Public Switched Telephone Networks:
A Network Analysis of Emerging Networks

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A recent focus in the area of network analysis has been on the comparison of technological, informational, social and biological networks (Newman 2003). Within the technological networks category, one comparison of interest is among infrastructure networks such as the power generation and distribution networks, the public switched telephone networks (PSTN), the Internet, and various transportation networks that we have come to rely heavily upon. In this paper we will use network analysis to study the PSTN.

Our analysis of the PSTN is focused on wired (copper and fiber) networks. It does not entail wireless networks such as microwave, satellite or other radio links. In the United States, telecommunications service providers that operate the PSTN fall under three categories: interexchange carriers (IXCs) that own networks for long-distance calling, incumbent local exchange carriers (ILECs) that own networks for inter and intrastate calling, and competitive local exchange carriers (CLECs) that own networks within a state[1]. For our analysis, we looked at the networks of a CLEC and an ILEC serving one US state.

Nomenclature and Data Sources

For the purpose of our analysis, we will refer to the CLEC whose network we are analyzing as a *Nano Bell*; the ILEC whose network we are analyzing as a *Mini Bell*; and IXCs, which are *not* a part of our analysis, *Maxi Bells*. We have decided to use this nomenclature in order to protect the identity of the companies that shared the data with us, as per our agreement with them. An example of a Nano Bell (CLEC) is Mid-Maine Communications in Maine, where Verizon is the Mini Bell (ILEC) and the Maxi Bell (IXC) is a long distance company such as AT&T.

The networks we will analyze – a Nano Bell network and a Mini Bell network – have two types of switches: *tandem switches* and *central office switches*. A tandem switch switches traffic between central offices and forms the core of the network. A central office switch has connections to homes' and offices' end systems, such as phones, faxes, etc. A central office switch often has two parts – the *host switch* and the *remotes*. The host is the part of the switch that carries out all of the switching functions, whereas the remotes only provide geographical coverage but rely entirely on the host for any switching functions its connections may require. A tandem switch is equivalent to a Class 4 of AT&T's original product line. A central office switch is typically a relatively smaller Class 5 switch.

Our data comes from two primary sources. The Mini Bell data was obtained from their public website: http://www.qwest.com/iconn/. The Nano Bell data comes from network plans a Nano Bell operating in one US state has shared with us under the aforementioned confidentiality agreement. The assumptions (discussed later) we made about the Nano Bell's network come from our interviews with an enthusiastic contact person at the Nano Bell.

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[1] Our focus on the ownership of the network is deliberate since it is no longer possible to separate the three types of providers by the service they provide. Today an IXC, ILEC or a CLEC is allowed to offer local or long-distance service.

History and Political Economy of PSTN

With a technology more than a century old, the US PSTN has a rich history of rapid changes in technology, regulation and industry structure. However, keeping in mind the focus of this paper, we will discuss the history and political economy of PSTN from the network analysis perspective. For our analysis, we have defined telephone switches as *nodes* and the connections between them as *edges*. Therefore, we will discuss the historical events that changed the characteristics of the nodes, the links and the connections between them.

The period of monopoly (until 1984)

The telephony, as we know it today, was born with a key breakthrough in 1875-76 when Alexander Graham Bell developed transducers from voice to electrical signal and vice versa. Bell had quickly realized the tremendous potential of his invention and formed the Bell Telephone Company in 1877. Although Bell himself stopped working on telephony one year after his invention, he left the company to his father-in-law Gardiner Hubbard and Watson (Boettinger 1977). Watson invented the ringer, the first switchboard, and many other things essential to transforming a laboratory toy into a commercial product. As the company grew, they hired Theodore Vail to manage the company. Vail worked hard to ensure that the Bell Telephone Company controlled a substantial portion of the telephone service in the United States even after the expiration of Bell's patent in 1894. He also used the ever-increasing capital to buy out other telephone companies. By the time he was done, the American Telephone and Telegraph Company (AT&T) owned every telephone instrument, every telephone switch, and every telephone pole in the country. Vail made sure that AT&T would survive the antimonopoly sentiments by promising that every American would have access to the telephone network.

AT&T's dominance continued for several decades before it was regulated as a natural monopoly with the creation of a federal regulatory body, the Federal Communications Commission (FCC). The FCC was established by the Communications Act of 1934 and was charged with regulating interstate and international communications by radio, television, wire, satellite and cable.

The Telecommunications Act imposed universal service obligations on AT&T, which led to planned growth (*designed network*) of PSTN in the subsequent years. Until then, the PSTN had been growing (*grown network*) in areas that were population centers and where the installation made business sense. Today, as most of the PSTN is modernized, it would be difficult to recreate the picture of what the network looked like during this pre-1934 era of grown networks.

The initial overriding obstacle to providing universal service was attenuation in copper lines, known as the challenge of conquering distance (Fagen, Joel et al. 1975). The improvement and general availability of vacuum tubes had a major impact on solving the distance challenge. With vacuum tubes, it became possible to interconnect widely separated cities with low loss and good quality circuits. In 1925, it was possible to call any big city in the continental United States over a circuit of good quality. The switching technology during the first half of the twentieth century was dominated by manual switching for both local and

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