ADVANCED MONITORING OF SWITCHED BROADCAST SYSTEMS

Ludovic Milin and Ran Oz
BigBand Networks

Abstract

Switched broadcast has become a viable technology for reclaiming bandwidth and optimizing spectrum, allowing richer program lineups and increasing personalization of content. By leveraging switched broadcast cable operators are able to offer subscribers hundreds of high definition programs and long tail content, such as coverage of local sporting events, without requiring plant upgrades to expand capacity.

This paper presents data gathered from multiple switched broadcast deployments to illustrate the imperative of monitoring system performance and the resulting benefits to operators.

The authors assert that performance monitoring should be applied at three key stages of deployment of a switched broadcast system:

1) Prior to Deployment – during this stage an operator must assess which programs in its broadcast lineup are viable candidates for putting on a switched tier. A non-intrusive analytical tool is, arguably, the best way to collect viewership statistics for all available programming, allowing identification of "long tail" content.

2) During Deployment – while a switched broadcast system is being implemented an operator will benefit from leveraging the same monitoring platform used in the prior characterization effort, potentially still gathering viewership data on broadcast programming.

3) After Deployment – once the installation has been completed the monitoring focus can be broadened to allow identification of trends, such as an unanticipated growth, that may lead to insufficient bandwidth being available to support all channel requests. Early identification of such trends can allow pro-active remedies, minimizing negative subscriber impact.

The authors also highlight the imperative of protecting consumers' privacy and describe how the techniques used to collect viewership data can be made to comply with the 1984 US Cable Privacy Act.

INTRODUCTION

Switched broadcast came of age recently as two major North American cable operators deployed the technology in several markets. Switched broadcast currently supports over six million homes passed and switches one million set-top boxes. With other cable operators evaluating the technology and undertaking field trials, the footprint of deployed switched broadcast systems is set to grow rapidly.

By reclaiming the bandwidth that would otherwise be consumed by delivering unwatched content, switched broadcast provides cable companies the opportunity to expand the amount of programming they offer subscribers. However, the oppprtunity to provide thousands, even tens of thousands, of programs requires operators to evolve the methodologies used to track viewership of that content. The ability to collect statistics, in real-time, about which programs subcribers are watching is necessary for successful capacity planning and deployment of switched broadcast systems. The insights gained from collection of this data facilitates rapid and smoother deployment of switched systems.

Valuable statistics include the viewership of linear and switched broadcast programs, the number of active STBs (set-top boxes) per service group, and the bandwidth utilization within service groups.

Additionally, the ongoing collection of information enables round-the-clock performance monitoring, leading to opportunites for pro-active network maintenance. Data about blocking events, failures for STBs to tune to the requested channel and network response times can all be analyzed, leading to enhanced performance and, ultimately, increased subscriber satisfaction.

In addition to the operations benefits obtained from deploying a statistics monitoring tool, the ability to build accurate and complete records of viewership behavior introduces new revenue possibilities. Personalized news is one example of ways that precise viewership records collected by a statistics monitoring tool could be leveraged for new revenue generation. Another is addressable advertising, which matches ads more closely to subscribers' interests, by leveraging insights into which content viewers are habitually tuning to.

Finally, while the use of third-party market research firms has generally been sufficient to obtain insights into subscriber viewing habits, the plethora of new programs that will be available to subscribers in switched environments makes this task more daunting. The value of this information is high because it provides insights into the viewing patterns of all subscribers on the switched tier, not just the subset of viewers that have been enlisted and whose viewing habits may not necessarily represent those of the majority.

This paper describes a method for collecting statistics that supports the applications described above, namely:

- Capacity planning;
- Diagnostics;
- Content personalization;
- Addressable advertising;
- Market research.

This paper discusses each of these applications in depth and cites the specific benefits of a statistics monitoring platform in each instance. It begins, however, with a description of how the platform functions.

ARCHITECTING NETWORKS FOR STATISTICS RETRIEVAL

The statistics monitoring / diagnostics platform proposed by the authors consists of the following components:

- Collection Engine – gathers STB activity logs from the servers, known as SBSSs (switched broadcast session servers), used to manage a switched broadcast network;
- Analytical Engine – processes the STB activity logs gathered from the network;
- Data Warehouse – stores the data and metadata obtained from the both the network and analytical components, and supports long-term storage for trending analysis;
- Webserver – provides a user-friendly interface to customize and view reports.

Figure 1 shows how these elements are combined in a generic switched network.

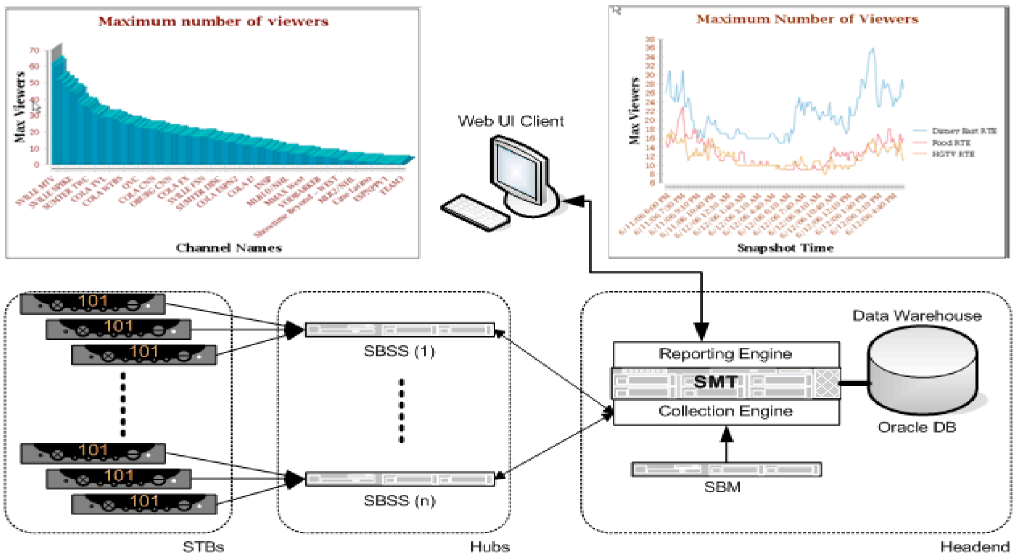


Figure 1: Components of a statistics management platform

Rather than the traditional store and forward approach in which each STB dedicates a portion of its memory footprint to recording activity and, on a regular basis, sends large UDP (user datagram protocol) packets over the OOB (out-of-band) upstream path to some collection server, the authors recommend an approach that has no impact on the STB memory footprint or the OOB network. This feature stems from each message requiring only about 64 bytes. This approach, which leverages standard switched broadcast protocols, is not sensitive to packet loss between an STB and the data collection engine. It is not tied to a specific switched broadcast client or headend environment – any LOB (load on boot) or native switched broadcast client can be utilized to send STB activity messages to the SBSS.

An example of these STB messages is presented in Figure 2.

The same protocols can also be leveraged to monitor linear broadcast channel activity via simple reconfiguration of the switched broadcast client on an STB. This enables activity messages for all channels to be sent upstream instead of only those on the switched tier.

The real-time metrics derived from the protocol messages can be grouped into general audience metrics and specific switched broadcast performance metrics.

General audience metrics (for both switched and linear programming) include:

- Number of viewed channels per service group;
- Overall bandwidth utilization per service group;
- Number of active STBs per channel and per service group;
- Number of tune-ins and tune-outs per channel and per service group.

Switched broadcast performance metrics include:

- Switched broadcast QAMs occupation ratio per service group;
- Number of tune-ins to previously unmapped channels per service group;
- Time to map previously unwatched channels per service group;
- Upstream bit rate per servce group;

- Number of blocking events (bandwidth not available) per channel and per service group;
- Number of other errors per service group (unresponsive STBs, tuning errors, and so on).

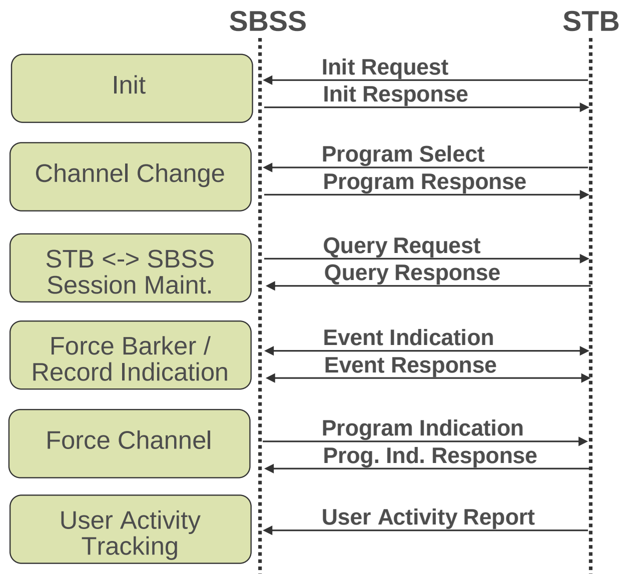


Figure 2: Example of protocol messages communicated between the STB and the SBSS

The following assumptions were made during development of the statistics collection and analysis tool described in this paper:

- A service group is a group of nodes;
- Each node serves multiple households
- A hub serves multiple service groups;
- An SBSS supports multiple service groups;
- All nodes in a service grup are served by common switched RF spectrum;
- The SBSS shares the RF spectrum;
- The SBSS logs all STB activity in real-time (channel changes, keep alives, last user activity, and so on.)

A common set of assumptions simplified and accelerated creation of a diagnostics tool and enables the analysis it performs to be more effective / broadly applicable.

The figures presented throughout this paper are screen captures from the web-based user interface of the diagnostics tool. The reports can also be configured to output pdf files for easy sharing amongst a working group, and CSV (comma–separated values) files so the raw data in the reports can be analyzed further. The data was gathered from deployed switched broadcast systems in multiple cable networks.

APPLYING PERFORMANCE MONITORING: THREE SCENARIOS

There are at least three scenarios where the ability to collect viewership statistics and performance diagnostics can be especially valuable:

- Before deployment;
- During deployment;
- After depoloyment.

Each of these scenarios is discussed in the following sections.

BEFORE DEPLOYMENT

To ensure best-of-breed network performance a cable perator should assess which programs to put on the switched tier. A non-intrusive analytical platform is, arguably, the best way to collect viewership statistics for all available programming, and enable identification of "long tail" content. This type of platform can also provide the parameters necessary for modeling switched infrastructures, allowing for optimization of Edge QAM numbers, service group size and over-subscription ratios.

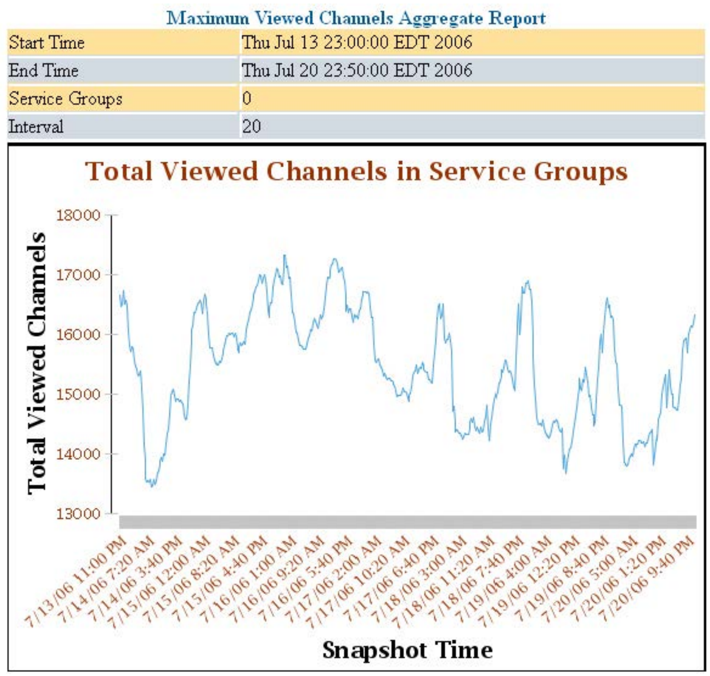


Figure 3: Typical weekly busy hour report (total number of viewed channels for all service groups)

Figure 3 provides the total number of viewed channels (active streams) for all service groups for a week. Notice the daily spikes between 10PM and midnight and more consistent viewership throughout weekend. It is possible to generate similar reports for each service group to check whether the conclusions made for the overall population apply, to compare service groups that are geographically distributed or whose population is different, and also to assess the impact of service group size. Examples are shown in Figure 4 of the maximum number of active streams, varying from single to triple at constant service group size, indicating that the number of switched broadcast QAMs per service group can be optimized, instead of being a constant.

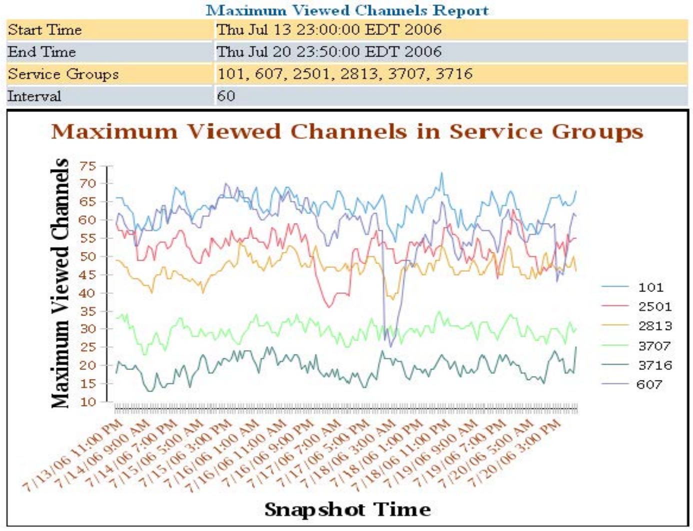


Figure 4: Example of weekly busy hour report for an individual service group

Once the busy hour has been identified one should analyze the viewership of individual channels audience to allow "long tail" content candidates suitable for being placed on the switched tier to be identified. It is important to narrow down this analysis to the busy hour as this is where the most significant bandwidth saving benefits can be accomplished.

Figure 5 shows a typical report for all service groups aggregated. Because this example provides insights into channels that are already on the switched broadcast lineup "long tail" programs can be identified easily

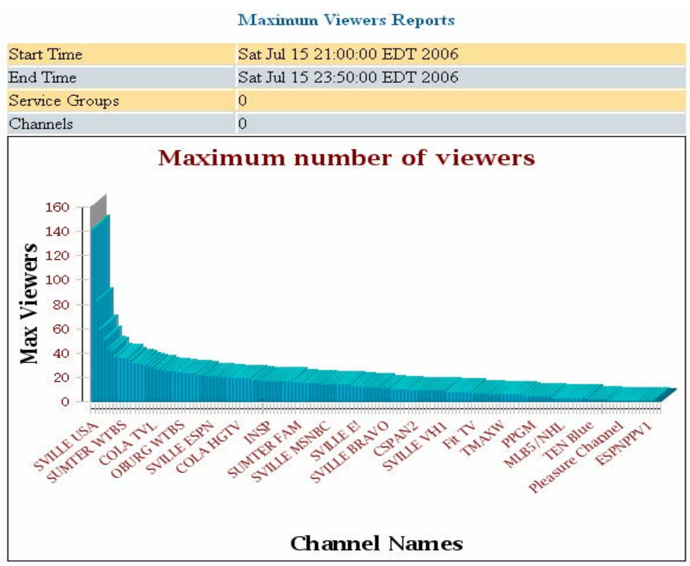


Figure 5: Distribution of "long tail" content

The channel audience in service group can also be used to predict the switched broadcast over-subscription ratio. This is achieved by examining the channel concentration ratio, (i.e. the ratio of unique viewed channels to the total number of available channels in the SWB tier.) Figure 6 shows that this ratio is at most 40%, leading to a minimum 2.5:1 oversubscription ratio in the switched tier. Using that data, one can again optimize the number of switched QAMs assigned per service group.

Channel Concentration Ratio Report

Start Time	Thu Jul 13 23:00:00 EDT 2006
End Time	Thu Jul 20 23:50:00 EDT 2006
Service Groups	0

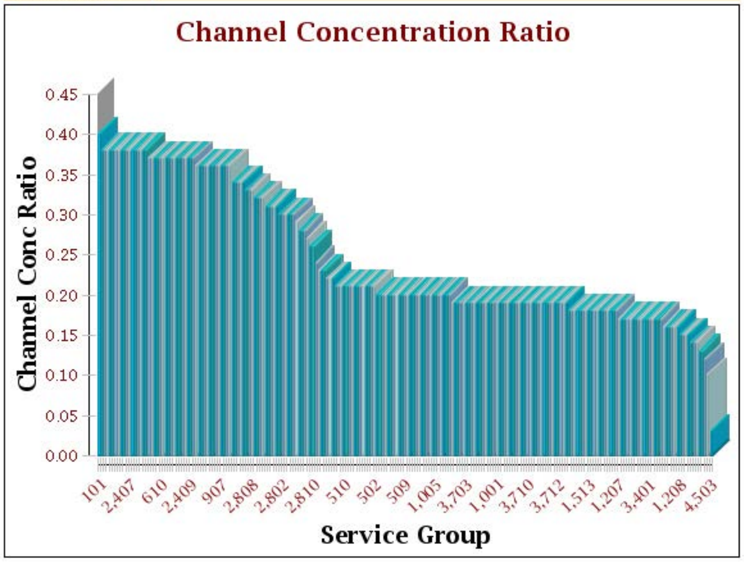


Figure 6: Channel concentration report

The reports presented in this section should not only be used in a preliminary switched broadcast deployment study but can also be used throughout the life of a switched broadcast deployment to ensure that the conditions are not changing and that the switched infrastructure remains optimized.

DURING DEPLOYMENT

A cable operator can benefit from leveraging the same monitoring platform used in the prior characterization effort when installing / turning-up a switched broadcast system: the statistics collected previously can facilitate easier troubleshooting of deployment issues such as STB upstream communication issues and QAM mis-configurations.

As new service groups are being migrated to the switched tier one should confirm that STBs are registering with the SBSS and there are no upstream communication issues. An example of such a report, showing the total number of active STBs as a function of time, is provided in figure 7.

A side benefit of this type of report is that it can be used to verify that the number of active tuners in each service group doesn't exceed expectations. Trending growth over time will indicate when a service group split may be appropiate.

Maximum Viewers Report

Start Time	Thu Jul 13 23:00:00 EDT 2006
End Time	Thu Jul 20 23:50:00 EDT 2006
Service Groups	3716
Channels	0
Interval	60

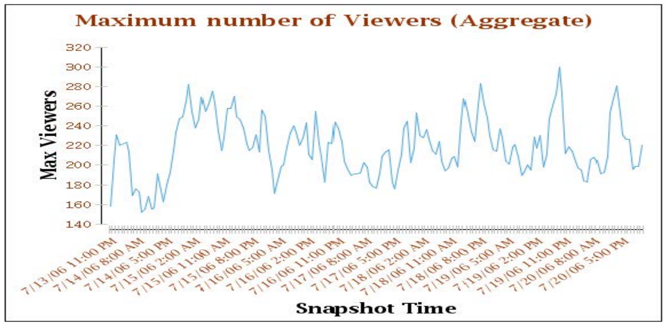


Figure 7: Number of active STBs in a specifc service group

Once a channel has been mapped to a QAM group a STB will tune to it without delay, a direct benefit of the protocols used in switched broadcast. Figure 8 shows that over 99.9% of the channel changes (not including the STB decoder actually locking into the stream) occurred in 5msec or less.

Channel Change Request Execution Time Report

Start Time	Sat Mar 10 23:00:00 EST 2007
End Time	Thu Mar 15 23:50:00 EDT 2007
Service Groups	0

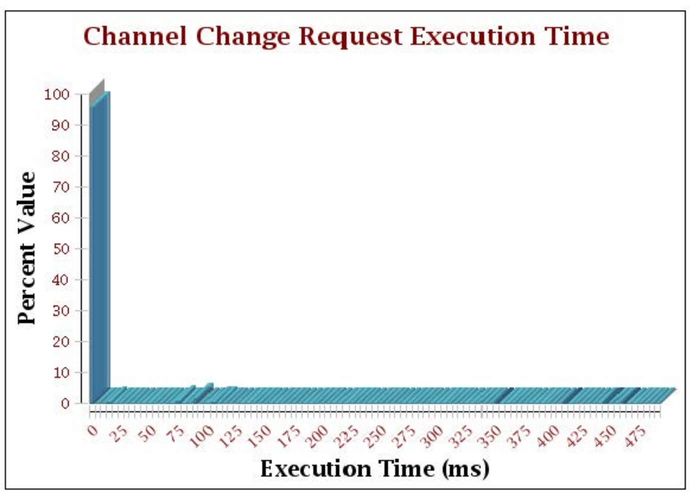


Figure 8: Channel change times already mapped on the switched tier

A departure from a 0 to 5msec range would indicate an issue with the system and along with likely impact to the subscriber's viewing experience.

On the other hand, when a channel is not already mapped to one of the switched QAMs because no one in that service group was previously watching it, additional steps will be required for the STB to tune to it. Figure 9 shows a typical distribution of such delays, which include the time for the request to go from the STB to the SBSS, the SBSS processing of the request and forwarding to the Edge QAM, the Edge QAM joining the multicast group for that stream, adding the session to one of the service group QAMs, and updating of the MCP to send the tuning information to the STB. It typically takes under 120msec to accomplish this, a negligible amount of time in terms of subscriber experience. This metric can be affected by delays in the network or SBSS overloads and is, therefore, important to closely monitor during and, after deployment. Doing so will help address potential issues and avoid subscriber complaints about tuning delays.

Switch Request Execution Time Report

Start Time	Sat Mar 10 23:00:00 EST 2007
End Time	Thu Mar 15 23:50:00 EDT 2007
Service Groups	0

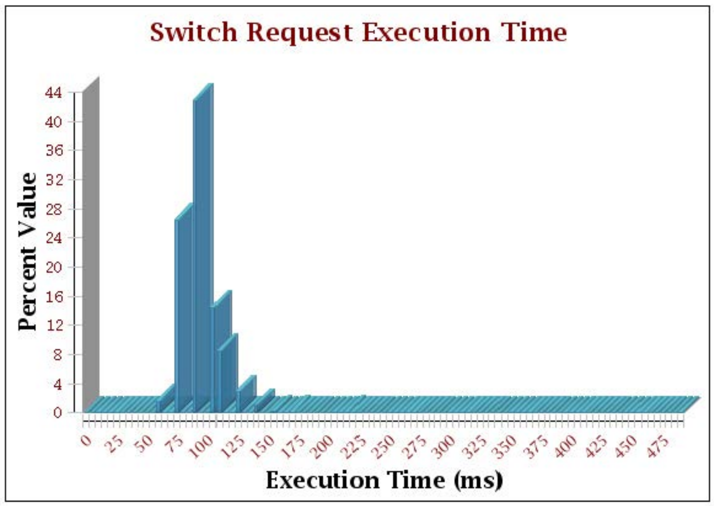


Figure 9: Additional delay for channel changes requiring mapping of an unwatched switched program

Because the OOB upstream bandwidth is limited it is important to keep track of how much is being used by switched traffic flows between the STBs and their respective SBSSs. Typical loads vary between 0 and 200Kbps depending on the number of active STBs per service group, as figure 10 illustrates.

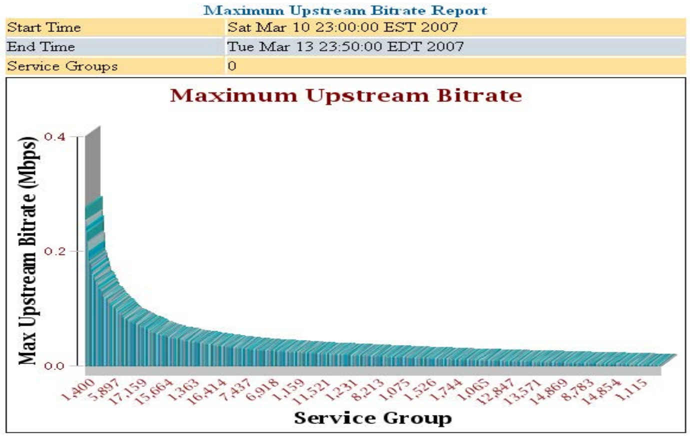
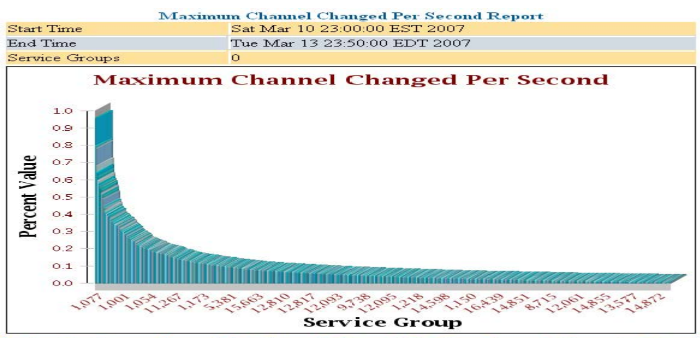


Figure 10: Maximum upstream bit rate for switched broadcast traffic per service group

The SBSS performance (see figures 8 and 9) is a strong function of the number of channel change requests the server has to handle. That metric is presented in Figure 11. Once a baseline has been established one can monitor how this metric changes with the number of active STBs (see figure 7) and measure the resulting impact on SBSS performance. A typical scenario would be an increase in the number of STBs and their respective traffic flows, requiring the addition of an SBSS to split the load and maintain an acceptable level of service.

Because the viewership and performance monitoring tool provides real-time visibility into the system behaviour, there is no need for empirical rules, since action can be taken as soon as the measured subscriber experience threatens to dip below the deemed acceptable thresholds.



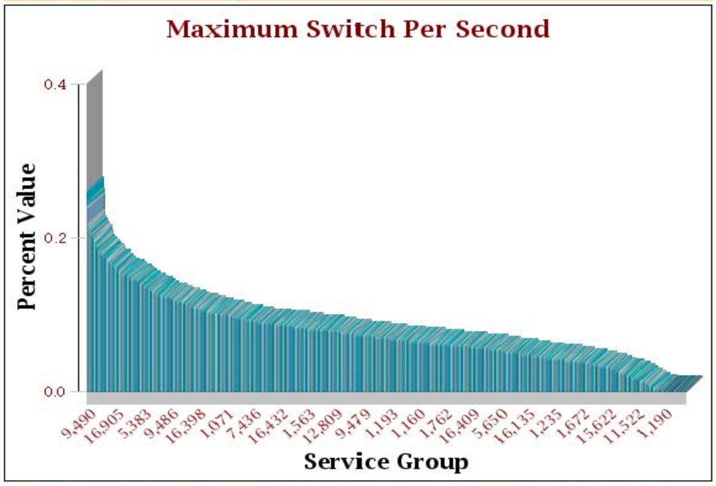
Service Group	Max Channel Changed Per Second	Percent value
1077	111.625	0.955
1476	92.705	0.793
5889	91.43	0.782
17421	79.468	0.68
5644	74.835	0.64
17666	72.038	0.616

Figure 11: Maxmum number of channel change requests per second per service group

The number of channel change requests requiring a new program t be mapped to the service group lineup should typically be fairly small unless the switched broadcast channel map is large and the over-subscription ratio high. As can be seen from the data provided in figure 11 and 12, the ratio between the two is about 1000 to 1. This ratio, however, does change significantly from one system to another. A large and sudden departure from the established baseline would typically indicate issues with system configuration or the MCP reaching the STBs.

Maximum Switch Per Second Report

Start Time	Sat Mar 10 23:00:00 EST 2007
End Time	Tue Mar 13 23:50:00 EDT 2007
Service Groups	0



Service Group	Max Switch Per Second	Percent Value
9490	0.157	0.259
17161	0.148	0.245
11267	0.145	0.24
7434	0.132	0.218
5889	0.127	0.209
17419	0.127	0.209

Figure 12: Maxmum number of channel change switch requests per second per service group

AFTER DEPLOYMENT

After installing a switched broadcast system the monitoring focus can be broadened to allow identification of trends such as un-forecasted growth that may lead to insufficient bandwidth being available to support all requested channels or management servers becoming overloaded. Early identification of such trends can allow pro-active remedies, minimizing negative subscriber impact.

Experience has shown that one of the most relevant metrics to follow is the occupied bit rate concentration ratio. This metric takes into account the number of switched QAMs available within each service group and the number of active streams (actively watched channels). It also encompasses the bandwidth of individual streams, something that is not necessarily constant when using multi-width CBR (constant bit rate) to maximize video quality, or when mixing standard and high definition progams. Trending this metric over time for each service group will characterize the growth rate, and a good rule of thumb is to consider adding more QAMs or splitting service groups when the ratio consistently surpasses 80 to 90%, or spikes to 100%.

Figure 13 shows one such daily summary of the maximum occupied bitrate concentration ratio for each service group.

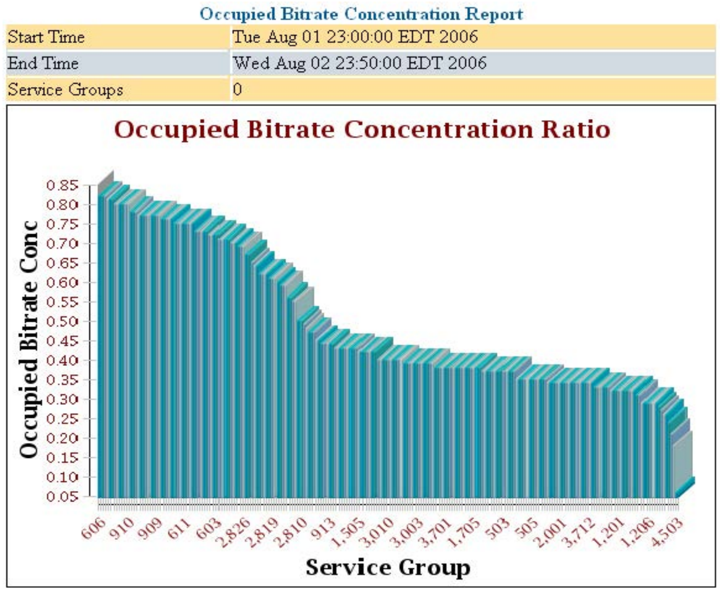


Figure 13: Maximum occupied bit rate concentration ratio per service group

Figure 14 examines the top three service groups in Figure 13 in more detail. One of the key things to note here is that the 80% utilization threshold is only surpassed briefly during the typical 10PM to midnight busy hour, meaning that there is no immediate need for any infrastructure changes.

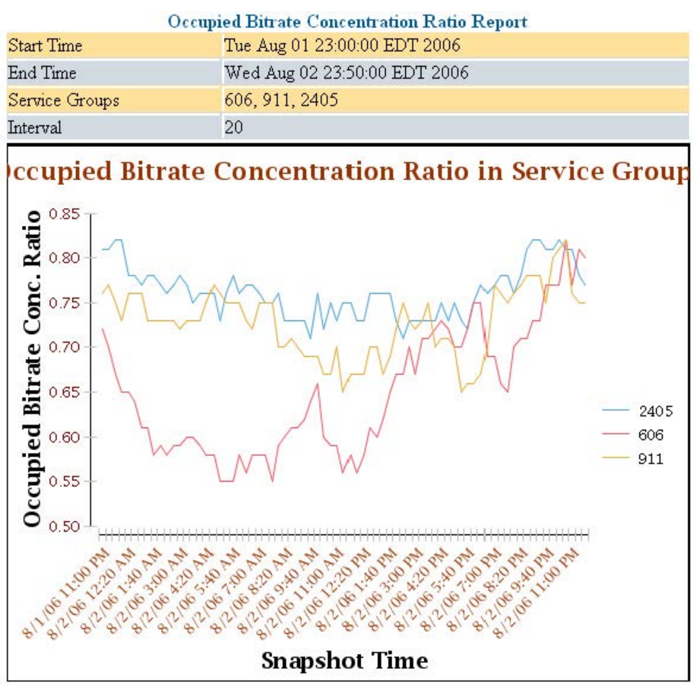


Figure 14: Daily variation of occupied bit rate concentration ratio for three service groups

Once the occupation ratio is consistently in 100% vicinity and the over-subscription ratio is greater than 1:1, the likelihood is high that no bandwidth will be available on the QAMs for new channels. This is defined as a blocking event and results in a subscriber receving a “Channel not available – Please try later” message, instead of the desired program. Figure 15 presents a summary, for each service group, of the number of blocking events over the duration of a few days. Approximately 15% of the service groups show a significant number of blocking events.

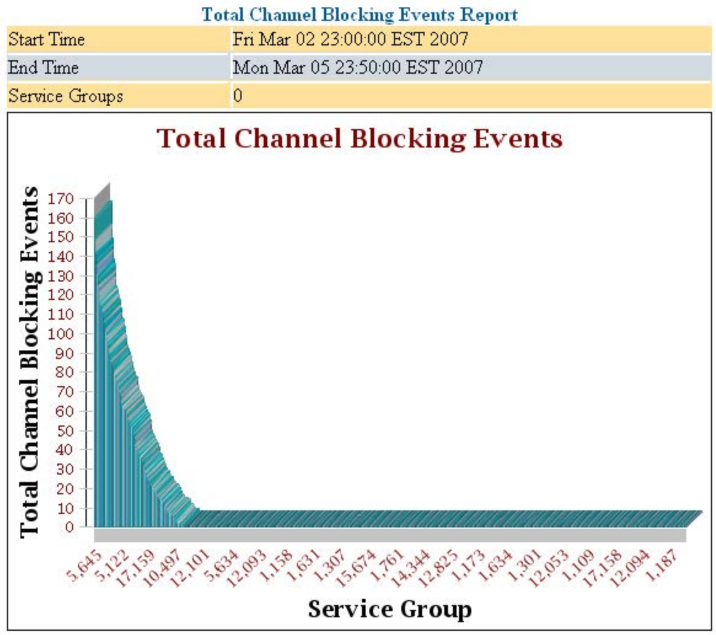


Figure 15: Maximum number of blocking events for all service groups

As a remedial step to bandwidth scarcity additional switched QAMs can be added to the service groups most affected by blocking. The results of doing so ae highlighted in Figure 16. This example shows that, in one of the service groups under consideration, the number of active streams on the switched tier jumped from about 20 to about 30 as soon as the additional QAM became available.

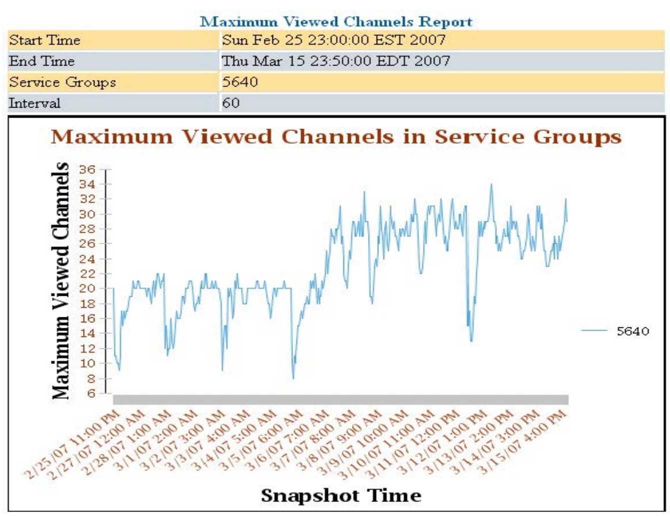


Figure 16: Maximum number of viewed channels for a specific service group across the addition of a switched QAM

Coincident with the increase in available bandwidth the numbers of blocking events virtually disappeared, as figure 17 shows. Additionally, the over-subscription ratio decreased from 2.5 to 1.7 in the affected service groups

Total Channel Blocking Events Report

Start Time	Sun Feb 25 23:00:00 EST 2007
End Time	Thu Mar 15 23:50:00 EDT 2007
Service Groups	5640
Interval	60

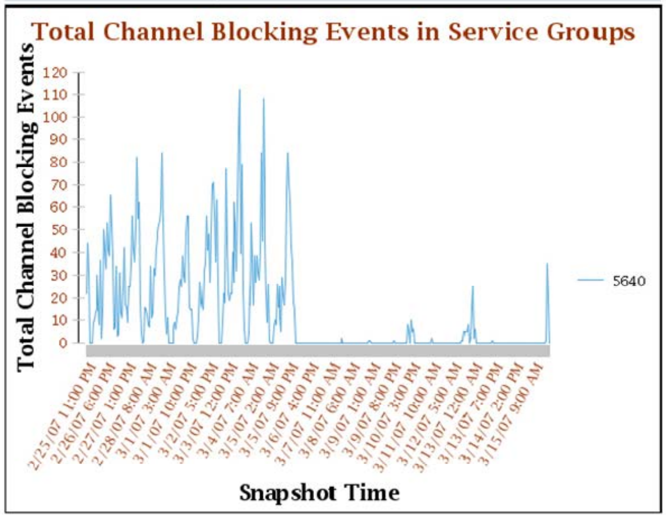


Figure 17: Blocking events for a specific service group across an additional switched QAM

This can be explained by the larger size of the service groups, subscriber demography and switched channels lineup. The positive point is that because of the detailed monitoring information available, the capital needed for an additional switched QAM was limited to a very small number of clearly identified service groups. Moreover, the expense could be delayed until the blocking situation became too affecting for the subscribers.

BUSINESS BENEFITS OF STATISTICS MONITORING

Benefits accrue when statistics monitoring is applied to both linear and switched broadcast networks. In addition to the operations benefits already described, namely capacity planning and diagnostics, the ability to collect accurate viewership data full-time introduces new revenues opportunities. These are examined in the following sections of this paper.

CONTENT PERSONALIZATION

Personalized news is one example of ways that precise viewership records collected by a statistics monitoring tool could be leveraged for new revenue generation. Since the real-time collection of viewership data allows content and subscriber interests to be accurately correlated, enterprising newrooms, or third-parties, could create news summaries that are more likely to retain the attention of viewers, as compared to traditional broadcast TV news programs. For example, newsrooms could record a series of short news stories on a wide range of topics, allowing cable operators to combine into personalized bulletins that address a subscriber's specific interests, whether it's baseball teams or Internet start-ups.

A personalized version of a music network is another example of how switched unicast provides cable operators the opportunity to offer increasingly customized content.

Customized services like these could be offered as premium services, potentially earning the operator additional revenues. Alternatively, personalized content could be offered at no additional charge, with the expectation that increased customer loyalty results.

ADDRESSABLE ADVERTISING

Addressable advertising is a methodology for more closely matching advertisements to subscribers' interests. Figure 18 illustrates how three subscribers, all watching the same program on the switched tier receive different ads during the commercial breaks. For example, subscriber #1, an avid teen snowboarder, receives an ad about snowboard sales. During the same commercial break, subscriber #2, a thirties-something bachelor, views an ad about an upcoming motor show. Subscriber #3, an avid traveler in her fifties, receives information about cruises in the Caribbean.

Studies, such as a recent CTAM report, reveal that marketers are willing to pay premium rates if their ads achieve improved response rates among their intended audiences.

By building precise databases about which programs individual subscribers are watching,

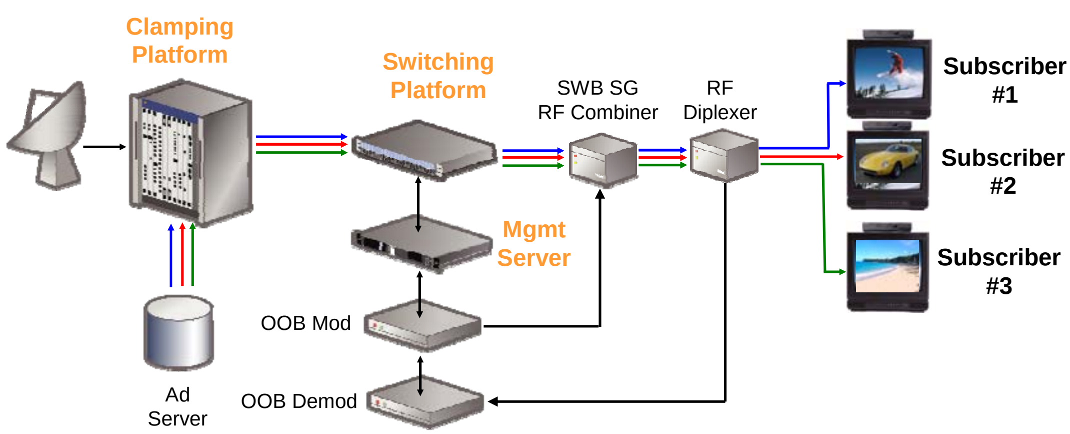


Figure 18: Subscribers receiving different ads though all view the same programming

cable operators can determine which ads to forward to viewers.

In contrast to third-party research firms that typically collect broadbrush viewership data, the statistics monitoring platform described in this paper can provide insights that would otherwise be lost. For example, a subscriber, that may have paused to watch a short segment about the fashion industry while channel surfing, may be a viable candidate for an advertisment about a relevant local fashon event. Other methods of recording consumer viewing habits are unlikely to yield this level of detail.

Additonally, a consumer that routinely tunes to a home improvement network may be receptive to an advertisement about a sale at a local hardware store, and could receive such an ad, even when watching a different network.

GUARDING PRIVACY RIGHTS

The Cable TV Privacy Act of 1984, is intended to protect personal information. In particular, it prohibits cable TV providers from disclosing personally identifiable information, and allows users to view and verify their information. Naturally this means that gathering and reporting on an individual's channel viewership history is likely illegal. In order to satisfy this requirement, the SBSS servers offer the option to scramble the STB MAC addresses in the logs making it impossible to identify any single user.

The gathering of individual subscriber data can be implemented on an "opt-in" basis. For example, the more enterprising cable operators could explicitly ask their subscribers about their ad preferences. In return for providing a cable operator with a list of the subjects and categories they'd be interested in viewing ads on, subscribers could receive a complimentary gift or upgrade to an expanded service package, or some other incentive.

CONCLUSIONS

The ablity to obtain precise viewership statistics assists cable operators in a variety of ways. These include providing the insights needed to engineer effective switched tiers and speed system deployment and turn-up. The capability to monitor network perfomance allows adjustments to be implemented that ensure channel change times and service quality are optimized.

Although primarily developed for switched broadcast environments, the non-invasive tool described in this paper has applications in linear broadcast networks also. Broader applications can include support for addressable advertising business models and other content personalization oppportunties.

However, maintaining subscribers' privacy is paramount and the viewership statistics needed to empower these benefits can be obtained / stored in ways that enable cable operators to meet their obligations under the Cable Privacy Act.