Measurements and Test Performance for Integrated Digital Loop Carrier for White Noise Impairment with Fast Mode

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Abstract— **This paper presents measurements and test performance for Integrated Digital Loop Carrier (IDLC) technology. We study the measurements which are based on upstream and downstream modes with statistical analysis approach. We focus on the statistical analysis measurement for noise margins on one type of loops – white noise impairment with fast mode.**

Keywords— integrated digital loop carrier; dsl; broadband

I. INTRODUCTION

Recently, telecommunications network providers improve and change their path in broadband technologies for better services and costs to customers. They have increased the number of lines with extended distances from Central Office (CO) with high quality of services in voice and data. From analog in Plain Old Telephone Services (POTs) to digital in Digital Loop Carrier (DLC), they have made great benefits to users [1-2]. The DLC technology is based on digital techniques to provide large services to users via copper lines. In today technologies, the IDLC system is broadly installed in delivering telecommunications services. Significant wiring and advantages of cost can be profited with the IDLC at remote locations. In this work, we illustrate the statistical analysis of the results of measurement of a test performance for the IDLC type of white noise impairment.

A baseline test for the Listening Quality (LQ) using Voice over Digital Subscriber Line (VoDSL) access technology was studied in [3]. The research used Voice/Listening Quality (V/LQ) transmission with voice compression while countinously downloading files. Indeed, those results enable the efficiency of the LQ and its statistical analysis based on the white noise impairment. Furthermore, based on the experimental VoDSL network architecture and the following DSL service levels 640K/ 640K, 1.5M / 384K, 3.0M/ 512K, and 1.5M/ 256K for each ANSI/CSA loops by using voice quality transmission testing with voice compression while continuously downloading files. It was found that on certain loops all eight derived lines were not supported on IADs for VoDSL solution [4].

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Additionally, a traffic study is undertaken to determine if a 64 kbit/s common signaling channel is sufficiently fast to meet the present and future call-processing needs of integrated digital loop carrier systems presented in [10]. Bell Communications Research has proposed the use of such a 64 kbit/s common signaling channel in a requirements document (technical reference TR-TSY-000303), to satisfy call-processing needs across the IDLC generic interface, whenever out-of-band signaling is used.

The authors characterize the IDLC call-processing traffic on this message-oriented common signaling channel and examine associated design requirements in TR-303 under certain modeling assumptions (Poisson arrivals and exponential service times.) They showed that under worst case conditions, the study concluded that a critical message requiring a response within 100 ms would practically always meet that delay criterion. Also, critical messages requiring a response within 40 ms would fail once every 10 busy hours. Since no specific signaling response requirement of 40 ms has been found, their study concludes that a 64 kbit/s common-signaling-channel for the IDLC systems is sufficiently fast to achieve required signaling response times.

II. DLC AND IDLC TECHNOLOGIES

Digital loop carrier is a technology that uses digital techniques over twisted-pair copper lines. The DLC systems used for voice traffic only traditionally convert the telephone voice frequency signals into digital signals, then transmits the digital signals between local digital switch in CO and remote digital terminals near the subscribers [5].

The DLC is remote terminal equipment used to transfer digital information between CO and the subscriber over copper or fiber cable [6]. The fiber/copper runs between the central office and the remote subscriber's terminal. Using the fiber will serve larger numbers of users than using copper. The DLC is a remote-site box located on ground and connected to CO through a distribution line (fiber/copper). The DLC is used to bundle out many channels of voice traffic to user's areas and remotely expand CO capabilities without placing expensive new cables. The DLC system provides telephone services for variety of POTS, digital data systems, and Integrated Services Digital Network (ISDN) over T1 and SONET digital facilities [7]. Indeed, the functional components of a DLC system are explained and discussed in [8].

The Integrated Digital Loop Carrier is required when a digital loop carrier system is integrated into a local digital link. The IDLC is capable of supporting broadband and POTS. IDLC can support a greater range of services and advanced access network technologies [9]. The IDLC system consists of a remote digital terminal and an integrated digital terminal interconnected via a digital facility [10]. The functional components of an IDLC system are investigated in [8]. The IDLC can support both voice and high speed data services. The IDLC systems are the integration of the integrated digital terminal and remote digital terminal. The IDLC system moves some of the switching services from the local switches into remote digital terminals to increase the efficiency of communication lines between customers and the CO.

III. Results and Discussion

Laboratory testing can measure conformance to many industry requirements and can uncover many operational problems, but cannot fully duplicate conditions experienced in the field. Digital loop carrier technology makes use of digital techniques to bring a wide range of services to users via twisted–pair copper phone lines. In this work, we use the test setup of the Integrated Digital Loop Carrier (IDLC) technology based on upstream and downstream modes shown in Figure 1. The traffic generator located between the IDLC and the modem used to generate and receive the traffic, and the Asymmetric Digital Subscriber Loop Wireline Simulator (ADSL WLS) used to simulate the loops and the impairments. Digital Subscriber Loop Access Multiplexer (DSLAM) with the DLC that make as the IDLC, the DSLAM used for data and server approximate 25 modems or more and is located at the CO. The Customer premises equipment (CPE) modem is located at the subscriber. The IDLC receives the voice and data and separates them by sending the data to network carrier and voice to the voice switch.

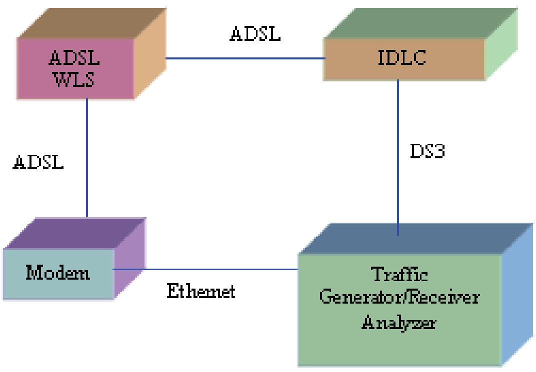

Fig. 1. Test setup for the IDLC for the white noise impairment.

Based on the above setup we found the following results using the measured value in kbps, and loop length (LL) in kft, 26 AWG: we used loop 26 AWG with noise AWGN at -140 dBm/Hz at both ends. The ADSL link has fast latency with 6 dB target noise margin. Table I shows the data for the upstream performance and the downstream performance of the white noise impairment, with the Fast Mode. We observe in Table I that the only measured value for loop lengths 13 kft through 17 kft at the downstream performance failed compared to the others, while all measured values are passed, for the upstream case.

TABLE I. White Noise Impairment in Fast Mode

Loop length (kft, 26 AWG)	Fast Mode							
	Upstream (UP)				Downstream (DW)			
	Sync Rate (kbps)			Noise UP Margin, Reported(dB)	Sync Rate (kbps)			Noise DW Margin, Reported(dB)
	Expected	Measured	Pass/Fail		Expected	Measured	Pass/Fail	
0	800	800	P	8	8000	8000	P	15
1	800	800	P	8	8000	8000	P	14.5
2	800	800	P	8.5	8000	8000	P	17
3	800	800	P	8.5	8000	8000	P	16
4	800	800	P	8.5	8000	8000	P	14
5	800	800	P	8.5	8000	8000	P	13.5
6	800	800	P	8.5	8000	8000	P	9.5
7	800	800	P	8.5	8000	8000	P	6.5
8	800	800	P	8.5	8000	8000	P	5.5
9	800	800	P	8	6944	6944	P	5
10	800	800	P	4.5	5824	5824	P	7
11	768	800	P	5.5	4448	4448	P	5
12	704	768	P	4.5	3200	3200	P	5
13	608	704	P	4.5	2176	2176	F	5
14	512	608	P	4.5	1408	1408	F	6
15	416	512	P	5	928	928	F	6
16	320	448	P	4.5	608	608	F	6
17	256	352	P	5	320	320	F	6

The statistical analysis will be based on regression analysis and hypotheses testing for the results of the measurement of the test performance of the IDLC one type of loop for white noise impairment.

A. *Regression Analysis*

For the data in Table I, we check the loop length against the noise margin for both cases, namely the upstream and the downstream for the Fast Mode. Since there is only one reading per the loop length setup, we will investigate the relationship between the loop length and the noise margin for the upstream and downstream separately. In addition to that, the data analysis will be carried on those setups that have data. For contrast the three cases of regression (Linear, Quadratic, and Cubic) will be calculated. In the three cases, the loop length will be taken as a variable, while the noise will be the response for that setting. The results of the analysis for the data in Table I are shown in Table II, where R stands for the correlation coefficient of the relationship between the loop length and the noise margin, and R^2 stands for the coefficient of determination which gives the percent of variation in the noise margin that was explained by putting the loop length in the function.

TABLE II. REGRESSION ANALYSIS ON FAST MODE

Fast Mode				
	Reg. Type	**Relation**	**R^2**	**R**
Up				
	Linear	y = -0.2988x + 9.2339	0.6912	-0.8314
	Quadratic	$y = -0.0097x^2 - 0.1337x + 8.7939$	0.7067	
	Cubic	$y = 0.0068x^3 - 0.1835x^2 + 1.0147x + 7.4035$	0.8621	
Down				
	Linear	y = -1.1236x +17.0110	0.8377	-0.9152
	Quadratic	$y = 0.0047x^2 – 1.1806x + 17.1154$	0.8378	
	Cubic	$y = 0.0366x^3 - 0.6535x^2 + 1.8545x + 14.7019$	0.9382	

It is clearly visible that the linear relationship between the loop length and noise margin for the upstream case is as strong as in the quadratic case, as far as the percentage of variation explanation. This is in contrast with cubic that shows a stronger explanation of the variation due to the inclusion of loop length. On the other hand for the downstream, the three relationships show a very high correlation between the two variables. In both cases of the upstream and downstream, and for the linear setup, the loop length and the noise margin are negatively correlated as shown by the analysis in Table II. In case we overlook the loop length setup for the upstream and downstream, for the Fast Mode data in Table I, we see that the standard deviation in the noise margin for the downstream is more than 6 times than that in the upstream, based on the data points in Table I and the calculations in Table II.

B. Statistical Analysis and Hypothesis Testing

Due to the small sizes in the sample for the data on the upstream and downstream, a T-test of statistical hypothesis will be carried on the equality of the means versus that they are different, where μ_1 is the mean on the data of the noise margin for upstream and μ_2 is the mean for downstream. Some restrictions will be taken into consideration, especially that the analysis was done for the data for the pass only, and on all the data as shown in the tables. Moreover, there will be no test on the equality of variances of the up and down streams data in all cases. Hence the test will be carried without pooling. That is, the two Hypotheses that will be tested are the following:

$$H_0 : \mu_1 - \mu_2 = 0 \ \ versus \ \ H_1 : \mu_1 - \mu_2 \neq 0 \quad (1)$$

Tables III and IV show the t-test analysis of the results of Table I, the Fast Mode case. The test was run with the assumption of unequal variances due to the big difference between the variances of upstream and downstream cases. The test is carried out on the means of the noise margins for the downstream and upstream settings on those which were labeled as P only and on all the values, respectively. The difference between the noise margin for the upstream and downstream is significant at the 0.05 level of significance, for both of the one-sided and two sided tests, as shown in Tables III and IV.

TABLE III. T-TEST ANALYSIS FOR FAST MODE, PASS DATA ONLY

t-Test: Two-Sample Assuming Unequal Variances		
Upstream versus Downstream , Fast Mode, Pass data only		
	Up Variable 1	**Down Variable 2**
Mean	6.750	10.269
Variance	3.478	22.859
Observations	18	13
Hypothesized Mean Difference	0	
df	15	
t Stat	-2.519	
P(T<=t) one-tail	0.012	
t Critical one-tail	1.753	
P(T<=t) two-tail	0.024	
t Critical two-tail	2.131	
t Critical two-tail	2.032	

TABLE IV. T-TEST ANALYSIS FOR FAST MODE, ALL POINTS

t-Test: Two-Sample Assuming Unequal Variances		
Upstream versus Downstream , Fast Mode, All 18 points		
	Up Variable 1	**Down Variable 2**
Mean	6.750	9.028
Variance	3.478	20.426
Observations	18	18
Hypothesized Mean Difference	0.000	
df	23	
t Stat	-1.977	
P(T<=t) one-tail	0.030	
t Critical one-tail	1.714	
P(T<=t) two-tail	0.060	
t Critical two-tail	2.069	

IV. Conclusion

We performed the measurement of a test performance for the IDLC technology based on upstream and downstream modes. Noise margins are measured in one type of loops for white noise impairment. Furthermore, the passing and failing loops had been identified for this type. In the statistical analysis, we found that for the upstream of the Fast Mode, the cubic regression for the Fast Mode gave the highest R^2 value of 0.8621 followed by the quadratic and then by the linear regression setup, with values of 0.7067 and 0.6912 respectively. While for the downstream, and the Fast Mode setting, the regression analysis gave the value of 0.9382, 0.8378, and 0.8377 for the cubic, quadratic and linear regression cases respectively. It is worth noting that the values of R^2 are larger for the downstream than in the upstream setup.

References

[1] Occam Networks," The evolution of digital loop carrier," white paper, *www.occamnetworks.com*.

[2] J. Marcus," Digital loop carrier," Current Analysis, www.currentanalysis.com.

[3] S. M. Musa, E. U. Opara, M. A. Shayib, and M. A. El-Aasser, "Statistical analysis of VoDSL Technology for the Efficiency of listening quality of 640k/640k," *Journal of International Technology and Information Management (JITIM),* Vol. 19, No. 1, pp. 97-110, 2010.

[4] S. M. Musa, C. M. Akujuobi, and N. F. Mir, "VoDSL Information Management for Broadband Communication Network Access," *Journal of Computing and Information Technology* - CIT 15, 2007, Vol.1, pp. 17–24.

[5] D. D. Zhang," Use case modeling for real-time application," *IEEE Fourth International Workshop on object Oriented Real time Dependable Systems*, 1999, pp. 56-64.

[6] F. T. Andrews," The evolution of digital loop carrier," *IEEE Communications Magazine*, Vol. 29, No. 3, March 1991, pp. 31-35.

[7] H.Y. Khoe, A. C. Bolling, and A. Bhuyan," Digital loop carrier solution for voice and data networks," *Bell Labs Technical Journal*, April-June 1999, pp. 209-217.

[8] W. P. Arvidson, "A generic operations system interface to support the next generation of digital loop carrier systems," *IEEE Journal on Selected Areas in Communications*, Vol. 6, No. 4, May 1988, pp. 677-684.

[9] M. Peck, J. Ruban, G. Marshman, and C. Carlson," Evolution of integrated digital loop carrier," *GLOBECOM 91*, 1991, pp. 2092-2099.

[10] H. M. Jablecki, R. B. Misra, and I. Saniee," A call-processing traffic study for integrated digital loop carrier applications," *IEEE Transactions on Communications*, Vol. 36, No. 9, Sep. 1988, pp. 1053-1061.