate the acceptable time the network interface on each of the devices may transmit data under the assumption that multiple devices will want to transmit at nearly the same time.

QoS **Packet Forwarding** is the process of transmitting packets that have arrived from one or more network interfaces within a single device according to set of rules that provide QoS. Typically, the Residential Gateway is the single device on a home network that has multiple network interfaces and some rules are necessary to forward between the multiple network technologies.

The two basic QoS functions can be realized in one of two different paradigms: prioritized (differentiated) QoS or parameterized (planned) QoS. The difference between the two are summarized:

- Prioritized (Differentiated) QoS paradigm
  - For shared-media technologies, differentiated media access (Layer-2).
  - Marking (at the entrance to the network, e.g. Hosts) and honoring by differentiated forwarding/queuing (e.g. at the Residential Gateway).

- Parameterized (Planned) QoS paradigm
  - For shared media technologies, planned (scheduled) media access opportunities (Layer –2).
  - Planned media forwarding based on per-flow state and signaling at every hop (e.g. at the Residential Gateway).

Practical Considerations of Media Access in Home Networks

There are four basic technologies that are used for home networking today: 10/100/1000baseT Ethernet, IEEE 802.11g/n (Wi-Fi™), Power Line communications (PLC) and Multimedia over Coax Alliance (MoCA™). While many people tend to divide those technologies along the lines of wired and wireless, for QoS considerations, a better categorization would be shared-media versus point-to-point. Switched 10/100/1000BaseT Ethernet is a point-to-point technology. Essentially, each piece of media only has a single device on it. All of the other technologies are shared-media technologies. Multiple devices share a single media segment and some mechanism is needed to control how devices transmit on the media.

For switched Ethernet, differentiated media access is not of much value since traffic is point-to-point and there is essentially no contention on such a link. Many Residential Gateways have a four or five port Ethernet switch built-in, so QoS is not much of an issue for each of the Ethernet ports. Finally, 1000BaseT and even 100BaseT bandwidth is sufficient to address most home networking bandwidth and latency requirements, especially when it is dedicated usage on a point-to-point link. Thus, for the purposes of QoS Media Access, Ethernet within the home can be considered a point-to-point technology and treated separately from shared media technologies.

All of the other standards-based shared media technologies such as 802.11n, PLC and MoCA support a priority-based QoS scheme. In general, these technologies' priority-based media access is accomplished by controlling which device gets to access the media first based upon priorities. The devices with highest priority traffic are allowed first opportunity to transmit and then, depending upon the bandwidth availability, devices with lower priority traffic will get the

opportunity to transmit their data on the media. The amount of bandwidth consumed by the highest priority traffic typically cannot be strictly controlled with the prioritized scheme.

Parameterized QoS relies on the assumption that the underlying PHY/MAC technology is able to deliver very constant bandwidth and minimal jitter. This assumption is acceptable for point-to-point networking technologies such as Ethernet but is inappropriate for home networking technologies such as wireless and PLC, where the underlying throughput/jitter can be strongly influenced by rapidly changing and sporadic interference. To have a high confidence for parameterized guarantees, very conservative estimates must be made on the underlying parameters. Conservative estimates lead to worst-case operation that may be significantly different from typical operation. Thus, the applications would tend to over subscribe the very bandwidth-limited media. In conclusion, priority-based media access is preferred for heterogeneous home networks.

Feasibility Considerations. Any in-home QoS scheme must function in the presence of legacy devices.

Prioritized Media Access can be overlaid on existing shared-media home networks. Even though the various home networking technologies mentioned above have a means for setting priority, in general there is no entity setting the priorities on legacy devices. Traffic using those technologies tends to only be transmitted at best effort. Thus, when QoS is added to a residential gateway, traffic transmitted from the residential gateway can be prioritized. Likewise, network client devices that conform to a QoS specification can use prioritized media access. Non-compliant devices will continue using best effort priority. Thus, QoS for a mix of devices that do and do not support QoS on a home network can be engineered by setting priorities on the shared interfaces and only sending appropriate traffic on the switched Ethernet interfaces of the Residential Gateway.

Unfortunately, parameterized Media Access cannot be overlaid on legacy networks since legacy devices can not be prevented from transmitting during times assigned by the central controller to (new) conforming devices. Parameters, reservations and bandwidth managers can not operate with legacy devices on shared networks.

Queuing and Packet Forwarding in a Residential Gateway

In any network device, such as a Residential Gateway with multiple network interfaces, a mechanism is necessary to control packets that are received from multiple interfaces that are to be retransmitted through a single interface. This control process is referred to as forwarding priorities or queuing. Several potential methodologies exist depending on the QoS capabilities of the interfaces. See IEEE802.1p/q or RFC2474 for a discussion on Differentiated Services queuing.

There are multiple ways to implement a priority-based packet forwarding mechanism. If the interfaces on which the packets are received contain a Layer-2 or Layer-3 priority mechanism, and if the priorities on different interfaces have global relevance, the packets may be queued for transmission simply by their relative priorities. Layer-3 mechanisms tend to require packets to be marked/labeled and the label must be mapped to Layer-2 mechanisms in order to enforce priorities on shared media. If the differentiation markings on Layer-2 and Layer-3 are mapped, queuing decisions can be made either on Layer-2 or Layer-3 indicators. The regeneration feature of 802.1p offers the ability to examine packet contents and to label the packets for priority treatment at the next packet forwarder. However, even if the contents of packet received at a Residential Gateway were examined to determine if it was high priority or not, there is little merit in tagging it for transmission on the WAN (DSL or Cable Modem) or back onto the LAN since the Residential Gateway simply must make an internal decision on which queue to place it in.

If a receiver interface implements a QoS mechanism based on parameters, queuing decisions probably can be based on the latency or jitter parameters for flow planning. However, it can be problematic to determine if a packet should be transmitted or not based on its length if the length would mean that a potential low latency packet were to be received and must be transmitted at a specific transmission opportunity.

Feasibility Considerations. Since a QoS priority packet forwarding methodology resides entirely within the Residential Gateway and can be thought of as a minor enhancement to the existing packet handling capability, this new QoS functionality is relatively easily accomplished through a software upgrade. Fortunately, this methodology also handles all legacy devices connected to the interfaces since QoS Packet Forwarding is implemented solely within the Residential Gateway.

MoCA

An exciting development is the availability of the MoCA standard developed to enable distribution of high-quality digital multimedia content throughout a home over existing coaxial cable. Created in 2004, the designers of MoCA wanted to reliably transport multimedia content without introducing new wires or interfering with existing services. As coax is already installed in many homes for terrestrial or cable television service, MoCA brings the coax infrastructure into the home network while providing a low-cost and efficient way to distribute content to other media appliances. MoCA provides aggregated net throughput of 175 Mbps across up to sixteen nodes while ensuring the reliability and quality of multiple video and data streams through managed packet delivery and reserved bandwidth mechanisms.

MoCA is a popular technology among cable, satellite and telecommunications service providers in the US and parts of Europe because it offers an inexpensive way to deploy networked set-top boxes within the home. With MoCA, service providers can install a networked box or gateway that manages TV distribution of live and recorded content to multiple rooms. In addition to keeping deployment costs down and reducing deployment complexity, MoCA has the added benefit of multi-room digital video recorder (DVR) or enabling consumers to view recorded content in any room they choose.

MoCA is designed to allow any node to be the Network Controller (NC).

The NC fully controls media access so that there are no collisions on the MoCA network. The NC assigns transmission slots for the devices based upon the priority of the packets to be transmitted. The NC also schedules periodic link evaluation operations to ensure the modulation parameters remained optimized even as link conditions change over time. This combination of techniques allows a packet error rate (PER) of less than 1E-6 yielding a very reliable transmission technology

MoCA is a mature standard, with more than 20 million nodes shipped worldwide and over sixty certified devices. It is also integrated into a variety of ICs designed in compliance with the DLNA QoS guidelines including HD multi-format video decoder SoCs (see Figure). These single-chip devices, complete with powerful application processors and integrated networking interfaces, enable developers to create highly differentiated products while further reducing design complexity, lowering system BOM, simplifying DLNA certification and accelerating the momentum of the next evolution of the digital home.

MoCA can form the backbone of a home network with bridges to other shared media technologies such as Wi-Fi and PLC. Priority based QoS is also bridged across the heterogeneous network.

Conclusion

A priorities-based media access and packet-forwarding approach is recommended for in home networks desiring QoS. This recommendation is based on the feasibility of managing bandwidth over varying home networking technologies in the presence of legacy network devices. The complementary in home QoS and access system QoS provides a cost-effective way to deliver high quality, revenue-generating services without the need to replace existing legacy in-home networking devices.

About the author

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Dr. Stephen Palm is currently technical director for Broadcom's Broadband Communications Group (BCG). He is responsible for driving Broadcom's home networking strategy to enable voice, video, data and multimedia services for distribution via residential wired and wireless networks with products that run over coaxial cable, wireless or Ethernet infrastructures. Broadcom Communications is a promoter member and board of director of MoCA.

About MoCA

The Multimedia over Coax Alliance (MoCA®) is the standard for home entertainment networking. MoCA is the only home entertainment network standard body that appeals to all three pay TV operators— telco, cable and satellite. The current MoCA specification offers 175 Mbps actual throughputs and offers an unparalleled user experience via parameterized quality of service (PQoS). MoCA members represent the home entertainment network value chain including service providers, OEMs, consumer electronics companies and chip vendors. Visit www.mocalliance.org for more information. Also visit MoCA's new video-based and consumer-specific web site, www.connect-mystuff.org

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