WHITE PAPER

PARAMETERIZED QOS FOR C.LINK NETWORKS

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1 Abstract

Quality of service (QoS) methods enabled in Entropic Communications' c.LINK solution ensure that asynchronous data, that need only be delivered on a best effort basis, does not interfere with the assured delivery of time sensitive multimedia data streams. This is a critical challenge system operators must address as subscribers and home networking usage models evolve from simply transferring and downloading best effort data to a usage model where media centric data is streamed around the home and must be delivered in real-time. Entropic's c.LINK architecture provides a parameterized QoS mechanism that enables operators to either build a standard Universal Plug and Play (UPnP) QoS system or create a custom QoS solution using alternative higher layer QoS services.

2 Quality of Service Challenges in Home Networks

Sharing Internet access and transferring files between personal computers is a subscriber's traditional notion of what home networks accomplish. However, as more multimedia applications take root in subscriber's everyday lives these networks must support a more enriching usage model that requires real-time streaming of data within the home LAN. Consumers now expect to be able to watch digitally video recorded (DVR) TV shows, access video on demand (VOD) services, stream music from their personal computers and play interactive games on the Internet, all in real-time from virtually any room in the home. System operators face the challenge of supporting these real-time streaming applications simultaneous with asynchronous data traffic like Internet access and coexisting with pre-existing premium services such as analog/digital/IP TV, all over their in-home networks. Critical to effectively serving all these data flows is a method to ensure that each application is guaranteed the bandwidth and latency requirements necessary to provide a satisfactory user experience.

Figure 1 illustrates how a c.LINK network can support a variety of devices, each with its own requirements and performance expectations, together over coaxial cable. The network could be carrying video, data, voice, and consist of a mixture of QoS, and non-QoS enabled devices. A network this complex poses significant network management challenges especially when multiple real-time streams sourced within the LAN or the WAN need to be transmitted to devices with varying capabilities.

An unsatisfactory user experience can be costly to system operators. During data transmissions that are delivered on a best effort basis such as Internet page downloads and file transfers, subscribers are accustomed to pauses and gaps that result in a relatively small impact to the overall user experience. However, this level of performance is not acceptable in the case of streaming multimedia data. Any disruption in the flow of streaming video or audio can result in stuttering playback, blocky video frames and a complete loss of audio, prompting a service call from the subscriber. In order to avoid situations in which the bandwidth of a streaming multimedia application is hijacked for non-real-time asynchronous applications, quality of service (QoS) methods can be used to manage the priorities of the different traffic flows on the network.

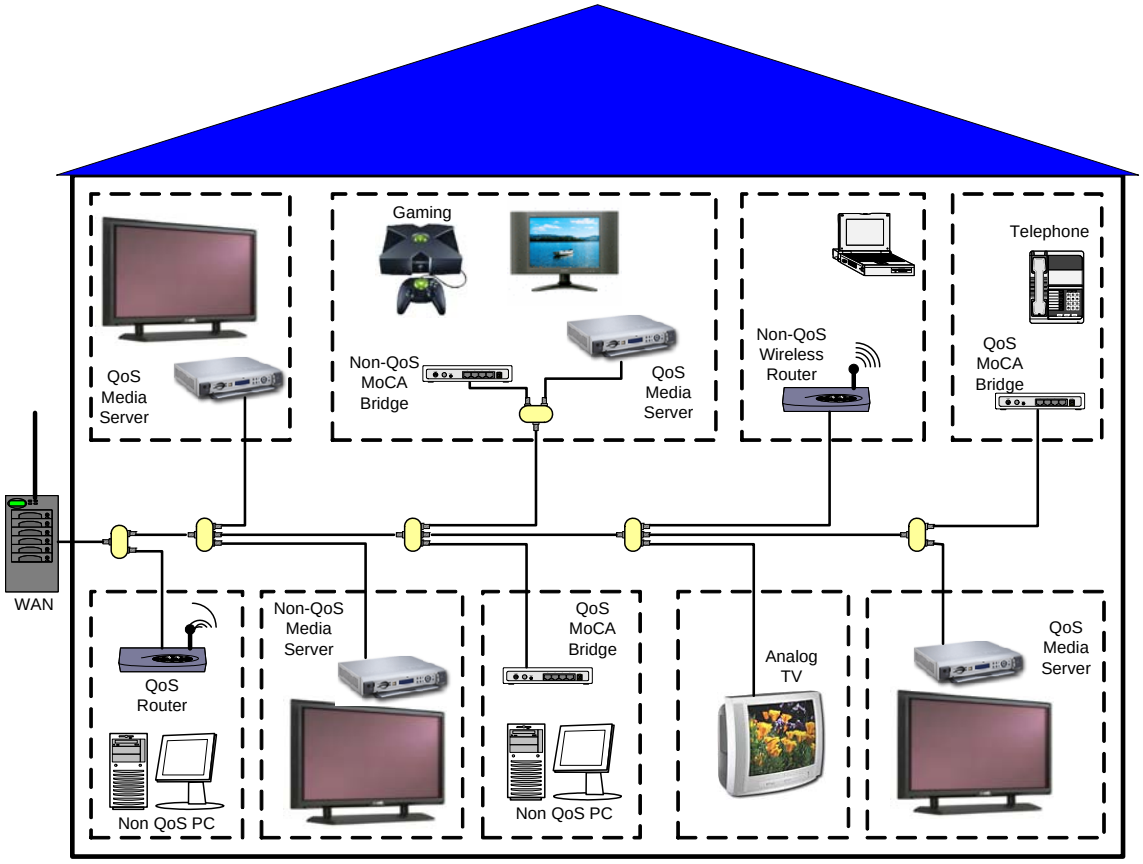

Figure 1: c.LINK Home Network

Today, 802.1p provides a method to prioritize traffic on the network. Unfortunately, this mechanism does not make distinctions between types of data nor does it guarantee bandwidth. It only provides the network with a method to weigh the importance of one priority against that of another priority. Asynchronous internet data tagged with a priority of 5 would be treated the same as video data tagged with a priority of 5. The result could still lead to an operator's high quality video service being impacted by regular data. Even multiple video streams can be tagged as high priority and a router will simply queue up the packets in its high priority buffer to be sent as soon as possible. If the bandwidth is insufficient to handle this amount of high priority traffic, packets will be dropped regardless. As subscribers begin to add third-party products and applications from retail the operators lose more control of their video network and network bandwidth conflicts between video and data intensify.

Another approach to insuring QoS is to use the brute force approach of simply increasing bandwidth. However, increasing bandwidth is a stopgap measure as applications are continually increasing their needs and will eventually use up this additional bandwidth. Relying on just adding more bandwidth also doesn't take into account that simple network file transfers can consume all of the bandwidth in transient bursts. Operators and subscribers require a QoS mechanism that protects their premium content yet is flexible enough to work in a mixed mode environment.

A parameterized QoS enabled network avoids costly operator support and a poor subscriber experience by providing a true guaranteed performance by reserving the required network bandwidth based on the characteristics or parameters of that data requesting access to the in-home network. The ability to limit over subscription of the network is enhanced through an intelligent negotiation between devices which determines whether the network can accept or reject the requested bandwidth.

Entropic's c.LINK solution separates itself from other networking solutions by mitigating bandwidth conflicts and prioritization with a two pronged approach. First, the networking technology ensures there is enough bandwidth within the home network to accommodate worst case loading scenarios. c.LINK provides 100 Mbps or better of stable bandwidth which is immune to dramatic bandwidth interferes and more than adequate to handle multiple HD streams throughout the home network. In addition, when heavy loads of asynchronous data traffic is mixed into the network c.LINK's parameterized quality of service (PQoS) mechanisms guarantee that video data flows have precedence over other data flows that do not require real-time streaming. Entropic's c.LINK PQoS has been carefully designed to support a mixture of time critical and best effort traffic over a c.LINK network.

Service call and truck roll costs are reduced by providing a robust network that can accommodate time sensitive data streams simultaneous with large ftp sessions for example, without negatively impacting the user's experience. An additional benefit of a PQoS enabled network is lower equipment costs. With guarantees of network bandwidth and latency client receivers can be cost reduced by eliminating the need for hard disk drives and large amounts of buffer memory that were once required to work around network uncertainties.

3 UPnP QoS Framework

In order to offer comprehensive support for all types of data services and a wide variety of end devices, Entropic has adopted a QoS framework inspired by the Universal Plug and Play (UPnP) 3.0 architecture. The UPnP forum is a widely supported industry initiative to enable simple and robust connectivity between consumer electronics and is at work on a draft UPnP QoS 3.0 standard. This newest revision adds parameterized QoS capability to the currently released QoS 2.0 standard that supports prioritized QoS today.

By implementing concepts in the UPnP framework to enable parameterized QoS (PQoS) on c.LINK networks, Entropic's solution offers a flexible PQoS structure that can be used by layer 3 and above UPnP compatible applications. However, Entropic's c.LINK layer 2 architecture is composed of a simple set of low-level services that provide the flexibility to also support vendor/operator specific proprietary QoS management architectures. Entropic envisions two deployment scenarios will coexist in the market.

- Standards Based Implementation - Vendors build upon the low level c.LINK service to realize a standards based UPnP implementation
- Proprietary Implementation - Vendors build upon c.LINK services to offer a value added QoS that is not standards based

UPnP defines three separate services that comprise the QoS architecture: QosPolicyHolder, QosManager and QosDevice. Figure 2 illustrates an example traffic flow from a sender (MS) to a receiver (MR) across three segments with intermediate QosDevices in between. Each segment is a section of the network between two devices capable of routing or bridging to one another over the same physical medium. However, it is not necessary that each segment within the network be the same medium. One segment could be using c.LINK and another segment could be using Ethernet over cat-5. For any particular traffic stream, the QosManager will attempt to establish either prioritized, parameterized or hybrid QoS according to the capabilities of the network. The type of QoS method used for each segment is based on the capabilities of the devices attached to each end. If a UPnP QoS Control Point requests a prioritized QoS traffic flow, the QosManager will attempt to setup a prioritized traffic stream through the segments. Similarly, if a Control Point requests parameterized QoS, the QosManager will attempt to setup a parameterized traffic stream. In the case where hybrid QoS is requested, the QosManager will attempt to establish prioritized QoS on segments that support priority based traffic flows and establish parameterized QoS on segments that support parameterized traffic flows. Each service is responsible for the following:

- QosPolicyHolder (QPH) – A logical entity that provides the overall traffic policy for the network which primarily consists of three QoS elements
  - AdmissionPolicy
  - TrafficImportanceNumber
  - UserImportanceNumber
- QosManager- A logical entity that manages each of the QosDevice services though three groups of management messages: device QoS state and capabilities, flow management (setup, update, release of a flow), and eventing. It also serves as the control point, responsible for discovery of QosDevice services on the network.
- QosDevice - Manages the individual device's network resources in response to action invocations from the QosManager, reporting back results of that action. It also responds to queries about QoS capabilities and status.

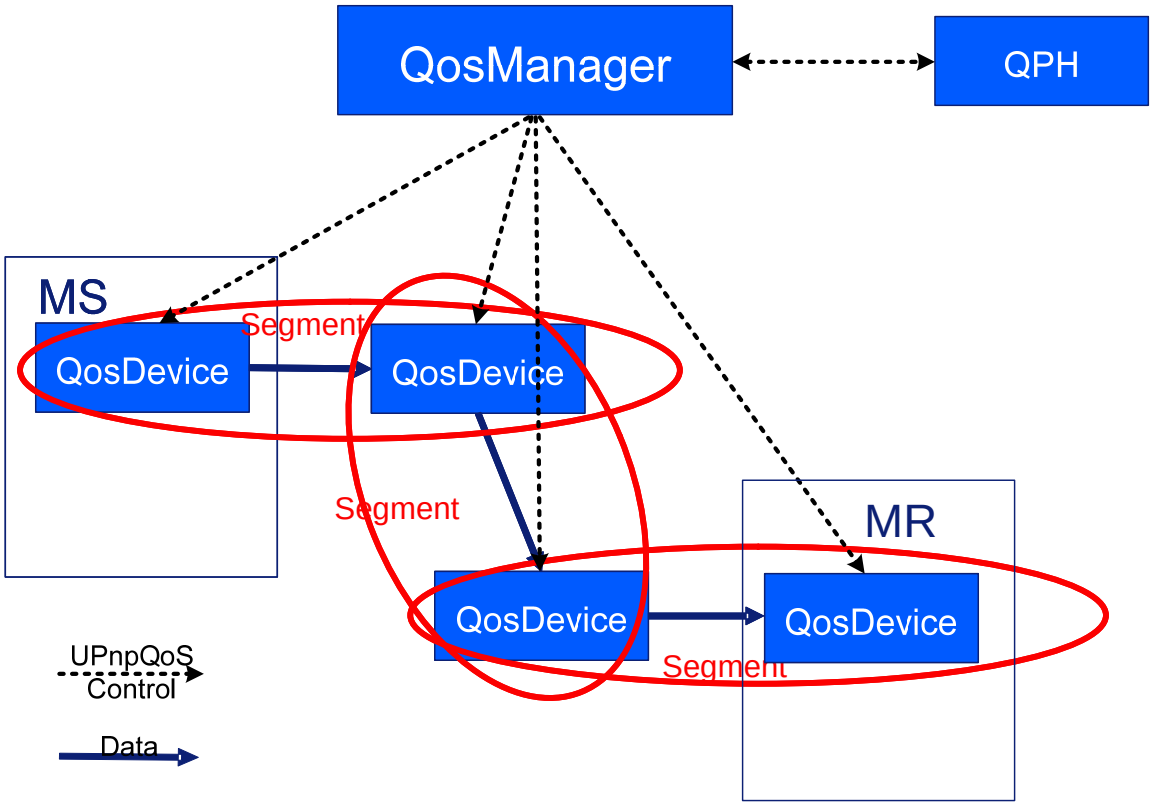

Figure 2 UPnP QoS Architecture

4 c.LINK Parameterized QoS

c.LINK enables PQoS device services such that system operators can assign higher precedence to streaming video flows above any other c.LINK traffic through higher level device negotiation. Parameterized QoS, also referred to as reserved bandwidth, allows c.LINK to precisely define its QoS needs, reserving just enough node-level and network-level resources to guarantee the necessary bandwidth. As a layer 2 device, Entropic's core software implements a set of PQoS autonomous behaviors. These low-level autonomous actions are used to build PQoS capability at higher network levels. Three c.LINK interfaces are provided and each is responsible for the following:

- QoS Operation Interface
  - Create unicast or broadcast flows
  - Modify flow attributes for existing flows without disrupting the stream
  - List flows on each node for which that node is ingress and query their attributes
  - Delete any flows
- QoS Event Detection Interface
  - Detect whenever a node is added or removed from the network
  - Detect when an ingress flow is added, deleted or updated
  - Detect when parameterized bandwidth has been exceeded
  - Detect when the network has enabled or disabled QoS
- General c.LINK Interface
  - Provides APIs/services to query about network topology information such as number of nodes, their capabilities and GUIDs

The overall c.LINK bandwidth can be thought of as being divided into two parts, parameterized flows and asynchronous flows. The maximum bandwidth for parameterized flows is typically set to a certain percentage of the overall c.LINK bandwidth. The remaining bandwidth is used for all asynchronous traffic, including prioritized traffic, best effort traffic and link maintenance. Higher level applications create a flow by making a request to the c.LINK PQoS interface which includes the peak bandwidth and nominal packet size parameters. These parameters are then converted into the scheduling elements necessary to calculate if the bandwidth is available. If the bandwidth is available, the flow is authorized and the bandwidth is taken out of the general resource pool and allocated to that specific flow. A flow is identified and assigned by a higher network layer by using the destination address field which is set to be a multicast MAC address and the VLAN tags corresponding to user priority of 4 or 5. Flows are terminated and the resources given back to the network either when the user terminates the session or an optional lease timer causes an automatic expiration of the flow.

In the event the network bandwidth requested based on the peak bandwidth and nominal packet size provided is not available, the flow request is denied and data traffic will not be permitted between those nodes using the PQoS mechanism.

Prioritized traffic can also coexist with parameterized flows on the network. However, prioritized traffic does not undergo the c.LINK flow admission process. Their QoS levels are relative and scheduled according to their priority bits so there is no guarantee of bandwidth or latency. Best effort traffic is always mapped into a low level of priority.

5 Summary

Mitigating costly service calls and preventing poor user experiences due to in-home network bandwidth issues is achievable. With the addition of parameterized QoS to Entropic's c.LINK architecture, c.LINK networks are enabled to effectively mix and match different types of traffic without sacrifice to the performance quality of time sensitive media streams. Yet c.LINK's PQoS architecture is flexible enough for system operators to implement a standard UPnP QoS 3.0 model or a proprietary scheme can be implemented using the c.LINK layer 2 QoS application interface with custom higher layers. Parameterized QoS enabled c.LINK solutions from Entropic Communications address the challenge of providing a robust home network for today's multimedia streaming applications.