Introduction to Telecommunications Network Measurements

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Abstract – **In this paper, a telecommunications network test and measurements are activities undertaken to characterize the operation of networks and network elements. Measurement determines performance parameters, either on an as-needed basis or continuously via dedicated monitoring equipment. Test adds the comparison of measured parameters to accept/reject thresholds, or the application of controlled stimuli.**

Keywords – **telecommunication, measurements and testing, protocol analyzer, digital performance testing, analog performance testing.**

I. INTRODUCTION

Network technology is changing at an increasing rate. In the past, major investments in transmission and switching technology took many years to depreciate. Today, however, the pressures of the market and the advances in technology demand more rapid turnover. The unrelenting rollout of new technology creates challenges for new test equipment and maintenance strategies.

The business climate in telecommunications is changing, too. Because of competition and deregulation, combined with the increasing importance of telecommunications for business activities, network operators are becoming more service- and customer-focused. Network performance is measured in terms of quality of service (QoS). Successful delivery is measured by the highest quality at the lowest prices. Network operators also need to bring new technology into service very quickly to create competitive advantage.

II. QUALITY OF SERVICE

Network quality of service can be characterized by five basic performance measures:

Network availability (low downtime).

Error performance.

Lost calls or transmissions due to network congestion.

Connection setup time.

Speed of fault detection and correction.

Network availability and error performance are usually the parameters that service providers guarantee in terms of QoS. Generally these parameters need to be checked while the network is in service (i.e., carrying traffic), using a network management system.

Lost calls and call setup time are the main criteria for measuring performance in switched networks, often indicating whether network planning is keeping up with traffic growth and changing traffic types. The move to common-channel signaling has greatly reduced call setup time, while also increasing system flexibility for offering new services. The growth of Internet traffic, however, with long holding times on the circuit-switched network, has again called into question network performance.

Some network operators now guarantee that they will fix faults within a specified time or pay compensation to the customer. This requires good processes for troubleshooting, well-trained technicians with access to powerful test equipment, and probably the use of centralized automatic test systems for rapid fault finding.

III. TESTING OBJECTIVES

An initial reaction to network testing might be that it is something to be avoided if possible because it cost time and money. On reflection, however, effective testing can add value rather than being an expense, and can enhance the network operator's business.

There are three major business problems that are driving operators today:

Time-to-market of new products and services.

Reducing the cost of delivering a service.

Improving and guaranteeing service quality.

Network testing can be divided into three application areas:

Bringing new equipment and systems into service.

Troubleshooting and detecting network degradation.

Monitoring and ensuring quality of service.

Bringing new equipment and systems into service. When new equipment is installed and brought into service, the installer (who may be the equipment manufacturer) makes a comprehensive series of tests. These tests usually are made to more restrictive limits than normal performance expectations. These limits are specified in ITU-T Recommendation M.2100 (formerly M.550), "Performance limits for bringing Into-Service and Maintenance of International PDH Paths, Sections and Transmission Systems".

Once a system is in use, performance standards must be maintained. When service degradation occurs, it must be determined whether the fault exists within a particular vendor's network or elsewhere. This information is determined most effectively by in-service testing or performance monitoring. Many test instruments also provide some degree of nonintrusive testing.

In-service maintenance. Once equipment is in service, long periods of downtime are unacceptable, so maintenance

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strategy has to be carefully thought out. ITU-T Recommendation M.20, “Maintenance Philosophy for telecommunications Networks”, defines three types of maintenance strategy:

Preventive maintenance
Corrective maintenance
Controlled maintenance

Preventive maintenance is carried out at predetermined intervals to reduce the probability of failure or degradation of performance. This method was commonly applied to older analog systems that needed periodic adjustment to compensate for drift.

Corrective maintenance is carried out after a failure or degradation is reported by a monitoring system or user.

Controlled maintenance involves centralized network monitoring and identification of degraded network performance. Centralized monitoring can be supplemented by field maintenance teams using portable test equipment.

Of these methods, controlled maintenance is preferred for maintaining high levels of QoS. It provides early warning of degradations and potential failures, thereby reducing system downtime. Repair work and adjustments can be anticipated and scheduled for quiet periods. In this way, disruption also is minimized.

IV. ANALOG PERFORMANCE TESTING

Figure 1 shows the major measurable elements of an analog transmission system. The simplest analog test is to measure the system gain and signal-to-noise (S/N) ratio between the end-to-end telephone connections. The test is usually made with a portable Transmission Impairment Measuring Set (TIMS). The test operator sends a fixed tone into the system and makes measurements at the opposite end to check for signal level and signal-to-noise ratio (noise with tone). When an analog data modem is to be used on the path, various data-impairment measurements may be specified, such as impulse noise, phase jitter and gain/phase hits.

Although telecommunications networks are now largely digitized, the connection between a telephone and the exchange continues in most cases to be analog. TIMS measurements are therefore still important. In the 1998s, wideband TIMS measurements up to 200 kHz have been used to evaluate local loops for ISDN and digital data transmission.

Similar kinds of measurement can be made in the analog multiplex system using a Selective Level Measuring Set (SLMS). Because this is a frequency Division Multiplex (FDM) system, possibly carrying several thousand separate telephone channels in a bandwidth of up to 65 MHz, the SLMS has to be able to select and measure individual channels as well as the pilot tones inserted to control system levels. FDM systems operate either over coaxial cable or microwave radio.

An FDM multichannel traffic signal resembles while noise; system impairments create degraded signal-to-noise ratio in individual telephone channels due to intermodulation distortion, particularly under heavy traffic loading. To evaluate this, the out-of-service noise-loading test is made using a notched white noise test stimulus. By measuring the noise level in the notch at the receiving end, the equivalent signal-to-noise degradation can be estimated as a function traffic load. In the analog era this was a very important test, particularly for microwave radio, because impairments are additive in analog systems.

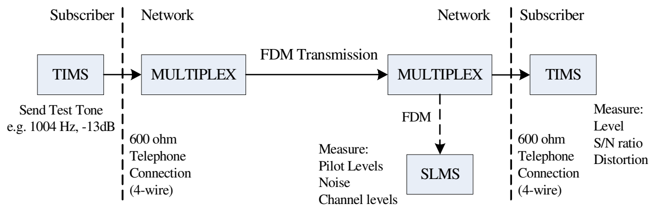

Fig. 1. Analog system performance measurements can be made either at the local loop access voice band frequencies using a TIMS, usually at the 4-wire 600-ohm line, or at the FDM line level is using a SLMS

V. DIGITAL PERFORMANCE TESTING

The tests made on digital transmission systems can be divided into several categories, as shown in Figure 2 and Table 1.

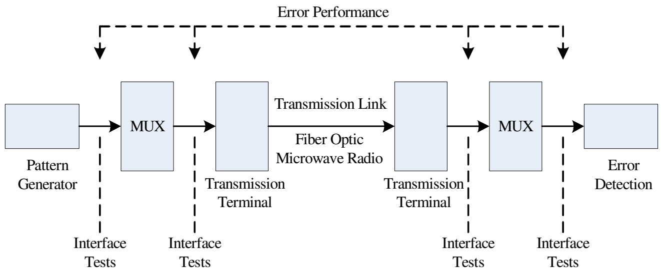

Fig. 2. Digital transmission measurements fall into two main categories. Interface tests check the compatibility of the electrical or optical interfaces of equipment to ensure error-free interconnection.

Interface specifications and tests. Anyone familiar with RF and microwave knows the importance of matching at interfaces so that the performance of cascaded networks equals the sum of the parts. The same is true in digital communications. If instrument parameters do not match equipment parameters, bit error appears when they are connected. This matching is defined in a series of interface specifications contained in ITU-T Recommendation G.703; Recommendations G.823/824 and G.825 address timing jitter.

Electrical interface specifications are usually measured during equipment design and manufacture to ensure compatible interconnection between network elements at a Network Node Interface (NNI) and User Network Interface (UNI).

The ITU-T specifications include pulse height (voltage level); pulse shape (rise time, fall time, overshoot, and duty cycle); and equality of positive and negative pulses in a ternary signal. These measurements usually are made with an oscilloscope to check that the pulse shape falls within a prescribed mask.

TABLE I
CATEGORIES OF DIGITAL TRANSMISSION TESTS AND APPROPRIATE ITU-T RECOMMENDATIONS

Type of test	Typical tests	Relevant ITU-T standards
Interface tests	PCM Codec	G.712/713/714 (Q.131-133 measurement)
	Pulse shape Clock frequency Voltage/impedance Coding	G.703
	Framing	G.704/706/708
	Jitter wander	G.823/824/825 (Q.171 measurement)
Out-of-service error Performance tests (Installations and commissioning)	BER using PRBS patterns	G.821/826 (O.151 measurement)
In-service error performance tests (maintenance, fault finding, quality of service)	Code error Frame error Parity error	G.821/826 M.2100/2110

The physical interface is usually 75-ohm coaxial cable with a return loss of 15 - 20 dB, although with higher-speed SONET/SDH equipment the physical interface may be fiber optic. In addition, bit rates must be maintained within strict limits, and the tester must check that receiving equipment can operate correctly within this tolerance. Interface coding specifications include algorithms for AMI, HDB3, CMI, B3ZS, etc.

Timing jitter is defined by ITU-T as short-term variations of a digital signal's significant instants from their ideal positions in time. The significant instant might be the rising or falling edge of a pulse.

The simplest way to measure jitter is with an oscilloscope and eye diagram. Jitter appears as a spread or "muzziness" in the vertical transitions. Most telecommunications systems, however, require more precise measurements. In these cases it is essential to know how the level of jitter varies with jitter frequency. This relationship is measured with a jitter test set that demodulates the jitter signal.

Jitter itself must be checked at the input by gradually increasing the level of jitter on a test signal until bit error occurs. In addition, the tester must check that jitter present at the input is not magnified by the equipment; otherwise, problems can arise when several pieces of equipment are cascaded in a network. This measurement is called jitter transfer.

If equipment conforms fully to all the interface specifications, in principle it should be possible to construct any arbitrary network without generating bit errors. Problems still can arise, however, if the live traffic signals have very extreme pattern densities that are not fully simulated by the out-of-service PRBS test.

Error performance tests. Digital network error performance can be measured over a complete end-to-end connection called a path, or over parts of the network called lines and sections. These network segments are illustrated in Figure 3. Path measurements indicate the overall quality of service to the customer. Line and section measurements are used for troubleshooting, installation and maintenance, and for assuring transmission objectives are met.

The fundamental measure of performance or quality in digital systems is the probability of a transmitted bit being received in error. With the latest equipment, the probabilities of this occurrence are very low, on the order of 10-12 or less. It is still necessary to measure the performance of these systems, however, and in particular to analyze the available margins of safety, and to explore potential weaknesses that later could lead to degrades performance.

In-service and out-of-service measurements. In-service error performance measurements rely on checking known bit patterns in an otherwise random data stream of live traffic. Some in-service measurements are more representative than others of the actual error performance of the traffic signal. Furthermore, some are applicable to the path measurement, provided the parameters are not reset at an intermediate network node. Others are only useful at the line or section level. The most commonly used error detection codes (EDCs) are frame word errors, parity errors, or cyclic redundancy checksum errors.

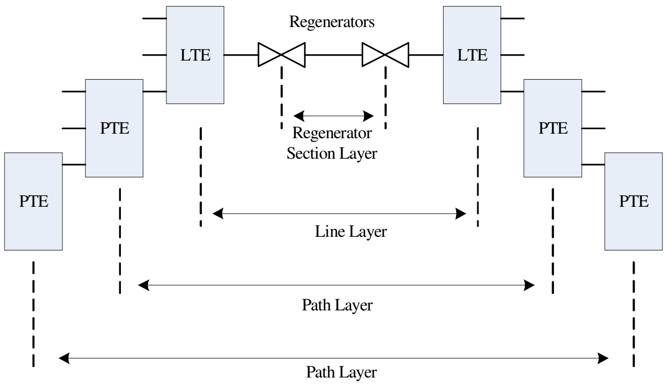

Fig. 3. A digital transmission system can be viewed as an overall end-to-end path terminated by Path Terminating Equipment (PTE).

Out-of-service measurements involve removing live traffic from the link and replacing it with a known test signal, usually a pseudorandom binary sequence (PRBS). These tests are disruptive if applied to working networks, but are ideal for installation and commissioning tests because they give precise performance measurement. Every bit is checked for error. Although the PRBS appears random to the digital system, the error detector (Figure 2) knows exactly what it should receive and so detects every error. The error detector calculates the probability of error as the bit error ratio (BER). BER is defined as the number of errors counted in the measurement period, divided by the total number of bits received in the measurement period.

Thus the bit errors or error events can be detected by out-of-service techniques. These are sometimes referred to as the performance primitives. To be useful for assessing quality of service, however, they must be analyzed statistically as a function of time according to the various error performance standards specified in Table 1. This analysis yields percentages for the availability of a digital communication link, and the portion of time that it exceeds certain performance criteria that are acceptable to the customer. One of the important standards is the ITU-T Recommendation M.2100/2110.

VI. Protocol analysis in the telecommunication network

Up to this point we have discussed the capability of the telecom network to transmit digital bits or analog signals over a path without errors or quality degradation. Testing BER, for example, assumes that the traffic carried by the network is completely random data, or at least that the payload within a frame structure is random. This apparently random traffic signal will, in fact, always have a structure. It might be a PCM voice signal, a data signal, a signaling message for controlling network switching, or possibly an ISDN signal or an ATM cell data stream for broadband services.

When telecom networks were predominantly carrying voice traffic using in-band signaling, there was little interest in checking the information content of traffic or knowing if it conformed to the rules or protocols of data communications, except for the X.25 packet-switched network.

Networks today are much more sophisticated and carry a wide range of different services among many vendors. Rather than being just the transporter of telecommunications traffic, increasingly the network is an integral part of the information structure created by the convergence of computers and communications. The most significant example of this is the common-channel signaling system (SS7), which interconnects the network switches and databases and controls all aspects of service delivery and billing. A large amount of analysis and monitoring is required, not so much of the data transmission itself, but of the messages and transactions taking place. An important example of signaling transactions occurs in a cellular telephone network, when constant reference to databases is necessary for tracking the location of mobile phones during handover from one cell to the next, and for billing and verifying legitimate users.

In order to analyze and troubleshoot these systems, a protocol analyzer is required, in some cases dedicated to the particular application such as SS7 or ATM. Protocol analyzers have been in use for many years in local and wide area networks, predominantly in enterprise networks (see Figure 4). This traditional data communications test tool is now finding its way into the telecom network as traffic becomes more data-intensive.

Often in data communications there is the need to observe and analyze, or even to simulate, the interactions between network devices interconnected by WANs or LANs. The need may be in the context of one or more of the following scenarios:

- The developer of network equipment or the network itself needs to analyze and simulate operation under a number of circumstances.
- The network planner needs to measure current levels of network use and then anticipate future needs as new services and capabilities are added.
- The installer (of computers, communications equipment, and/or networks) needs to commission and test a network system's devices and their interactions.
- Field service personnel for a computer and communications equipment vendor, or for a service provider, are faced with troubleshooting an intermittent problem.
- The network manager of a private network operates with system elements from several vendors and uses multiple service providers in order to get the best performance, reliability, and price. When a problem arises, a tool is needed to determine its source so as to avoid finger-pointing among the vendors.

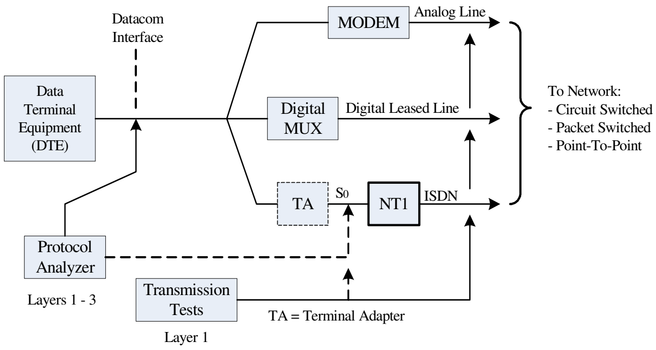

Fig. 4. Protocol analyzers traditionally have been used for testing data communications networks at datacom interfaces, usually at the customer's premises.

In each of these scenarios, there is need for an instrument that can observe nonintrusively and help the user interpret the complex interactions within the data communications protocols that control the behaviors of the devices. In some cases there is need to simulate network elements to test for problems. In other situations, there is an application to measure the performance and utilization of the network and of the devices within it.

These tests and measurements may be made reactively when a problem occurs, or may be made proactively when looking for trends that indicate developing problems. When new services are being introduced, or new equipment is being installed or system software upgraded, it is necessary to emulate specific messages or protocols to confirm correct operation of the network.

VII. Conclusion

In this paper, the telecommunications network measurements introduced the terms of quality of service. Successful delivery is measured by the highest quality at the lowest prices. Network operators also need to bring new technology into service very quickly to create competitive advantage.

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