OBJECTIVES:

- To introduce SCTP as a new transport-layer protocol.
- To discuss SCTP services and compare them with TCP.
- To list and explain different packet types used in SCTP and discuss the purpose and of each field in each packet.
- To discuss SCTP association and explain different scenarios such as association establishment, data transfer, association termination, and association abortion.
- To compare and contrast the state transition diagram of SCTP with the corresponding diagram of TCP.
- To explain flow control, error control, and congestion control mechanism in SCTP and compare them with the similar mechanisms in TCP.
Chapter Outline

16.1 Introduction
16.2 SCTP Services
16.3 STCP Features
16.4 Packet Format
16.5 An SCTP Association
16.6 State Transition Diagram
16.7 Flow Control
16.8 Error Control
16.9 Congestion Control
Stream Control Transmission Protocol (SCTP) is a new reliable, message-oriented transport-layer protocol. Figure 16.1 shows the relationship of SCTP to the other protocols in the Internet protocol suite. SCTP lies between the application layer and the network layer and serves as the intermediary between the application programs and the network operations.
Figure 16.1  TCP/IP Protocol suite

TCP/IP Protocol Suite

Application layer
- SMTP
- FTP
- H.248
- H.323
- DHCP

Transport layer
- SCTP
- TCP
- UDP

Network layer
- IGMP
- ICMP
- IP
- ARP

Data link layer
- Underlying LAN or WAN technology

Physical layer
SCTP is a message-oriented, reliable protocol that combines the best features of UDP and TCP.
Before discussing the operation of SCTP, let us explain the services offered by SCTP to the application layer processes.
Topics Discussed in the Section

✓ Process-to-Process Communication
✓ Multiple Streams
✓ Multihoming
✓ Full-Duplex Communication
✓ Connection-Oriented Service
✓ Reliable Service
Table 16.1 Some SCTP applications

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Port Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IUA</td>
<td>9990</td>
<td>ISDN over IP</td>
</tr>
<tr>
<td>M2UA</td>
<td>2904</td>
<td>SS7 telephony signaling</td>
</tr>
<tr>
<td>M3UA</td>
<td>2905</td>
<td>SS7 telephony signaling</td>
</tr>
<tr>
<td>H.248</td>
<td>2945</td>
<td>Media gateway control</td>
</tr>
<tr>
<td>H.323</td>
<td>1718, 1719, 1720, 11720</td>
<td>IP telephony</td>
</tr>
<tr>
<td>SIP</td>
<td>5060</td>
<td>IP telephony</td>
</tr>
</tbody>
</table>
Figure 16.2  Multiple-stream concept
An association in SCTP can involve multiple streams.
Figure 16.3 Multihoming concept

[Diagram showing multihoming concept with multiple IP addresses connected to a single Internet node]
Note

SCTP association allows multiple IP addresses for each end.
Let us first discuss the general features of SCTP and then compare them with those of TCP.
Topics Discussed in the Section

- Transmission Sequence Number (TSN)
- Stream Identifier (SI)
- Stream Sequence Number (SSN)
- Packets
- Acknowledgment Number
- Flow Control
- Error Control
- Congestion Control
In SCTP, a data chunk is numbered using a TSN.

Note
To distinguish between different streams, SCTP uses an SI.
To distinguish between different data chunks belonging to the same stream, SCTP uses SSNs.
Figure 16.4 Comparison between a TCP segment and an SCTP packet

A segment in TCP

- Source port address
- Destination port address
- Sequence number
- Acknowledgment number
- HL
- Control flags
- Window size
- Checksum
- Urgent pointer
- Options
- Data bytes

A packet in SCTP

- Source port address
- Destination port address
- Verification tag
- Checksum
- Control chunks
- Data chunks
TCP has segments; SCTP has packets.
In SCTP, control information and data information are carried in separate chunks.
Example

Process A needs to send 11 messages to Process B in 3 streams. The first 4 messages are in the first stream, the second 3 messages are in the second stream, and the last 4 messages are in the third stream. The network allow only 3 data chunk per package.
Figure 16.5  Packet, data chunks, and streams

Flow of packets from sender to receiver
Data chunks are identified by three identifiers: TSN, SI, and SSN. TSN is a cumulative number identifying the association; SI defines the stream; SSN defines the chunk in a stream.
In SCTP, acknowledgment numbers are used to acknowledge only data chunks; control chunks are acknowledged by other control chunks if necessary.
In this section, we show the format of a packet and different types of chunks. Most of the information presented in this section will become clear later; this section can be skipped in the first reading or used only as the reference. An SCTP packet has a mandatory general general header and a set of blocks called chunks. There are two types of chunks: control chunks and data chunks.
Topics Discussed in the Section

✓ General Header
✓ Chunks
Figure 16.6  *SCTP packet format*

<table>
<thead>
<tr>
<th>General header</th>
<th>Chunk 1 (variable length)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(12 bytes)</td>
<td></td>
</tr>
</tbody>
</table>

|                           |
|                           |
|                           |

<table>
<thead>
<tr>
<th>Chunk N (variable length)</th>
</tr>
</thead>
</table>
In an SCTP packet, control chunks come before data chunks.
**Figure 16.7  Common layout of a chunk**

<table>
<thead>
<tr>
<th>Source port address 16 bits</th>
<th>Destination port address 16 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verification tag 32 bits</td>
<td></td>
</tr>
<tr>
<td>Checksum 32 bits</td>
<td></td>
</tr>
</tbody>
</table>
Figure 16.8  Multiple-stream concept

<table>
<thead>
<tr>
<th>Type</th>
<th>Flag</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Chunk Information (multiple of 4 bytes)</td>
</tr>
</tbody>
</table>
Note

Chunks need to terminate on a 32-bit (4-byte) boundary.
<table>
<thead>
<tr>
<th>Type</th>
<th>Chunk</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>DATA</td>
<td>User data</td>
</tr>
<tr>
<td>1</td>
<td>INIT</td>
<td>Sets up an association</td>
</tr>
<tr>
<td>2</td>
<td>INIT ACK</td>
<td>Acknowledges INIT chunk</td>
</tr>
<tr>
<td>3</td>
<td>SACK</td>
<td>Selective acknowledgment</td>
</tr>
<tr>
<td>4</td>
<td>HEARTBEAT</td>
<td>Probes the peer for liveliness</td>
</tr>
<tr>
<td>5</td>
<td>HEARTBEAT ACK</td>
<td>Acknowledges HEARTBEAT chunk</td>
</tr>
<tr>
<td>6</td>
<td>ABORT</td>
<td>Abort an association</td>
</tr>
<tr>
<td>7</td>
<td>SHUTDOWN</td>
<td>Terminates an association</td>
</tr>
<tr>
<td>8</td>
<td>SHUTDOWN ACK</td>
<td>Acknowledges SHUTDOWN chunk</td>
</tr>
<tr>
<td>9</td>
<td>ERROR</td>
<td>Reports errors without shutting down</td>
</tr>
<tr>
<td>10</td>
<td>COOKIE ECHO</td>
<td>Third packet in association establishment</td>
</tr>
<tr>
<td>11</td>
<td>COOKIE ACK</td>
<td>Acknowledges COOKIE ECHO chunk</td>
</tr>
<tr>
<td>14</td>
<td>SHUTDOWN COMPLETE</td>
<td>Third packet in association termination</td>
</tr>
<tr>
<td>192</td>
<td>FORWARD TSN</td>
<td>For adjusting cumulating TSN</td>
</tr>
</tbody>
</table>
The number of padding bytes is not included in the value of the length field.
Figure 16.9  Data chunk

The diagram illustrates a data chunk with the following fields:

- **Type**: 0
- **Reserved**: Bits 7-8
- **U, B, E**: Bits 13-16
- **Length**: Bits 17-31
- **Transmission sequence number**: Bits 32-47
- **Stream identifier**: Bits 48-63
- **Stream sequence number**: Bits 64-79
- **Protocol identifier**: Bits 80-95
- **User data**: Bits 96-102

This structure is used to encapsulate data in a stream, with fields for sequence and identifier information.
A DATA chunk cannot carry data belonging to more than one message, but a message can be split into several chunks. The data field of the DATA chunk must carry at least one byte of data, which means the value of length field cannot be less than 17.
SCTP, like TCP, is a connection-oriented protocol. However, a connection in SCTP is called an association to emphasize multihoming.
Topics Discussed in the Section

- Association Establishment
- Data Transfer
- Association Termination
- Association Abortion
A connection in SCTP is called an association.
Figure 16.19  Four-way handshaking

1. Active open
   - Client: INIT (Init tag: 1200, Init TSN: 100, rwnd: 1000)

2. Cookie ECHO
   - Client: Cookie
   - Server: COOKIE ACK (VT: 1200)

3. Cookie
   - Client: Cookie
   - Server: COOKIE ECHO (VT: 5000)

4. Time
   - Client: Time
   - Server: Time
No other chunk is allowed in a packet carrying an INIT or INIT ACK chunk. A COOKIE ECHO or a COOKIE ACK chunk can carry data chunks.
In SCTP, only data chunks consume TSNs; data chunks are the only chunks that are acknowledged.
Figure 16.20  Simple data transfer

**Diagram Description:**
- **Client** initiates the transfer (1).
- The client sends a **VT: 85** TSN: 7105 **DATA chunk** (2).
- The server sends a **VT: 85** TSN: 7106 **DATA chunk** (3).
- The client sends a **VT: 85** TSN: 7107 and 7108 **DATA chunks** (4).
- The server sends a **VT: 700** cumTSN: 7108 **SACK chunk** (5).
- The server sends a **VT: 700** TSN: 121 **DATA chunk** (6).
- The server sends a **VT: 700** TSN: 122 **DATA chunk** (7).
- The client receives the **VT: 85** cumTSN: 122 **SACK chunk** (8).
The acknowledgment in SCTP defines the cumulative TSN, the TSN of the last data chunk received in order.
Figure 16.21  Association termination
Figure 16.22  Association abortion

An end

1

ABORT

VT: x

Causes (optional)

Time

An end

Time
Flow control in SCTP is similar to that in TCP. In TCP, we need to deal with only one unit of data, the byte. In SCTP, we need to handle two units of data, the byte and the chunk. The values of rwnd and cwnd are expressed in bytes; the values of TSN and acknowledgments are expressed in chunks.
Topics Discussed in the Section

- Receiver Site
- Sender Site
- A Scenario
Figure 16.27  Flow control, receiver site
Figure 16.28  Flow control, sender site

Flow control at the sender site involves managing the order and timing of data transmission. The diagram illustrates a sending queue containing data chunks, with numbers indicating their sequence. The chunks are marked as 'Outstanding chunks' and 'To send.'

The process involves:
- Data chunks are sent from the process to the sending queue.
- The sending queue manages these chunks, ready to be sent.
- The out-of-sequence chunks (36, 35, 30, 29, 28, 27, 26) are not sent immediately but are held until their correct sequence is ensured.
- The current TSN (Sequence Number) is 37, and the window size (rwnd) is 2000.
- The number of chunks in transit (inTransit) is 700.
Figure 16.29  *Flow control scenario*

Sender

1. curTSN: 1, TSN: 1, 1000 bytes
   - rwnd: 2000
   - inTransit: 0

2. curTSN: 2, TSN: 2, 1000 bytes
   - rwnd: 2000
   - inTransit: 2

3. SACK
   - curTSN: 3, TSN: 3
   - rwnd: 2000
   - inTransit: 0

4. ACK: 2
   - rwnd: 2000

Receiver

- cumTSN: 2000
- winSize: 2000
- lastACK: 0

- cumTSN: 2
- winSize: 0
- lastACK: 1

- cumTSN: 1
- winSize: 1000
- lastACK: 2

- Process reads 1 and 2

- Process writes 5 and 6
SCTP, like TCP, is a reliable transport-layer protocol. It uses a SACK chunk to report the state of the receiver buffer to the sender. Each implementation uses a different set of entities and timers for the receiver and sender sites. We use a very simple design to convey the concept to the reader.
Topics Discussed in the Section

✓ Receiver Site
✓ Sender Site
✓ Sending Data Chunks
✓ Generating SANK Chunks
Figure 16.30  Error-control receiver site

TCP/IP Protocol Suite
Figure 16.31  Error control, sender site

From process

Sending Queue

outstanding chunks

To send

add when timer expires or three SACKs received.

Retransmission Queue

To send

curTSN
rwnd
inTransit

37
2000
1400
SCTP, like TCP, is a transport layer protocol with packets subject to congestion in the network. The SCTP designers have used the same strategies we described for congestion control in Chapter 15 for TCP. SCTP has slow start, congestion avoidance, and congestion detection phases. Like TCP, SCTP also uses fast retransmission and fast recovery.