INTERNATIONAL TELECOMMUNICATION UNION

TELECOMMUNICATION STANDARDIZATION SECTOR

STUDY PERIOD 2005-2008

COM 12 – D 95 – E

English only

Original: English

Questions:	11, 13/12	Geneva, 17-21 October 2005

STUDY GROUP 12 – DELAYED CONTRIBUTION 95

Source:	Telchemy Incorporated
Title:	Behaviour of data modems in lossy, packet-based transport systems

Abstract

This document discusses QOS aspects of the usage of Modems and Fax modulations over packet based transport networks such as IP.

1 Introduction

On the surface, it would appear that data networks such as the Internet would quickly obviate the need for the use of data and Fax modems. In general, data – IP – traffic is faster, more reliable and robust than modems and fax over VBD or VoIP/VoP connections. However, certain aspects of fax and data keep their use entrenched even as the use of Internet for PSTN-like traffic becomes ubiquitous, for example, the legality of a "faxed" signature on documents.

In this document we present a general discussion of some testing results of standard modems over VoIP connections and then discuss some aspects of the design of modems and gateway devices, and possible improvements.

2 Test methodology

In order to further evaluate the behaviour of off-the-shelf data modems we took ATAs from two different manufacturers and connected them to each other using open source call control and routing systems, and a commercial network impairment bridge to emulate some of the various conditions that are normally found on data networks; mostly loss models, random and bursty in nature. We then allowed the modems to connect normally and observed their behaviour with regards to call completion, call longevity, and data throughput and integrity.

2.1 Modems

In various tests, we measured the data throughput, bit error rates and training/retraining time for a wide range of conditions. In general the modems were used with factory settings, as the typical

Contact:	Alan Clark Telchemy Incorporated USA	Tel: Fax: Email:	+1 770 614-6944 +1 770 614-3951 alan.clark@telchemy.com
Contact:	Bruce Adams Telchemy Incorporated USA	Tel: Fax: Email:	+1 770 614-6944 +1 770 614-3951 bruce.adams@telchemy.com

user would do, with the exception of disabling forward error correction and compression in some circumstances so as not to skew observations of rates and errors.

The modems we used were a collection of both recent and older modems, all V.34-capable or better and from a variety of manufacturers. The modems included, soft, internal and external modems.

The modems were then controlled using a standard modem communications package.

2.2 ATAs

We used off the shelf ATAs configured much as the modems were with factory default configurations where possible. We did fix the jitter-buffers to fixed length, and assured as necessary that they would default to G.711 Codecs, as others are unsuitable for data over packet. We allowed the ATAs to set input and output power levels as default and checked the status of frame erasure concealment (PLC) algorithms as it effected the operation of the modems.

2.3 Network configuration

We set up a test IP network with two distinct subnets with a generic call-control server sitting on both subnets. A second system, also sitting on both subnets, was configured to run as a router doing IP-pass-through from one subnet to the other with the introduction of packet loss and jitter impairments to traffic passing across the connection between the two subnets.

One ATA was attached to each different subnet, and was configured to register with the control server (we used both SIP and MGCP call control).

2.4 Data and audio capture

In order to do after-the-fact an analysis of the data passed over the network, a third computer was used to run Ethernet packet capture software. The packet captures were analyzed for packet loss statistics and data-stream capture and analysis.

In addition, audio capture of the two-wire telephone interface connections were done passively to make additional observations on the reactions and operations of the modems. These captures were also used to measure call start-up time and retrain times.

2.5 Test setup issues

Unfortunately, the emulator that was available for these tests was not capable of imparting asymmetric impairments to the two directions of traffic through it. Although not identical, the emulator would initiate periodic impairments on both channels at approximately the same time. For example, in bursty-mode impairments, although not the same identical packets were lost in each direction, the timing, length and loss density in each direction was almost identical.

3 Observations and results

Because all the tests were end-to-end, no V.9x calls could be attempted, so unless forced to other modes, most calls that connected resulted in V.34 connections at various rates. After running the tests, several interesting observations came to light. Several hundred connections were attempted during the testing.

Originally, we were expecting the modems to fail almost as soon as data losses began occurring on the connections, but soon found that this was not the case. In addition, we discovered several things that both modem manufacturers and ATA manufactures can do to improve the QoS experience when using data modems – and by extension fax modems.

3.1 Power levels

In the PSTN, data modems generally run at power levels of from –13 to –19 dBm0. In addition, most PSTN connections attenuate the end-to-end connections by 6 to 18 dB, 6 being the most common. Consequently, modems generally are designed to operate best at receive power levels of –19 dBm0 and below. Higher levels than that may cause fixed-point number issues to some extent in some modem designs.

In our tests, both ATAs by default only imparted a 3dB attenuation in the end-to-end channel, resulting in a hotter than normal signal received at the other end of connections. This contributed to an almost 10% initial call failure rate – even in otherwise impairment-free connections.

3.2 Loss and retrains

We were expecting most loss events to cause almost immediate retrain events in the V.34 modes because at 10ms packet length, each packet loss is from 2.4 to 3.4 full symbol periods. In addition, modems would need at least this may symbols to recover various internal settings after an event. This turned out to not be the case. Instead, the modems often quite happily rode through isolated and even bursty loss events with the expected loss of data, but not retraining as often as we had anticipated.

We speculate that the reason for this is the normal use of Packet Loss Concealment in the ATAs (both of which defaulted to ON). For example, ANNEX II of G.711 describes a waveform matching PLC algorithm that when applied to a modulated modem signal, generally will preserve signal phase at one end of the loss event and only have a distinct discontinuity at the other end. This would manifest it self as incorrect symbols for the duration of audio replacement, and for several symbols thereafter. However, because the signal power remains constant due to the PLC, neither carrier detectors nor AGC circuits notice anything amiss. This makes isolated lost packets appear as short-term impulse noise events – which modems are designed to handle.

However, as the loss density increased, retrains become quite common. Up until packet loss rates passed 0.1% (1/1000) the modem connections were quite stable and robust. As the loss rates climbed, however, retrains occurred more and more often. Between 0.1 and 1% packet loss rates (random) most connections eventually failed in from 2 to 15 minutes.

With bursty losses, the modems behaved similarly as with random losses. As burst length increased, as expected, retrain frequency increased. As with random loss, loss rates of up to around 0.1 % caused little problem, but after than, retrains increased until gap length fell below nominal retrain times, at which point, retrains almost always failed.

In either case, by the time loss rates reached 1-10% calls failed very quickly or never connected at all.

3.3 Loss and throughput

Tests on isolated loss events (disabling EC and Compression) showed that each lost packet resulted in the corruption of approximately 2 packets worth of incoming data. This makes sense because obviously the lost packet is errored, and 3 symbols or 6-9 samples of new good signal data after the replaced packet (by PLC) is a reasonable amount of time for a modem receiver to recover from a transient event.

By 0.1% loss, throughput decreased by 10% and by 1% packet loss throughput dropped to about 50% and at 10%(when the connections stayed up long enough to measure) throughput dropped to approximately 10% of error free.

3.4 Bursts and retrain failures

As long as bursts of packet loss occurred far enough apart, the modems were often able to successfully complete retrains (The success rates are similar to the modem connect rates in error-free conditions, about 10% failure rate.) However, as soon as the gap length decreased to the vicinity of a retrain time (approximately 10-17 seconds) the retrain failure rate increased dramatically. Again, this makes sense because if a second error event occurs when the modems are attempting a retrain, the recovery mechanisms will engage because of the new errors and retrains will restart. Each subsequent error event during retraining restarts the process. Eventually the retrain timers and or counter in the modems expire and the call is dropped.

4 Suggestions for implementers of Modems and ATAs or similar PSTN gateways

4.1 Gateways

Two items proved to be the most effective at increasing connection robustness:

- Power level
- PLC

If the ATAs detect a data connection (detection of ANS, ANSam, CNG or other data/fax identification signal) they should increase attenuation of the encoded signal up to approximately 6-12 dB end to end. In setting this in the test ATAs, initial connection rates increased to near 100% in no-loss/low-loss conditions. Since this is the power environment modems are designed to operate in, the ATAs should provide it.

In addition, the use of PLC increased connection robustness through loss events, both random and packet. The replacement of lost signals by similar ones of equal power, frequency and phase diminishes the damage done to trained filter values in echo cancellers and equalizers making it easier for the receivers to recover. It is further suggested that new PLC schemes be conditioned for use in modem connections and not for speech.

Also, jitter-buffers should be fixed in length.

4.2 Modems

We were happily surprised at the performance of some of the modems in our tests, and not so with others. When the modems failed it often seemed that the modems were too quick to “give up” in suddenly bad conditions. We noticed that some modems did a poor job of re-aligning with the V.34 recovery procedures such that by the time both modems got back in sync, it was to near the end of other general time-outs for the retrains causing failures. This was due to some extent to corruption of signals because loss events were still happening. In addition, this was somewhat influenced by the inability of our test bed to impart asymmetric impairments. If it had been able to we suspect that this cause of failure would less likely. What we did notice most though was the failure of modems to quickly identify signals A and or B during or after loss events.

We do however suggest that perhaps time-outs on retrains, or retrain count disconnects or other internal working of the modem handshake be relaxed for time in order to ride out longer events, and not to be so quick to give up. For example, equalizer MSE measurements during error-free periods will be minimal, and during error events high. Using the step-nature of this measurement can be used to conclude that instead of a PSTN connection, this is possibly a packet connection and therefore procedural adjustments can be made.

Finally, in many conditions we found that slower, modulations with longer symbol times, both FSK and QAM, were somewhat less error-prone owing to the corruption of fewer consecutive symbols.

By not having an effective way to move among modulations possibly more robust methods are not available once a call has moved past V.8 negotiations, in some circumstances, data will not get passed when it otherwise could have, albeit at a much slower rate.

5 Modem QoS Metrics

A companion contribution discusses two suggested QoS metrics for use with data/fax over packet connections.

6 Summary

In our tests, modems at first seemed to respond better than we had expected. But after further analysis, we believe that they are in general not as robust as they could be. By making adjustments to design and operation of modems and gateways, we believe that robustness of modem connections, and as a result successful fax operations, could be improved dramatically. These changes do not require changes to existing Recommendations, nor the creation of new ones, simply better implementations of the existing V Series modem Recommendations.

References

[1] ITU-T Recommendation V.8 - 1998 - Procedures for starting and ending sessions of data transmission over the public switched telephone network.

[2] ITU-T Recommendation V.8 *bis* - 1996 - Procedures for the identification and selection of common modes of operation between data circuit-terminating equipments (DCEs) and between data terminal equipments (DTEs) over the general switched telephone network and on leased point-to-point telephone-type circuits.

[3] ITU-T Recommendation V.21 - 1988 - 300 bits per second duplex modem standardized for use in the general switched telephone network.

[4] ITU-T Recommendation V.22 *bis* - 1988 - 2 400 bits per second duplex modem using the frequency division technique standardized for use on the general switched telephone network and on point-to-point 2-wire leased telephone-type circuits.

[5] ITU-T Recommendation V.34 - 1998 - A modem operating at data signalling rates of up to 33 600 bit/s for use on the general switched telephone network and on leased point-to-point 2-wire telephone-type circuits.

[6] COM 12 – D 96, Geneva, 17-21 October 2005, Telchemy Incorporated, QoS Metrics for use in VoIP for Data and Fax modems.

____