Managing The HFC Environment Using Cable Modem Derived Performance Data

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Abstract

Analysts estimate that there are well over 1/2 million cable modems in use today in HFC networks. Due to a lack of adequate installation and maintenance tools a portion of these modems are operating with suboptimal receive and transmit levels.

The results of a survey of a number of modems show that upstream and downstream levels are often not ideal. The result of this is that a part of the network bandwidth in the HFC link layer is potentially being consumed in error correction.

Some tools currently available to the cable modem installer, network troubleshooter, and network maintenance technicians are described.

INTRODUCTION

Transporting data over cable TV networks is not new. For many years I-nets (Institutional Broadband mid-split RF Networks) have carried data using early RF modems from a half dozen or so pioneer vendors. Also not new is the transport of data over impaired environments; ones in which a certain level of data loss is assumed and designed for.

What is new is the developing ubiquity and raw data density of digital data signals 64 and 256 QAM on cable. Also on the very near horizon is the ubiquity of telephony over cable. Though telephony's raw data throughput may not be as demanding as cable modems or digital TV, at least in the downstream, the need to eliminate perceived gaps in speech means it does require greater signal isochronal integrity.

So the suitability of the cable TV environment for the carriage of data has been a subject of discussion for many years and continues to be. The purpose of this paper is to discuss current actual field practices in the evaluation and monitoring of the cable TV physical RF environment with respect to cable modem two-way data carriage.

IMPLICATIONS OF CURRENT PENETRATION RATES

Over the air radio frequency (RF) transmissions as well as RF transmissions over copper paths that are longer than a few tens of feet can and will suffer impairments. To counter these impairments transmission protocols have been developed which contain error correction capabilities. Similar error correction capabilities exist and are utilized in the data signals carried on cable as well[1]. Some of these methods such as FEC (Forward Error Correction) are unidirectional and are used in digital TV transmissions where there is no return path, as well as in cable modem signals. But where a return path exists, other levels of data error correction are possible such as TCP retransmissions. In today's carriage of data over cable, error correction is much in use. But how much? This is not well known.

Error correction is a wonderful capability but it is not free. The price to be paid is network capacity or bandwidth. For FEC this bandwidth hit is up front in that it is built into the signal as overhead whether it is used or not. When a two way path exists TCP retransmissions are possible as another layer of error correction capability. When subscriber penetration is low there can exist heavy retransmissions for error correction and/or packet loss without it being very noticeable to users. But as subscriber penetration grows and the extra bandwidth needed to support them is already being used for error correction, network performance may seem to degrade more rapidly than the network design would suggest.

This means that since we currently don't know the amount of error correction that is actually being employed to support current subscriber levels we don't know how much HFC capacity headroom we have. Clearly, we need means to assess when HFC performance is marginal so attention can be focussed on improving the HFC plant with the goal of driving error correction to zero. This would make both the data path more reliable as well as free up bandwidth being wasted on error correction.

ANALOG TESTING AND CERTIFICATION

A current industry practice is to require certification of each node before releasing it for cable modem service. This certification is based solely on traditional RF measurements assuming that if the plant meets these requirements then data carriage will be successful. This leap of faith has been successful so far. Meeting FCC Proof of Performance specifications and diligence in CLI (Cumulative Leakage Index) seems to be adequate. So, for the downstream, clean pictures do generally mean clean data.

For the upstream path, however, the situation is a bit less straightforward. In spite of this, though, pursuing the same philosophy of certifying with a suite of analog RF tests has been generally working with upstream data signals as well.

However, certification at the time of data service launch in a particular node says nothing about the *ongoing* capability of the node to support data service.

DIGITAL TESTING

The term "digital testing" as used here describes the concept of both retrieving analog parameters through the network (through digital means) as well as the retrieval of purely digital parameters such as packet error rates.

Strip Charts

During some of the first cable modem deployment activities the need for a simple graphical view of performance became evident. In response to this need a single packet error rate parameter was chosen and charted as a time series over a 1-week period. Packet error rates are charted on a per CMTS upstream receiver port basis with data points taken every few minutes[2]. Figure 1 is an example.

Strip charts provide an intuitive graphical display of performance but they still require a human to do the examination and interpretation. The data is taken and the resulting graphs are created automatically, but no limit checking is done nor are out of

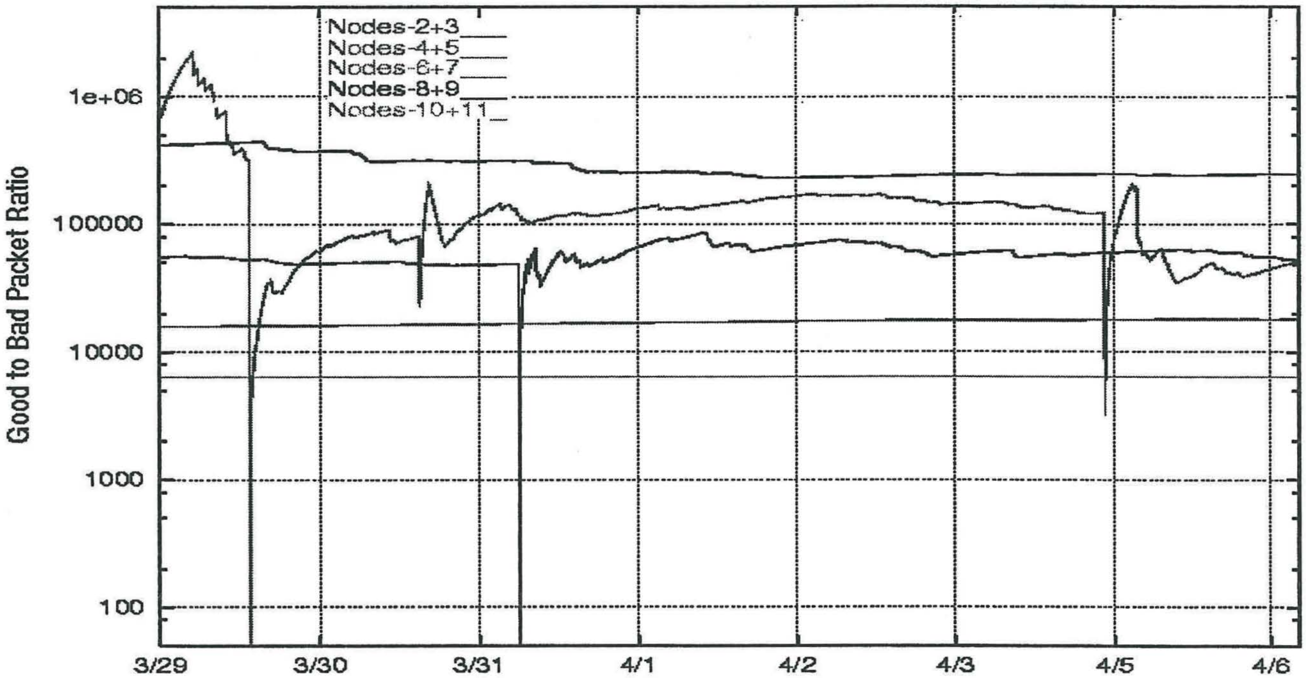

Figure 1 - Strip Chart Example

limit condition alerts generated. Human interpretation and action is still needed.

Perftest

@Home Network engineers have developed a cable modem installation performance acceptance test specifically to evaluate the HFC physical layer. It is called Perftest and measures data transfer speed between the memory of the subscriber's PC and the memory of the local proxy server. This eliminates any disk transfer speed effects as well as limiting the scope of the test to the only part of the network that really matters during the installation.

Because every CMTS in the @Home Network has high speed, local access to a proxy server, testing upstream and downstream data transfer rates between the subscriber's PC memory and the memory of the local proxy server gives a reliable and repeatable result. Figure 2 illustrates the concept.

Perftest reports to the installer the average result of 3 twenty-second test runs in each direction, the standard deviation of these results as well as the number of retransmissions experienced. The results are also logged to a test history file on the proxy server. Perftest can be executed remotely by network operations center technicians. But as with strip charts, no automatic evaluation or condition alerts are generated without human interaction.

Modem Levels

Much can be learned from examining two parameters: the downstream signal level as reported by the modem at its input port, and the level the modem is reporting that it is transmitting back upstream.

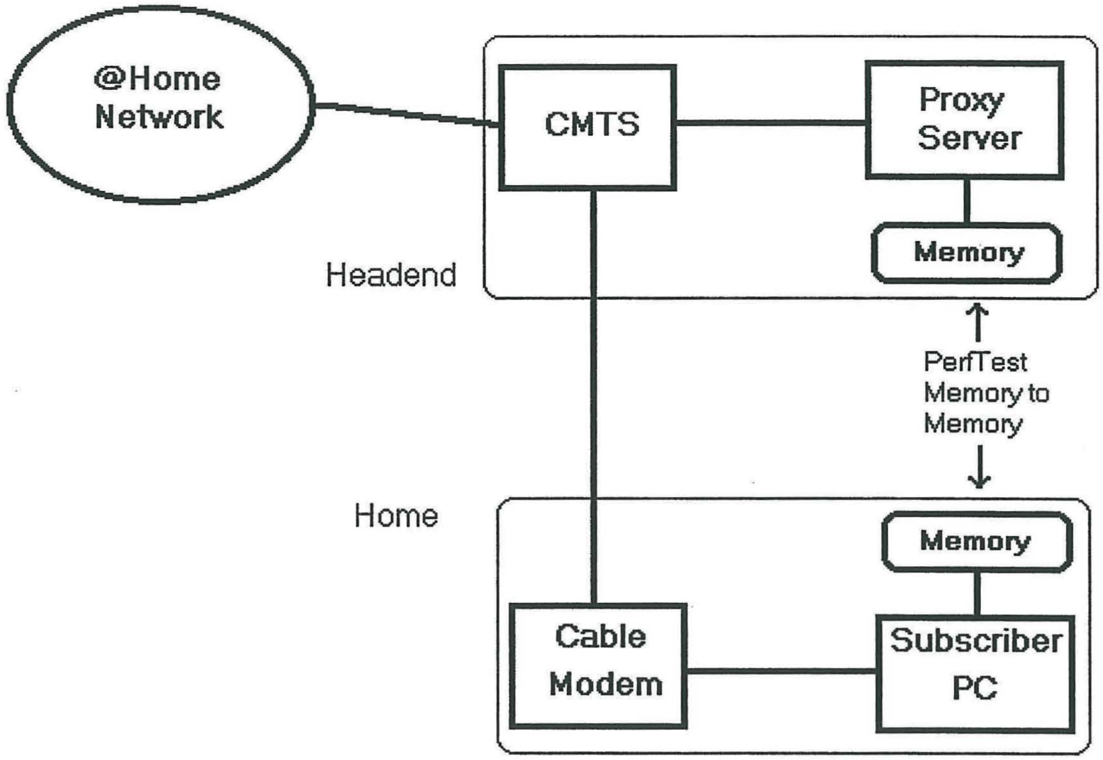

Figure 2 – Perftest Concept

If the modem is reporting that the downstream signal it is receiving is not optimum, it can be inferred that errors are more likely than if the signal was at an optimum level. If errors are more likely then error correction mechanisms such as forward error correction and TCP retransmissions are likely to be in use. Requests for retransmission will reduce available bandwidth between the subscriber PC and the CMTS. Thus, it is desirable from a HFC link point of view to have the downstream received level be solidly in the optimum range.

All modern cable modem systems utilize the "long loop ALC (automatic level control)" technique to manage cable modem upstream transmit levels. This is where the CMTS commands each individual modem to adjust its transmit level, up or down, such that the level received at the CMTS upstream receiver port becomes optimum[3].

If the modem is instructed to reduce its transmit power to a level below about +35 dBmV, experience has shown that the signal to noise becomes less than desired. This can also indicate a plant setup and/or balance problem.

A modem being instructed to raise its transmit power to a level above that which it is capable is also an undesirable condition. This means that the signal to noise ratio at the CMTS upstream receiver port is very likely to be poor as well as in other parts of the plant.

Recently an unscientific survey was done of several hundred modems at various locations around the United States looking for modems that were either transmitting or receiving at levels outside of the manufacturer's specified optimum range. A small number, 3 - 5% were found to have their downstream receive levels outside of the specified range, and a larger number, about 20%, were transmitting above or below the specified range or were even "railed out", transmitting at their maximum power. The vast majority of modem transmit level variations were on the high side. This sampling included 3 MSO's and 3 proprietary technologies. Results across these variables were consistent. No correlations were found to either MSO or technology. If this sampling is truly representative of the general case, then this is a concern and implies some HFC link bandwidth is being used for retransmissions and is thus not available for normal service or new subscribers.

Other Digital Parameters

There are approximately 33 DOCSIS MIB parameters describing various error rates of bytes, packets, frames and synchronization as well as others for proprietary products[4]. How these can be exploited individually or in combinations has yet to be fully explored.

IMPLICATIONS OF DOCSIS

For the DOCSIS market to achieve its full potential, cable modems must be self-installed with automatic provisioning. Ideally then, the optimum RF and MAC MIB parameters would have been identified and would then be polled and checked automatically as part of the DOCSIS installation.

The drive toward self-provisioning clouds the picture for determining where installer tools are going. Ideally, there would be no truck rolls, but when one is necessary, it is desirable for the technician on site to have tools to quickly locate and fix the fault and move on. This implies a box into which the modem drop cable is connected that would quickly evaluate and predict exact modem performance.

CONCLUSION

The current state of the art of evaluation and monitoring of the HFC physical layer can be made better. Just as with the higher layers of the network, automatic monitoring tools with limit checking of modem levels with one or more data transmission quality parameters are needed for the HFC layer.

The tools now available such as strip charts, Perftest, and manual monitoring of modem levels show promise. However, much progress is needed in making these functions as convenient, easy to use and as automated as possible.

The following stages are suggested going forward: 1)achieve modem level convergence to optimum for both downstream as well as upstream, 2)correlate modem level trap thresholds with actual data throughput limits for both downstream and upstream, 3)determine which DOCSIS MIB parameters, individually or in combinations, give the most useful information and create automatic systems to monitor them such as described by Sandino and Kim[5].

These steps would also lay the groundwork for "digital certification" of nodes. Not only could nodes be more automatically tested for certification but the same MIB variables could then be used for ongoing monitoring to assure permanent fitness of the node for data carriage.

Initially, though, it is believed that the biggest "bang for the buck" can be achieved through just step 1 above, the convergence of modem levels to a target optimum level, especially modem transmit levels. This suspicion stems from a year of experience assisting technicians in troubleshooting cable modem installations.

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