

# Determining the Topology of a Telephone System Using Internally Sensed Network Tomography

John R. Treichler   Michael G. Larimore  
Applied Signal Technology  
Sunnyvale California

Sally L. Wood  
Santa Clara University  
Santa Clara, California

Michael Rabbat  
University of Wisconsin  
Madison, Wisconsin

This paper develops methods of characterizing telephone network topology using a small number of internal network sensors. The growing body of technical literature on the topic of “network tomography” explores the concept of using packet probes through a data network to determine its topology, discover network nodes, or to measure internal network characteristics such as its bandwidth or level of congestion<sup>i</sup>. In strong analogy to the medical imaging techniques from which they take their name<sup>ii</sup>, most of these methods can be described as “active, endpoint-to-endpoint” or transmission techniques, since they send probes, in the form of IP packets, from one side of the network to the other. The property of the network that we desire to discover or characterize (e.g. its topology) is inferred by measuring the arrival times of the probes and performing various mathematical calculations.

Our technique differs in three ways – two simple ways and one more fundamental. For probes we will use telephone call attempts from many locations throughout the world instead using of IP “pings”, and the timing and nature of those calls will be chosen ahead of time and known to all of the participants. The more fundamental difference we assume here is that the sensors of the probes are located somewhere in the middle of the network rather than at the edges. Figure 1 illustrates this difference. Instead of probes being emitted by the points marked T, then passing through the network and being received at the network’s edges at the points marked R, as shown in Figure 1a, the probes are sensed as they pass through the network and are ignored when and if they reach the network’s edge. Thus the receiving nodes R are located within the network rather than at its edges. We’ll term this *internally sensed* tomography to distinguish it from classical medical and network tomography in which the probes are externally sensed.

The simplest version assumes that the telephone call attempts will be automatically made from many locations around the world at prescheduled times. The sensors that we position around the world will passively watch for these events, and report their passage to a central processing facility. This central facility will compare the time, locations, and trunks on which the probes occur with the times and locations of their originations and construct from that data an estimate of the network’s topology, and, later, perhaps other attributes or characteristics of the network. However timing information will not be assumed to be precise enough to measure delay or accurately sequence the sensor observations, if there are more than one, within a specific call attempt.

The measurement acquisition methods discussed above lead to some very important differences between the theoretical underpinnings associated with medical tomography and the techniques suggested here. While the issue of internal versus external sensing has already been discussed, a more important theoretical issue is the fact that most tomographic imaging algorithms assume that the probing signals travel in straight lines and that they are attenuated monotonically as they transit “the system”. The reason that the “imaging” of a telephonic network is different can be seen by examining Figure 2. This figure shows a telephone network consisting of ten users and four switches. The configuration of the switches and their interconnecting trunks means that calls from one terminal point to another do not travel in a straight line and, in fact, in many cases there

are intentionally several “alternative routes” between the same pair of terminals. The problem here is one of estimating a graph rather than a two dimensional array of attenuation coefficients. These differences are not thought to be fatal, but they do mean that the existing theory of tomographic image reconstruction must be adapted and extended to solve this problem.

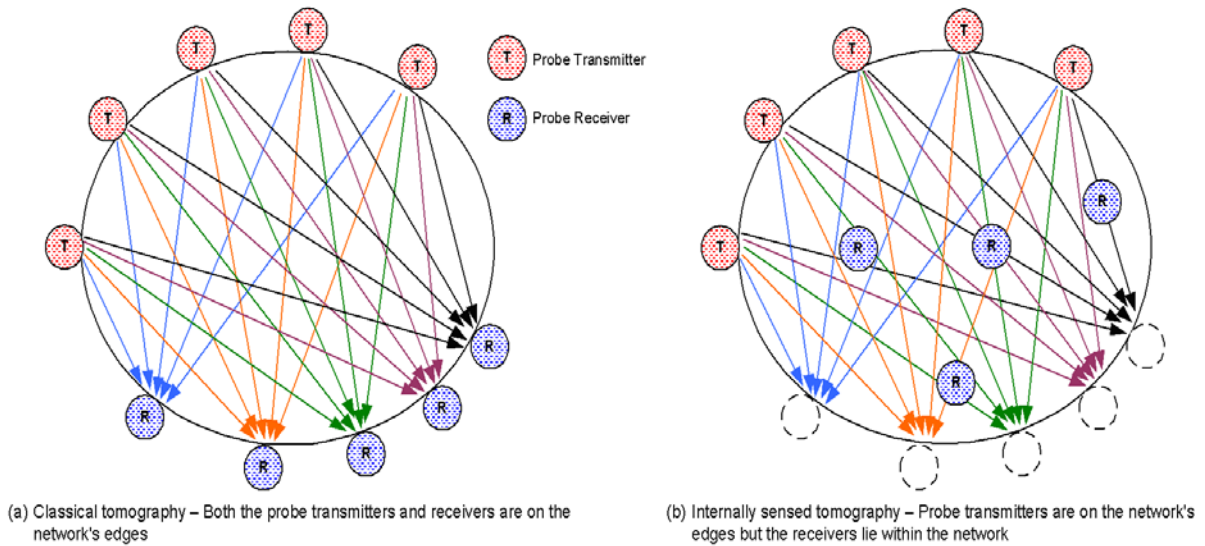


Figure 1: Contrast Between Edge-sensed Tomography and Internally-sensed Tomography -- In both cases the probing signals are sent from the network's edges but in the two cases they are sensed in different ways.

The ability to determine the topology of worldwide telephone networks offers the promise of substantially improving their operating efficiency. The tomographic ideas presented here have the operational advantage that 1) on the transmitting end they are relatively cheap and require minimal attention and 2) the receivers can be operated autonomously and with little supervision. This approach for the telephony problem, can be extended gracefully to determine the topology and other characteristics of data networks as well.

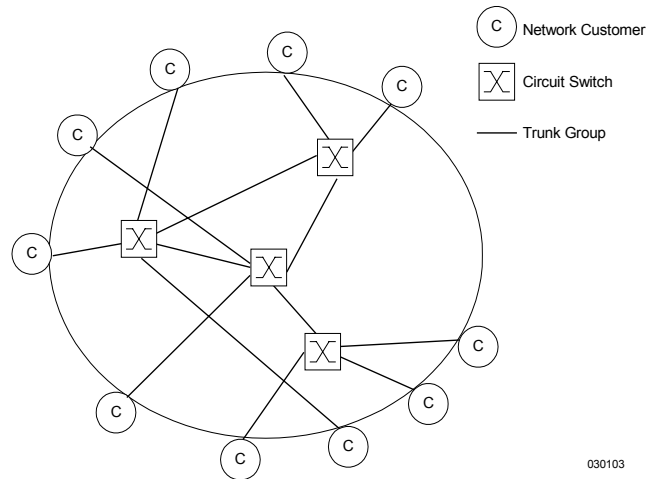


Figure 2: A simple telephone network interconnecting ten users with four circuit switches

<sup>i</sup> M. Rabbat, R. Nowak, and M. Coates, “Network Tomography and the Identification of Shared Infrastructure”, Proceedings of the Asilomar Conference on Signals, Systems, and Computers, Pacific Grove, CA, November 2002

<sup>ii</sup> R. N. Bracewell, Two-Dimensional Imaging, Prentice-Hall, Upper Saddle River, N.J., 1995.