♦ The Lucent Technologies Softswitch—Realizing the Promise of Convergence

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The Lucent Technologies Softswitch was created as a result of Project Saras, which was initiated by two Bell Labs researchers. The purpose of Project Saras was to develop a software system that solves several major problems that providers of telephony services now face. Today's public switched communications infrastructure consists of a variety of different networks, technologies and systems, most of which are still based on the wireline circuit-switched structure. The technology, however, is evolving to packet-based networks, and service providers need the ability to interconnect their customers with these flexible and cost-effective networks without losing the reliability, convenience, and functionality of the public switched telephone network. The Lucent Softswitch, formerly known as the PacketStar† IP Services Platform, resulted from a focus on these needs. This Softswitch was initially marketed as a signaling-interoperability and services-creation platform under the umbrella brand name PacketStar for Lucent data networking products. It was renamed in light of the recognition that it represented an emerging concept in the industry called a "softswitch," referring to a software-based distributed switching-and-control platform. This paper provides a high-level description of the Lucent Softswitch and its application to building next-generation converged networks.

Introduction and Background

The demand for communications services continues to explode and grow at an unprecedented rate. It is widely accepted that in just the next 15 to 20 years we will see the level of growth in communications that was seen in the entire last 100 years. Today voice and data networks coexist, with approximately equal amounts of traffic; however, data traffic rates are growing 10 to 15 times faster than voice, driven by an explosion in the use of the Internet. In 1999, one-third of all homes in the United States will be on line. The International Data Corporation predicts that the level of electronic commerce will increase to $400 billion in the year 2000, up from $12.5 billion in 1997. Add to these indicators the fact that less than one out of four people in the world have ever made a phone call and also that all the countries of the globe are racing to develop the communications infrastructures that fuel their economies as they prepare to meet the next millennium.

Global deregulation, privatization, and drastic restructuring of the communications services industry are fueling this demand further. The U.S. Telecommunications Act of 1996 led a worldwide sea change in telecom deregulation. As a consequence of the act, there was an explosion in the emergence of new competitive service providers launching new communication service enterprises, based either on reselling unbundled elements of the incumbent carriers' infrastructures or on building facilities of their own. While the earlier competitive carriers focused on the resale model, the current landscape is dominated by the acquisition and construction of competitive network

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Panel 1. Abbreviations, Acronyms, and Terms

AAL—ATM adaptation layer
AIN—advanced intelligent network
A-link—physical termination for SS7 interconnectivity
API—application programming interface
ATM—asynchronous transfer mode
CAS—channel-associated signaling
CCS—common channel signaling
CLEC—competitive local exchange carrier
DS0—Digital signal level 0; transmission rate of 64 kb/s (1 channel) in time division multiplex hierarchy
DS1—Digital signal level 1; transmission rate of 1.544 Mb/s (24 64-kb/s channels) in TDM hierarchy
DS3—Digital signal level 3; transmission rate of 44.736 Mb/s (672 64-kb/s channels) in TDM hierarchy
DSL—digital subscriber line
e&m—"ear" and "mouth" leads from customer to central office
IMT—intermachine trunk
IN—intelligent network
INAP—intelligent network application protocol
IP—Internet protocol
IPDC—Internet protocol device control
ISDN—integrated services digital network
ISP—Internet service provider
ISUP—ISDN user part
ISV—independent software vendor
ITU-T—International Telecommunication Union—Telecommunication Standardization Sector
JVM—Java* virtual machine (Sun Microsystems)
LCDS—Lucent Communication Directory Server
LDAP—lightweight directory access protocol
Mantra—Lucent proprietary canonical multi-party call model
MGCP—media gateway control protocol
MTP—message transfer part
OA&M—operations, administration, and maintenance
OC-3—optical carrier digital signal rate of 155 Mb/s in a SONET system
PBX—private branch exchange
PDL—policy description language
PEP—policy enforcement point
PIP—packet intelligent peripheral
POTS—"plain old telephone service"
PRI—primary rate interface (ISDN)
PSTN—public switched telephone network
RADIUS—remote authentication dial-in user service
RAS—remote access server/service
RDBMS—relational database management system
RTP—real-time transport protocol
Sapphire—Lucent gateway control protocol
SCCP—signaling section and control part
SCP—service control point
SDK—software development kit
SIP—session-initiation protocol
SNMP—simple network-management protocol
SPS—service provider servlet
SS7—Signaling System 7
SSP—service switching point
STP—signal transfer point
T1—terrestrial facility (North America) to transport primary rate of 1.544 Mb/s (24 64-kb/s channels)
TCAP—transaction capabilities applications part (SS7 protocol)
TCP—transmission control protocol
TDM—time division multiplexed
UDP—user datagram protocol
UFA—user feature applet
UNI—user network interface
VTOA—voice and telephony over ATM
VoIP—voice over IP
VPN—virtual private network

facilities, driven by a huge influx of investment capital.

The post–U.S. Telecom Act landscape of the communications service-provider marketplace is going through significant restructuring. Technology advances in software, transport, and interconnection are rapidly making it feasible for service providers to bundle and create so-called converged service offerings. These are little more than the packaging of disparate services such as local, cellular, and long distance telephony with paging and Internet-access services into one billing and customer-service bundle. Alternatively, some carriers are attempting to build

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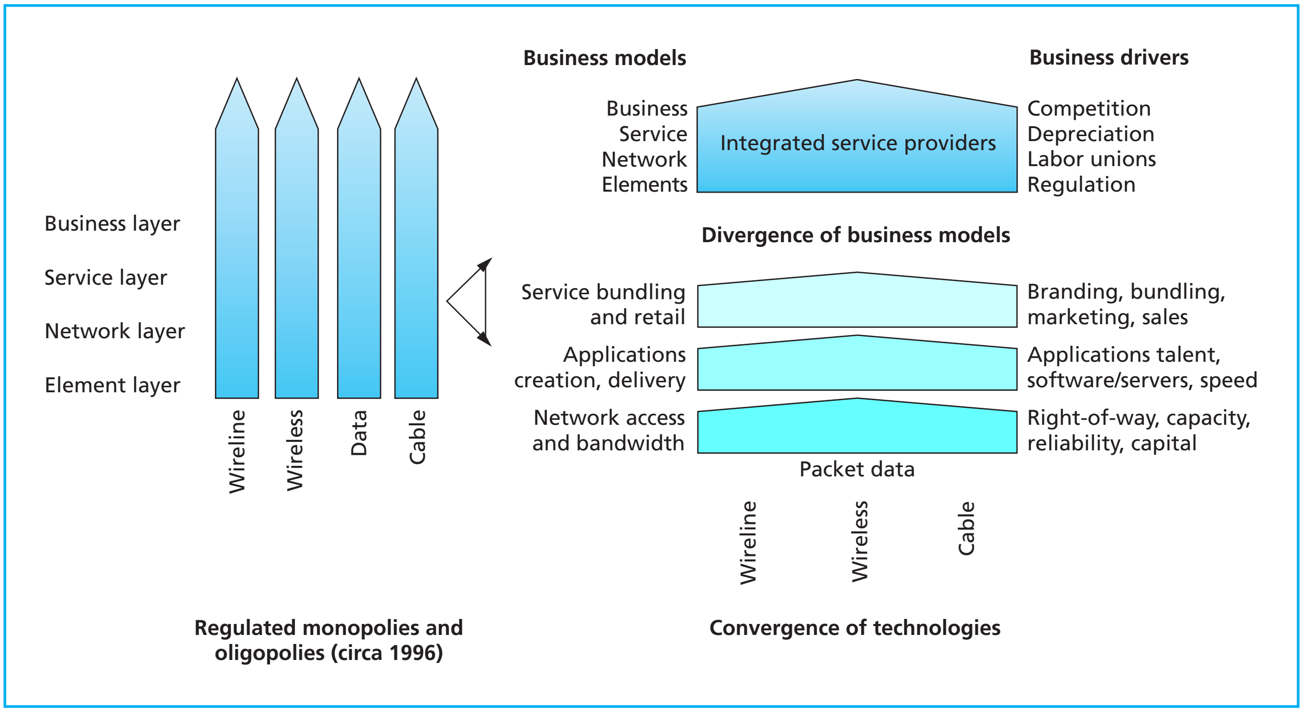

Figure 1.
Telecommunications industry structure evolution.

truly converged infrastructures that provide voice, data, and multimedia services over the same network using packet-based technologies in backbone networks. This convergence of network infrastructure technologies is being accompanied by a divergence of business models, with specialized carriers emerging in many different niches (**Figure 1**). On the one hand, some of the major carriers are still building fully vertically integrated service businesses. On the other hand, there is an emergence of three new types of business models: (1) the infrastructure provider model, which leverages of rights of way and investment capital for construction; (2) the service applications provider model, which leverages speed in creating new service applications, together with the modern data-based infrastructures to deliver them; and (3) the service retailer and marketer model, which leverages brand image, marketing, and customer franchises.

The Lucent Technologies Softswitch is particularly useful to the business model involving infrastructure providers. The next section of this paper "The Evolution of Public Communications Networks," characterizes the public switched telecommunications infrastructure, its movement toward packet-based technology, and the challenges network service providers face as it moves in that direction. The following section, "Lucent Technologies Softswitch Technology," presents Lucent's Softswitch as an approach to meeting these challenges. That section discusses the technology design philosophy, the network architectures, and the systems architectures of the Lucent Softswitch.

The Evolution of Public Communications Networks

Today's public switched telecommunications infrastructure consists of a variety of different networks, technologies, and systems. Most of this is still the wireline circuit-switched infrastructure, represented in **Figure 2**. Analog local loops, usually after being aggregated by a subscriber loop carrier, are connected to a local (Class 5) switch where the connection carries both media and control signaling for all of the aggregated loops. The local switch is connected through two separate networks to other toll/tandem and local switches. One network of intermachine trunks (IMTs) carries the media in the form of 64-kb/s time division multiplexed (TDM) streams. All of the associated control information is carried on a separate

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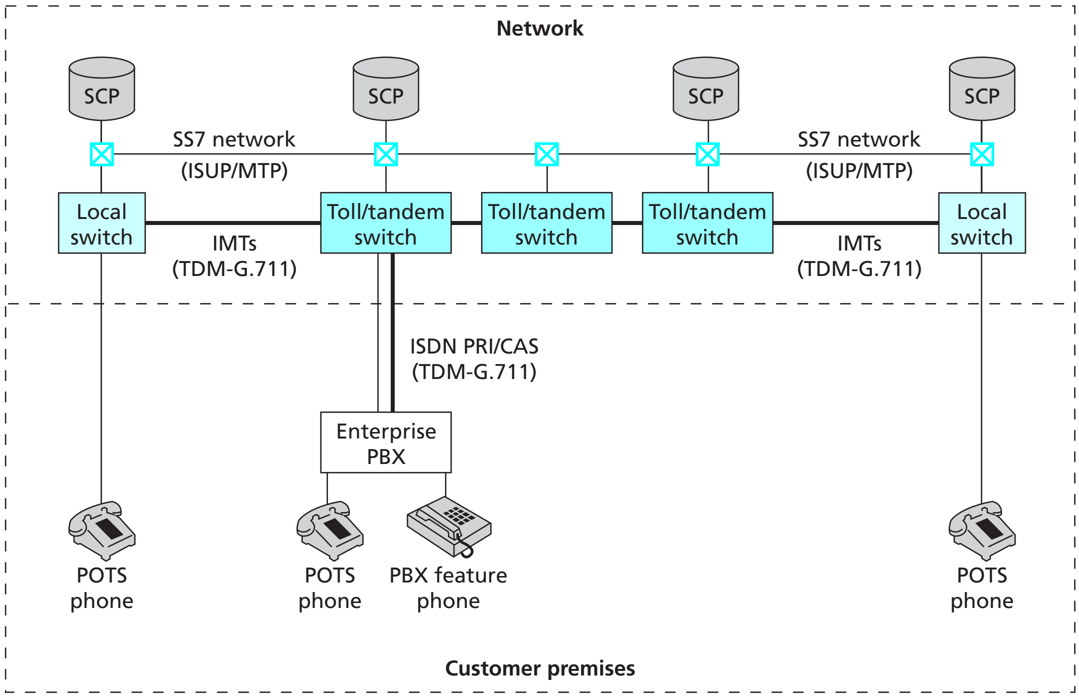

CAS – Channel-associated signaling
G.711 – ITU-T Recommendation G.711
IMT – Intermachine trunk
ISDN – Integrated services digital network
ISUP – ISDN User Part
ITU-T – International Telecommunication Union—Telecommunication Standardization Sector
MTP – Message transfer part
PBX – Private branch exchange
POTS – "Plain old telephone service"
PRI – Primary rate interface
SCP – Service control point
SS7 – Signaling System 7
TDM – Time division multiplexed

Figure 2.
Today's public switched telephone network (PSTN).

packet-based signaling-and-control network (typically using ITU-T Signaling System 7 [SS7][1,2] or Common Channel Signaling System 7 [CCS7]).

The SS7 network basically consists of three kinds of signaling points—service switching points (SSPs), signal transfer points (STPs), and service control points (SCPs). Each signaling point is identified by a unique numeric point code, analogous to an Internet protocol (IP) address in an IP network.

SSPs are switches that originate, terminate, or tandem calls. *STPs* are packet switches that interconnect and route traffic in the SS7 network. An STP's role is similar to that of an IP router but it has significant differences. *SCPs* are centralized database servers for such functions as 800-number translation and personalized information.

PRI trunks refer usually to DS1 lines or, more popularly, T1 lines that have one channel reserved for primary rate interface (PRI) signaling. Prominent variants include fractional T1s and non-facility associated signaling trunks. *Channel-associated signaling trunks,* or *CAS trunks,* refer to in-band signaling variants that can run on DS1 or T1 trunks.

Much of the logic needed for establishment of connections and routes for the media through the network are resident in the switches. Additional logic and

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information for enhanced services (such as 800/900/700 national/personal number services) are drawn from SCPs, which are connected through the SS7 network to the switches. In some cases other adjuncts called *intelligent peripherals* provide media resources such as dual-tone multiple-frequency digit recognition, spoken announcements, speech recognition, and synthesized (text-to-speech) announcements as part of these enhanced services. In general, a *circuit intelligent peripheral* refers to an external media-processing engine capable of terminating TDM audio streams and performing some processing on those streams.

Next-Generation Networks

The direction that the industry is taking in conceiving and building next-generation networks and in evolving the current public switched telephone network (PSTN) is largely premised on replacing much of the TDM-based circuit-switched infrastructure with an Internet-protocol (IP)–based or asynchronous-transfer-mode (ATM)–based packet-switched infrastructure. **Figure 3** describes the replacement of the toll/tandem or long distance part of the PSTN with a packet backbone. The packet backbone is essentially thought of as carrying the media traffic. The signaling-and-control traffic can be carried, as before, on a separate packet-based network, or else can be carried in secure and protected bandwidth flows within the packet backbone network.

Drivers of Packet-Based Technology

As carriers attempt to marshal investment capital to fund network construction, their business cases are strongly influenced by the time value of investments, which in turn are driven by the rate of innovation and economic learning effects in the core technologies chosen for the networks. These learning-curve effects are best characterized by the length of the period observed in which the performance/price ratio doubles (**Table I**). The period for commercial computing is the shortest at about 18 months. It is driven by the learning curve for semiconductors (often referred to as Moore's Law, named after Intel co-founder Gordon Moore). The performance-doubling period for TDM circuit-switching technology is the longest of those shown, at about 60 to 80 months. Packet-based IP and ATM technologies have displayed intervals of 20 and 40 months, respectively.

Table I. Technology innovation periods.

Networking technology platforms	Performance/price ratio doubling period
Commercial computing	18 months
IP technology	20 months
ATM technology	40 months
TDM-circuit switching	60–80 months

In addition to their more rapid rate of development, it is estimated that the simpler topologies of packet-based networks would lead to significant reduction in operations and administration costs. It is no wonder that there is an increasing focus on IP and ATM technologies by network operators. However, severe challenges face operators building out new networks or extending/replacing existing circuit-switched networks with packet-based infrastructures.

Challenges of Network Service Providers

Carriers looking to create new service businesses or to evolve existing ones face the immediate problem that they must, at a minimum, provide services over their new/evolved networks with the same composition, convenience, and quality as the PSTN services to which the markets are accustomed. This implies that they must build new IP-based or ATM-based packet networks that interconnect with the existing wired or wireless PSTN, as well as other networks such as cable networks, in order to provide ubiquitous interconnectivity and seamless services.

To begin with, there are many different protocols used in the packet-circuit gateways that interconnect circuit and packet networks and in the devices and client appliances used on those networks. These include, for example, H.323 and its subsidiary protocols (an ITU-T packet-telephony protocol suite),[3-9] Internet-protocol device control (IPDC), session-initiation protocol (SIP),[10] Microsoft's NetMeeting*, and media-gateway–control protocol *(MGCP)*.[11] Even if the protocol choices were made, there are many vendors of the gateways and devices, and one vendor's implementation of a protocol is not guaranteed to interwork with another's. Any implementation must, of course, transparently handle both PSTN and IP clients and must

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