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T-Carrier Characterization Program—Overview

By J. R. DAVIS and A. K. REILLY

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This is the first of a series of four papers describing a characterization program aimed at building a better understanding of the makeup and performance of the T-carrier network. In this paper, we provide a brief historical background of T-carrier and show the need for an increased understanding of the network and its performance. We also describe the characterization program conducted in conjunction with several operating telephone companies.

I. T-CARRIER EVOLUTION

T-carrier was first put into service in 1962 to provide interoffice trunks in the operating telephone company (OTC) plant. The carrier consisted of the T1 digital repeatered line and its associated terminal, the D1 channel bank. The channel bank encodes 24 voice-frequency (4kHz) channels by pulse-code modulation and multiplexes them by time-division into a 1.544-Mb/s pulse stream for transmission over the T1 digital line, which operates in the paired cable trunk plant. T1 has grown rapidly in the metropolitan trunk plant and today there exist more than 160,000 T1 systems operating on more than 5,000 interoffice spans. Nearly half of all metropolitan interoffice trunks are now provided by T-carrier.

Since the introduction of T1, two additional paired cable systems have been deployed in the trunk plant. The first of these is T2—introduced in 1971—which provides 96 voice-frequency channels and is configured for intercity applications. The second is T1C, which was introduced in 1975 and provides 48 voice-frequency channels primarily in the metropolitan area trunk network. T1C accounts for a large fraction of the growth in the metropolitan trunk plant. New versions of digital terminals have been developed as well. Direct digital interfaces between digital lines and switching machines have been deployed with certain switches. Still others are being developed. Such arrangements can, for example, avoid the need to convert digital carrier signals to voice-frequency before interfacing with digital switching machines.

II. INCREASING IMPORTANCE OF T-CARRIER PERFORMANCE

The original service for which T1 was engineered and used was POTS, or "plain old telephone service." Now, special services account for approximately 40 percent of the T-carrier capacity. In addition, however, the T-carrier plant is considered more and more as a part of an evolving overall switched digital network. The present metropolitan digital trunk and switching plant is interfacing with the emerging digital technologies in the loop plant and intercity plants (long-haul and short-haul) as well. Various new services, some of which have more stringent performance requirements than needed for voice are being planned for this switched digital network. While performance objectives can be specified for new transmission facilities consistent with overall objectives, all of these services and networks must use existing T-carrier for the metropolitan trunking portion of the network. At the same time, OTCs want to use the in-place trunk plant more effectively, expanding the carrier capacity of existing cables to defer new cable installations as long as practical. The emergence of new and sometimes more demanding services, as well as the desire to exploit fully the existing trunk plant, place greatly increased importance on an understanding of the performance level of the T-carrier plant, on what elements control that performance, and on what might be done to improve poorly performing systems.

The performance of a T1 digital system—from terminal to terminal—is the sum of the performance of the component repeater sections that are placed in tandem to comprise that system. Thus, given a performance model for a repeater section, the overall network performance can be modeled with a knowledge of the parameters and statistics of repeater sections, interoffice spans, and systems. In addition, these statistics are useful in examining in a more general way the nature of the existing metropolitan trunk plant, the magnitude of the remaining exploitable capacity, and the need and market for various new trunk transmission technologies in relation to the existing plant and its projected growth.

III. CHARACTERIZATION PROGRAM

Given the increasing importance of understanding T-carrier performance, as well as the need for knowledge of the physical makeup of the T-carrier plant, a T-carrier characterization program was chartered in the summer of 1976. Since the basic element of overall system performance is the performance of the individual repeater sections that comprise the system, we decided to start the performance characterization with the individual repeater section. The objective of this program was to determine the statistical distribution of margin and other parameters of the repeatered line. (Margin is the amount of signal-to-noise degradation that can be tolerated before the error-rate objective is violated.) Among the other parameters to be determined were those properties of the cable, repeaters, apparatus cases, and section layout which affect section margin.

To allow a variety of measurements to be made rapidly and accurately on a repeater section, we developed an automated measurement system. This system consists of various transmission equipment (i.e., digital signal sources, meters, etc.) placed in two vehicles, one located at each end of the repeater section under test. A minicomputer controls the switching of various equipment for different measurements at its location and at the other location as well, via telemetry provided over a voice-frequency pair. In addition, the minicomputer controls the entire sequence of tests and records the results on both paper printout and cassette tape. A special computer language was developed to permit a flexible program structure that is easy for people not experienced with computer programming to understand, and that allows very rapid change of the measurement algorithms and sequences if the need arises. The automated measurement system provides rapid, accurate measurements to be made by personnel with a minimum of experience and training.

To provide a measure of repeater end-section performance, a companion set of equipment was developed. (The end section is the section adjacent to a central office.) Since switching noise in central offices was known to be a potential problem when T1 was first engineered, the end sections are limited in loss or length to approximately two-thirds of the value allowed for intermediate sections. Thus, sources of crosstalk, which potentially limit T1 performance in intermediate sections, are much less influential. The central office measurement equipment was designed specifically to examine the characteristics of the noise on the incoming T1 pairs. A complete description of both measurement systems and the measurements made are provided in the paper on the automated measurement system.

The automated measurement system has been used to examine the performance of more than 2000 T1 repeatered lines in 22 different intermediate repeatered sections in three OTCs, as well as end sections terminating at central offices in two companies. These sections were chosen on the basis of having characteristics that should limit the performance of digital systems containing those sections, based upon the a priori understanding of T1 system performance; they are generally maximum-length sections operating on full-sized (900- and 1100-

pair) 22-gauge pulp cables, by far the most common cable type in the present metropolitan T-carrier plant. The third paper describes field measurements results, details a model that accurately characterizes the T1 repeater section performance, and establishes parameters for the model.

The description of the physical makeup of the T-carrier plant is given in the paper on the metropolitan digital trunk plant. This paper includes basic statistics of the interoffice T-carrier spans that comprise the digital systems. Various OTC records, both mechanized and manual, were obtained to provide this information. The data represent a sample of seven companies that have more than 25 percent of the metropolitan digital trunk plant.