Switched Broadcast: Statistics From the Field

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Introduction

In a Switched Broadcast network, broadcast video programming is only transmitted to subscribers in node groups that specifically request such programming, as opposed to the status quo practice of flooding the digital cable spectrum with static programming at all times. As a result, traffic on the cable network is dynamic and subscriber-dependent, as opposed to being constant and determined by the range of content offered. At the January 2003 SCTE Conference on Emerging Technologies, BigBand Networks and Time Warner Cable illustrated these concepts in a presented paper, "Planning and Managing the Rollout of Switched Broadcast Services".

A number of factors related to the viewing demands of cable subscribers, the topology of today's modern HFC networks, and innovations in digital video switching technology have paved the way for Switched Broadcast to become a viable method for delivering expanded content. In a Switched Broadcast paradigm, cable spectrum is no longer looked at as a static collection of channels classified by static EIA frequency plans, but as a dynamic pool of digital transmission resources that, at any moment, could be serving any broadcast programming from any source. Logically, for even greater content expansion, this could eventually be extended to also encompass narrowcast VOD content, interactive television, or any digital service that could be developed and introduced in the future. Several commercial and technical forces are converging to raise the visibility of a Switched Broadcast delivery model.

In this prior paper it was stated that the bandwidth efficiency, cost effectiveness and overall power of this program delivery method is determined largely by the channel selection patterns of set-top boxes. Therefore, empirical data from actual deployments would be valuable not only for efficiency analysis, but also as an operational validation of the service itself.

This technical submission on statistics from the field provides a follow-on to the points presented in the ET paper by examining the results of a Switched Broadcast field trial conducted from November 2002-January 2003 with a major MSO.

In November 2002, a division of a major MSO began a Switched Broadcast field trial. A subset of the digital programming tier was offered on a switched basis to a limited population of set-top boxes in the system. Extensive logs of channel transaction activity were captured, and analysis of these logs provides insight into the performance of the solution in terms of user transparency and responsiveness, and in terms of dynamic stream allocation efficiency.

Switched Broadcast System Overview

The actions that take place when tuning a Switched Broadcast program differ from traditional broadcast tuning. In a traditional broadcast environment, *all* programming is sent downstream to a set-top box, along with tables that convey the Program Specific Information (PSI) and System Information (SI) for the transmitted programs. Using these

tables, a set-top box can determine the specific EIA frequency and program number associated with the desired program, and command the set-top box tuner and MPEG decoder to receive and display the selected program.

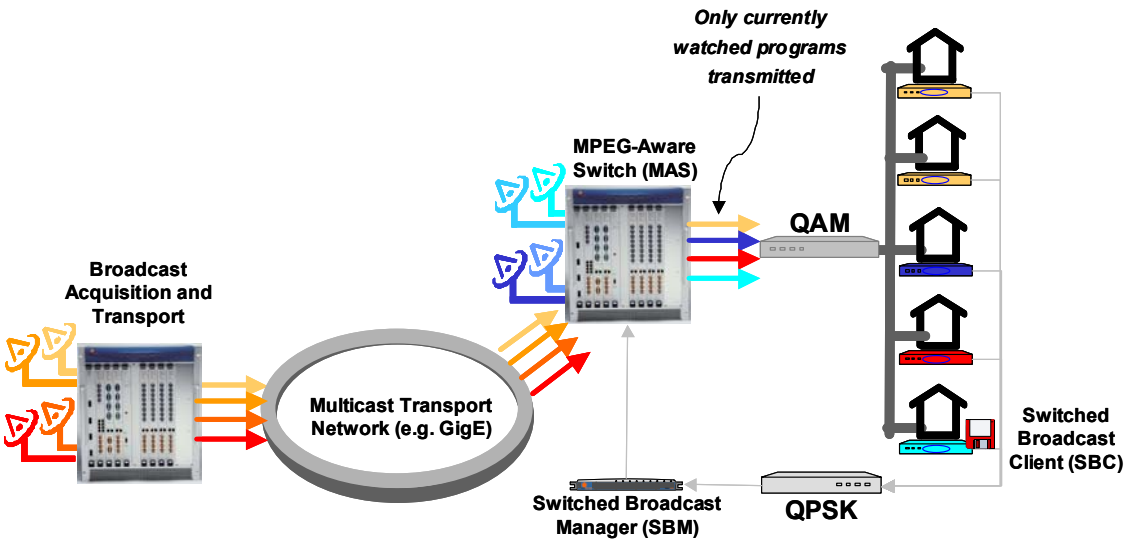

Figure 1 – Switched Broadcast Architecture

In a Switched Broadcast environment, the same tuning methodology is used, with a slight modification. The tables that carry the frequency and program information for the broadcast channels now vary with time. Therefore, the set-top box uses the QPSK out-of-band network to acquire the (now time-variant) tuning information. When this information is retrieved, the tuning process proceeds as normal. To the end user selecting a program via the electronic program guide or the remote control keypad, this is a visually seamless process.

Three components are essential to the provision of Switched Broadcast. These are: client software resident in the set-top, controller functionality at the headend, and, of course, the switch itself.

Switched Broadcast Client (SBC)

A Switched Broadcast Client (SBC) is a small software application resident on the set-top box. This client functionality can just as easily be integrated into the tuning firmware of future set-top boxes. This application is downloaded to the set-top box, typically on power-up, using the same application distribution carousel that is used for other set-top box software and applications. When a Switched Broadcast program is selected, this software component conveys the channel request as a short UDP/IP message via the out-of-band QPSK network, along with information that identifies the service group of the set-top box.

Switched Broadcast Manager (SBM)

The Switched Broadcast Manager (SBM) application is located in the hub or headend. The SBM uses the channel number received to identify the requested program, and consequently, the MPEG-Aware Switch (MAS) input port where the program is being received. Similarly, the SBM uses the service group identifier of the set-top box, either inferred from the set-top box address or directly conveyed by the set-top box itself, and determines the downstream connection (MAS output port) where the subscriber can be reached. In many cases, a subscriber can be reached by more than one downstream QAM channel. This collection of one or more QAM channels, and the dozen or so programs that can be carried in each QAM channel, represent a pool of stream resources that the SBM has at its disposal to fulfill programming requests within each service group.

When an available downstream QAM and the program resource are identified, the frequency and program information is returned via the downstream out-of-band channel to the set-top box, which decodes and displays the program using the normal tuning mechanisms. While the specific frequency and program number for a Switched Broadcast program may vary in time, the channel number as seen by the subscriber will always remain the same.

MPEG-Aware Switch (MAS)

Completing the solution and providing real-time video switching capability is an MPEG-Aware Switch (MAS). In order to perform the switching role effectively, an MAS should exhibit the following characteristics:

- High Input Fan-in: An effective Switched Broadcast solution allows a substantial and theoretically unlimited amount of programming to be switched into a bandwidth-limited set of downstream transmission resources. To achieve this, an MAS should support an input bandwidth that greatly exceeds its per port output bandwidth.
- Fast Switching Time: The amount of time required to switch an input program to an output port should be as small as possible, since this switching time is a component of the overall channel change time. Furthermore, the switching should take place in such a way that the switching process does not syntactically corrupt the output stream.
- Supplemental Media Processing: In addition to the pure switching process that takes place, it is useful for an MAS to have supplemental media processing capabilities as well. Such processing functions include, but are not limited to:
    - Remapping of PIDs and reconstruction of PSI
    - Processing of transport streams to correct PCR jitter
    - Remultiplexing and rate shaping of output streams as necessary
    - Transcoding of elementary streams from other formats as necessary

Channel Selection Process Flow

A Switched Broadcast channel change starts with the SBC application on the set-top box sending a channel request message upstream to the SBM. The SBM receives this message and reconciles the request against the available downstream resources. If a downstream resource is available, the SBM instructs the MAS to complete the downstream video connection (if it is not present already) and perform any stream processing that may be necessary. The downstream resource information (the QAM frequency and Program Number) is returned to the set-top box, which tunes the program.

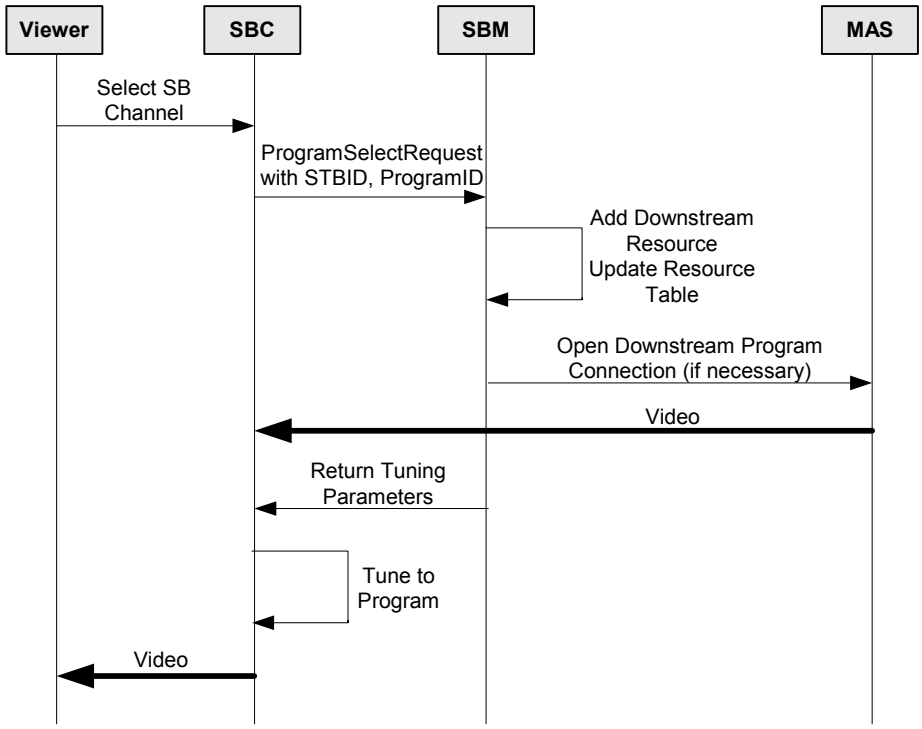

Figure 2 - Switched Broadcast Channel Selection Sequence Diagram

Channel selection for subsequent viewers of the same program follows a similar sequence, but the process is simplified. If the requested program is already being transmitted downstream, then the SBM simply needs to return the appropriate tuning information to the set-top box.

Field Trial Description

A field trial was conducted to validate the operation and statistical efficiency of a Switched Broadcast implementation. In this trial, specific broadcast content was designated as part of a Switched Broadcast tier. When one of these Switched Broadcast programs was selected, a small set-top box client application would communicate the channel request using the

upstream out-of-band network. The corresponding tuning information for the program would be returned to the set-top box using the same out-of-band network, and the set-top box would tune the channel using the normal tuning APIs provided by the set-top box operating system.

Location and Duration

At the time of this writing, permission had not yet been granted to publicly disclose the location and sponsor of the field trial. However, it can be stated that the trial was conducted by a top 5 North American MSO at a location in the United States. This system passes 450,000 homes, and features 72% cable penetration and 35% digital penetration (of cable subscribers).

In this system, broadcast programming is delivered from a small number of headends located in the region. Programming is distributed via a combination of QAM/RF and DVB-ASI transport to a number of subtending hubs.

For the trial, a specific hub was identified that had ASI transport and an ample subset of subscribers to allow for manageable and observable system operation, as well as provide meaningful insight into the operation and statistical behavior of the subscribers.

The trial officially commenced on November 19, 2002. It continued without incident until January 29, 2003, yielding a trial period of approximately 10 weeks. Log files for the entire month of December 2002 were pulled and analyzed, and served as the basis for the data analysis provided in this paper.

System Environment

The division that sponsored the trial runs a digital cable network with system components from Scientific-Atlanta (SA). The Switched Broadcast system interfaced with DNCS version 1.5, and was qualified with SA Explorer 2010, 2100 and 3100 set-top boxes running PowerTV OS v3.1 and SARA v1.21, and SA Explorer 8000 set-top boxes running PowerTV OS 6.0.3sp(6) and SARA 1.80.43s9(0). In addition, the system was qualified with Pace 5101 and 5510 set-top boxes running PowerTV OS v2.4.2 and SARA 1.21.

The SA DNCS system is configured to transparently execute the Switched Broadcast Client (SBC) whenever a Switched Broadcast channel number is selected.

Programming and Subscribers

A subset of the digital programming package was segregated into a separate Switched Broadcast tier. Specifically, a popular subscription sports programming package was identified as a candidate for the trial. Statistically, broadcast content subscription sports packages [do you mean a multiplex sports package?] make excellent candidates for Switched Broadcast, given their low subscription penetration and high use of stream/QAM resources.

In the hub that was chosen for the trial, 51 digital subscribers were identified who had subscriptions to the sports package carried on the digital tier. When the trial was commenced, these subscribers were able to watch the same sports programming as they always had, except that the streams were now being delivered downstream to the set-top boxes on a dynamic "on-demand" basis.

The sports package programming content was selected for a number of reasons. Since the majority of programming for content of this nature falls on evenings and weekends, this programming serves as an excellent candidate for Switched Broadcast, given its aperiodic viewing profile. Secondly, the nature of the sports programming being offered also exhibits a wide variance in popularity. A contest between two regional basketball teams would likely be of only limited interest when that program is broadcasted out-of-region, thus making it even less attractive to broadcast to wide subscriber distribution. Finally, sports programming packages represent a premier class of service for the operator, thus efficient means of bringing more programming of this nature to the broadcast tier raises the profile and potential revenue opportunity for the operator itself.

During the trial, detailed log files were maintained to track the channel changing activity. The analysis of these log files reveals valuable information to understand the nature of program viewing, as well as assess the efficiency of the Switched Broadcast service and to make intelligent speculations about the viability of Switched Broadcast as a larger-scale generalized delivery service.

Trial Objectives

The trial location, selection of programming and subscriber group were carefully chosen to allow a level of system operation that would be easy to manage and monitor, while yielding statistics that could be extrapolated to assess the performance with different sets of programming and subscriber pools.

While the fundamental goal of the trial was to empirically assess the viability of Switched Broadcast as an effective delivery service, a number of supporting goals were identified to monitor and assess. These were:

1. *Operational Integrity*. The deployment of Switched Broadcast requires the efficient and fault-tolerant operation of the functional components that perform the dynamic switching of broadcast streams. Since a fundamental product of the cable industry, the delivery of broadcast television programming, was dependent on these components, it was important to deploy a bug-free solution that could reliably meet the performance requirements of thousands of channel change messages from set-top boxes.

2. *User Transparency*. A key success factor of Switched Broadcast is in its ability to "look like" a regular broadcast program to the end subscriber. This requires a fast and scalable system to process channel change request messages and switch streams to the end user. It also requires a set-top box application and architecture that can

seamlessly link to the existing electronic program guide and tuning firmware to select, decode and display a Switched Broadcast program.

3. *Statistical Efficiency*. The true power of Switched Broadcast lies in its ability to offer *more* programs than can be simultaneously supported by the physical stream resources that are provisioned in the network. This delivery model is supported by a look at the statistical nature of program selection and viewing, which reveals that some programs are more popular than others, while others are not very popular at all. This paper takes a look at trial log data to gain a better understanding of the nature of program selection and viewing. By intelligently measuring and analyzing the time-variant viewership patterns of each program, intelligent stream resource allocation techniques can be applied to allow the highest number of programs to be offered with the lowest amount of investment in general stream resources.

Statistical Results

The logs that are captured by the Switched Broadcast Manager reveal a lot of useful information in understanding the nature of channel selection by subscribers. While it is true that ratings services such as Nielsen can provide information relating to the general popularity of a given problem [program?], the Switched Broadcast logs can reveal a finer level of information, e.g. the duration that viewers remain on a particular channel, or the period of time in the day when channel changing activity is the greatest/lowest.

The graphs shown in this paper are the result of the preliminary analysis of 31 days of Switched Broadcast log data, representing the entire month of December 2002. For the preliminary analysis, two types of statistics were sought from the logs:

1. General channel activity – to better understand the nature of channel selection over a period of time. This information provides insight into the temporal nature of channel selection and allows system designers to assess the bandwidth and processing requirements of Switched Broadcast functional components.

2. Program Popularity – to understand, over an aggregated period of time, the relative popularity of programming, as determined by the quantity and type of channel selection messages received by the Switched Broadcast Manager.

Channel Message Activity Over Time

Figure 3 represents the number of channel change messages logged over the December 1 – December 31 period. It serves as a simple view over time of the channel activity.

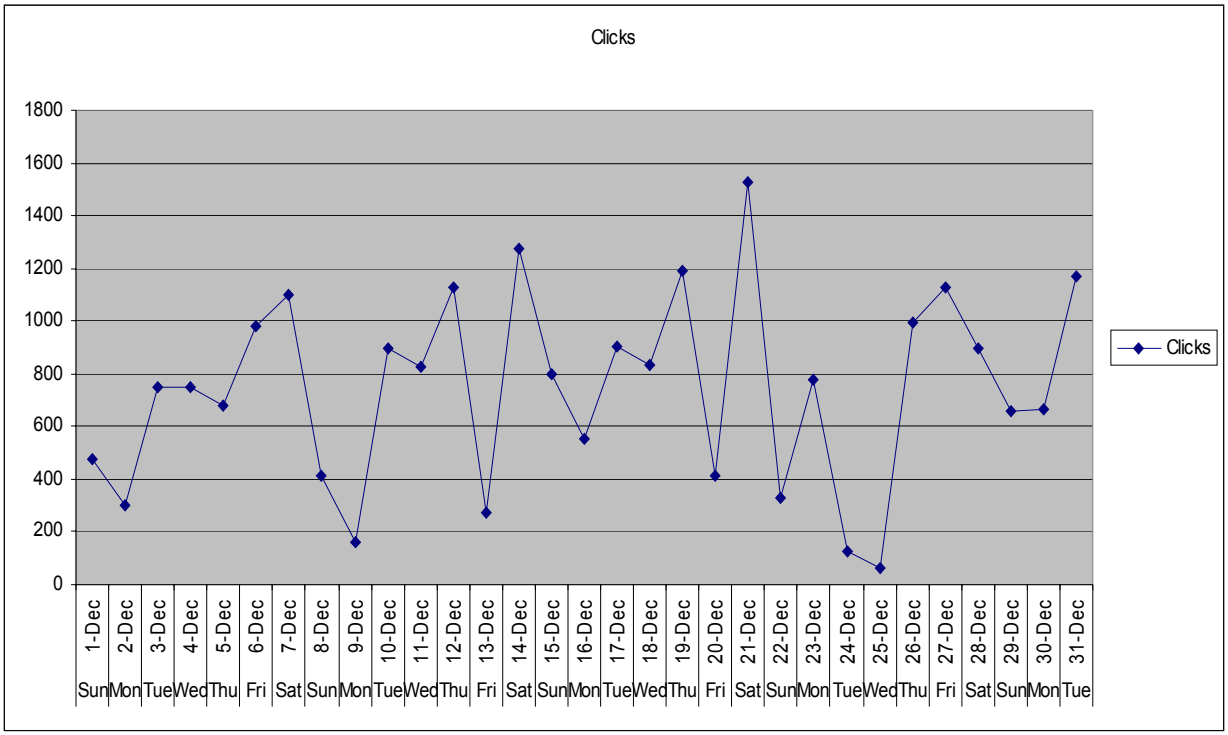

Figure 3 – Channel Change Messages per day, December 1-31

The graph provides a number of interesting points of observation. The channel change messages, or "clicks", are plotted over the course of the month. From the data, it is interesting to observe that the times of high activity tends to fall on weekends. This is consistent with expected viewer behavior, and is possibly further explained by the genre of the offered programming content, subscription sports programming in this case. Also note that the low point in channel selection traffic occurs during the holiday window of December 24-25.

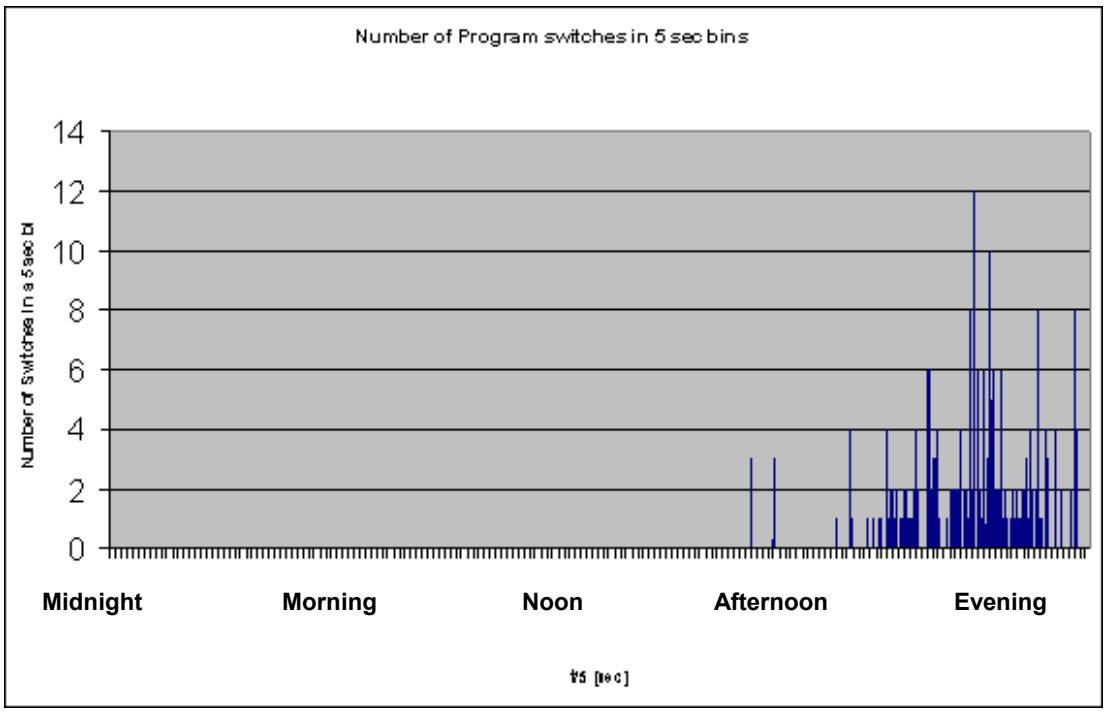

Figure 4 – Channel Change Messages per day, December 1-31

Figure 4 shows the same level of activity, except as viewed over the course of a 24-hour period (starting at midnight) on December 5th. Note that the bulk of channel viewing activity takes place between the hours of 6pm and midnight, which is also consistent with the genre of sports event programming being the main source of content. As a stream resource, this data is also indicating to us that this programming could easily blend with programming that makes temporal demands during a different time period, e.g. a financial news channel that would experience more viewership during the daytime.

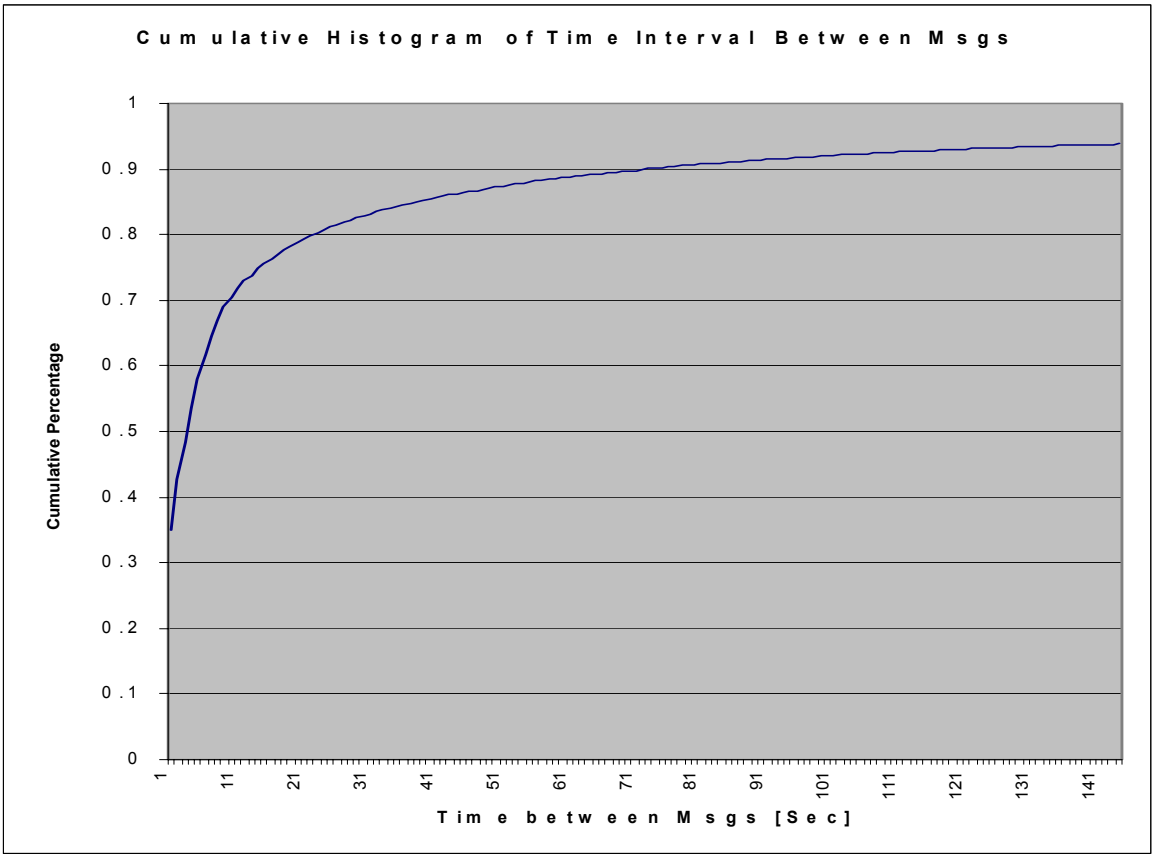

Figure 5 – Cumulative Histogram of Channel Viewing Duration

Figure 5 shows another perspective in channel changing. In this graph, the duration that a viewer stays on a channel is measured. From the graph, we can see that 70% of the time, the viewing duration is less than 10 seconds. This suggests a substantial amount of short-duration channel changes or "surfing" is present. A good Switched Broadcast system should contain a rapid and robust channel message processor and MPEG-Aware switch that can intelligently filter and process this type of traffic.

From any perspective, data on content activity is certainly valuable to assist in lineup and advertising planning.

QAM Utilization

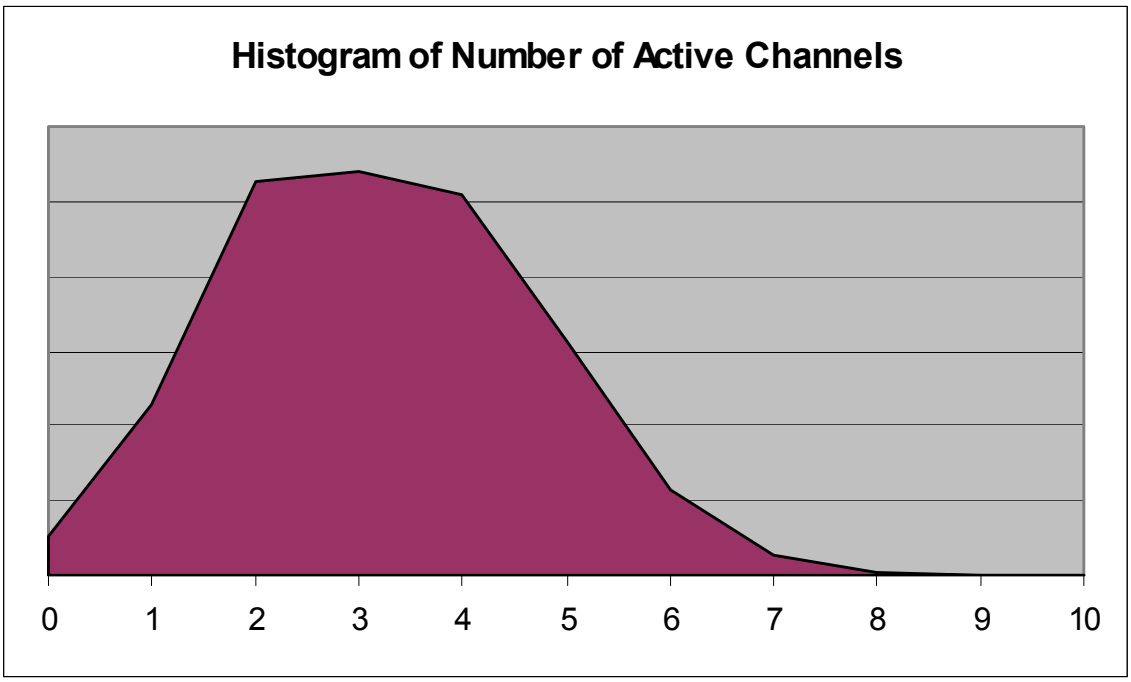

Figure 6 – Histogram of QAM Channel Utilization, December 1-31

Figure 6 shows the utilization of the downstream switched QAM channel during the trial. 10 programs were offered on a single QAM on the Switched Broadcast tier. In this graph, we can see that on average for the months of December, 3.2 programs, or 32% of the channel was occupied. The log data also revealed that at any given point in the month of December, no more than 8 streams or 80% of the channel was occupied at any given time. These numbers are encouraging, and support the hypothesis that the channel is not fully occupied most of the time.

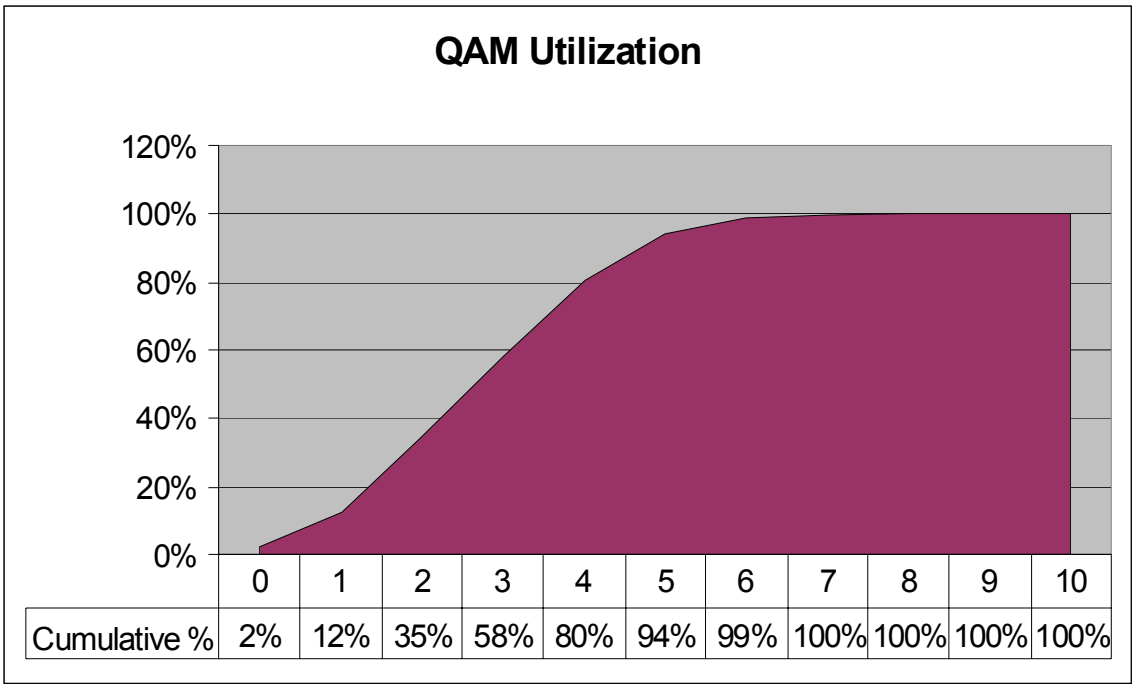

Figure 7 – Cumulative Histogram of QAM Utilization, December 1-31

A more revealing view of the same information is shown in Figure 7 as a cumulative probability. In this graph, we see that 80% of the time, 4 or fewer programs are occupying the channel, and 99% of the time, 6 or fewer programs are occupying the channel. This is an important observation, and suggests that there is ample capacity to allow the channel to be "superprovisioned" with more programming.

Summary

To summarize this paper, let us review the original goals of the trial, and the resulting trial data that supports these goals.

1. *Operational Integrity*. While the statistics for set-top box viewership present some interesting perspectives, a parallel goal of the trial was to demonstrate that the technology to enable the dynamic switching of broadcast streams was present and viable. During the 10-week trial, the Switched Broadcast Manager serviced channel request messages and switched program streams without incident, and required no downtime support for debugging or performance reasons. Channel message logs provided a good measure of subscriber viewing and "clicking" activity, which will provide valuable feedback for the design of packet processing subsystems for the Switched Broadcast Manager.

2. *User Transparency*. Prior to the trial, the operation of the Switched Broadcast system underwent an extensive lab qualification with a variety of set-top boxes, in the labs of both the vendor and the MSO sponsor. When the trial was launched, it was done as a "midnight upgrade" in the designated hub for the trial system. The trial

subscribers thus underwent the trial without any knowledge that the broadcast programming they were selecting was being dynamically made available for viewing. During the trial the MSO sponsor reported that no service calls were taken regarding the quality of service offered on the Switched Broadcast tier.

3. *Statistical Efficiency*. The utilization graphs presented show a great opportunity for the superprovisioning of programming content in a Switched Broadcast system. This allows a greater level of content to be offered with the same physical number of QAM resources.

Switched Broadcast represents a shift in the way of considering broadcast service delivery that can cost-effectively enable the next generation of service expansion for operators. While initial operator interest in Switched Broadcast was centered on finding an efficient means to deliver niche programming, the interest in Switched Broadcast has since expanded in scope. Operators in some systems are now considering deployments of Switched Broadcast across the entire digital broadcast tier, especially in systems that have not yet been upgraded in plant capacity and need a more intelligent and cost-efficient vehicle for programming capacity expansion.

The statistics drawn from the trial represent a limited set of subscribers and programs, which was done by design. Yet, the log data was revealing enough to validate the basic principles of Switched Broadcast as an effective and promising means of program capacity expansion.

The successful execution of this trial represents a great milestone in the introduction of this technology, with a very affirming demonstration of the possibilities of channel expansion with *no plant modifications*, using the *existing base of set-top boxes*. Future studies and deployments of Switched Broadcast will continue to provide more illuminating information about efficient program delivery and viewership in the digital cable network.