Measurement and Analysis of Copper Access Network for Isdn Basic Rate Interface

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Abstract

Improper combination of copper pair properties like gauge, longitudinal balance, loop resistance, insulation resistance and distance for Integrated Services Digital Network Basic Rate Interface (ISDN BRI) leads to users experiencing connectivity problems and fluctuating link speeds. Installations, configurations, troubleshooting and maintenance of ISDN BRI services can be very complex to the technical team of the service provider. There may be many reasons causing this in developing countries. Troubleshooting at Uganda telecom, for instance, has been cumbersome due to the absence of manuals that guide technicians on proper installation of copper lines.

In this paper, we report measurements study to analyze and asses the impact of the copper pair parameters/properties combination to the copper line speeds. The study aimed at simplifying the installations, configurations, troubleshooting and maintenance of the ISDN BRI services on the side of the technical people. This was achieved by taking measurements at different parameters (distance, gauge, longitudinal balance, loop resistance, and insulation resistance) in order to come up with optimal values for the design of the computer based program for optimization of data connectivity in ISDN BRI. We use the measurement results to design and develop a computer based program that can be used to verify the measurements and identify the expected optimal parameters in troubleshooting.

Keywords: Measurements, Analysis and Access Network.

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1. INTRODUCTION

Integrated Services Digital Network Basic Rate Interface (ISDN BRI) is commonly used as a solution to provide low bandwidth Internet access to small offices or dial-in users with traditional analogue dial-in services. In general, it is a network that provides end-to-end digital connectivity to support a wide range of services including voice and data services. Some readers, mainly from developed world, may wonder why we are still talking about ISDN technology, while may appear obsolete in developed world; ISDN is still used as Internet access technology in developing countries albeit at a very small scale. In this paper we are not proposing using copper as a communication medium, but we are analyzing the performance of the

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currently used copper system / technologies (ISDN BRI) and what we show are the typical mistakes that can be done in developing countries due to lack of expertise and negligence.

ISDN allows multiple digital channels that operate simultaneously through the same regular phone wiring used for analog lines. Latency is much lower on an ISDN line than on an analog line. The technology is implemented over copper access network for voice and data communication; however it should be implemented with proper combinations of copper pairs' properties/parameters like *gauge*, *longitudinal balance*, *loop resistance*, *insulation resistance*, and the *distance*. Distance refers to the length of a pair of copper conductors from the central telephone office to the customers' premises. Longitudinal balance is the electric symmetry, with respect to ground, of the two wires of a pair or an expression of the difference in impedance of the two sides of a circuit [Technical F., 20074] Loop resistance is the total resistance of a thermocouple circuit caused by the resistance of the thermocouple wire (total resistance of a closed circuit of two wires measured at one end). Insulation resistance is the DC resistance expressed in ohms measured between any electrical connector pins or lead wires and the transducer body or case [Grace B., 2009].

In the event that ISDN BRI connectivity is not working well the developers of the technology developed error codes and their likely causes [Itu, 2002] which are supposed to assist the technical team in coming up with the proper installations, repairs/troubleshooting and maintenance. Despite using error codes, installation manuals of ISDN BRI and several trainings to the technical team of the service providers, users experience connectivity problems and new installations at times take long to be completed. This was got through a verbal interview we carried out on both the technicians and clients of ISDN BRI technology at *Uganda Telecom*, a telecom provider in Uganda. However, these manuals and guidelines for the existing copper are no where to be found, and it is not clear if the guidelines were properly used when installing them.

ISDN users have been constantly reporting connectivity problems ranging from low speed to poor connectivity. This is the main motivation of this work: Firstly, we carried out a measurement study for 150 copper cables using a dynatel 965 test meter to determine the dependency of speed to the copper parameter values. Dynatel 965 test meter is used to determine the speed of copper cable in addition to inherent parameters of the copper at any distance from the central office of the ISP. Analysis of the measurement results enabled us to know the dependency of link speeds to copper parameters. We used the measurement results to implement a computer based tool that can be used to automatically check if the values from the Dynatel are optimal.

This paper is structured as follows. Section 2 describes how the measurements were done, and Section 3 outlines the results of the measurements. In Section 4, analysis of the results is explained and we briefly describe the computer based tool that was developed as a result of the measurement analysis. Finally, we conclude the findings in Section 6.

1.1 Measurements

We measured parameters for 150 copper cables of Uganda Telecom that support ISDN connectivity to users. As mentioned earlier, a Dynatel 965 test meter was used to give the values of all parameters of a given copper cable, namely gauge, longitudinal balance, loop resistance, insulation resistance. We measured the distance from the ISDN central operational office of the telecom provider to the measurement point (at the end user) in order to assess the impact of the combination of the copper pairs' parameters to the distance. The 150 lines were chosen because users of those lines had reported faulty behaviors more than four times in the past two months, information (Location and technical details) about the lines was collected so that measurements could be made. Each ISDN BRI line in question was disconnected from the switch and the network terminal was also disconnected at the customer's premises so that the copper pair was free from any electrical signal, then the measurements were taken by a digital meter.

A 1 MB test file that we named testfile.tar.gz was put on one of the servers at the service provider's end, the ISDN BRI line was reconnected and the test file was downloaded at the customer's end. This allowed us to record download rates (data transfer rates) at three different intervals during the download (i.e., at the beginning, middle and the end). The average download rate was taken as the data transfer rate at the measured parameters / properties and the results were tabulated. Latter all the data was analyzed to establish the dependency of link speed to various parameters of copper cables and the distance between end user (measuring point) to the server.

The results of the measurements exhibited two categories; those with data transfer rates above 50 kbps and those that were below. We consider 50 Kbps as the best line speed because bearer channel of ISDN is 64 Kbps, with assumed overhead of 14 Kbps, then the optimal link speed is 50 Kbps for one bearer channel of ISDN BRI to be fully optimized. The results that exhibited data transfer rate above 50 kbps were used for the implementation of computer based program for the optimization of ISDN BRI under fixed gauge with varying distance, loop resistance, insulation resistance and longitudinal balance.

1.2 Analysis of Measurement Results

In this section, we present analysis of the measured data in order to determine the variation of line speed as a function of increasing values of the parameters of the copper line and the distance. We classify the analysis into different categories; the basis was on copper pairs' gauge / property under study. Data was grouped and analyzed into two groups, namely, 1) data that resulted in link speed above 50Kbps, and 2) data that led to link speed of less than 50 Kbps. Our analysis in this paper will emphasize the first case. For analysis of complete data set the reader is referred to Grace B., (2009. Four gauge values (0.4mm, 0.5mm, 0.55mm (Mixed gauge), and 0.6mm) were put into consideration because there are only four copper pair gauges being used by the service provider.

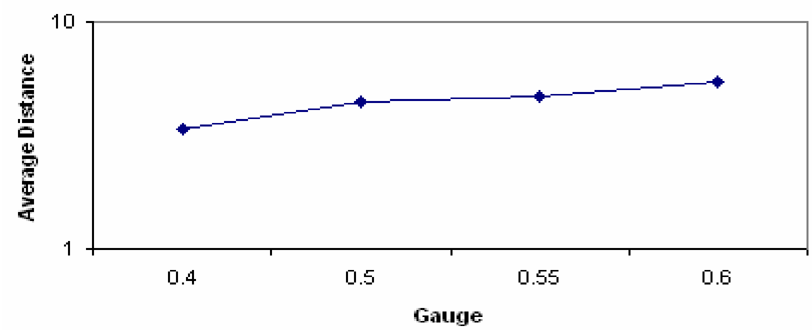

Fig. 1 The average distance as a function of gauge

The average distance for different gauges for all ISDN BRI lines (below and above 50 kbps data transfer rate) were collected and a graph of average distance as a function of gauge is seen in Figure 1. The figure shows general dependency between distance and gauge. It can be observed from the Figure 1 that the gauge increases as the distance increases. These results suggest that the installation was deliberately done to favor higher gauges for longer cables in average sense.

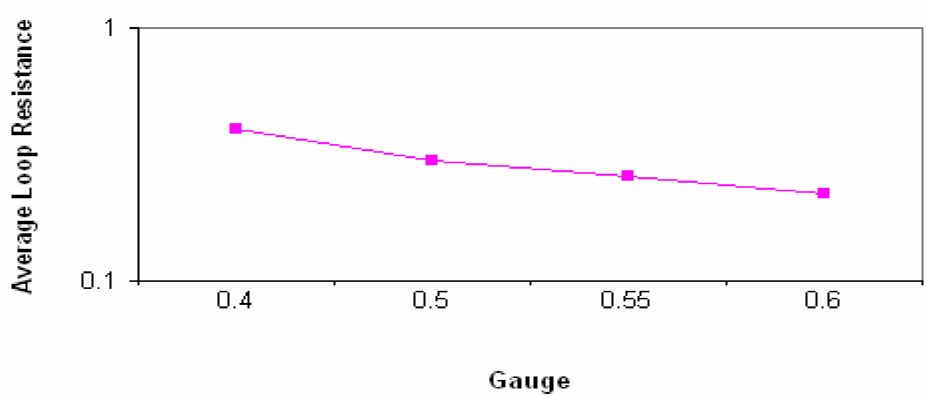

Fig. 2 The average loop resistance function of gauge

Figure 2 shows the average loop resistance as a function of gauge. It can be observed from the figure hat as the gauge increases the average loop resistance decreases. Similar trend can also be observed for the longitudinal balance from Figure 3; that as gauge increases the longitudinal balance decreases.

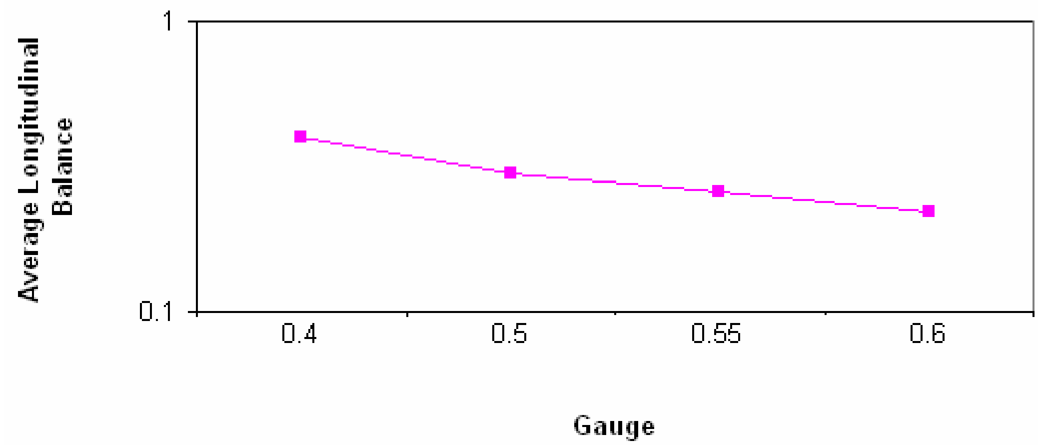

Fig. 3 The average longitudinal balance as a function of gauge

The average data transfer rate as a function of distance for copper conductors was also plotted and it is observed from Figure 4 that for all data transfer rates, as the distance increases the data transfer rate decreases. This show that distance has an impact on the data transfer rate, the further you go the lower the data transfer rate or speed. This implies that a copper cable with higher gauge value is required to extend the ISDN BRI services to subscribers located a longer distance from the service provider and the bigger the gauge the better the service.

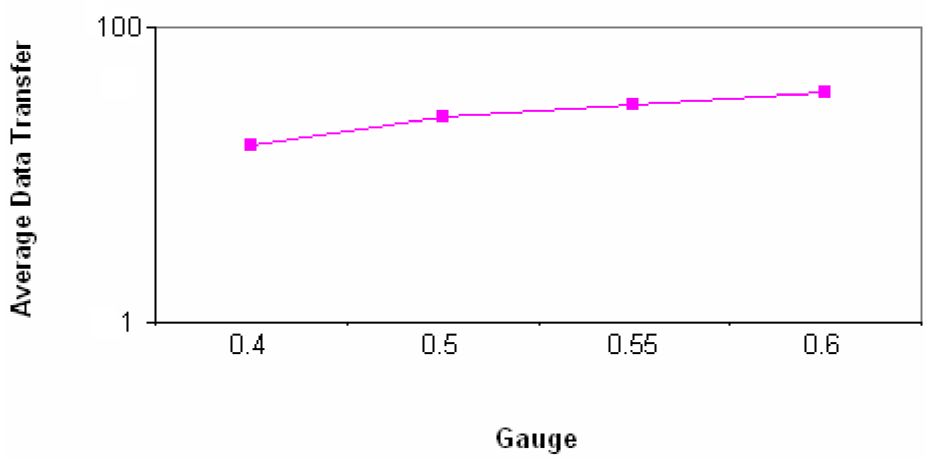

Fig. 4 The average data transfer as a function of gauge

2 COMPUTER BASED TOOL

The computer based tool for optimization of ISDN BRI was developed after the analysis of the results of measurements carried out using the *confidence interval* (μ). Confidence Interval refers to a condition given that if a and b are limits of a parameter, then $a \leq \mu \leq b$, where *a and b* are called confidence limits, *a* being the lower confidence limit while *b* is the upper confidence limit. The probability that the true population parameter will lie with in the stated interval is denoted by $(1-\alpha)$ and this is referred to as confidence coefficient or degree of coefficient. Standard deviation on the other hand is a measure of the dispersion of outcomes around the mean of a given sample size denoted by sigma well as mean refers to the mathematical average of a given sample size. In our case, optimal values are measurements which exhibited data transfer rates or link speeds above 50 kbps.

The confidence interval values for each parameter were used the confidence limits under which we are confident that ISDN BRI can optimally work. It was also used in the analysis of the measurements in order to come up with optimal ranges under which ISDN BRI should operate. Table 1 shows the optimal values or degree of confidence after measurements and analysis.

The results of the analysis were further filtered in order to come up with measurements which were used as a yard stick for the development of the computer based program. Then Windows XP was used as an operating system, Visual Basic 6 as the software and a Laptop as the hardware for the computer based program.

TABLE I: DEGREE OF CONFIDENCE

Gauge	**Distance Km**	**LT/BAL**	**L/Res**	**INS/RES**
0.4	(2.7 ≥ μ ≤ 4.1)	(-53.3≥ μ ≤ -67.1) (-	(1121.7≥ μ ≤ 1311.5)	(375.4≤ μ _644.4)
0.5	(3.5≥ μ ≤ 5.4)	61.4≥ μ ≤ -69.4) (-	(1176.3≥ μ ≤ 1350.7)	(530.7≥ μ ≤ 766.1)
0.55	(4.66≥ μ ≤ 6.74)	48.8 ≥ μ ≤ -65.2) (-	(1176.3≥ μ ≤ 1342.9)	(497.4 ≥ μ ≤ 791.8)
0.6	(4.5≥ μ ≤ 6.5)	56.8 ≥ μ ≤ -73.2)	(1204≥ μ ≤ 1374)	(550 ≥ μ ≤ 766)

Table I shows the degree of confidence for measured distances, longitudinal balance (LT/BAL), loop resistance (L/Res), and insulation resistance (Ins/Res) as a function of gauge. These are the results which were used in the development of the computer based program for optimization of ISDN BRI. For distance, the upper limits to the nearest whole number were used as the maximum distance for optimal data transfer except for a 0.55 mm (mixed) gauge the mean of 0.55 was considered since it was a mixed gauge.

The table shows that the maximum longitudinal balance for gauge o.6 mm is -56.8 dBm (approx -57 dBm) and was used as the benchmark for all gauges since longitudinal balance increased with decreased in gauge. In the loop resistance, the upper limits to the nearest whole number were used as the benchmark. For insulation resistance, the 375.4 mega ohms (approx 375 mega ohms) was used as the benchmark for all gauges as the minimum insulation for optimal data transfer.

The tool was tested in practice in conjunction with the dynatel and it was shown to comply with the expected results from the measurements. In general, the tool can help technicians when troubleshooting different lines. It provides a basis for the expected copper parameters as well as the expected line speed.

3 CONCLUSION

The analysis of copper access networks was performed in order to obtain optimum parameters under which ISDN BRI provides good performance. And after the analysis of measurements, results showed that as the gauge values increased, the distance increased hence a bigger gauge was required to extend the services to a longer distance.

The measurement results showed that as the gauge increased the loop resistance decreased, hence more and more links offered high speeds in low and low values of loop resistance, in order to achieve optimal data connectivity, a maximum of 1312 Ohms for a 0.4mm gauge, 1351 Ohms for a 0.5mm gauge, 1342 Ohms for a 0.55mm gauge, and 1374 Ohms for a 0.6mm gauge was required maximum loop resistance and anything above those values exhibited a drop in data connectivity.

For the increased gauge, the longitudinal balance decreased hence more and more links offered high speeds in lower and lower magnitudes of longitudinal balance values, so to achieve optimal data connectivity, -57 dBm was the maximum longitudinal balance required for all gauges. As the gauge increased the insulation resistance increased hence high speeds were attained in high magnitudes of insulation resistance, so to achieve optimal data connectivity, 375 mega ohms was the minimum insulation resistance required for all gauges. We also found out that distance had an impact on the data transfer rate, as distance increased, less and less links offered high speeds, in order to achieve optimal data connectivity, a maximum of 4 Km for a 0.4mm gauge, 5 Km for a 0.5mm gauge, 5.5 for a 0.55mm gauge, and 6 Km for a 0.6mm gauge was the required maximum distance and anything above those values exhibited a drop in data connectivity. Measurements results were used to develop a computer tool that provides a base line for expected measurements values of copper parameters and line speed that help technicians to troubleshoot copper lines.

Measurement results suggest that the reported connectivity problems by end-users are probably due to improper installation of copper lines. The scope of this paper was limited to copper pairs parameters/properties combination for ISDN BRI connectivity, however further investigations can be carried out to cover other technologies like Asymmetrical Digital Subscriber Line (ADSL) which use copper access networks.

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