Matthew Stafford

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Contents

CHAPTER 1
Introduction

1.1 In the Beginning, There was Voice

Voice telephony was arguably the first telecommunications service to achieve truly widespread deployment. Data services came into their own much later. To be sure, data telecommunication (in the form of smoke signals and other visual semaphore schemes, for example) has been around for a very long time. Note also that the telegraph preceded the telephone, and that innumerable messaging schemes of all sorts have been devised and used for military purposes. Morse code telegraphy is an interesting example of a data service: this scheme for electrical transmission of text messages was commercially viable before telephony became available.

In scale of deployment, however, telegraph service never came close to the level subsequently reached by telephony. The average person in a developed country has direct access to telephones at home and at work. Moreover, this has been the case for many years; nowadays, wireless telephones add mobility to the equation.

Data telecommunication became common in the consumer market only within the last 10 to 20 years. Uptake in the academic and business communities came somewhat earlier (but still much later than voice). Thus voice networks were already ubiquitous when data networking technologies reached mass-market scale, and it was perfectly natural to ask whether one could also use these networks to transmit large volumes of data between distant sites.

In a nutshell, the question was:

> "We have extensive voice networks; are they useful for carrying data as well?"

The answer to this question was definitely "Yes!" The biggest reason for this resounding affirmative was that, starting in the 1960s, the voice network in the United States evolved from analog to digital. In other words, this network was already transporting bits.

For years, data networks were islands in a voice-based world. Data networking technologies designed for so-called local area networks (LANs) suffered from severe distance limitations. Long-haul data transmission in the consumer, academic and business markets was achieved using networks initially designed for voice. In fact, telephone carriers' networks provided the only viable means of interconnecting distant data networks. In many instances, data traffic is still transported in this fashion; fax and dial-up modem transmissions are familiar examples. Widespread access to dedicated wide area data networks (such as the Internet) is a relatively recent phenomenon.

Dedicated data networks are increasingly common and far-reaching, however. This begs the following question: "We have extensive data networks; are they useful for carrying voice traffic?" (Although voice telephony is our primary focus in this book, note that the question remains equally pertinent for other real-time services such as videoconferencing.)

Today, telephone networks and data networks are very different beasts, designed according to different philosophies. Here is a crucial distinction to keep in mind:

- In traditional telephone networks, transmission capacity is meted out in a continuous fashion. That is, a fixed amount of capacity is allocated to each call and deallocated when the call ends. Meanwhile, this transmission capacity cannot be shared with any other call (even when the parties on the first call are silent). We say that traditional telephone networks are circuit-switched; here the term circuit refers to the end-to-end transmission capacity that is reserved throughout the life of a call.
- In data networks, transmission capacity is allocated in a discrete fashion. Suppose two pairs of users are conducting ongoing sessions that use a shared transmission link. When transmission of a packet for one session is completed, the other session can transmit a packet, although neither session has ended. Here a packet is a chunk of digital data (i.e., a sequence of bits); we say that data networks are packet-switched.

Note that these are somewhat oversimplified in the interest of brevity.

1.2 Motivation: What Is the Case for Packet Telephony?

1.2.1 One Network Versus Two

To understand why there is a great deal of interest in packet telephony, one need look no further than the corporate environment. A typical office site has two completely separate in-building networks: a circuit-switched network for telephones and a packet-switched network for computers. The latter is called a local area network. Each of these networks must be provisioned and maintained. Could we combine telephone and data traffic on one of the two networks (thereby allowing us to reduce cost by eliminating the other network)?

Of the two in-building networks, the computer network undoubtedly has much greater bandwidth than the phone network. Thus, if we try to interconnect our computers via the phone lines (abandoning the local area network), there is essentially no hope of a satisfactory result.

Therefore, if we want to dispense with one of the two networks, eliminating the in-building phone network is the only reasonable choice. And this option entails placing voice traffic over a packet-based medium.

The situation is substantially different in the consumer market. A local telephone company that already has a revenue-producing "legacy" voice network has little motivation to invest in voice over packet technologies. However, cable companies might become interested in doing just that, so as to compete with local telephone companies. In recent years, cable companies have upgraded their networks so they can provide broadband Internet access. In the process, cable has become a bidirectional packet-based medium, suitable for packet voice traffic. We note that, as of this writing, cable telephony has not taken off (at least in the United States).

1.2.2 Services

Packet telephony solutions must provide some economic benefit (that is, increased revenue and/or reduced cost); otherwise, they will not be widely deployed. We have already begun to address reduced cost with our previous example. We will return to this topic later, exploring the service provider's point of view.

Now we look at revenue generation. To increase revenue, a telephone service provider must add new customers (and this is becoming increasingly difficult) or must come up with new features that customers will want to buy. This brings us to the development of enhanced services.

As an example, we look at "find me/follow me" services. The basic idea of find me/follow me is a simple one: to offer flexible configuration options for call-forwarding behavior on a per-user basis. Suppose, for example, a traveler wants certain callers (identified by calling party numbers, say) to be able to reach him/her via automatic forwarding from his/her landline phone to a wireless phone. All other calls will be forwarded to voice mail. Such features are offered by today's Private Branch Exchanges, but are not generally available to consumers.

Moreover, it is easy to envision useful "add-on" functionalities that are difficult to implement in today's networks. For example, it would be nice if one could configure out-of-office settings for voice mail and e-mail from the same menu, perhaps employing a speech-to-text processor to convert the voice mail greeting to a text message that is automatically sent in reply to incoming e-mail messages.

Other desirable options include the ability to reconfigure (wireline) forwarding options from a wireless phone. This is difficult partly because wireless and wireline networks grew up separately; so-called "Intelligent Network" features in the two realms are based on different signaling protocols. (We flesh out this topic in Chapter 13.) Moreover, with the User Interface limitations of today's phones, subscribers may find such features difficult to use. Admittedly, packetized voice does not automatically bring about "convergence" between wireless and wireline networks. Well-designed service control schemes that can cross network boundaries, however, may facilitate convergence. Therefore such schemes promise to be an important part of the overall evolution toward packet telephony.

1.3 Switch Design

Packet voice equipment is available and in use today, so packet-based telephony is certainly feasible. If people only wanted to call others located in the same building as themselves, the case for packet telephony in the corporate environment would be overwhelmingly positive.

In reality, one of the best features of existing telephone networks is that it is possible to call almost anyone. To maintain this universality, interworking with the outside world is a must. This boils down to interworking with circuit-switched networks, since the vast majority of telephones today are connected to circuit switches. In particular, circuit switching is utterly predominant in public telephone networks; packet voice is only just beginning to make inroads in this market.

How should packet voice switches be designed? This is one of the main topics of discussion in this book. Specifically, we will talk extensively about the telco environment and design principles that are expedient for operating in this environment. In this context, we will draw comparisons with legacy voice switches. We note that the design principles discussed here are equally applicable to cable operators, if and when they decide that they want to become large-scale telephone service providers.

1.3.1 Separating Bearer and Control Planes

The separation of bearer and control planes is a fundamental concept in next generation switch design. The bearer plane is the part of the network that carries end-user traffic (e.g., voice samples, in the case of telephony). As the name suggests, the control plane is the part of the network that carries call-control signaling. In circuit switches, the bearer and control planes are not clearly separated.

In a nutshell, the reason for separating the bearer and control planes is the promise of increased flexibility. This flexibility can take several forms, notably:

- *Distributed architecture.* A rich set of options for placement of switch components: the elements of a switch can be geographically dispersed.
- A rich set of options [based on packet technologies such as Internet Protocol (IP), Asynchronous Transfer Mode (ATM) and Ethernet as well as sophisticated vocoders] for representing, encapsulating, routing, and transporting voice traffic.
- The ability to base the creation and implementation of new services on standardized open interfaces. This is an important step toward the "holy grail" of services that combine voice, video, and data in useful ways.
- Flexibility in choosing suppliers. That is, different components can potentially be purchased from different equipment vendors.

We will return to these topics in the Section 1.4 (where we argue that these advantages make a compelling case for packet telephony) and elsewhere.

At this point, the reader can begin to see that packet telephony is much more than replacing circuit-switched bearer channels with packet-switched alternatives. It is possible to build switches that internally employ packet bearers, but for all intents and purposes act exactly like circuit switches. There is a place for such technology. However, we will see that next generation switching concepts hold the potential for much more.

1.4 Motive and Opportunity for Carriers

Why would a telephone service provider want to invest in voice over packet technology? We saw one reason in Section 1.2: to enable enhanced services (and thereby realize new revenue streams). In the following example, the goal is to reduce cost.

We said earlier that separation of bearer and control allows for the components of a switch to be geographically dispersed. To see why this is important, we direct the reader's attention to Figure 1.1. (The *fabric* of a switch is the conduit through which voice samples flow from the calling party to the called party and vice versa. Each *area* in the figure might represent a local switch, along with all of the customers that are homed to that switch, or a private branch exchange, etc.) Note that areas 1 and 2 are not directly connected. Therefore, when a customer in area 1 calls a customer in area 2, the bearer path must include the nearest switch that connects to both areas (switch A in this example). If areas 1 and 2 are much closer to one another than they are to switch A, then we are faced with so-called "backhaul" costs. That is, the voice- encoding bit stream must travel the long way around for the duration of the call.

Suppose that the volume of traffic between areas 1 and 2 is not sufficient to justify either of the following alternatives:

- Reserving dedicated transmission capacity between areas 1 and 2;
- Installing an additional switch closer to areas 1 and 2.

Suppose, however, that the volume of traffic is large enough that it grieves us to pay for backhaul transmission capacity. If, by shifting to a distributed design, we could dramatically reduce the cost of adding switching capacity at a nearby location, then we would have a viable alternative.

In Figure 1.2, we illustrate the notion that the fabric under the command of a given controller can consist of geographically-dispersed nodes. If these fabric nodes are very inexpensive (relative to the cost of a "legacy" voice switch), and if one controller can direct the operation of many fabric nodes, then the cost of introducing switching capacity to new locations can indeed be reduced a great deal.

Note that a new type of traffic appears in Figure 1.2: control messages between the controller and the fabric component at location B. (The Controller also sends commands to the colocated fabric component at location A, but these messages do not require interlocation transmission facilities.)

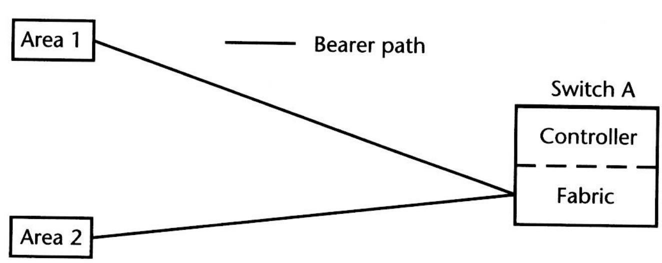

Figure 1.1 Bearer path must traverse closest switch.