ANALYSIS OF BANDWIDTH-CONSERVATIVE SERVICE OPPORTUNITY

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Abstract

A significant challenge for cable operators is to leverage the high-speed data infrastructure to implement services for which customers are willing to pay an additional monthly charge without the burden of a significant increase in capital costs. @Security Broadband's SafeVillage™ system (patents pending) creates such an opportunity through a residential monitored security service, which provides audio and video alarm verification by monitoring personnel in a centralized center, and live viewing and two-way audio by homeowners over the public Internet.

A critical design consideration has been the capacity implications of carrying streaming video and audio over the high-speed data infrastructure and thus the impact on the cable operator's capital expenditures. To characterize this impact, @Security conducted an extended study as part of an 85-home technology trial carried out in cooperation with a major cable operator. This paper describes the data collection and analysis methodology, and provides a quantitative description of the findings.

INTRODUCTION

The introduction and rapid growth of high-speed data (HSD) services have been enabled by the large investment by cable operators in two-way, hybrid fiber-coax (HFC) systems. Currently, these services center largely on public Internet access.

In addition to the growing penetration of HSD service, significant increases in per-subscriber usage are occurring. While growth in penetration generally is accompanied by corresponding increases in revenue, growth in per-subscriber traffic does not produce commensurate revenue growth for the cable operator. Bandwidth-intensive applications deployed by end users such as peer-to-peer music and video file sharing and network-enabled gaming produce no incremental service revenues, but increase cost by accelerating the need for capacity expansion through fiber node splits, upgrades to modulation hardware, or additional DOCSIS channel assignments.

Opportunities to create additional revenue streams through services provided over the high-speed infrastructure are attractive to cable operators, especially services with a relatively modest impact on upstream data-carrying capacity. Potential synergies from bundling, and possible reductions in HSD churn, are also of interest.

The SafeVillage™ system was designed with those considerations in mind. It leverages the HSD infrastructure to provide a service comprising:

- Video and two-way audio enabled, centrally monitored residential security.

- Web-based communication using video and two-way audio between family members in the home and those at remote locations such as their places of work.

The service is designed to do this in a manner that minimizes the impact on HSD bandwidth utilization.

Because implementation reality often diverges from design intent, it was important to verify the bandwidth performance of the service through field measurements. This was done as part of a technology trial of the service hosted by Cox Communications using systems installed in 85 homes in the Las Vegas area. The methodology and results of this bandwidth utilization study are described below.

SERVICE OVERVIEW

The centrally monitored security aspect of the service allows abnormal situations in the home, such as intrusions, to be detected. The triggering event, which might be a trip of a motion detector, is reported to a central monitoring station staffed on a 24x7 basis by professional security operators. Upon reception of an alarm report, the operator must make a timely decision as to whether to dispatch police, fire, or emergency services personnel in the appropriate jurisdiction. To aid in this decision process, the service provides a live video feed from the home to the operator. The operator also can review potentially relevant recorded clips such as video from an outdoor camera overlooking the front door. In addition, the operator can use the system to listen to the home and, if appropriate, talk to people on the premises to verify the nature of the situation.

Authenticated members of the homeowner's family also can use the system on a demand basis to view the home from a Web-connected PC. In the technology trial, audio communication for such customer access was not supported, though two-way audio is supported in the commercial service. The customer also can select cameras and perform other control actions remotely.

Privacy and information security are extremely important elements of the service but are not discussed in this paper because they have little bearing on the question of HSD bandwidth utilization. Similarly, account and service management functions are not described.

DESIGN GOALS

System design goals with significance for bandwidth usage included:

- Provide video and audio suitable for use in rapid assessment of alarm situations at the central monitoring station (i.e., acceptable resolution, quality, and frame rate).
- Ensure that upstream traffic (alarm, control, audio, video, heartbeat) fits within a channel rate - limited to 128 Kbps.
- Limit the length of on-demand video viewing sessions to prevent abuse (e.g., to prevent continuous streaming to the customer's PC at work).
- Avoid excessive management traffic that contributes to background load on the HSD system.

SYSTEM ARCHITECTURE

An overview of the technology trial system architecture appears in Figure 1.

The service-enabling equipment installed at the customer premises included:

- A cable modem, access to which was shared with the customer's PC.
- Wireless motion detectors and door/window contact sensors.
- Video cameras.
- A user control unit for arming/disarming.
- An audio intercom and a wireless event receiver, both of which were integrated with the user control unit.
- A video transmission unit (VTU) for video capture and compression, audio analog/digital conversion, and video, audio and alarm communications over the IP infrastructure.

At the cable headend, in addition to the HSD Cable Modem Termination System, a digital video recorder (DVR) was installed. The DVR received and forwarded alarm event information reported from the customer premises equipment; received, stored, and forwarded video and audio transmitted to and from the customer premises; and maintained heartbeat communication with the equipment at the premises.

At the central monitoring station in Orlando, Florida, an automation system provided monitoring and business application support to security operators. The automation system received alarm event reports from the home and displayed them to the operators at PC-based workstations along with site and emergency contact information on a 24x7 basis. The operator workstations also allowed operators to view video streamed from the home during an alarm condition and to use two-way audio to listen to and interact with the home.

At the data center, which was located in a commercial co-location facility, a Web site mediated access by the user to remote viewing and control functions.

From an Internet-connected PC at an arbitrary location such as the homeowner's office, the user could interact with the Web site and with the DVR to carry out remote viewing and remote control such as camera selection. Both live viewing and viewing of video recorded at the DVR, e.g., a video clip showing a package being delivered to the front door, could be performed.

IP-based communications between the VTU in the home and the headend-based DVR took place over the HSD infrastructure, including event reporting, video, audio, control, and heartbeat traffic.

Communications between the DVR and the systems in the central monitoring station used IP over a frame relay permanent virtual circuit.

Communications between remote PCs and the Web site, and between remote PCs and the DVR, occurred over the public Internet.

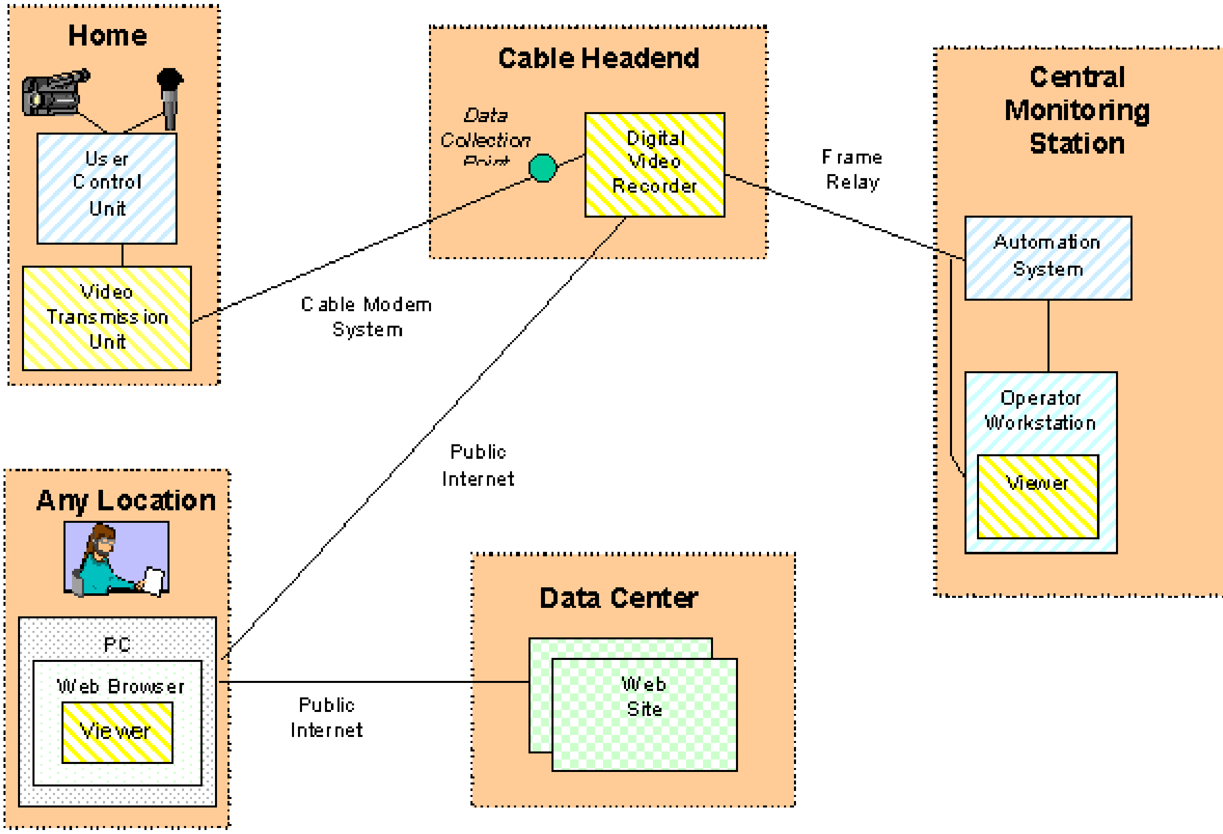

Figure 1. Technology Trial System Architecture

<u>BANDWIDTH STUDY OBJECTIVES</u>

Beyond the need to gain empirical evidence of the capacity impact of the service, a field study was warranted for additional reasons:

- Laboratory measurements cannot quantify individual user behavior such as the frequency of on-demand viewing and the length of a viewing period (although sessions had automatic timeouts, a user could request session renewals to extend the viewing period).
- Aggregate or collective behavior across a user population cannot be gauged in the lab to understand, for example, high levels of on-demand traffic and the relationship between service busy periods and overall HSD busy periods.

With this in mind, key objectives of the trial service bandwidth study were to measure:

- the effect of the service on the upstream HFC path,
- the effect of the service on the downstream HFC path, and
- the effect on the headend Internet connection (both outbound and inbound).

An additional objective was to estimate the potential capacity impact on the HFC infrastructure that would result from high service penetration in an area served by a single fiber node.

DATA COLLECTION METHODOLOGY

In the trial system configuration, all service traffic was routed through the DVR in the cable headend, which provided a convenient data collection point, as noted in Figure 1. This was exploited for these purposes by enabling port spanning in an adjacent Layer 2 switch, allowing all Ethernet frames into and out of the DVR to be sent to a port sniffer on a PC attached to the switch.

Data reduction software allowed time-stamped Ethernet frame headers and IP packet headers to be captured without recording of payload data. Daily uploads and post-processing (filtering, correlation, etc.) were performed off-line using various tools.

MEASUREMENT RESULTS

Typical measurements of upstream traffic from the entire trial population of 85 installations appear in Figure 2 using 30-minute averaging intervals. The aggregate traffic floor, largely consisting of heartbeat messages, typically totaled around 5-6 Kbps (about 70 bps per installation). Traffic peaks correspond to video streaming activity between one or more VTUs in homes and the DVR in the headend. Nearly all of this activity was due to on-demand viewing by homeowners or automatic, non-alarm video recording (triggered by exterior, front-door activity).

Peak on-demand viewing periods tended to occur on weekdays during the afternoon and early evening.

The 30-minute averaging in this chart does not provide a good indication of average per-video session data rates during streaming, but measurements using one-minute granularity showed a consistent average of around 95 Kbps per video or video/audio stream.

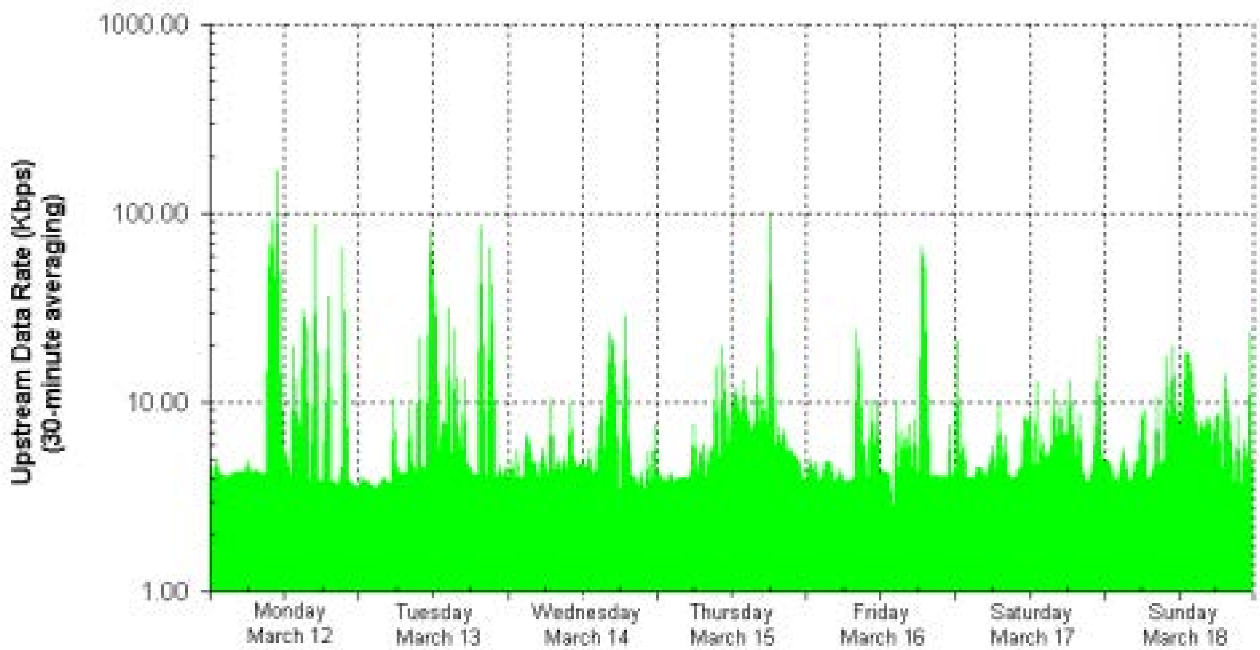

Figure 2. Aggregate Upstream Service Traffic

As shown in Figure 3, the number of concurrent video sessions across the trial population was small, ranging from zero to three in the week shown (and never rising above four actual sessions during the study). This is consistent with the fact that session durations for on-demand viewing and non-alarm event video recording were typically no more than a few minutes, and with the fact that there were no obvious influences that would cause a strong correlation in the timing of viewing by users from different households.

It should be noted that scenarios can be anticipated that could induce correlated behavior, e.g., a tornado warning on a weekday that stimulates many users to attempt to view their homes around the same time. Service-based admission control and congestion management techniques may be appropriate for dealing with such situations.

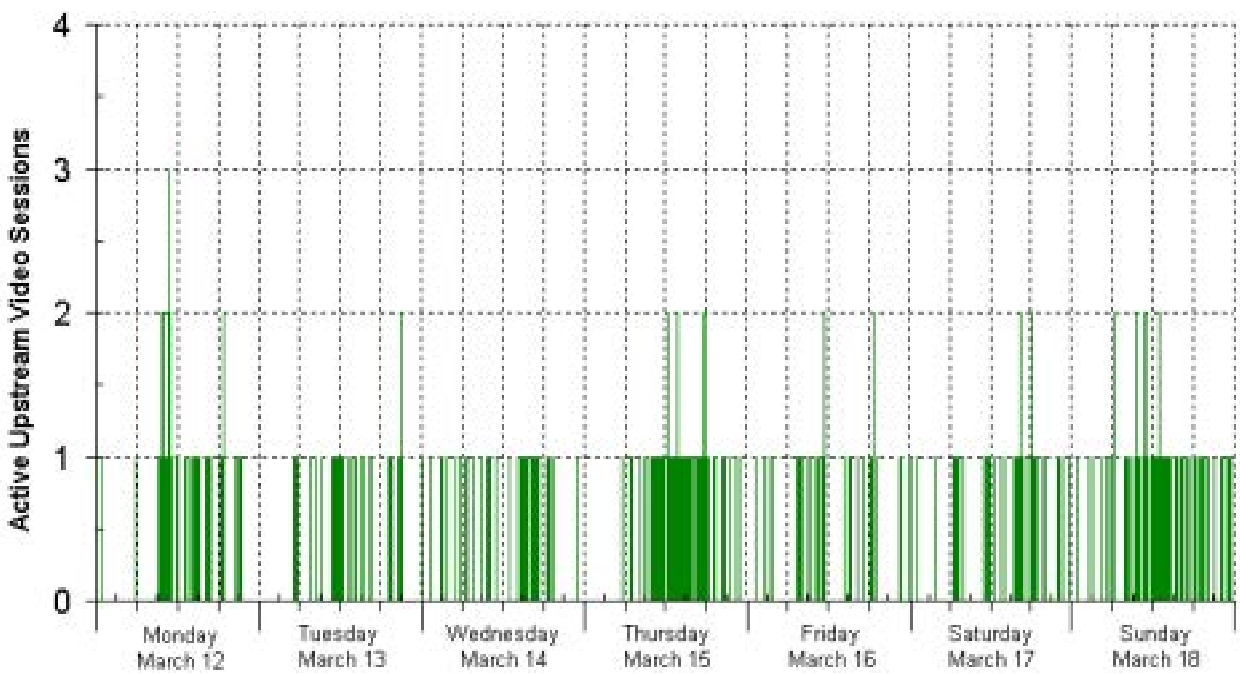

Figure 3. Active Video Sessions

From Figure 4 it may be seen that ten out of 85 installations (11 percent of the trial population) accounted for about 42 percent of the total traffic in the week shown. Over the entire course of the study (roughly ten weeks), the top ten accounted for about 36 percent of the total traffic.

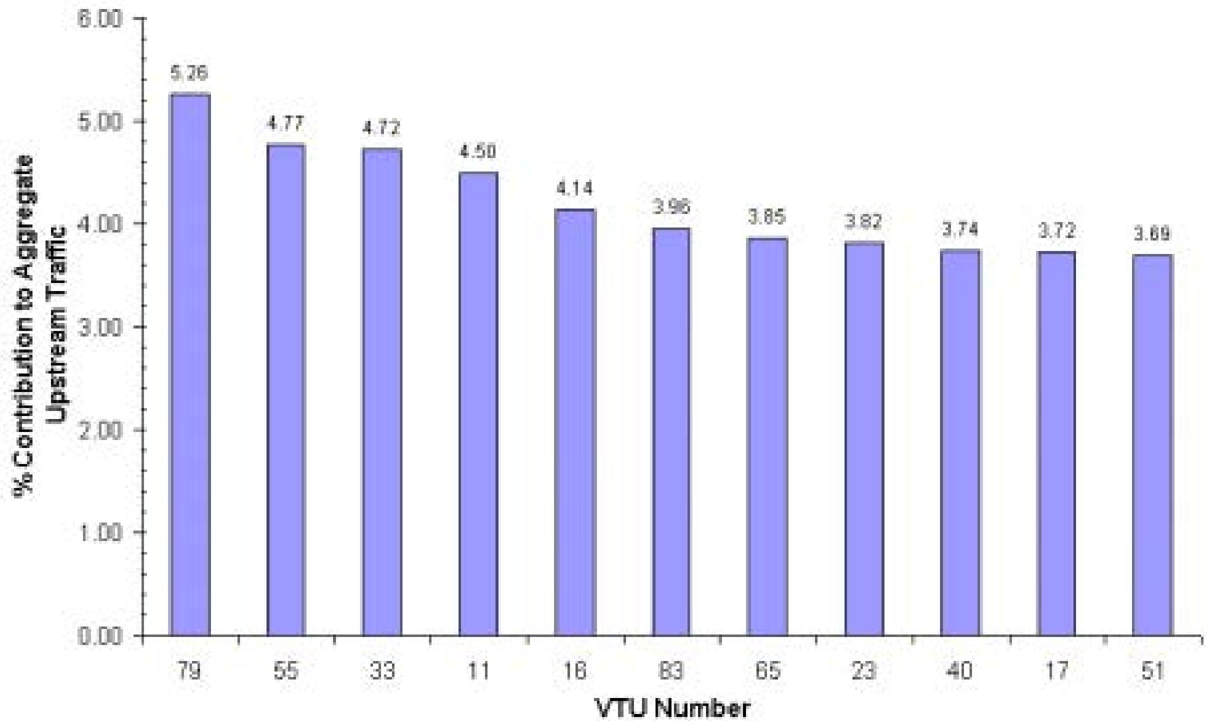

Figure 4. Contributions by Individual Users to Aggregate Upstream Service Traffic

As indicated in Figure 5, most video streaming sessions were only a few minutes in length. It should be noted, however, that the distribution is skewed downward by video recording performed automatically as a result of front-door activity (as opposed to user-initiated, on-demand viewing); these two forms of streaming could not be distinguished with the data collection instrumentation used.

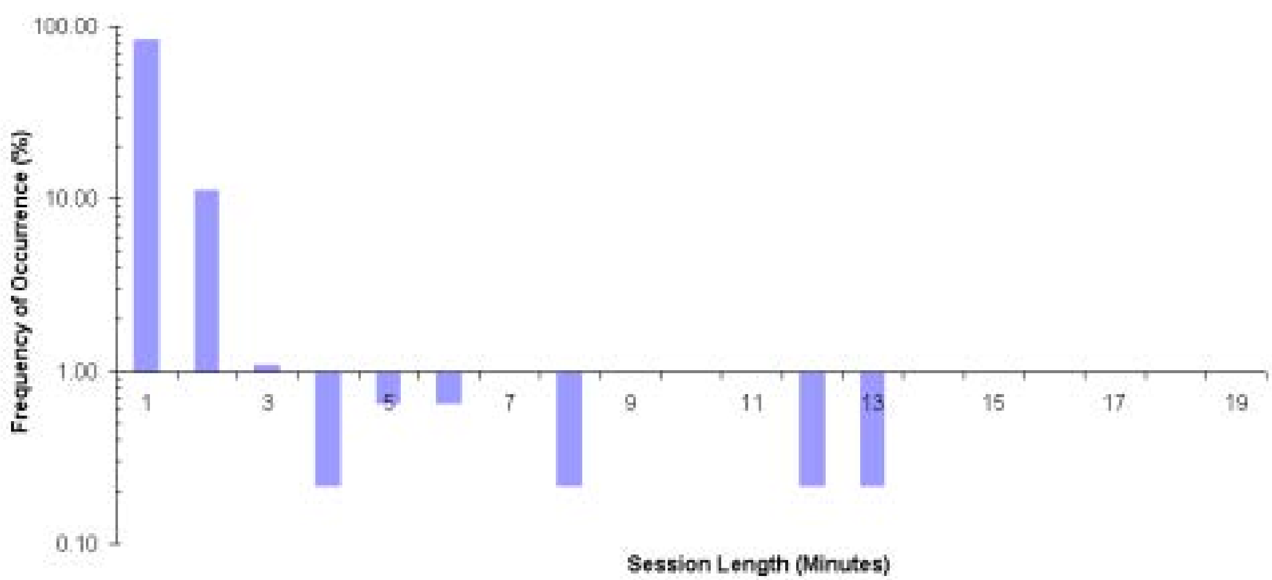

Figure 5. Video Session Durations

Aggregate downstream traffic is shown in Figure 6. The traffic floor averaged 11-12 Kbps across the trial population. The larger peaks reflect system management activity (e.g., software downloads to VTUs installed in homes).

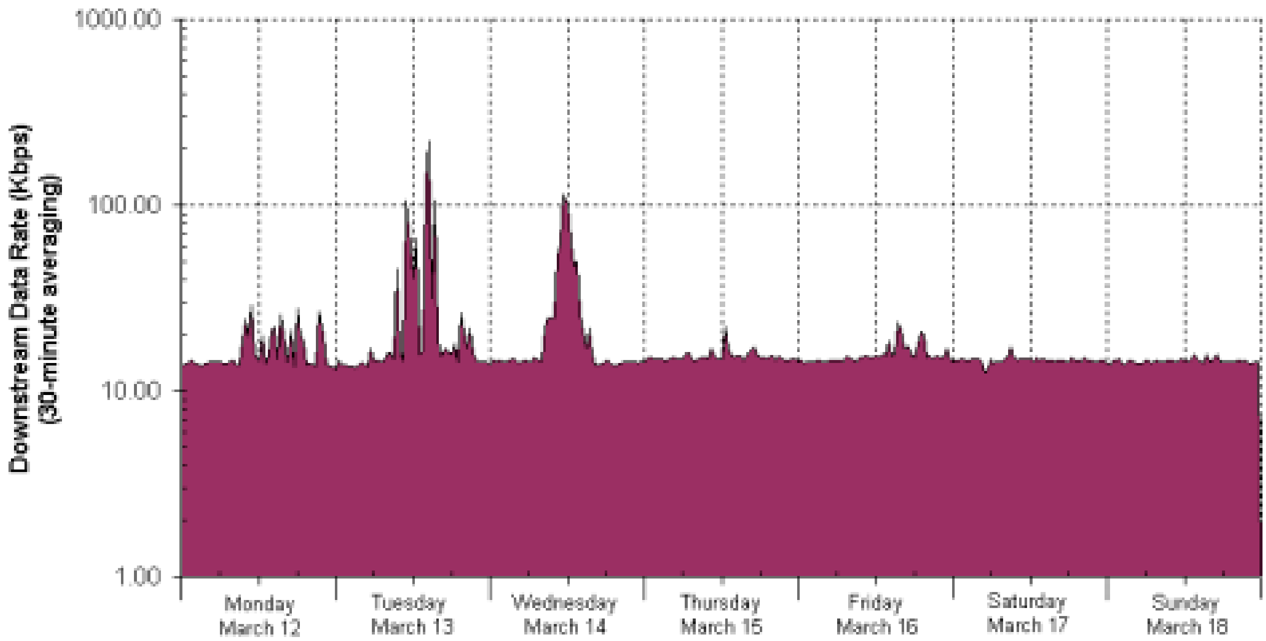

Figure 6. Aggregate Downstream Service Traffic

Aggregate outbound Internet traffic from the DVR in the headend is shown in Figure 7. A comparison with Figure 2 highlights the absence of the 5-6 Kbps floor from heartbeat traffic, which was not relayed by the DVR onto the public Internet connection. Also, peaks in Figures 2 and 7 differ to some extent due to the fact that non-alarm video recorded on the DVR was not relayed over the Internet connection.

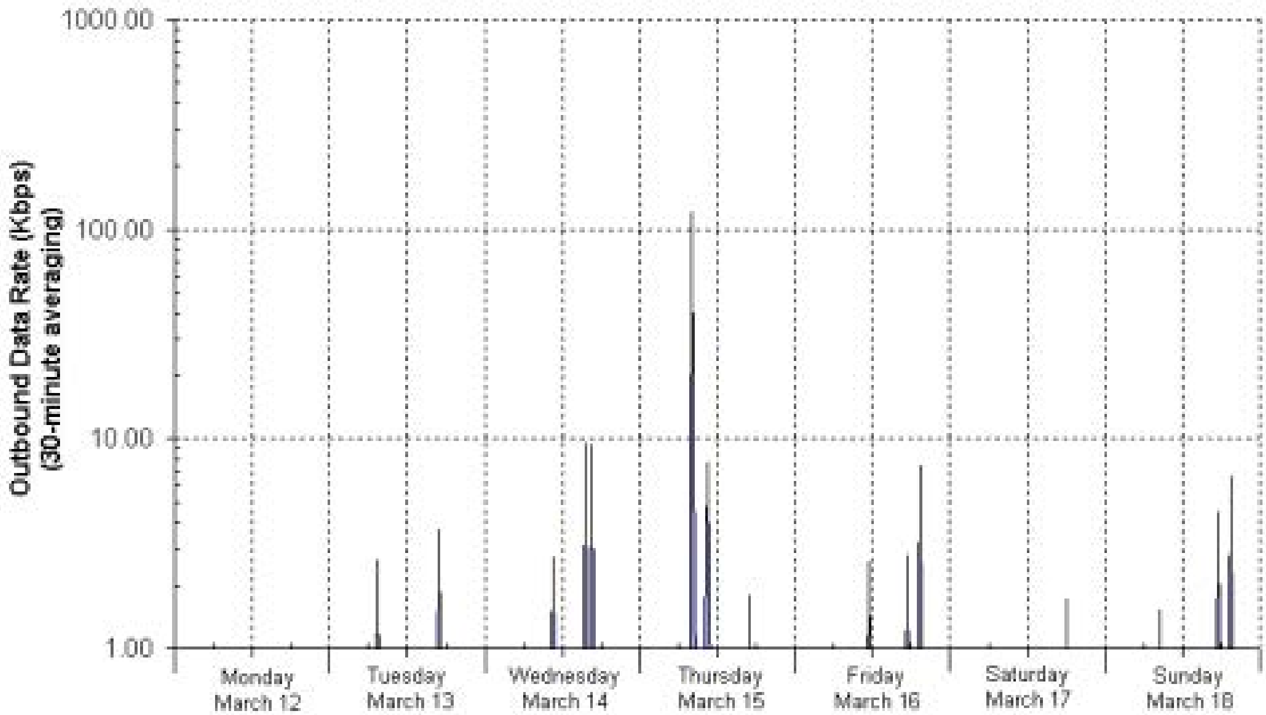

Figure 7. Aggregate Service Traffic Outbound to Internet

Total inbound traffic from the public Internet across the trial population as depicted in Figure 8 was minimal because it comprised only simple control messages such as viewing and camera change requests.

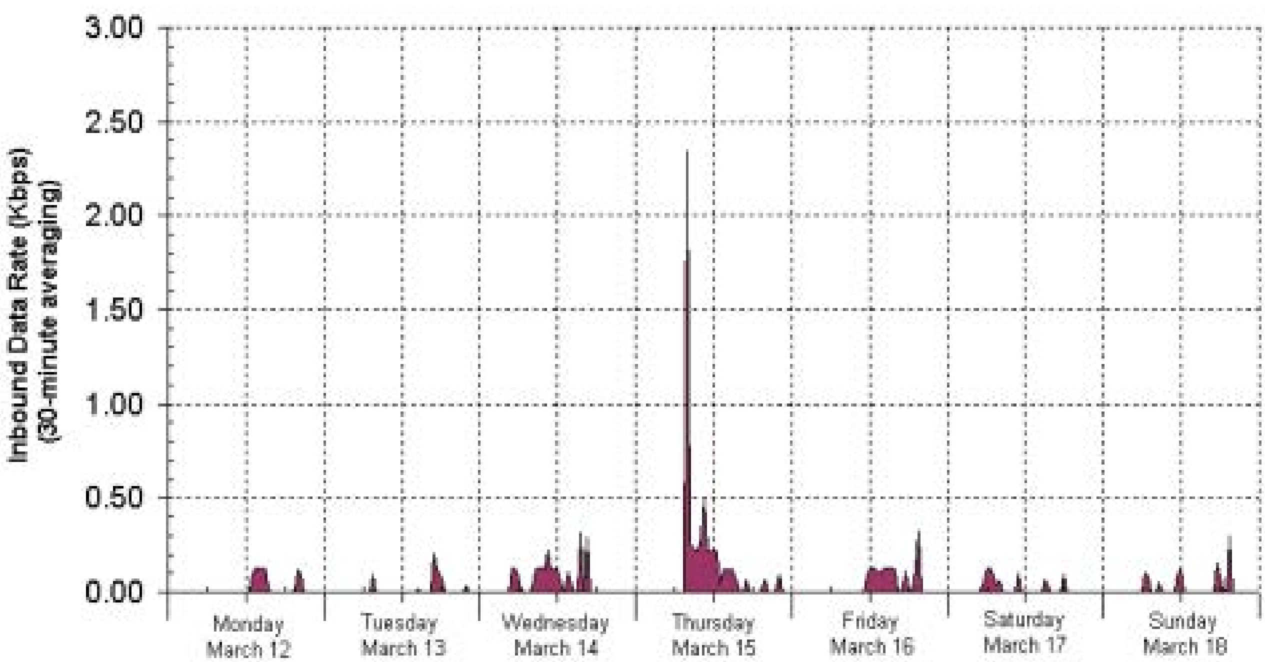

Figure 8. Aggregate Service Traffic Inbound from Internet

CONCLUSIONS

Essential findings – based on the trial service measurements and analysis – are summarized below.

Effect of the service on the upstream HFC path:

- The upstream bandwidth impact of the service was minimal with a traffic floor of 5-6 Kbps (largely heartbeat data) totaled across all 85 trial participants, and peaks rarely exceeding 120 Kbps.
- The top ten traffic generators (11 percent of the trial population) produced roughly 36 percent of the upstream traffic.
- The typical peak number of concurrent video sessions was two to three.
- The average length of a video session was 2 minutes 48 seconds.
- The typical data rate for a single video stream was 95 Kbps.
- Most on-demand viewing occurred during weekdays in the afternoon and early evening. The majority of the traffic seen in other parts of the day and during the weekend was from non-alarm and system testing activity.

Effect of the service on the downstream HFC path:

- The downstream impact of the service was insignificant with a traffic floor of 11-12 Kbps (primarily heartbeat data) totaled across all 85 trial participants.
- Downstream traffic peaks rarely exceeded 120 Kbps.

Effect of the service on the headend Internet connection:

- Both outbound and inbound Internet traffic were minimal. Outbound traffic peaks rarely exceeded 120 Kbps. Inbound traffic peaked at 4 Kbps and consisted of control messages only.

Projected impact of high penetration of the service on the HFC infrastructure under a given node:

To estimate this, assume an average fiber node size of 1,200 homes passed, an available upstream data rate per node of 1.9 Mbps, and a service penetration rate of 15 percent. Based on the technology trial bandwidth utilization measurements, estimates of the loads on the upstream HFC using one-minute averaging are as follows:

- Aggregate traffic floor on the HFC upstream: 11.6 Kbps.
- Peak concurrent live video user sessions: six to seven.
- Peak HFC upstream bandwidth utilization: 603 Kbps or 31 percent of the available upstream bandwidth per node.

Furthermore, use of the trial service measurements overestimates what the commercial service would exhibit assuming similar user behavior. This is because the architecture for the commercial service differs from that of the trial service. In the trial, all traffic was routed through the DVR located in the headend, including recorded non-alarm traffic from outdoor cameras overlooking the front entrance of each home, which used HFC bandwidth. In the commercial service, recording of all normal, non-alarm video is local to the equipment at the customer premises.

Thus, even with this high level of penetration, the service would not impose a significant burden on the upstream bandwidth. It therefore is an example of the type of service that can be very attractive by virtue of its potential as an additional source of recurring revenue with relatively modest impact on the HFC cost structure.

FUTURE WORK

Similar bandwidth utilization studies of the commercial service are planned to quantify the effects of changes to the system architecture such as the one described above. In addition, such studies are needed to understand the effect of possible differences in user behavior due to the addition of on-demand audio, and from the fact that users will be paying customers rather than trial participants.

ACKNOWLEDGEMENTS

The results reported in this paper reflect the efforts of a sizable team. Special recognition, however, is made of the following individuals:

- *Venkatesh Iyer,* for carrying out the majority of the data collection and analysis.
- *Kyle Cooper,* for trial system deployment and data collection instrumentation.
- *Richard Jennings and Harris Bass,* for driving the technology trial definition, implementation, and management.
- *Michael Hale and John Fountain (Cox Communications),* for guidance and review of the bandwidth study design and execution.
- *Jayson Juraska and Anthony Lee (Cox Communications),* for sponsorship and project management on behalf of the technology trial host company.

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