Efficient Architecture for Performing Out-of-band Signaling

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Abstract

*SS7 or Signaling System Number 7 is a set of protocols that describes a means of communication between telephone switches in public telephone networks.SS7 is a highly sophisticated and powerful form of Common Channel Signaling (CCS). The **use of out-of-band signaling** procedures offers considerable benefits over and above other signaling methodologies. The primary function of SS7 is to provide call control, remote network management, and maintenance capabilities for the inter- office telephone network. SS7 performs these functions by exchanging control messages between SS7 telephone exchanges (signaling points or SPs) and SS7 signaling transfer points (STPs). The switching offices (SPs) handle the SS7 control network as well as the user circuit switched network. Basically, the SS7 control network tells the switching office which paths to establish over the circuit-switched network. The STPs route SS7 control packets across the signaling network. A switching office may or may not be an STP.*

Keywords: *Common Channel Signaling (CCS), Signaling Transfer Points (STP)., Public Switched Telephone Network (PSTN), European Telecommunications Standards Institute (ETSI), Local Number Portability (LNP) , Personal Communications Services (PCS), Intelligent Network (IN), Global Title Translation (GTT), Backwards Sequence Number (BSN), Backwards Indicator Bit (BIB), Forward Sequence Number (FSN), Forward Indicator Bit (FIB).*

1. INTRODUCTION

Signaling System 7 (SS7) is architecture for performing **out-of-band signaling** in support of the call-establishment, billing, routing, and information-exchange functions of the public switched telephone network (PSTN). It identifies functions to be performed by a signaling-system network and a protocol to enable their performance.Common Channel Signaling System No. 7 (i.e., SS7 or C7) is a global standard for telecommunications defined by the International Telecommunication Union (ITU) Telecommunication Standardization Sector (ITU-T). The standard defines the procedures and protocol by which network elements in the public switched telephone network (PSTN) exchange information over a digital signaling network to effect wireless (cellular) and wireline call setup, routing and control. The ITU definition of SS7 allows for national variants such as the American National Standards Institute (ANSI) and Bell Communications Research (Telcordia Technologies) standards used in North America and the European Telecommunications Standards Institute (ETSI) standard used in Europe.

The SS7 network and protocol are used for:

- personal communications services (PCS) and wireless roaming
- mobile subscriber authentication
- local number portability (LNP)
- toll-free (800/888) and toll (900) wireline services
- enhanced call features such as call forwarding, calling party name/number display
- three-way calling
- basic call setup, management, and tear down

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2. SIGNALING

Signaling refers to the exchange of information between call components required to provide and maintain service. As users of the PSTN, we exchange signaling with network elements all the time. Examples of signaling between a telephone user and the telephone network include: dialing digits, providing dial tone, accessing a voice mailbox, sending a call-waiting tone, dialing *66 (to retry a busy number), etc. SS7 is a means by which elements of the telephone network exchange information. Information is conveyed in the form of messages. SS7 is characterized by *high-speed packet data* and *out-of-band signaling*.

3. SIGNALING LINKS

SS7 messages are exchanged between network elements over 56 or 64 kilobit per second (kbps) bidirectional channels called **signaling links**. Signaling occurs **out-of-band** on dedicated channels rather than **in-band** on voice channels. Compared to in-band signaling, out-of-band signaling provides:

support for Intelligent Network (IN) services

improved control over fraudulent network usage

faster call setup times (compared to in-band signaling using multi-frequency (MF) signaling tones)

more efficient use of voice circuits

Save network operating costs by reducing SS7 links.

4. SIGNALING POINTS

Each signaling point in the SS7 network is uniquely identified by a numeric **point code**. Point codes are carried in signaling messages exchanged between signaling points to identify the source and destination of each message. Each signaling point uses a routing table to select the appropriate signaling path for each message.There are three kinds of signaling points in the SS7 network (Fig. 1):

SSP (Service Switching Point), **STP** (Signal Transfer Point), **SCP** (Service Control Point)

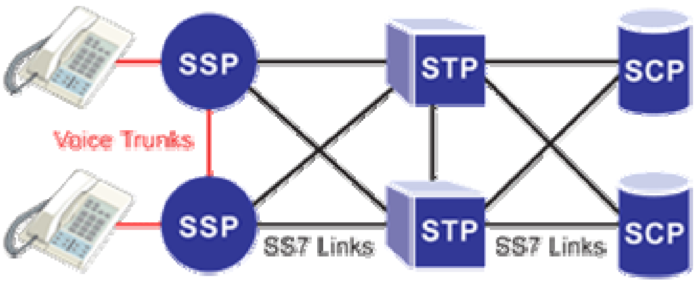

Figure 1. SS7 Signaling Points

SSPs are switches that originate, terminate, or tandem calls. An SSP sends signaling messages to other SSPs to setup, manage, and release voice circuits required to complete a call. An SSP may also send a query message to a centralized database (an **SCP**) to determine how to route a call (e.g., a toll-free 1-800/888 call in North America). An SCP sends a response to the originating SSP containing the routing number(s) associated with the dialed number. An alternate routing number may be used by the SSP if the primary number is busy or the call is unanswered within a specified time. Actual call features vary from network to network and from service to service.

Network traffic between signaling points may be routed via a packet switch called an **STP**. An STP routes each incoming message to an outgoing signaling link based on routing information contained in the SS7 message. Because it acts as a network hub, an STP provides improved utilization of the SS7 network by eliminating the need for direct links between signaling points. An

STP may perform **global title translation**, a procedure by which the destination signaling point is determined from digits present in the signaling message (e.g., the dialed 800 number, calling card number, or mobile subscriber identification number). An STP can also act as a "firewall" to screen SS7 messages exchanged with other networks.

Because the SS7 network is critical to call processing, SCPs and STPs are usually deployed in mated pair configurations in separate physical locations to ensure network-wide service in the event of an isolated failure. Links between signaling points are also provisioned in pairs. Traffic is shared across all links in the linkset. If one of the links fails, the signaling traffic is rerouted over another link in the **linkset**. The SS7 protocol provides both error correction and retransmission capabilities to allow continued service in the event of signaling point or link failures.

Signaling gateways can be configured as an STP or SEP (Signaling End Point).

5. SIGNALING LINK TYPES

Signaling links are logically organized by link type ("A" through "F") according to their use in the SS7 signaling network.

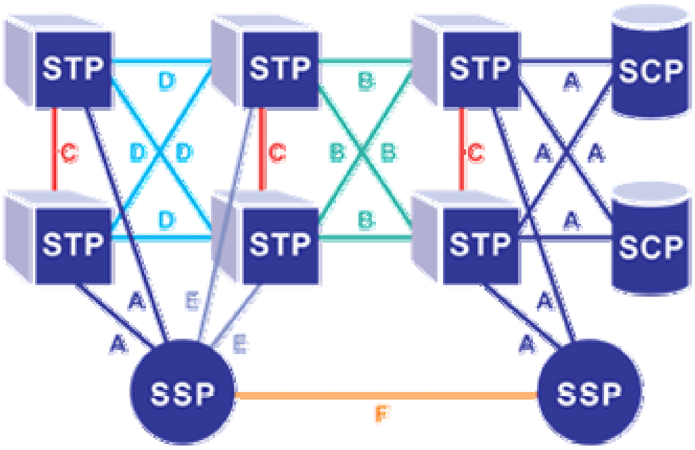

Figure 2. SS7 Signaling Link Types

A Link: An "A" (access) link connects a signaling end point (e.g., an SCP or SSP) to an STP. Only messages originating from or destined to the signaling end point are transmitted on an "A" link.

B Link: A "B" (bridge) link connects an STP to another STP. Typically, a quad of "B" links interconnect peer (or primary) STPs (e.g., the STPs from one network to the STPs of another network). The distinction between a "B" link and a "D" link is rather arbitrary. For this reason, such links may be referred to as "B/D" links.

C Link: A "C" (cross) link connects STPs performing identical functions into a **mated pair**. A "C" link is used only when an STP has no other route available to a destination signaling point due to link failure(s). Note that SCPs may also be deployed in pairs to improve reliability; unlike STPs, however, mated SCPs are not interconnected by signaling links.

D Link: A "D" (diagonal) link connects a secondary (e.g., local or regional) STP pair to a primary (e.g., inter-network gateway) STP pair in a quad-link configuration. Secondary STPs within the same network are connected via a quad of "D" links. The distinction between a "B" link and a "D" link is rather arbitrary. For this reason, such links may be referred to as "B/D" links.

E Link: An "E" (extended) link connects an SSP to an alternate STP. "E" links provide an alternate signaling path if an SSP's "home" STP cannot be reached via an "A" link. "E" links are not usually provisioned unless the benefit of a marginally higher degree of reliability justifies the added expense.

F Link: An "F" (fully associated) link connects two signaling end points (i.e., SSPs and SCPs). "F" links are not usually used in networks with STPs. In networks without STPs, "F" links directly connect signaling points.

6. SIGNALING NETWORK ARCHITECTURE

If signaling is to be carried on a different path from the voice and data traffic it supports, then what should that path look like? The simplest design would be to allocate one of the paths between each interconnected pair of switches as the signaling link. Subject to capacity constraints, all signaling traffic between the two switches could traverse this link. This type of signaling is known as associated signaling, and is shown below in *Figure 3*.

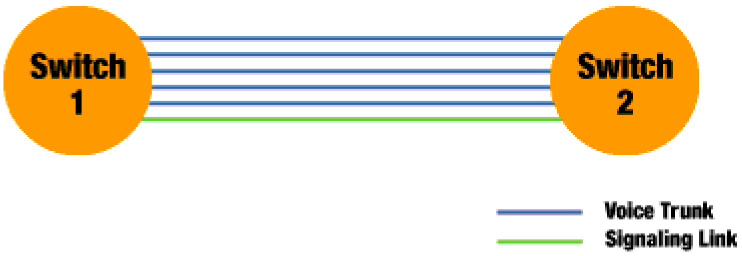

Figure 3. Associated Signaling

Associated signaling works well as long as a switch's only signaling requirements are between itself and other switches to which it has trunks. If call setup and management was the only application of SS7, associated signaling would meet that need simply and efficiently. In fact, much of the out-of-band signaling deployed in Europe today uses associated mode.

The North American implementers of SS7, however, wanted to design a signaling network that would enable any node to exchange signaling with any other SS7–capable node. Clearly, associated signaling becomes much more complicated when it is used to exchange signaling between nodes which do not have a direct connection. From this need, the North American SS7 architecture was born.

7. BASIC SIGNALING ARCHITECTURE

Figure 4 shows a small example of how the basic elements of an SS7 network are deployed to form two interconnected networks.

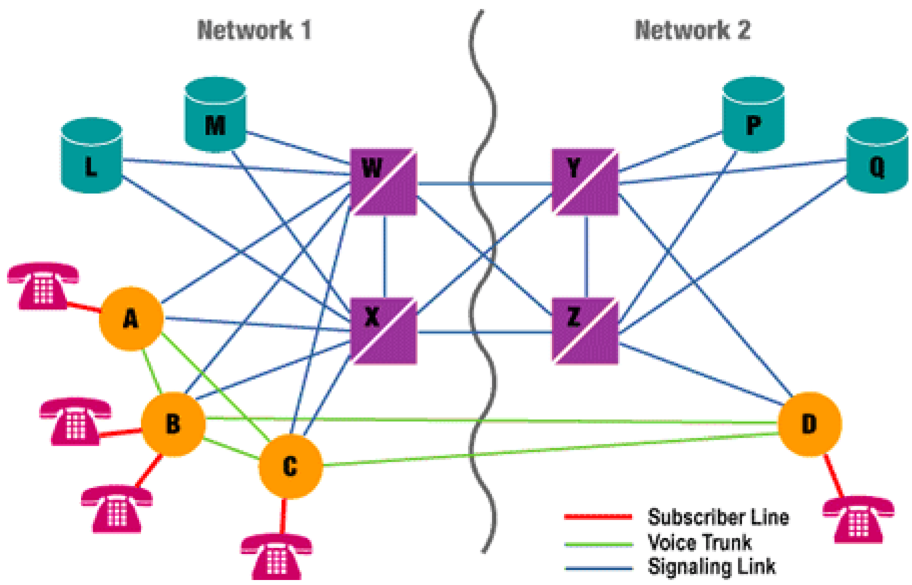

Figure 4. Sample Network

The following points should be noted:

1. STPs W and X perform identical functions. They are redundant. Together, they are referred to as a mated pair of STPs. Similarly, STPs Y and Z form a mated pair.
2. Each SSP has two links (or sets of links), one to each STP of a mated pair. All SS7 signaling to the rest of the world is sent out over these links. Because the STPs of a mated pair are redundant, messages sent over either link (to either STP) will be treated equivalently.
3. The STPs of a mated pair are joined by a link (or set of links).
4. Two mated pairs of STPs are interconnected by four links (or sets of links). These links are referred to as a quad.
5. SCPs are usually (though not always) deployed in pairs. As with STPs, the SCPs of a pair are intended to function identically. Pairs of SCPs are also referred to as mated pairs of SCPs. Note that they are not directly joined by a pair of links.
6. Signaling architectures such as this, which provide indirect signaling paths between network elements, are referred to as providing quasi-associated signaling.

8. LAYERS

The SS7 network is an interconnected set of network elements that is used to exchange messages in support of telecommunications functions. The SS7 protocol is designed to both facilitate these functions and to maintain the network over which they are provided. Like most modern protocols, the SS7 protocol is layered.

Physical Layer

This defines the physical and electrical characteristics of the signaling links of the SS7 network. Signaling links utilize DS–0 channels and carry raw signaling data at a rate of 56 kbps or 64 kbps (56 kbps is the more common implementation).

Message Transfer Part—Level 2

The level 2 portion of the message transfer part (MTP Level 2) provides link-layer functionality. It ensures that the two end points of a signaling link can reliably exchange signaling messages. It incorporates such capabilities as error checking, flow control, and sequence checking.

Message Transfer Part—Level 3

The level 3 portion of the message transfer part (MTP Level 3) extends the functionality provided by MTP level 2 to provide network layer functionality. It ensures that messages can be delivered between signaling points across the SS7 network regardless of whether they are directly connected. It includes such capabilities as node addressing, routing, alternate routing, and congestion control.

Collectively, MTP levels 2 and 3 are referred to as the message transfer part (MTP).

Signaling Connection Control Part

The signaling connection control part (SCCP) provides two major functions that are lacking in the MTP. The first of these is the capability to address applications within a signaling point. The MTP can only receive and deliver messages from a node as a whole; it does not deal with 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 network (AIN), and custom local-area signaling services (CLASS) services (e.g., repeat dialing and call return). The SCCP allows these subsystems to be addressed explicitly.

Global Title Translation

The second function provided by the SCCP is the ability to perform incremental routing using a capability called global title translation (GTT). GTT 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, for example, and address it to an 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.

For example, calling-card queries (used to verify that a call can be properly billed to a calling card) 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 (based on the calling-card number), switches generate queries addressed to their local STPs, which, using GTT, select the correct destination to which the message should be routed. Note that 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) that has been designed to perform this function.

In performing GTT, an STP does not need to know the exact 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 that are far removed from them. GTT also is used at the STP to share load among mated SCPs in both normal and failure scenarios. In these instances, when messages arrive at an STP for final GTT and routing to a database, the STP can select from among available redundant SCPs. It can select an SCP on either a priority basis (referred to as primary backup) or so as to equalize the load across all available SCPs (referred to as load sharing).

ISDN User Part (ISUP)

ISUP user part defines the messages and protocol used in the establishment and tear down of voice and data calls over the public switched network (PSN), and to manage the trunk network on which they rely. Despite its name, ISUP is used for both ISDN and non–ISDN calls. In the North American version of SS7, ISUP messages rely exclusively on MTP to transport messages between concerned nodes.

Transaction Capabilities Application Part (TCAP)

TCAP defines the messages and protocol used to communicate between applications (deployed as subsystems) in nodes. It is used for database services such as calling card, 800, and AIN as well as 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.

Operations, Maintenance, and Administration Part (OMAP)

OMAP defines messages and protocol designed to assist administrators of the SS7 network. To date, the most fully developed and deployed of these capabilities are procedures for validating network routing tables and for diagnosing link troubles. OMAP includes messages that use both the MTP and SCCP for routing.

9. ADDRESSING

Every network must have an addressing scheme, and the SS7 network is no different. Network addresses are required so that a node can exchange signaling nodes to which it does not have a physical signaling link. In SS7, addresses are assigned using a three-level hierarchy. Individual signaling points are identified as belonging to a cluster of signaling points. Within that cluster, each signaling point is assigned a member number. Similarly, a cluster is defined as being part of a network. Any node in the American SS7 network can be addressed by a three-level number defined by its network, cluster, and member numbers. Each of these numbers is an 8-bit number and can assume values from 0 to 255. This three-level address is known as the point code of the signaling point. A point code uniquely identifies a signaling point within the American SS7 network and is used whenever it is necessary to address that signaling point.

Network numbers are assigned on a nationwide basis by a neutral party. Regional Bell operating companies (RBOCs), major independent telephone companies, and interexchange carriers (IXCs) already have network numbers assigned. Because network numbers are a relatively scarce resource, companies' networks are expected to meet certain size requirements in order to be assigned a network number. Smaller networks can be assigned one or more cluster numbers within network numbers 1, 2, 3, and 4. The smallest networks are assigned point codes within network number 5. The cluster to which they are assigned is determined by the state in which they are located. The network number 0 is not available for assignment and network number 255 is reserved for future use.

10. SIGNAL UNIT STRUCTURE

SUs of each type follow a format unique to that type. A high-level view of those formats is shown in *Figure 5*.

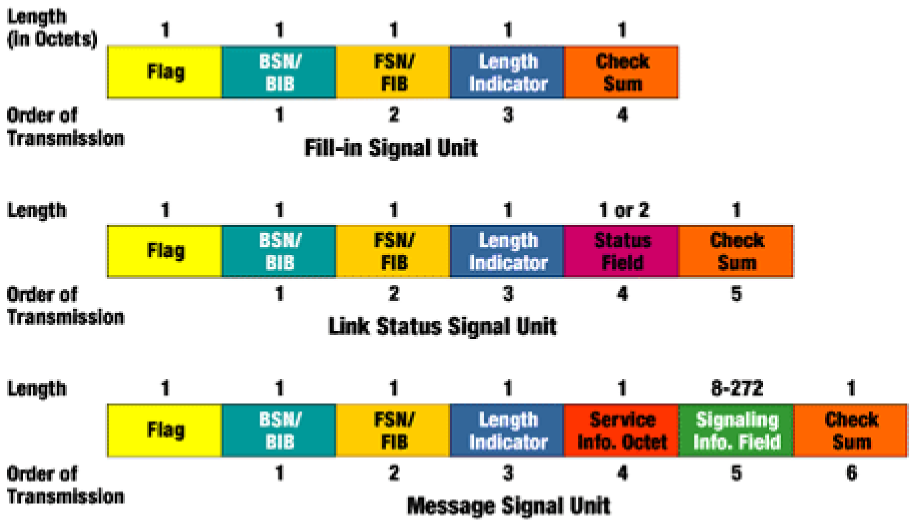

Figure 5. Signaling Unit Formats

All three SU types have a set of common fields that are used by MTP Level 2. They are as follows:

Flag

Flags delimit SUs. A flag marks the end of one SU and the start of the next.

Checksum

The checksum is an 8-bit sum intended to verify that the SU has passed across the link error-free. The checksum is calculated from the transmitted message by the transmitting signaling point and inserted in the message. On receipt, it is recalculated by the receiving signaling point. If the calculated result differs from the received checksum, the received SU has been corrupted. A retransmission is requested.

Length Indicator

The length indicator indicates the number of octets between itself and the checksum. It serves both as a check on the integrity of the SU and as a means of discriminating between different types of SUs at level 2. As can be inferred from Figure 8, FISUs have a length indicator of 0; LSSUs have a length indicator of 1 or 2 (currently all LSSUs have a length indicator of 1), and MSUs have a length-indicator greater than 2. According to the protocol, only 6 of the 8 bits in the length indicator field are actually used to store this length; thus the largest value that can be accommodated in the length indicator is 63. For MSUs with more than 63 octets following the length indicator, the value of 63 is used.

BSN/BIB FSN/FIB

These octets hold the backwards sequence number (BSN), the backwards indicator bit (BIB), the forward sequence number (FSN), and the forward indicator bit (FIB). These fields are used to confirm receipt of SUs and to ensure that they are received in the order in which they were transmitted. They also are used to provide flow control. MSUs and LSSUs, when transmitted, are assigned a sequence number that is placed in the forward sequence number field of the outgoing SU. This SU is stored by the transmitting signaling point until it is acknowledged by the receiving signaling point. Because the seven bits allocated to the forward sequence number can store 128 distinct values, it follows that a signaling point is restricted to sending 128 unacknowledged SUs before it must await an acknowledgment. By acknowledging an SU, the receiving node frees that SU's sequence number at the transmitting node, making it available for a new outgoing SU. Signaling points acknowledge receipt of SUs by placing the sequence number of the last correctly received and in-sequence SU in the backwards sequence number of every SU they transmit. In that way, they acknowledge all previously received SUs as well. The forward and backwards indicator bits are used to indicate sequencing or data-corruption errors and to request retransmission.

11. CONCLUSION

The SS7 network has emerged as a common, low-delay, highly secure, and reliable infrastructure designed to support voice transport and services over the circuit-switched network. SS7 establishes a framework by which data is exchanged between systems in the network via dedicated signaling channels. The signaling link underpins the complete SS7 architecture. It enables communication to take place between entities within the network, permits the exchange of information and is essential for the effectiveness of the security features that make the network so resilient.

12. REFERENCES

[1] Lawrence Harte,Richard Dreher,Dave Bowler, Details of Signalling System 7 basics,3rd edition,Althos Publisher, ISBN 0972805370, Pp 21-97.

[2] D. R. Manfield, G. Millsteed, and M. Zukerman, "Congestion controls in SS7 signaling networks," IEEE Commun., June 1993.

[3] Harte, Lawrence, Bowler, David , Dreher, Richard, " Introduction to Ss7; SSP, Scp, Stp, and Ss7 Protocol Layers Operation", Althos Publisher,ISBN: 1932813020,Pp 19-98.

[4] Dryburgh, Lee , Hewitt, Jeff , "Signaling System No. 7 (SS7/C7): Protocol, Architecture, and Services", Publisher: Cisco Press, ISBN: 1587050404, 2004,Pp 31-102.

[5] Ron Jonathan Davidson; James Peters; Manoj Bhatia; Satish Kalidindi; Sudipto Mukherje,"Voice over IP fundamentals, Second Edition, 2006, Cisco Press.

[6] Russell, Travis, "Signaling System #7", McGraw-Hill Professional Publishing, ISBN: 007146879X, Pp 179-286.

[7] Rufa, Gerhard,"Developments in Telecommunications: With a Focus on Ss7 Network Reliability",Publisher: Springer,ISBN: 3540749853,Pp 72-161.

[8] ayne, John P. "The Digital Network". *Introduction to Digital Communications Switching* (1st edition). Indianapolis: Howard W. Sams & Co., Inc.. ISBN 0-672-22498-4, Pp 61-92.

[9] Bellcore, "Bell communications research specification of signalling system number 7," TR-NPL- 00246, issue 2, vol. I and 2, June 1991 and revisions.

[10] "Signaling transfer point (STP} generic requirements," TR- NWT-000082, issue 5, Dec. 1993.

[11] "Switching system requirements for call control using the integrated services digital network user part (ISDNUP),' TR-TSY- 000317, issue 2, July 1989 and subsequent revisions.

[12] K. J. Lee and Y. Lim, "Performance analysis of the congestion control scheme in signaling system no. 7," in Proc. 8th IEEE INFOCOM, Ottawa, Canada.

[13] D. R. Manfield and M. Zukerman, "Analysis of congestion onset thresholds for CCI'IT SS7 net-works." in Proc. Globecnm 92. Orlando, USA, Dec. 1992.

[14] Michael P. Rumsewicz, Analysis of the effects of SS7 message discard schemes on call completion rates during overload, IEEE/ACM Transactions on Networking (TON), v.1 n.4, Pp.491-502, Aug. 1993.

[15] "On the efficacy of using the transfer-controlled procedure during periods of STP processor overload in SS7 networks," IEEE J. Select. Areas Commun., vol. 12, Apr. 1994.

[16] "Critical congestion control issues in the evolution of CCS Networks," in Proc. Int. Teletraffic Congr., Antibes, France, June 1994.

[17] Donald E. Smith, Ensuring robust call throughput and fairness for SCP overload controls, IEEE/ACM Transactions on Networking (TON), v.3 n.5, p.538-548, Oct. 1995

[18] "Effects of feedback delay on the performance of the Transfer- Controlled procedure in controlling CCS network overloads," IEEE J. Select. Areas Commun., vol. 12, Apr. 1994.

[19] J. Zepf, G. Willmann, and G. Rufa, "Transient analysis of congestion and flow control mechanisms in common channel signalling networks," in Proc. 13th Int. Teletrtc Congr., Copenhagen, Denmark, 1991.

[20] J. Zepf and G. Rufa, "Congestion and flow control in signaling system no. 7 - Impacts of intelligent networks and new services," IEEEJ. Select. Areas Commun. Special Issue CCS Networks, vol 12, Apt. 1994.

[21] Russell, Travis, *Signaling System #7* (4th Edition ed.). New York: McGraw-Hill. ISBN 978-0071387729., 2002, Pp 52-112.

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