An Analysis of Speed Drop in ADSL Lines in Sri Lanka

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Abstract: *This paper investigates the possible reasons for the very common problem faced by internet users at present: speed drop in ADSL lines in Sri Lanka. ADSL is a variant of DSL in which unused bandwidth of existing copper cable network is taken into used to provide high speed data. ADSL has a high data rate downlink and is low in the uplink. Although ADSL has ability of self-adjusting towards channel conditions still speed drop has its own reasons. Line conditions, distances from base switching station to home premises are few such. Using fiber optic cables is the most popular and decent solution though it is not practical in Sri Lankan scenario. This paper analyzes international ADSL standards, implementation and architecture with which the Sri Lankan concept is compared. Analysis then follows toward identifying the reasons for the speed drop, in order to minimize flaws in the system to provide an increased data rate.*

Keywords*— DSL, ADSL, PSTN, Optical Fiber*

I. INTRODUCTION

The paper investigates on the theoretical background of the ADSL technology and has looked into the commonly asked question of the ADSL customers "the speed drop of the ADSL connections". This paper suggests solutions for the mentioned issue rises from the ADSL customers.

II. AN OVERVIEW OF ADSL TECHNOLOGY

ADSL technology fulfills the need of high speed data in the fast developing world. From the name itself, ADSL is a technology that has asymmetric data rates at downlink and the uplink where the downlink speed is higher than the uplink speed. The technology uses the traditional twisted pair telephone line with modems at each end to create three information channels.

- A high speed downstream channel
- A medium speed upstream and downstream duplex channel
- A basic telephone service channel

ADSL provides the ability of simultaneous access by the computer and the telephone service. Here the basic telephone service line and the data internet line are split off from the digital modem at the client site. Moreover the splitter action can be seen at the service provider base too. The advantage of ADSL service is "always on" nature. In any situation of power failure or the ADSL failure, the data transmission will be lost but still the telephone service will operate.

ADSL initially provide a data rate of
16-896kbps upstream
1.5-9Mbps downstream

ADSL basically works up to a distance of 3.7 to 5.5kms. There are several ADSL standards that have been introduced by International Telecommunication Union (ITU).Table1 shows the standards introduced by ITU.

Table 1. Various ADSL standards introduced by ITU

Family	Description	Upstream rate	Downstream rate	Max. range
ADSL	G.992.1/G.DMT	640 kbps	8 Mbps	5.5 km
ADSL Lite	G.992.2/G.Lite	384 kbps	2 Mbps	6 km
ADSL2	G.992.3/.dmt.bis	1-1.5 Mbps	12-16 Mbps	5.7 km
ADSL2+	G.992.5/ADSL2 plus	1 Mbps	26 Mbps	5.7 km
ADSL2 Re	G.992.3	1 Mbps	12 Mbps	7 km

The standard used in Sri Lanka is ADSL2+ which provides a better compromise for the short comes of the traditional ADSL by increasing data rates and quality of ADSL lines.

III. TECHNICAL BACKGROUND

As previously mentioned ADSL uses the fact that there is plenty of unused frequency band available on the traditional telephone cables. Usually the telephone devices use the frequency range of not more than 4 kHz. So the rest of the frequency band is used by ADSL to transmit data. Therefore frequency splitter at the customer premises is used to split these two frequencies of the telephone line. ADSL1 and ADSL2 use the frequencies up to 1.1MHz and ADSL2+ use the frequencies up to 2.2MHz [1]. ADSL uses the port bonding. Several ports are provisioned to the end customer base and the total bandwidth will be the sum of the ports that were provisioned [5]. All DSLAM brands do not have this feature. In Sri Lanka many of the DSLAMs are being upgraded and now most of them are enabled with this feature.

IV. ADSL MODULATION

A MODEM is used for the purpose of demodulating and modulating between the analog and digital signals. This process is carried out by using modulation techniques and the process is carried out by the modems/routers and the DSLAM (will be discussed in latter parts of the paper) at the service provider’s base or at the exchange. There are two standards of modulating methods are used to modulate the ADSL signal.

- Carrier-less Amplitude Phase (CAP)
- Discrete Multi-Tone (DMT)

A. Carrier-less Amplitude Phase (CAP) Modulation

CAP is a variant of Quadrature Amplitude Modulation (QAM) technique which was used in early days of ADSL modulation. Although the name says that it is “carrier less” it actually uses a carrier where it is suppressed at even before it is transmitted and again it is reconstructed at the receiver end. This technique divides the data signal into two distinct bands the upstream data channel to the service provider and the downstream data channel for the user. The upstream symbol rate is 136K baud for a carrier of frequency 13.2kHz and the downstream symbol rate of 680 baud for a carrier of frequency 631kHz, 340K baud for a 435.5kHz carrier or 952K baud for a carrier of 787.5kHz [2]. Therefore the modem is adaptive to the symbol rate according to the varying channel conditions. The two channels are separated widely so as to minimize the interferences occurring between the two channels. But still the interference is a significant fact in this technique that it is no longer in use. Instead, DMT is now used in the incumbent local exchange carriers (ILEC) which has a lesser effect of the interference. But still some competitive service providers use CAP in ADSL because they have to deal with the local copper loop where DMT is supported only about half the time but CAP is supported for about 85% of the time [3]. As stated and approved by both American National Standards Institute (ANSI) and International Telecommunication Union (ITU) DMT is the technique used for ADSL.
In Srilankan context, the modulation scheme used is DMT.

B. Discrete Multi-tone Modulation

This modulation technique came from the concept of operating an N-array, relatively low-rated transceivers simultaneously, to achieve an overall high rate on one line. The N low rate data streams are sent over N separate frequency sub-channels or sub-band. Also it is called sub-carriers in order to keep them separated from one another. As the name implies “tone” is for a single sub channel. This sub-carrier arraying is achieved by IFFT (Inverse Fast Fourier Transform) and FFT (Fast Fourier Transform). FFT is not a perfect way to separate channels but it does well enough to separately obtain the sub channels at the receiving end [2]. And FFT is also considered computationally efficient than using other orthogonal transmission techniques like discrete wavelet transform. The division into multiple channels is to facilitate the better performance of data transmission with less interference from sources such as AM radio transmitters.

The modulation scheme uses multiple, harmonically related channels or the carriers. In transmitter this is implemented by IFFT and implemented by FFT in the receiver. The transmission bandwidth utilization is 1.1 MHz downstream and 256 kHz upstream. The limitation of 1.1 MHz is to allow the power constraints imposed by FCC. In the Sri-Lankan scenario there can be seen an attenuation of-120dB at 1.1 MHz for 18 kft telephone lines. The frequency domain is divided into 256 bins of each 4.3 kHz. Different ADSL flavors have different number of sub-channels according to the frequency spectrum being used [1].

- ADSL 1 has 256 sub-channels
- ADSL2 has 256 sub-channels
- ADSL2+ has 512 sub-channels

The double subcarriers amount for ADSL2+ is due to the doubled frequency spectrum used in its modulation. So at the Sri Lankan concept 512 subcarriers are used which improve the data rates and efficiency of the transmission.

DMT uses bandwidth ranging from 0 – 1.1 MHz and is divided into 256 sub channels or tones with each having a width of 4.3 kHz. The lower tones from 1 – 6 is allocated to pass the analog voice of 4 kHz, 32 upstream channels and 218 downstream channels. The frequency domain division is given as in the Figure 1 and Figure 2 gives the ADSL2+ spectrum.

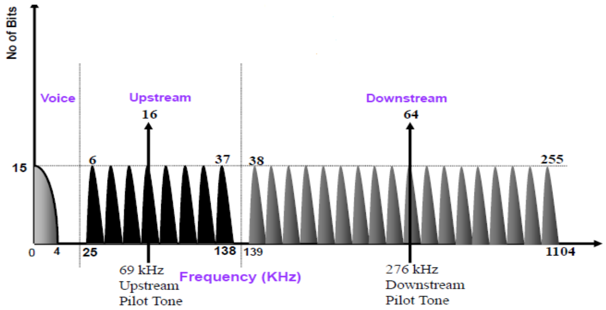

Figure 1. ADSL DMT modulation frequency spectrum

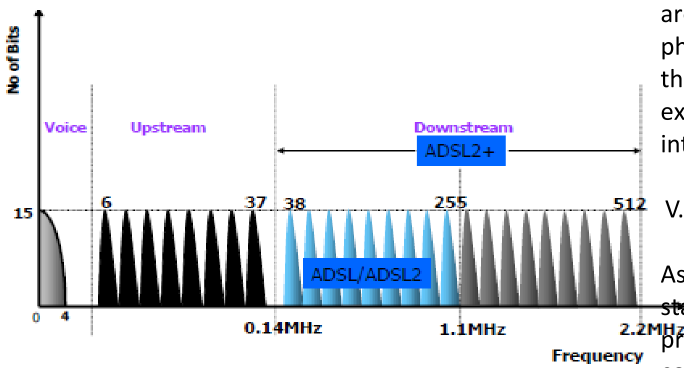

Figure 2. ADSL2+ DMT modulation frequency spectrum.

From Figure 2 it can be seen that ADSL2+ has doubled the bandwidth used to send data.

Each sub-channel can support up to 15 bits/Hz. According to the SNR of each sub-channel the amount of bits that it can carry will depend. This makes the MODEM to be flexible on changing the bit rates. Because of FDM, MODEM will select the best carrier to transmit data. Table 2 shows for various ADSL standards the available frequencies and the corresponding frequency tones being used [1].

Although the frequency spectrum is divided into several channels, all the channels are not being used due to various bottleneck factors. Channel/ tone 0 is reserved for POTS (voice). This channel is separated by a POTS splitter. Channel/tone 1 – 5 are not used to avoid interference between voice and data. These selections of unused channels depend on DSLAM/MSAN manufacturer and some of them are standards adopted by g.DMT. Upstream and downstream tones are separated by either FDM using LPF or HPF respectively, or by a combination of FDM and echo cancellation. The use of echo cancellation is that it improves the bandwidth throughput in the downstream direction.

Table 2. Available frequencies for various ADSL standards and corresponding frequency tones being used.

ADSL Type	Max Freq (Mbps)	Up Start (kHz)	Up Tones	Down Start (kHz)	Down Tones
ADSL1	8	25	6-31	142.3	33-255
ADSL2	12	25	6-31	142.3	33-255
ADSL2+	24	25	6-31	142.3	33-511
AnnexM	24	25	6-56	258	60-511

Each sub-channel uses QAM to feed in the data. All the specifications, standards and technical recommendations are adapted by the ISP in Srilanka in the individual physical devices in the network and also in the theoretical approach as well.so that the customer experiences the quality of ADSL2+ connection without interruptions.

V. LIMITATIONS OF ADSL, IN ITS SRI LANKAN CONCEPT OF VIEW

As discussed above all the recommended mandatory standards of ADSL2+ have been adapted by the ISP to provide a quality service. But still the customer complaints are higher regarding the line quality and the speed of the ADSL lines. By analyzing the circumstances it can be seen that all the limitations and the drop in the speeds happens at the last mile of the connection. That is, all the problems are in the connection from exchange to the customer premises. The reasons for this speed drop are analyzed.

A. Distance from local exchange to the customer premises.

This is the most critical factor in the ADSL connections. Each ADSL variant and the standards have defined their maximum speeds up to a certain maximum distance to the customer premises from the switching station. The standard distances for the maximum speeds are given in the Table 1.

According to the Sri Lankan context distance is the major problem affecting the speed. As the service provider provides ADSL2+ according to Table 2 the maximum speed of 26Mbps downstream should be experienced by customers at a radius of 5.7km but the practical values are different from this. The service provider guarantees a maximum speed of 20Mbps downstream and the maximum distance is 4km. According to fig.3 about 30% of the customers complain about the speed drop(due to distance). The complains of other portions are not directly related the distance(discussed in the latter part of the paper).

B. Bridge taps

The bridge taps are unterminated lines. During a scenario of bridge tapping, the customer premises wires are taken toward the junction box and the wires are taped to the spare copper pair that is running. This is like an extra-long antenna acting at the customer's premises causing mismatches because there is an isolated open end [4]. During in initialization of the modem, the effect of bridge taps is taken into consideration in channel estimation. Their effect is that it will reduce the possible channel capacity. The bridge taps will be saturated at the front end during the data transmission. This is unpleasant for the echo canceller. So the echo canceller should have an estimate of the bridge taps and the echo channel. But in G.lite, echo canceller is optional. So there will be a drop in the ADSL connection due to this reason which will in turn affect the speed of the connection.

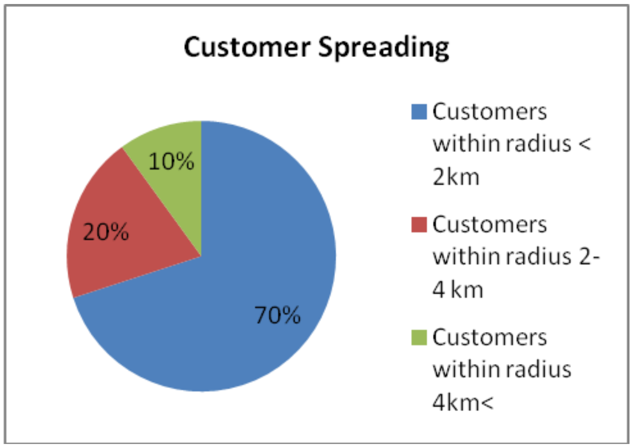

Figure 3. How the customers have spread over the ADSL usage from the exchange .

Although the real scenario of bridge taps are not implemented in Sri Lankan base we still can see this effect in the "stumping" process followed in laying the copper cables in customer premises. The "stumping" is done at the distribution points (DPs) where there are unused excess loops occurring.

C. Cross talk

Cross talk is another type of disturbance that will happen due to magnetic or electric field of one signal affecting the other telecommunication signal. There are two types of cross talks occurring. Near end cross talks (NEXT) which occurs due to the connectors that are connected to the twisted pair cables. NEXT may occur simply by the close proximity of the two cables. Other type of cross talks are far end cross talks (FEXT). These occur due to couple lines carrying signals in same direction. In ADSL there are no near end cross talks, but only the far end cross talks can be seen.

D. The cable quality and sizing

The quality of the cable and the sizing affect at large towards the quality of the ADSL service and directly to the speeds. Table 3 shows the wire sizes along with the data rates and the maximum distance from the DSLAM to the customer premises allowed.

Table 3. Cables sizes along with the defined data rates and the distances.

Data rate	Wire gauge	Wire size	Distance
1.5 or 2 Mbps	24 AWG	0.5 mm	5.5 km
1.5 or 2 Mbps	26 AWG	0.4 mm	4.6 km
6.1 Mbps	24 AWG	0.5 mm	3.7 km
1.5 or 2 Mbps	26 AWG	0.4 mm	2.7 km

At the Sri Lankan context 24 gauge wires are used with the wire size of 0.5 mm. The telephone lines attenuate signals and the attenuation is increased with the increasing frequency. At the highest transmitted frequency which is 1.1 MHz, attenuation for the 24 gauge wire is given found as in table4.

Table 4. Attenuation of the 24 gauge cable at the highest transmitted frequency.

Distance	Attenuation
10 kft	-70 dB
12 kft	-90 dB
14 kft	-100 dB
16 kft	-110 dB
18 kft	-120 dB

Therefore the signal attenuation due to the conditions of the cable finally results in the drop in the speeds of the ADSL lines.

E. Number of joints in the cable

Another fact that affects the speed of the ADSL line is the number of joints in the cable. The joints occur at several places in the cable installation from customer to the switch. The maximum number of joints allowed is 4. But a single customer experience more than 4 joints. From main switch to the MDF flexible joint can be found with a jumper cable. These cables lead towards underground (UG) and another 1 joint can be found. From UG cables to OH cables there are minimum 3 joints according to the variations of the cross section and diversions. From OH to the DP point there is a termination, where a dry joint can be found. From DP to the fuse box again a dry joint and finally leads to the rosette box and then to the splitter.

Therefore it can be seen a minimum of 7 joints for one customer.

Another problem in the cables in Srilanka is once a physical fault occurs in the cables the service provider will not completely replace the cable due to cost issues. But will rectify the situation with a drop wire connector. Drop wire connectors after the time being creates dry joint where heavy losses occur at that termination due to the leakages.

Therefore higher the number of drop wire connectors and the termination points in a single line leading the customer premises, the drop in the speed and the quality of the ADSL line is very high.

F. Insulation problems in the cable

Insulation problems regarding the cables is another reason affecting the quality of ADSL connections. The leakages due to poor insulations at the dry joints as well as at the loop connections the quality of the ADSL line will drop. In Sri Lanka this is a major reason for speed drop in ADSL. There are many poor insulations found at the loop connection.

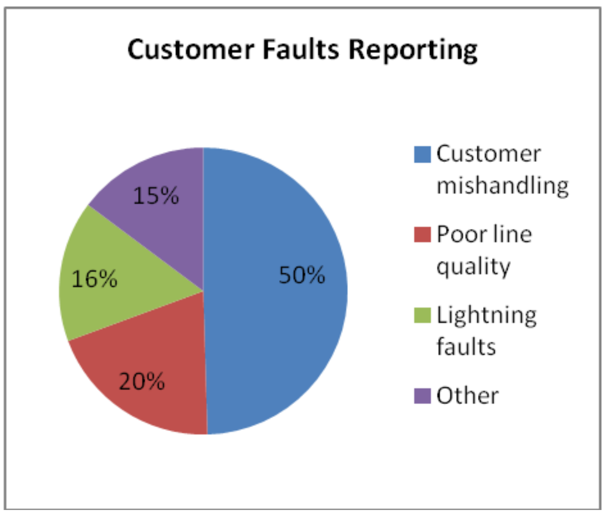

Figure 4. Common faults reported by ADSL customers.

G. Customer premises equipment and DSLAM problems

Even though the line conditions are at better level, the speed drop may occur due to incorrect installation at the customer premises. As shown in Figure 4 nearly 50% of the customer complaints were due to the poor installation of customer premises and software problems in the modems and routers.

Another minor Reason for the speed drop is the heavy number of connection cables at the DSLAM. This will result cross talk.

Currently the service provider exchanges are being upgraded to use combo card which provides a better reliability in the transmission process.

VI. CONCLUSION

Among the high data requirement solutions, ADSL is the prominent solution and Sri Lanka uses the ADSL2+ to fulfill the need for high speed data. There are a set of standards for the technology by ITU (International Telecommunication Union) and all the necessary standards are adopted by the Internet Service Provider (ISP) in Sri Lanka. The technical aspects including the modulation techniques, technical precautions and error correction methods are used as it is by the ISP. Some of the not-mandatory clauses of the standards like the deployments at the base stations have been omitted because they do not affect a lot in the ADSL line quality. Almost all the reasons for the speed drop in the ADSL lines and the poor quality is seen at the last mile, i.e.: the establishment from the base station to the customer premises. Some problems were inherent to the ADSL technology while some of them were very commonly seen in the Sri Lankan context deployments. Precautions and solutions should be taken to improve these problems and increase the quality and speed of the ADSL lines in Sri Lanka.

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