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Statistical Analysis of VoDSL Technology for the Efficiency of Listening Quality of 640k/640k

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ABSTRACT

Next-generation Internet technology will offer high performance and high capacity traffic aggregation and scalability. Voice over Digital Subscriber Line (VoDSL) technology allows service providers to offer multiple telephone lines over a single subscriber line in addition to high speed data transmission services. This article provides a baseline test for the Listening Quality (LQ) using VoDSL access technology by using Voice/Listening Quality (V/LQ) transmission with voice compression while countinously downloading files. The result will be to enable the efficiency of the LQ and its statistical analysis based on a Digital Subscriber Line (DSL) service at level 640K/640K for each American National Standards Institute (ANSI) and Carrier Serving Area (CSA) loops.

INTRODUCTION

The market for VoDSL loops to provide broadband services is currently experiencing explosive growth as the preferred last-mile deployment method for integrated communications providers in United States. Due to the explosiveness of the Internet and the massive data traffic through network convergence of voice and data technologies, VoDSL came into existence (Franz, 2000). VoDSL service has the capability to provide the customers with converged voice and data, including local and long distance telephone service, in addition to high speed Internet access on a single DSL copper line.

The dial-up modem has in the past represented the means of connectivity for on-line access and Internet access. Enterprise systems have since migrated away from 56K dial-up to a faster methodology of communication. This move was necessitated as a result of the extensive copper networks, owned by exchange carriers. As the Digital Subscriber Line (DSL) continues its emergence as the choice of transportation for high speed data over existing telephone lines, enterprise systems are challenged on how to converge and maximize voice calls and high speed data over these same lines (Opara, 2004).

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As businesses continue to maneuver in the 21st century competitive environments, enterprise systems will thrive for excellence on how their network will remain effective, efficient, and reliable, while maintaining a relatively low overall cost of doing business.

This study focuses on the use of the Asymmetric Digital Subscriber Lines (ADSL) technology, because it provides a "life-line" capability. This means that if there is power loss at any giving time, one telephone line will still be functional. This is because the technology has a lower bandwidth as the system travels upstream as compared to the downstream movement.

Further, the technology transmits a high bit rate data in the downwards direction from the central office (CO) to the subscriber (downstream), with typical bit rates from 1.5 to 8 Mb/s, and lower bit rate data in the reverse (up) direction from the subscriber to the CO (upstream), with bit rates from 64 to 640 Kb/s (ANSI 1995). ADSL is used for asymmetric services to residential and small office home office (SOHO) customers.

This paper will show outcomes that can be used in evaluating VoDSL solutions that offers multiple voice connections simultaneously with data onto the high speed digital line offered by an ADSL line. The results are based on the V/LQ of VoDSL. After the literature review, we present the description of the network architecture for V/LQ test setup. Then, we have discussions on the subscriber loop plant noise, concludes with the results of the tests performed.

LITERATURE REVIEW

Andersen (2007) found evidence that asymmetric DSL (also known as ADSL) has gained substantial interest in residential, small and medium size enterprise markets as a convenient way to gain access to high speed internet services. The reason is the continuous drive of enterprise systems toward voice/data convergence with the goal of reducing overall network usage costs.

Finweek (2008) reported that VoDSL is a simplified voice solution effortlessly integrating with the provider's existing connection to the PSTN (Public Switched Telephone Network).

Earlier studies found that convergence of voice and data in telecommunications is not a new paradigm, however, both ATM and IP or IP over ATM protocols are now used as technologies for convergence networking since both enhances lower network, operational and maintenance cost (Opara, 2004; Galli & Kerpez, 2002).

Most recent studies (Andersen, 2007), found evidence that VoDSL technology has a similar architecture to the legendary public switch telephone network (PSTN). The studies summarized by stating that this technology is a promising breakthrough to the so-called next generation networks (NGNs).

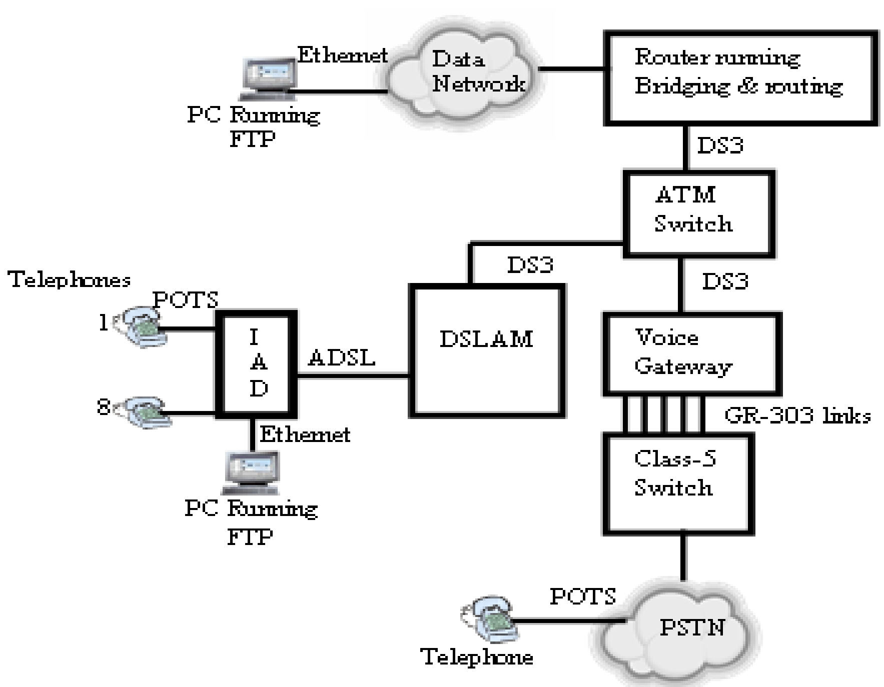
Aiello and Rogerson (2003), Drew (2002), Whitten (2004), Lu (2005), and Finweek (2008) among others stated that the ultimate convergence of next generation voice and data networks will be driven by the adoption of digital subscriber line (DSL) technology. (Aiello et al., 2003), summarized by stating that, the vision of a network, based on the internet model, will begin to materialize when enterprise systems and residential customers attain a wideband access connection to the network. Arunagiri (2005) further found evidence that companies using VoDSL technology can keep their existing PBX phone sets unlike the Voice over IP (VoIP) which requires IP phones for it to be functional.

Drew (2002) reported in it DSL Forum technology publication that VoDSL leverages the copper infrastructure platform, by providing both quality voice services as well as support functions to a wide range of data quality applications over an existing line of a consumer's site.

NETWORK ARCHITECTURE AT WORK

As files were continuously downloaded, the study used voice quality transmission with voice compression technology to substantiate the capability of the system to support up to eight derived lines on the Integrated Access Device (IADs) for VoDSL. The DSL service level used include the 640K/ 640K designed for each ANSI/CSA loops. The diagram in figure 1 shows the fixed wire line networks setup for the access progression of broadband services using VoDSL technology for voice quality transmission. The study indicates that the voice quality transmission with voice compression was verified as having the maximum number of line connections in compressed mode operation. This process could be supported without encountering problems, see Figure1.

Figure 1: Voice quality information transmission.



Source: (Musa, Akujuobi, & Mir, 2007).

The study further showed that the sample target can have multiple IADs based on their respective needs. Every IAD has 4-8 telephone interfaces and an Ethernet interface. Due to this configuration, one IAD was tested based on VoDSL solutions. The diagram shows that eight

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telephones were connected to the IAD that resides in the customer premises through Plain Old Telephone Service (POTS). Figure 1 further showed that data from the PC source running Files Transfer Protocol (FTP) was provided to the IAD via the Ethernet.

IAD interconnects the Customer's Premises Equipment (CPE) and ADSL service. Further, it converts POTS to Asynchronous Transfer Mode Adaptation Layer type 2 (AAL2). The system also uses the same Virtual Path Identifier/Virtual Channel Identifier (VPI/VCI) for voice and data. As a result, these have to be mapped to unique values before transmission on the same pipe line out of the Digital Subscriber Line Access Multiplexer (DSLAM).

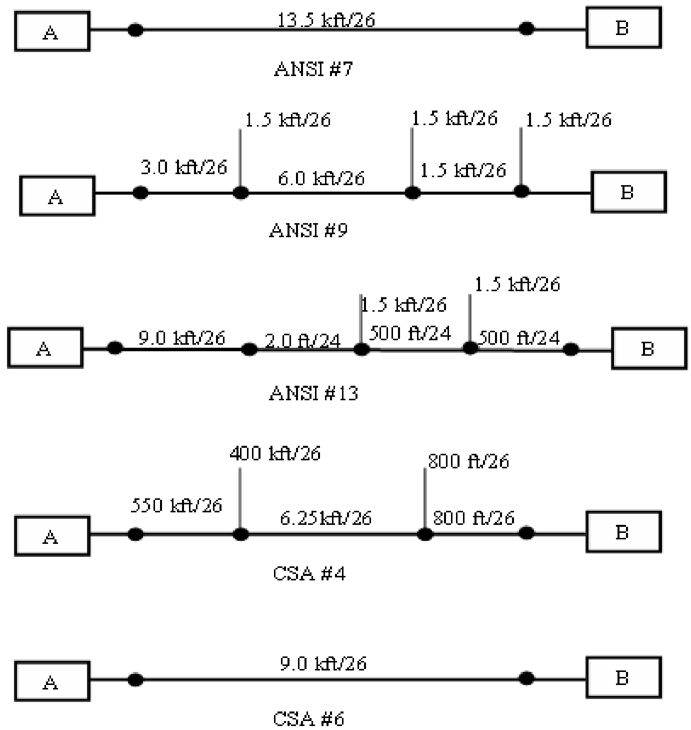
The entire voice calls are digitized in the shape of AAL2 cells and sent over the same Permanent Virtual Circuit (PVC). It was also shown that AAL2 makes it possible for the use of the same VPI/VCI for the convenience of numerous users. Enterprise system users are not expected to coexist in an ATM cell. The reason is that each cell can carry data from just one user. The data permeates through separate PVC. The diagram further shows that both of these PVCs can travel over the ADSL copper connection to a DSLAM. The DSLAM at this time aggregates all the PVCs onto a single connection line and then transported to a switch. The switch separates the voice and data calls. The voice PVCs travels to a voice gateway and the voice gateway converts the ATM traffic into Time Division Multiplexing (TDM)-analog traffic. This process further interfaces to a Class 5 switch via GR-303 Interfaces. As the process continues, the voice calls go to Public Switched Telephone Network (PSTN) that is connected to POTS system. This technology carries the voice calls to the respective telephone systems. Further, the data is sent to a router through Digital Signal-level 3 (DS-3) and to the Internet then to a PC running FTP via Ethernet. (Musa et. al. 2007)

A test is performed to confirm for dial tone on all the ports of the IAD. This testing was performed by connecting phones to the ports and taking them off the hook at the same time while recording the number of phones that simultaneously had dial tones. Calls were made from each port of the IAD to a phone connected to the PSTN and repeated the same way from a PSTN phone to each port of the IAD.

Voice compression was enabled and the number of phones having dial tones was verified. This study test analyses are based on the Asymmetric Digital Subscriber Line Wire line Simulator (ADSL WLS) which is located between the IAD (at customer) and DSLAM (at Central Office (CO)). The test model used ADSL WLS to generate and receive the traffic between the customer and CO after assigning the following loops: CSA loop #6 (9kft of 26 AWG wire), ANSI loop #7 with 24 DSL disturbers, ANSI loop #9 with 24 DSL disturbers, ANSI loop #13 with 24 DSL disturbers, CSA loop #4 with 10 ADSL disturbers, 10 HDSL disturbers and 24 DSL disturbers, CSA loop #6 with 10 ADSL disturbers, 10 HDSL disturbers and 24 DSL disturbers, CSA loop #8 with 10 ADSL disturbers, 10 HDSL disturbers and 24 DSL disturbers, mid-CSA loop #6 with 10 T1 disturbers in an adjacent binder group, and mid-CSA loop #6 with 10 DSL disturbers and 24 T1 disturbers in an adjacent binder group, 9kft, 12kft and 15kft of 26 AWG cable operating at 6 dB margin.

Figure 2 shows some examples of the copper loops problems as made up of pairs from sections of several cables between the central office and the customer.

Figure 2: A Sample of ANSI/ CSA loops. (Musa et al., 2007).



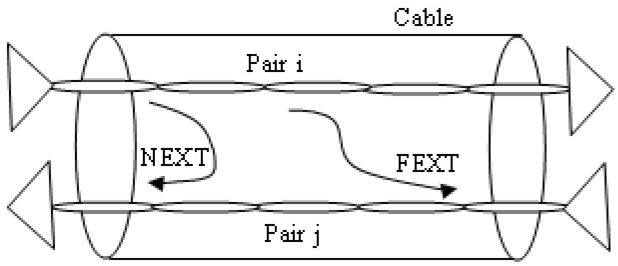
Subscriber loop plant analogy

The connections of the telephones by the twisted pair of copper wires to the network can experience some form of noise. The noise arises from the thermal noise of the twisted pair itself, the noise generated internally by the receiving modem, and signals electromagnetically coupled into the phone line.

To identify potential problems, the study will concentrate on crosstalk noise, that is, the undesired coupling of a signal from one communication channel to another. This process occurs when some of the transmissions signal energy leaks from the cable. As the study shows, there are two types of crosstalk. The first is the “near-end crosstalk” (NEXT) and the other is the “far-end crosstalk” (FEXT).

NEXT is the result of a leakage from nearby transmitting source into a receiver through the coupling pairs. FEXT is the noise detected by the receiver located at the far end of the cable from the transmitter (noise source). Figure 3 shows two types of DSL crosstalk. Where pairs j and i (see figure 3) belong to the same distribution cable and operate in full duplex. NEXT and FEXT models are specified in appropriate DSL standards for the purpose of guiding simulation study.

Figure 3: NEXT and FEXT crosstalk.



Galli et al. (2002) studied the theoretical analysis methods of summing crosstalk mixed sources. The following equation will further explain the algorism involved in the process. According to (Galli et. al., 2002) the received power spectral densities (PDSs) of NEXT and FEXT due to more than one crosstalk disturber for n interfering signals of the same kind become

$$N_{ext}[f,n] = S(f)X_N f^{1.5} n^{0.6} \quad , \qquad (1)$$

$$F_{ext}[f,n,l] = S(f)X_F f^2 l\,|H(f)|^2\, n^{0.6} \quad , \qquad (2)$$

where n is the number of interfering signals, f is the frequency, $S(f)$ is the PSD of the disturbing signal, l is the loop length , $H(f)$ is the transfer function of the loop, and X_N and X_F are constants determined by measurements. Now, when $n=1$, that is, one pair-to-pair crosstalk disturber, thus

$$N_{ext}[f] = S(f)X_N f^{1.5} \quad , \qquad (3)$$

$$F_{ext}[f,l] = S(f)X_F f^2 l\,|H(f)|^2 \quad , \qquad (4)$$

the starting point is expressed in the 1 % worst case for crosstalk. Crosstalk noise at high frequency can be a major limitation for providing high speed digital communications through the twisted pair loop plant. However, it can be ignored at voice frequency because it is very small. According to Werner (6) the signal-to-noise ratio (SNR) under NEXT can be expressed as

$$SNR_n \approx \frac{e^{-2d\zeta\sqrt{f}}}{\chi f^{1.5}} \quad , \qquad (5)$$

where d is the loop distance in feet, ζ is constant equal to 9 x 10^{-7} for 2 gauge loop, χ is constant equal to 8.8 x 10^{-14} for the 49 disturber 1 % worst case NEXT model, and f is the frequency in Hz. The SNR under FEXT can be expressed as

$$SNR_f = \frac{1}{\psi f^2 d} \quad , \qquad (6)$$

where ψ is constant equal to 8 x 10^{-20} for the 49 disturber 1% worst case FEXT model. The SNR bandwidth limited by a receiver background white noise (AWGN) can be expressed as

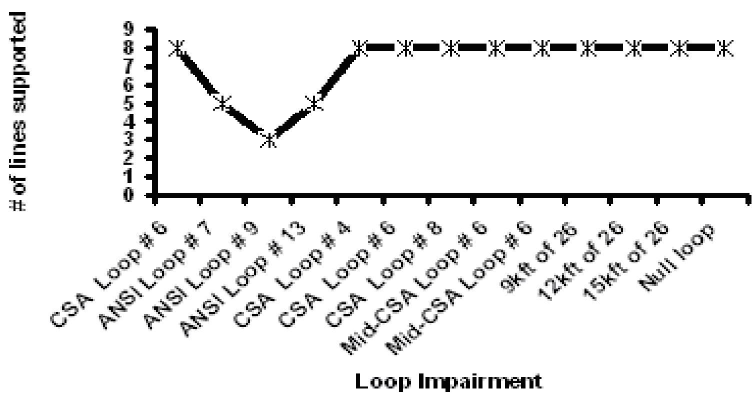
$$SNR_w = 1 \times 10^{10} e^{-2d\zeta\sqrt{f}} \quad , \tag{7}$$

where assuming that a -40dbm/Hz transmitted power density level and a -14 dbm/Hz receiver background noise power density level.

RESULTS AND DISCUSSIONS

During the voice quality transmission testing that included ADSL loops problems; it was found that on certain loops not all eight derived lines were supported. Figure 4 shows the statistics of DSL service level over different loops versus the number of lines supported at 640K / 640K. It could be seen that ANSI loops (#7, #9, and #13) with 24 DSL disturbers support five, three, and five lines respectively. However, the rest of the loops are supported by eight lines (Musa et.al 2007).

Figure 4: Number of supported lines of DSL service level 640K / 640K for each ANSI/CSA loops.



We used analog phones for testing, and the V/LQ is done using a digital speech level analyzer (DSLA) from Malden Electronics. This generates phonetically balanced speech samples and assesses the Mean Opinion Score (MOS) value which is claimed to have very good correlation with actual subjective assessment. The scaling for LQ based on five categories: 4 +x (Excellent), 3 +x (Good), 2 +x (Fair), 1+x (Poor), 0 or other (Unacceptable), where x is a decimal number.

Statistical analysis on the LQ values has been carried on the service level of 640k/640k for each ANSI/CSA loops for the following cases: -10AB vs.-10BA, -40AB vs. -40BA, -40BA vs.-10BA, and -40AB vs -10AB. A t-test on paired two samples for means was done. In three out of cases the p-value for the one-tailed and two-tailed test was 0.0000, while for the case -10AB vs -10 BA the p-value for the one-tailed test is 0.0031, and for the two-tailed test for the same case the p-value is 0.0061.

All the values and correaltion coefficients are shown in the tables 1-4. The correlation coefficients were positive in the case of -40AB vs -40BA, while in the other three cases w the Pearson r was negative. Moreover, the test was highly significant for the four cases. Also, the following results in Figures 5-8 were observed for the VoDSL service level 640K/640K for ANSI and CSA loops mentioned previously: First, the LQ_s are accepted at the speed for the customer and the variations are very small in range of 1% for each DSL level. However, if we need to be more concerned on the 1% range, it is clearly shown that the LQ for -10 dBm (excellent quality) is greater than -40dbm (good quality) for the VoDSL service levels. Second, the LQ is better for the customer when the perceptual analysis measurement systems (PAMS) from the CO to the customer (BA) than the verse. Third, the highest LQ for the customer (at -10dBm) is 4.31 for ANSI loop #13 with 24 DSL disturbers. The lowest LQ for the customer (at -10dBm) is 4.24 for Mid-CSA Loop #6 with 10 DSL disturbers and 24 T1 disturbers in an adjacent binder group at 9kft of 26 AWG cable operating at 6 dB margin. Fourth, the highest LQ for the customer (at -40dBm) is 3.63 for CSA loop #8 with 10 ADSL disturbers, 10 HDSL disturbers and 24 DSL disturbers. The lowest LQ for the customer (at -40dBm) is 3.6 for CSA loop #4 with 10 ADSL disturbers, 10 HDSL disturbers and 24 DSL disturbers.

Figure 5: LQ of VoDSL service level 640K / 640K for each ANSI/CSA loops at -10dBm.

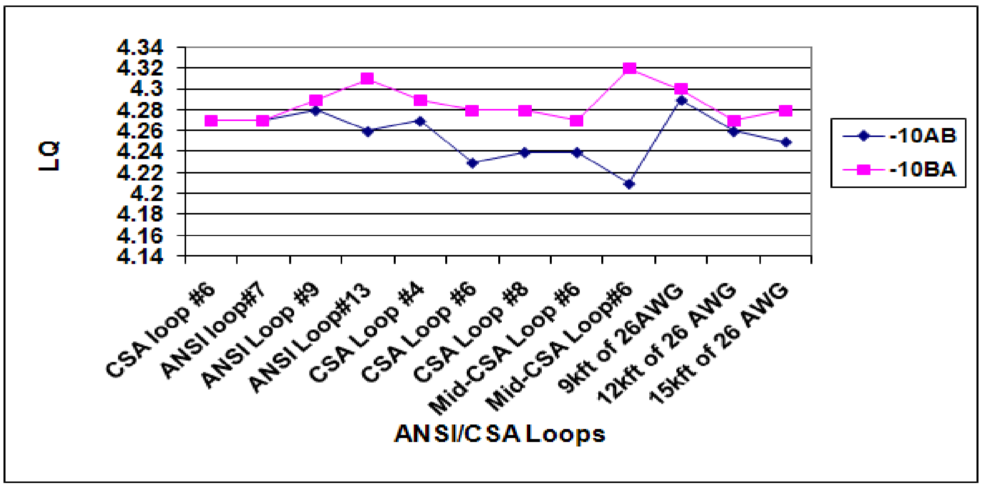


Table 1: T-test for VoDSL service level 640K / 640K at -10dBm

Case A 640K/640K			
10AB vs 10BA			
t-Test: Paired Two Sample for Means			
	Variable 1	*Variable 2*	
Mean	4.2558	4.2858	
Variance	0.0005	0.0003	
Observations	12	12	
Pearson Correlation	-0.1927		
Hypothesized Mean Difference	0.0000		
df	11		
t Stat	-3.3798		
P(T<=t) one-tail	0.0031		
t Critical one-tail	1.7959		
P(T<=t) two-tail	0.0061		
t Critical two-tail	2.2010		
The P-value is 0.0031 for the one-tailed and 0.0061 for two-tailed tests.			
The two variables are positively correlated.			
The test is highly significant.			

Figure 6: LQ of VoDSL service level 640K / 640K for each ANSI/CSA loops at -40dBm.

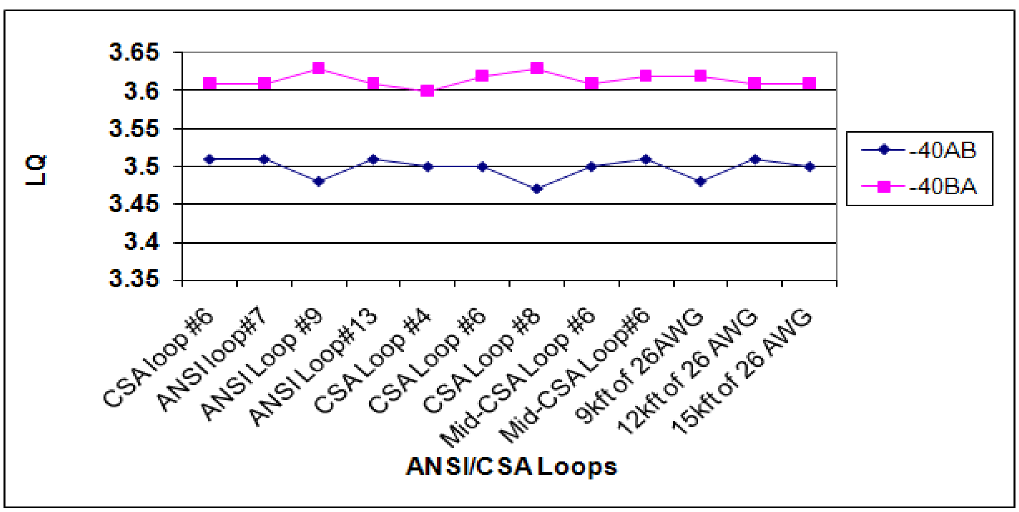


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Table 2: T-test for VoDSL service level 640K / 640K at -40dBm.

Case A 640K/640K		
40AB vs 40 BA		
t-Test: Paired Two Sample for Means		
	Variable 1	*Variable 2*
Mean	3.4983	3.6150
Variance	0.0002	0.0001
Observations	12	12
Pearson Correlation	-0.7161	
Hypothesized Mean Difference	0.0000	
df	11	
t Stat	-18.8310	
P(T<=t) one-tail	0.0000	
t Critical one-tail	1.7959	
P(T<=t) two-tail	0.0000	
t Critical two-tail	2.2010	
The P-value is 0.0000 for the one-tailed and two-tailed tests.		
The two variables arenegatively correlated.		
The test is highly significant.		

Figure 7: Comparison of LQ of VoDSL service level 640K / 640K for each ANSI/CSA loops at -10dBm and -40dBm from CO to Customer.

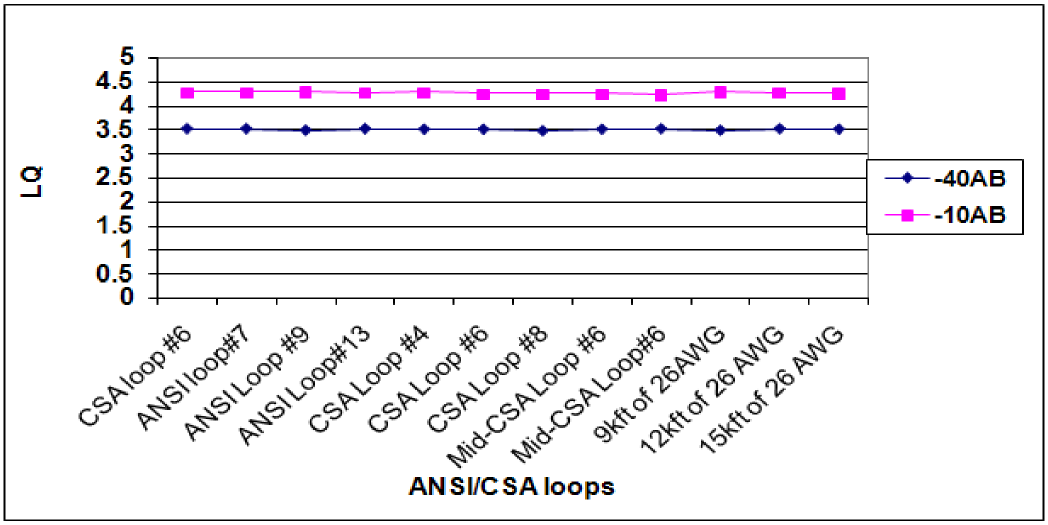

Table 3. T-test for VoDSL service level 640K / 640K at -10dBm and -40dBm from CO to Customer

Case A 640K/640K		
40AB vs 10AB		
t-Test: Paired Two Sample for Means		
	Variable 1	*Variable 2*
Mean	3.4983	4.2558
Variance	0.0002	0.0005
Observations	12	12
Pearson Correlation	-0.2231	
Hypothesized Mean Difference	0.0000	
df	11	
t Stat	-89.6456	
P(T<=t) one-tail	0.0000	
t Critical one-tail	1.7959	
P(T<=t) two-tail	0.0000	
t Critical two-tail	2.2010	
The P-value is 0.0000 for the one-tailed and two-tailed tests.		
The two variables are negatively correlated.		
The test is highly significant.		

Figure 8: Comparison of LQ of VoDSL service level 640K / 640K for each ANSI/CSA loops at -10dBm and -40dBm form Customer to CO.

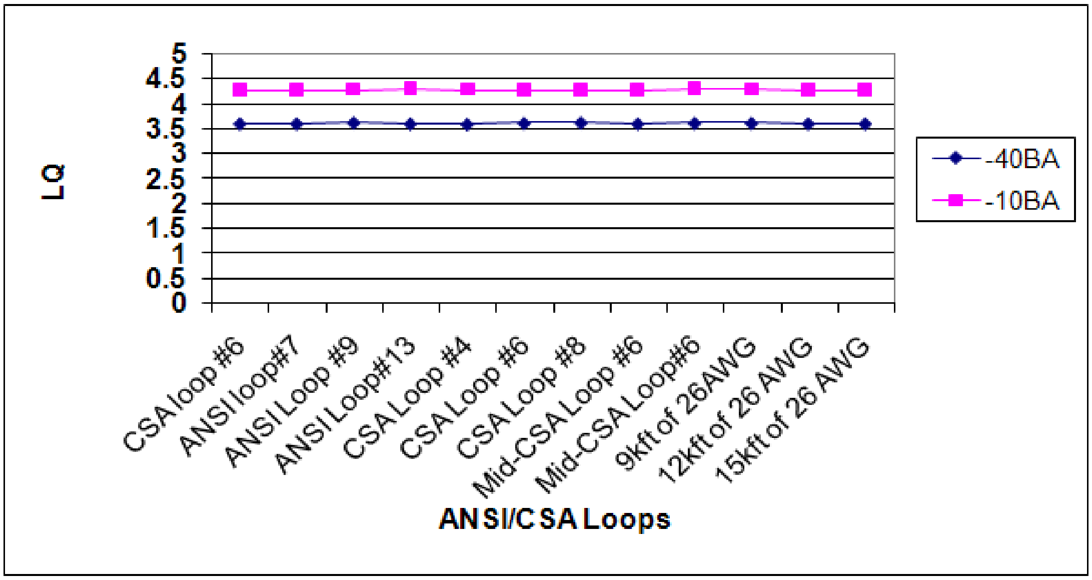

Table 4. **T-test for VoDSL service level 640K / 640K at -10dBm and -40dBm from Customer to CO**

Case A 640K/640K		
40BA vs 10 BA		
t-Test: Paired Two Sample for Means		
	Variable 1	*Variable 2*
Mean	3.6150	4.2858
Variance	0.0001	0.0003
Observations	12	12
Pearson Correlation	0.2098	
Hypothesized Mean Difference	0.0000	
df	11	
t Stat	-134.3364	
P(T<=t) one-tail	0.0000	
t Critical one-tail	1.7959	
P(T<=t) two-tail	0.0000	
t Critical two-tail	2.2010	
The P-value is 0.0000 for the one-tailed and two-tailed tests.		
The two variables are positively correlated.		
The test is highly significant.		

IMLPICATIONS FOR RESEACHERS

The continuous challenge for VoDSL architecture includes how to enhance voice gateway (VGW) functionality because of its capability to migrate into an access gateway that connects the packet network. Another challenge is that DSL has distance limitations.

The process of ordering, provisioning, installing, and testing DSL is currently configured within the industrial setting. Most of the sites are within a very short distance of the central office (CO). However, ADSL is available up to 12000 feet while symmetrical digital subscriber line (SDSL) can be about 18000 feet. Others such as ISDN can reach approximately 30,000 feet. These challengers are useful to developers who are interested in studying how to optimize the next generation technology.

CONCLUSION

VoDSL is a major component in the evolution of digital subscriber line technology. The study has shown that VoDSL makes it possible for end-users to chomp through voice-band telecommunication services that use contemporary devices such as the plain old telephone technology while integrating the deployed data access systems on copper wires. The benefit to consumers includes the cost savings achieved through the combined data and voice access. It was further noted that the end user does not have to replace their old devices.

It has also been shown that the DSL service level 640K/640K, for each American National Standards Institute (ANSI) and Carrier Serving Area (CSA) loops have been used to provide better voice/listening quality for Customers. From the previous Figures 5-8 and tables 1-4, it is clearly shown that -40dbm has more attenuation (cable loss) than -10dbm, which made the last produce better LQ using VoDSL. The downstream band is greater than the upstream that can make the LQ better for customer who receives the call from the CO than verse. The listening qualities are in excellent service for customer and the variation is very small limited to 1% range for the DSL service level 640K/640K for each ANSI/CSA loop. The statistical analysis on the LQ values of the test was highly significant for all cases.

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