Technology Analysis

Signaling System 7 Facilitates PSTN Applications

Abstract: Signaling System 7 is the human body equivalent of the central nervous system for the public switched telephone network. SS7 is used to control the PSTN and facilitate applications networkwide.

By David L. Fraley

Strategic Planning Assumptions

Signaling System 7 (SS7) and time division switching infrastructure will support significant traffic loads through the end of the decade (0.8 probability).

The next-generation network (NGN) will drive SS7 infrastructure and, in particular, SS7 signaling gateways through 2005 (0.7 probability).
PSTN Signaling

The signaling intelligence of the public switched telephone network (PSTN) resides in the SS7 network. The SS7 is a packet network virtually separated from the circuit-switched bearer network. SS7 enables the following:

- Calls are directed and routed within and among networks.
- Advanced services (800, 900, caller ID, local number portability, 911 and so on) are enabled and delivered to end users.
- Operation, administration and management information is collected and provided to drive back-office operation support system applications.

When we speak of SS7, we are speaking of two things. First is the digital signaling standard, or SS7 protocol stack. This open-system interface-like structure describes a series of messages used to communicate across the network. The network topology is the second SS7 concept. The SS7 network elements form building blocks combined to form a hierarchical signaling network. Together the protocol and network elements make up SS7.

SS7 Signaling Types

Individual forms of signaling have many variants. For example, SS7 signaling has been ratified by the following organizations:

- American National Standards Institute (ANSI)
- European Telecommunications Standards Institute (ETSI)
- International Telecommunication Union (ITU-T) — Telecommunications standardization
- National variants — Local variants based on one or more of the above

Signaling used in the PSTN include the following:

- SS7 — SS7 is a series of ITU-T specifications for digital signaling as described throughout this document.
- ISDN — ISDN is an out-of-band signaling methodology with two primary flavors: Basic Rate Interface (BRI) and Primary Rate Interface (PRI). BRI is 144 Kbps and contains two 64 Kbps bearer channels and one 16 Kbps signaling channel. PRI contains one 64 Kbps signaling channel and either 23 (North America) or 31 (Europe) 64 Kbps bearer channels.
- R2 — R2 is a series of ITU-T specifications regarding analog and digital trunk signaling. R2 refers to a type of trunk that uses compelled handshaking on every multifrequency tone. R2 is used in Asia.
- V5 — V5 is an ETSI signaling standard for the interface between the access network and carrier switch for ISDN, basic telephony and semi-permanent leased lines. V5 is used in Europe and Asia.
Network Topologies — PSTN and SS7
The SS7 network is an integral part of the PSTN. Accordingly, one must understand the PSTN architecture to understand the SS7 network. Before we can present a detailed discussion of the SS7 network, we must first look at the PSTN. The PSTN is divided into transmission elements, service switching points (SSP), service transfer points (STP) and service control points (SCP).

The bearer or call-transmission portion of the network consists of a series of switches and optical/electrical transmission components. The connection between a user and the PSTN is maintained using a line-side or Class 5 switch located in the central office (CO). The Class 5 switches direct traffic gathered from enterprises and homes over local loops (generally copper twisted-pair wire). Multiple Class 5 switches are connected to tandem or Class 4 switches.

These in turn connect to other networks. In Figure 1, the Class 4 connection is to a long-distance provider. The traffic through the provider is directed through trunks (generally high-speed fiber-optic cabling) connected by switches. Finally, the data is passed to another local provider’s CO where the final connection to the end user’s destination is made.

The SS7 network is a separate parallel connectionless packet network that routes call-control messages. The call control interacts with the PSTN switches to establish a direct-connection circuit “call” through the network. This basic SS7 architecture is shown in Figure 2.

Basic SS7 Network Elements
Service Switching Point
The SSP consists of the hardware switch and basic call-control software with the added functionality of intelligent networks (INs). IN software provides the capability to separate basic calls from IN-based calls when they arrive at the switch. IN calls contain events and triggers — and when one of these is detected, the SSP temporarily suspends call processing and initiates a series of transactions with the SCP using SS7 to determine how it should process the call. In fully implemented INs, these SSP/SCP transactions can also be handled by an STP.

Service Transfer Point
STP functions can be contained within the primary switch or implemented via a separate piece of equipment. In a switching network that contains a separate signaling network based on SS7, the transactions between the SSP and SCP are achieved via the STP. The STP is a highly reliable packet switch that allows the concentration of signaling for a large number of trunks and handles the routing of signaling messages. Additionally, the STP can contain extra functionality such as the translation of virtual-to-physical destinations and security screening.

The STP also monitors the health and status of the signaling links and is responsible for ensuring connectivity by rerouting in case of network...
failures. STPs are the most reliable of SS7 elements, with an allowance of less than one in 100 million packets to be lost or misrouted and an availability of 99.999 percent (three minutes of downtime per year).

**Figure 1**
**PSTN From a Signaling Perspective**

<table>
<thead>
<tr>
<th>SG</th>
<th>MG</th>
<th>MSC</th>
<th>HLR</th>
<th>VLR</th>
<th>EIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signaling gateway</td>
<td>Media gateway</td>
<td>Mobile switching center</td>
<td>Home location registry</td>
<td>Visitor location registry</td>
<td>Equipment identification registry</td>
</tr>
</tbody>
</table>

Source: Gartner Dataquest (November 2003)

**Service Control Point**

The SCP is a real-time database that stores customer records. When accessed by an inquiry from the SSP, the SCP executes one of a range of software routines customized for particular applications. Following the execution of the code, the SCP sends instructions back to the SSP on how to process the call. The bulk of IN transactions consists of translating the number dialed by the caller into another number, which is then used by the STP and other switches to route the call using normal procedures. The SCP is also sometimes referred to as the data access point.
Figure 2
Basic SS7 Architecture

SS7 Connection Links
To increase reliability, the SCPs are deployed in mated-pair configurations and developed as mirror images to assure redundancy. Signaling links are also provided in pairs. As such, failure of any link or point will not crash the network. The SS7 protocol also provides for error detection and correction to allow continued service in case of disruption or failure of system components.

The SS7 network elements are connected using dedicated communication circuits. There are several different link types, as shown in Figure 3. SS7 links are named by their connection type and usage and are listed in Table 1.
Figure 3  
SS7 Links

Source: Gartner Dataquest (November 2003)

Table 1  
Definitions of Links and Their Usage

<table>
<thead>
<tr>
<th>Type of Link</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Access: Connection from the edge to the STP via the SS7 network. These links originate at either the SSP, SCP or an Intelligent Peripheral (IP).</td>
</tr>
<tr>
<td>B</td>
<td>Bridge: Interconnect STP pairs of the same hierarchical level (regional to regional or local to local)</td>
</tr>
<tr>
<td>C</td>
<td>Cross: Link-connect STP pairs for rerouted traffic in case of failure or congestion plus network management messages, not administrative messages, which implies table updates and so on</td>
</tr>
<tr>
<td>D</td>
<td>Diagonal: Connect STPs of different hierarchical levels (local to regional)</td>
</tr>
<tr>
<td>E</td>
<td>Extended: Connects an SSP to an STP other than its &quot;home&quot; STP</td>
</tr>
<tr>
<td>F</td>
<td>Fully associated: Connects SSPs to SSPs, used for associated signaling between SSPs. These are usually geographically adjacent SSPs within one provider's network</td>
</tr>
</tbody>
</table>

Source: Gartner Dataquest (November 2003)

Global Title Translation  
As the number of SCPs increased because of demand for services, it became impractical to have each switch know the specific address of every network database. To solve this problem, the concept of global title translation (GTT) was introduced.

The signaling connection control part (SCCP) layer of SS7 is used to perform incremental routing using GTT, which frees originating signaling points from the burden of having to know every potential destination to
which they might have to route a message. A switch can originate a query and address it to the STP, along with a request for GTT. The receiving STP can then examine a portion of the message, make a determination as to where the message should be routed and then route it.

This is important to network designers and operators. It may seem easier for the SSP to know the specific address of every database in the network, but this increases the amount of databases that must be administered and managed. Every time a database is changed or added, that information would have to be changed in every SSP in the network. By using GTT in the STP, the information in the SSP does not need to change, as it only needs to know the address of the STP. By using this architecture, SCPs can be changed or added, affecting only the STPs.

An example of the power of GTT is calling-card queries — used to verify that a call can be properly billed to a calling-card — which must be routed to an SCP designated by the company that issued the calling card. Rather than maintaining a nationwide database of where such queries should be routed, switches generate queries addressed to their local STPs, which, using GTT, select the correct destination to which the message should be routed. There is no magic here; STPs must maintain a database that enables them to determine where a query should be routed. GTT effectively centralizes the problem and places it in a node (the STP), which has been designated to perform this function.

In performing GTT, the STP does not need to know the final destination of a message. It can, instead, perform intermediate GTT, in which it uses its tables to find another STP further along the route to the destination. That STP, in turn, can perform final GTT, routing the message to its actual destination.

Intermediate GTT minimizes the need for STPs to maintain extensive information about nodes far removed from them. GTT is used at the STP to distribute the load among mated SCPs in both normal and failure scenarios. In these instances, when messages arrive at the STP for final GTT and routing to a database, the STP can select from the available redundant SCPs. It can select the SCP on either a priority basis (primary backup) or to equalize the load across all available SCPs (load sharing).

**SS7 Flavors**

**International Telecommunication Union Signaling System 7**

The SS7 protocol stack is an adopted standard recognized by all telecommunications providers as the unified way to communicate across network boundaries. The ITU-T sector has the charter to define and regulate the SS7 standard, a voluntary standard accepted by all countries that deploy an SS7 signaling network. However, the national network of all countries is different. To accommodate network differences, national SS7 variants have been created. This has led to the creation of an international SS7 network and many national SS7 networks. The national SS7 networks are based on the ITU-T standard but adapted to the individual needs of the network. These differences are most often the
assignment of network addresses (point codes) and network management features.

Within the United States, the ANSI is responsible for defining and approving SS7 standards for interconnection and operability within North America.

The international SS7 network ensures connectivity between worldwide networks despite the use of different point codes and network management. The North American ANSI/Bellcore point code structure is 24 bits, China’s is 24 bits and Japan’s is 16 bits. Most other countries have adopted the ITU-T standard point code structure of 14 bits.

Nodes connecting to the international SS7 network must be compatible with the ITU-T protocol standard. A gateway STP provides protocol conversion from the national SS7 variant to the ITU-T standard. This protocol conversion allows ITU-T messages into the network by converting the messages into the national format before transmitting them to the national network. The process works in reverse for messages originating in the national network bound for an international destination. The gateway STP also uses screening features to maintain network security and to protect both networks from individual national network instability and failures.

**European Telecommunications Standards Institute Signaling System 7**

ETSI is the European equivalent of ANSI and Bellcore for North America. While ANSI defines standards for North America, Bellcore has historically defined specifications for vendors to comply with.

Historically, in the United States and Canada, operating companies typically defined system features, specifications and interworking. Since Bellcore was co-owned by the RBOCs and the RBOCs comprised over 80 percent of all access lines in the United States, it could easily set standards and specifications for the industry — and did. In Canada, Stentor played the role of Bellcore. This is unlike much of the world and Europe where vendors typically drove standards and feature sets. In either case, the customer did not define the features — except that the operating companies considered themselves to be the customer. SS7 and open-network architecture have paved the way to turn that around.

**American National Standards Institute Signaling System 7**

ITU-T defines standards for the world. ANSI defines a subset for North America. In the United States and Canada, Bellcore specifically defined SS7 in generic requirements documents, formerly known as technical requirements (TR), such as TR-NWT-000246.

**National Variants of SS7**

Any country is free to use a subset of ITU-T. If they wish to interconnect via SS7 country to country, a gateway switch is usually required at both countries’ ports of entry with differing flavors of SS7 on each side.
**SS7 Protocol Stack**

The SS7 protocol is designed to exchange messages in support of telecommunications functions and maintain the network over which they are provided. When a call is originated, the signaling information is carried to the local Class 5 switch. If the call is within the domain of the SSP, the call is routed to the destination. This special case happens when both the calling and called parties terminate on the same SSP. If the called party terminates on a secondary SSP, the SS7 network is invoked. The SSP creates an SS7 message signal unit (MSU). MSUs are the basic envelope for all call setup, teardown, database query and response. Like most modern protocols, the SS7 protocol is layered. The SS7 protocol stack is shown in Figure 4.

**Figure 4**
The SS7 Protocol Stack

<table>
<thead>
<tr>
<th>ISUP/ TUP/ IUP</th>
<th>IS-41/ MAP</th>
<th>INAP/ AIN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TCAP</td>
<td>SCCP</td>
</tr>
<tr>
<td>MTP Layer 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MTP Layer 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MTP Layer 1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TUP = Telephone user part  
IUP = Interconnect user part  
IS-41 = Interim standard-41  
INAP = Intelligent network application part  
Source: Gartner Dataquest (November 2003)

**MTP Layers**

The three lowest layers of the stack are collectively called the message transfer part (MTP). MTP is the SS7 transport protocol and is responsible for moving traffic through the network and providing connectionless services. MTP is divided into three levels with ultimate responsibility for sequenced message delivery: MTP-1, MTP-2 and MTP-3.

MTP-1 defines the physical and electrical characteristics of the signaling link. MTP-2 and MTP-3 control message handling, error detection and recovery, network management, data flow and addressing, and routing between STP nodes.
Signaling Connection Control Part
The SCCP provides two major functions lacking in the MTP. The first is the capability to address applications within an STP. Each STP has multiple applications. The MTP can only receive and deliver messages from a node as a whole; it does not deal with how to address the software applications within a node.

While MTP network-management messages and basic call setup messages are addressed to a node as a whole, other messages are used by separate applications (referred to as subsystems) within a node. Examples of subsystems are 800 call processing, calling-card processing, advanced intelligent networks (AIN) and CLASS services (such as repeat dialing and call return). The SCCP allows these subsystems to be addressed explicitly.

Transaction Capabilities Application Part
Transaction capabilities application parts (TCAP) define the messages and protocol used to communicate between applications (deployed as subsystems) in nodes. The most common type of application for TCAP is database services, such as calling card, 800 and AIN. These are commonly known as connectionless services. It is also used for switch-to-switch services, including repeat dialing and call return. Because TCAP messages must be delivered to individual applications within the nodes they address, they use the SCCP for transport.

TCAP enables the deployment of AIN services by supporting the non-circuit-related information exchange between signaling points using the SCCP connectionless service. An SSP uses TCAP to query an SCP to determine the routing number(s) associated with a dialed 800, 888 or 900 number. The SCP uses TCAP to return a response containing the routing number(s) (or an error or reject component) back to the SSP. Calling-card calls are validated using TCAP query-and-response messages. When a mobile subscriber roams into a new mobile switching center area, the integrated visitor location register requests service profile information from the subscriber's home location register using mobile application part information carried within TCAP messages. While most connectionless services involve the use of an SCP database for decision-making information, TCAP is used switch-to-switch to support some CLASS features, such as automatic busy recall.

The ability to access remote databases and invoke switch-to-switch features is a fundamental part of any modern phone system. These are the basis for invoking revenue-generating services. For this reason alone, TCAP is a central part of the PSTN. An example is in order to demonstrate how TCAP is used. We will describe this in the next section.

An 800 number does not represent a routable address; 800 numbers are virtual telephone numbers. Although they point to real telephone numbers, they are not assigned to the subscriber line itself; 800 numbers must be converted into routable numbers. This requires a database that provides a routing number, which the local switch can then use to route the call in the same manner. For network efficiency the database is
centrally located within the service provider's network. It doesn’t make sense to have every switch have its own copy of the database; this presents a large administrative burden.

When a subscriber dials an 800 number, it is a signal to the switch to suspend the call and seek further instruction from a database. The database will provide either a real phone number to which the call should be directed, or it will identify another network (such as a long-distance carrier) to which the call should be routed for further processing. While the response from the database could be the same for every call (as, for example, if you have a personal 800 number), it can vary, based on the calling number, time of day, day of the week and a number of other factors.

When a subscriber wants directions to the nearest store of a national hardware chain, he or she dials the company’s advertised 800 number. The local switch recognizes the 800 number and formulates a TCAP query, which includes the dialed 800 number, as well as the subscriber’s number. This is forwarded to the STP. The STP recognizes it is an 800 number and selects an SCP capable of processing the query. The SCP receives the TCAP query, extracts the 800 and subscriber’s number and, based on its stored records, selects the number of the nearest hardware store to which the call should be routed. The SCP creates a TCAP response containing this number and routes the response to the STP, which returns it to the originating switch. The switches then use this information to set up and complete the call.

**ISDN User Part**

The ISDN user part (ISUP) defines the protocol used to set up, manage and release trunk circuits that carry voice and data between terminating line exchanges (such as between a calling and called party). ISUP is used for ISDN and non-ISDN calls.

After the connection has been established, ISUP supports communication of signaling information between the two endpoint switches. This is used to set up and support switch-to-switch services, such as conference calling or automatic callback. Any information about the subscriber or network features, or anything not directly related to the call-setup circuit itself uses TCAP.

**Operation Maintenance and Administration Part**

Operation maintenance and administration part (OMAP) specifies the protocol for managing the CCS network using SS7 to transport information between signaling points. Architecturally, OMAP lies above TCAP in the SS7 protocol stack, using the remote operations service to TCAP to communicate between OMAP applications. OMAP specifies four procedures:

- MTP routing verification test — Verifies MTP routing data for a network node
SCCP routing verification test — Verifies SCCP routing data for a global title address

Link equipment failure — Notifies a signaling point of a signaling terminal or interface equipment failure at the far end of the signaling link

Link fault "sectionalization" — Identifies the failed component of the signaling link

**Switch-to-Switch Services**
TCAP and ISUP provide the ability to transfer service information from one switch to another, even if large distances separate them. In addition to the network databases, such as 800 numbers, every phone number has records associated with it. These are used to identify the subscriber and what services they have subscribed to. These databases are called line information databases. The individual telephone companies that provide service own these databases.

An example of this type of service is automatic callback. In this service a subscriber dials a number that is busy. On invoking automatic callback, the caller hangs up the phone. When the called number becomes available, the switch generates a trigger that notifies the caller’s local switch via TCAP and ISUP messages. The calling party’s phone rings, and when it is picked up, normal call setup procedures establish the connection between the two parties. This same concept has been extended to many other types of applications where remote invocation is an option.

**Standard Bodies**

**International Telecommunication Union**
The ITU, headquartered in Geneva, Switzerland, is an international organization that coordinates global telecommunications networks and service issues. The ITU has three main sectors: radio communications (ITU-R), standards (ITU-T), and development (ITU-D).

**Radio Communications**
ITU-R is responsible for overseeing and facilitating the intergovernmental negotiations referenced in the use of the radio spectrum. These agreements are embodied in the Radio Regulations and in regional plans adopted for broadcasting and mobile services.

**Standards**
ITU-T develops internationally agreed technical and operating standards and protocols. It also defines tariff and accounting principles for international telecommunications services. The work of ITU-T aims to foster seamless interconnection of the world’s communications network and systems.

The ITU-T has 14 study groups that cover topics including numbering systems, multimedia services and systems, network and service operation, tariff and accounting principles, telecommunications network

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management systems, signaling, transmission and transport systems, data networks, and new value-added services, such as universal international free-phone numbers.

In addition, ITU-T is charged with coordinating the development of the systems and technologies that constitute the emerging global information infrastructure. Areas under study include broadband ISDN, IP-based networks and groundbreaking technologies related to new multimedia systems, including special protocols and signal processing systems, high-speed modems, xDSL, and new types of multimedia terminal.

**Development**

A lack of reliable access to basic telecommunications services affects around two-thirds of ITU’s 189 member states (countries). It is the vital task of the ITU-D to help redress this imbalance, promote investment and foster the expansion of telecommunications infrastructure in developing nations.

**European Telecommunications Standards Institute**

ETSI is an industry consortium that last December had 812 member organizations from 53 countries. The European Commission officially recognizes ETSI in their role promoting communications standards. ETSI’s members include equipment manufacturers, network operators, service providers, research bodies and users. While the IETF is the main organization promoting standards and technical documentation for Europe, they do promote standards and interworking on a global basis. ETSI’s prime objective is to support global harmonization by providing a forum in which all the key players can contribute actively.

**American National Standards Institute**

ANSI is the North American organization with responsibility for protocol and media standards used in the United States. ANSI is a nonprofit organization primarily consisting of service providers and equipment manufacturers.

**Gartner Dataquest Perspective**

SS7, as the network control element of the PSTN, has set the gold standard for call control and service delivery. As the NGN begins to take form, its signaling and service-delivery schemes will be judged against SS7.

The PSTN is the product of over 100 years of evolution. SS7 is its crowning achievement. SS7 is the world’s largest data communications network, linking telephone companies, cellular providers and long-distance providers into one information-sharing network.

SS7 is robust and flexible especially in its longevity. SS7 was conceived in the early 1980s. There were no cellular phones; telephone numbers could not be ported and had to be surrendered if the subscriber wanted to change providers. Many features commonly available — caller ID, network-based voice mail, interactive voice-answering systems, callback,
call-forwarding — did not exist. SS7 has adapted to meet the explosion of telecommunications over the past 20 years.

In addition to service delivery, an SS7 user can initiate a connection with most other phones in the world (the most notable exception is Cuba). This can be done without operator intervention. There is no planned standards-based upgrade to SS7 (such as Signaling System 8). SS7 has adapted to meet the explosion of telecommunications over the past 20 years and is expected to adapt to future needs as well.

**Gartner Dataquest Recommendations**

The SS7 signaling network has set the gold standard for service delivery and internetworking. For the rest of this decade, and into the next, SS7 will continue to be used around the world. However, as the NGN and end-to-end IP calls increase as a percentage of total real-time calls, the SS7 network will decrease in relative importance. At some point the SS7 network will implode because of a lack of time division multiplexing traffic. At that point, the NGN will need a replacement network that supports SS7 signaling.

At this time it appears that a family of "next generation" protocols will replace the family of SS7 protocols for the NGN. Those protocols include Session Initiation Protocol, Megaco and electronic numbering. Equipment vendors and network operators should work in conjunction with standards bodies and organizations to ensure an orderly transition to the NGN and next-generation signaling.

**Key Issue**

How will developments in signaling technology affect network evolution?

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