Transport Layer

Introduction

The transport layer is the fourth layer from the bottom in the OSI reference model.

It is responsible for message delivery from process running in source computer to the process running in the destination computer.

Transport layer does not perform any function in the intermediate nodes.

It is active only in the end systems.

Introduction

Data Link Layer is responsible for delivery of frames between two neighboring nodes over a link.

This is called ***node-to-node delivery***.

Network Layer is responsible for delivery of datagrams between two hosts.

This is called ***host-to-host delivery***.

Transport Layer is responsible for delivery of entire message from one process running on source to another process running on destination.

This is called ***process-to process delivery***.

Transport Layer Design Issues

The transport layer delivers the message from one process to another process running on two different hosts.

Thus, it has to perform number of functions to ensure the accurate delivery of message.

The various functions of transport layer are:

- Establishing, Maintaining & Releasing Connection
- Addressing
- Data Transfer
- Flow Control
- Error Control
- Congestion Control

Transport Layer Design Issues

Establishing, Maintaining & Releasing Connection:

The transport layer establishes, maintains & releases end-to-end transport connection on the request of upper layers.

Establishing a connection involves allocation of buffers for storing user data, synchronizing the sequence numbers of packets etc.

A connection is released at the request of upper layer.

Transport Layer Design Issues

Addressing:

In order to deliver the message from one process to another, an addressing scheme is required.

Several process may be running on a system at a time.

In order to identify the correct process out of the various running processes, transport layer uses an addressing scheme called ***port number***.

Each process has a specific port number.

Transport Layer Design Issues

Data Transfer:

Transport layer breaks user data into smaller units and attaches a transport layer header to each unit forming a TPDU (TransPort Layer Data Unit).

The TPDU is handed over to the network layer for its delivery to destination.

The TPDU header contains port number, sequence number, acknowledgement number, checksum and other fields.

Transport Layer Design Issues

Flow Control:

Like data link layer, transport layer also performs flow control.

However, flow control at transport layer is performed end-to-end rather than node-to-node.

Transport Layer uses a sliding window protocol to perform flow control.

Transport Layer Design Issues

Error Control:

Transport layer also provides end-to-end error control facility.

Transport layer deals with several different types of errors:

Error due to damaged bits.

Error due to non delivery of TPDUs.

Error due to duplicate delivery of TPDUs.

Error due to delivery of TPDU to a wrong destination.

Transport Layer Design Issues

Congestion Control:

Transport layer also handles congestion in the networks.

Several different congestion control algorithms are used to avoid congestion.

Transport Layer Services

Transport layer protocols can provide two types of services:

- Connection Oriented Service
- Connectionless Service

Transport Layer Services

Connection Oriented Service:

In connection oriented service, a connection is first established between sender and the receiver.

Then, transfer of user data takes place.

At the end, connection is released.

The connection oriented service is generally reliable.

Transport layer protocols that provide connection oriented service are **TCP** and **SCTP** (Stream Control Transmission Protocol).

Transport Layer Services

Connectionless Service:

In the service, the packets are sent from sender to receiver without the establishment of connection.

In such service, packets are not numbered.

The packets may be lost, corrupted, delayed or disordered.

Connectionless service is unreliable.

Transport layer protocol that provides this service is **UDP**.

Elements of Transport Protocols

Addressing:

In order to deliver data from one process to another, address is required.

In order to deliver data from one node to another, MAC address is required.

Such an address is implemented at Data Link Layer and is called **Physical Addressing**.

Elements of Transport Protocols

Addressing (Cont.):

In order to deliver data from one network to another, IP address is required.

Such an address is implemented at Network Layer and is called **Logical Addressing**.

Similarly, in order to deliver data from a process running on source to process running on destination, transport layer defines the **Service Point Address** or **Port Numbers**.

Elements of Transport Protocols

Port Numbers:

Each communicating process is assigned a specific port number.

In order to select among multiple processes running on a destination host, a port number is required.

The port numbers are 16-bit integers between 0 and 65,535.

Elements of Transport Protocols

Port Numbers (Cont.):

Port numbers are assigned by Internet Assigned Number Authority (IANA).

IANA has divided the port numbers in three categories:

Well Known Ports: The ports ranging from 0 to 1023. For e.g.: HTTP: 80, SMTP: 25, FTP: 21.

Registered Ports: The ports ranging from 1024 to 49,151. These are not controlled by IANA.

Dynamic Ports: The ports ranging from 49,152 to 65,535. These can be used by any process.

Elements of Transport Protocols

Socket Address:

Socket address is a combination of IP address and port number.

In order to provide communication between two different processes on different networks, both IP address and port number, i.e. socket address is required.

Elements of Transport Protocols

Multiplexing & Demultiplexing:

A network connection can be shared by various applications running on a system.

There may be several running processes that want to send data and only one transport layer connection available, then transport layer protocols may perform multiplexing.

The protocol accepts the messages from different processes having their respective port numbers, and add headers to them.

Elements of Transport Protocols

Multiplexing & Demultiplexing (Cont.):

The transport layer at the receiver end performs demultiplexing to separate the messages for different processes.

After checking for errors, the headers of messages are dropped and each message is handed over to the respective processes based on their port numbers.

Elements of Transport Protocols

Connection Establishment:

Before communicating, the source device must first determine the availability of the other to exchange data.

Path must be found through the network by which the data can be sent.

This is called Connection Establishment.

Elements of Transport Protocols

Connection Establishment (Cont.):

Connection establishment involves **Three-Way Handshaking** mechanism:

The source sends a **connection request** packet to the destination.

The destination returns a confirmation packet back to the source.

The source returns a packet acknowledging the confirmation.

Elements of Transport Protocols

Connection Release:

Once all of the data has been transferred, the connection must be released.

It also requires a **Three-Way Handshaking** mechanism:

- The source sends a **disconnect request** packet to the destination.
- The destination returns a confirmation packet back to the source.
- The source returns a packet acknowledging the confirmation.

Transport Layer Protocols

Transport layer provides two types of services:

- Connection Oriented Service
- Connectionless Service

For this, transport layer defines two different protocols:

- Transmission Control Protocol (TCP)
- User Datagram Protocol (UDP)

Transmission Control Protocol

Transmission Control Protocol (TCP) is a connection oriented protocol that provides reliable services between processes on different hosts.

It uses the services of lower layer which provide connectionless and unreliable service.

Transmission Control Protocol

The basic features of TCP are:

It provides efficient method for numbering different bytes of data.

It provides stream data transfer.

It offers reliability.

It provides efficient flow control.

It provides full duplex operation.

It provides multiplexing.

It provides connection oriented service.

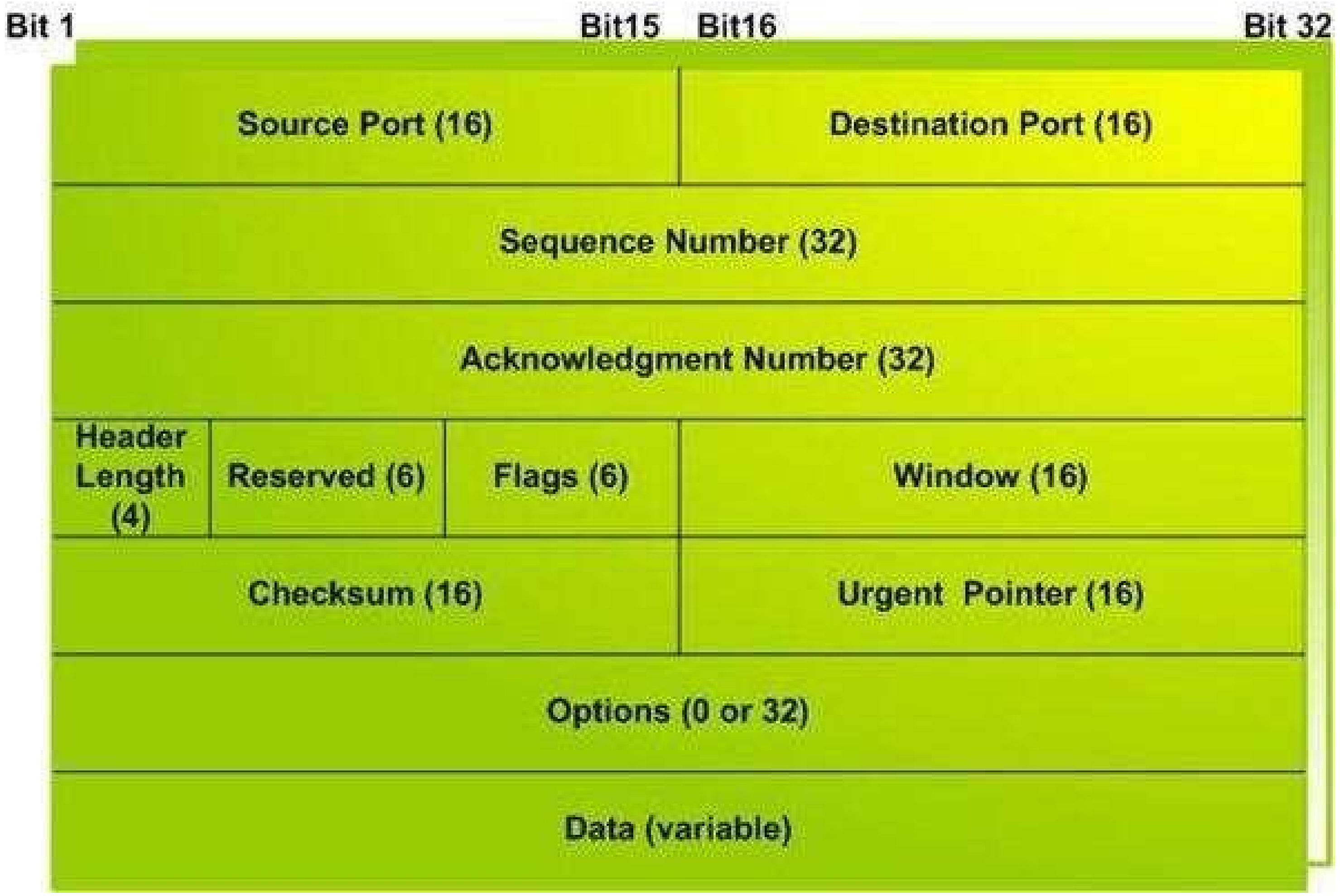
TCP Segment

TCP segment is the unit of data transferred between two processes.

Each TCP segment consists of two parts:

- Header Part
- Data Part

Format of TCP Segment



Format of TCP Segment

Source Port:

It indicates the port number of a source process. It is of 2 bytes.

Destination Port:

It indicates the port number of destination process. It is also 2 bytes.

Sequence Number:

It specifies the number assigned to the current message. It is of 4 bytes.

Format of TCP Segment

Acknowledgement Number:

It indicates the sequence number of the next byte of data. It is of 4 bytes.

Header Length:

It indicates number of words in the TCP header. It is a 4 bit field.

Reserved:

This 6 bit field is reserved for future use.

Format of TCP Segment

Flags:

This 6 bit field consists of 6 different flags:

UGR (Urgent Pointer)

ACK (Acknowledgement)

PSH (Request for Push)

RST (Reset the Connection)

SYN (Synchronize)

FIN (Final or Terminate the Connection)

Format of TCP Segment

Window:

It specifies the size of sender’s receiving window, i.e., the buffer space available for incoming data. It is of 2 bytes.

Checksum:

This 16-bit field contains the checksum.

Urgent Pointer:

This 16-bit field is valid only if urgent pointer in flags is set to 1.

Format of TCP Segment

Options:

It contains the optional information in the TCP header. It is of 32 bytes.

Data:

This field contains the upper layer information. It is of variable size.

TCP Timers

TCP uses several timers to ensure that excessive delays are not encountered during communications.

1.Time Out Timer or Retransmission Timer

- A timeout timer begins, when the sender transmits a segment to the receiver.
- Before expiring the timer, if the ACK is received, then nothing is lost.
- Otherwise, that particular segment is considered lost and it becomes necessary to retransmit the segment again and restart the timer.
- It is required to look at the various RTTs for finding out how the retransmission timeout interval is being calculated.

Time Out Timer or Retransmission Timer

Measured RTT(RTTm)

The time needed by the segment to reach the destination and also get acknowledgement, even though the acknowledgement includes another segment also, is known as measured round trip time(RTTm).

Smoothed RTT(RTTs)

It is the weighted average of RTTm. RTTm is likely to change and its fluctuation is so high that a single measurement cannot be used to calculate RTO.

Initially -> No value
After the first measurement -> RTTs=RTTm
After each measurement -> RTTs= (1-t)*RTTs + t*RTTm
Note: t=1/8 (default if not given)

Time Out Timer

Deviated RTT(RTTd)

RTTs alone are not used by most implementation. So, for finding the RTO(Retransmission Time Out) , RTT deviated also needs to be calculated.

Initially -> No value
After the first measurement -> RTTd=RTTm/2
After each measurement -> RTTd= (1-k)*RTTd + k*(RTTm-RTTs)
Note: k=1/4 (default if not given)

Time Wait Timer

- Time Wait Timer is one of the TCP timers that is used at the time of connection termination.
- After transmitting the last ACK for the second FIN, the sender begins the time wait timer and terminates the TCP connection.
- When the TCP connection is closed, there is a possibility that some datagrams still try to make their way using the internet so that they can access the closed port.
- The quiet timer is designed so that it can prevent just a closed port to reopen again quickly.
- Generally, the quiet timer is set to twice the maximum segment lifeline so that it makes sure that all the segments still heading for the port must be terminated.

Keep Alive Timer

- The keep alive timer is used by the TCP for preventing the long idle connections between the TCPs.
- Keep alive timer is used in the situation when the client starts a TCP connection for transmitting data to the server, and after some time stops sending the data, then the connection opens forever.
- Whenever the server hears from the client, the server resets the keep-alive timer for 2 hours.

Keep Alive Timer

- Sometimes the condition occurs when the server does not hear from the client for 2 hours, then 10 probe segments are transmitted by the server to the client.
- The server transmits these probe segments at a time interval of 75 seconds.
- After transmitting these segments, if the server does not get any response from the client then it is supposed that the client seems to be down.
- When the client seems to be down, the connection is discarded by the server automatically.

Persistent Timer

- The persistent timer is one of the TCP timers used in TCP for dealing with one of the deadlock situations,i.e. zero-window-size deadlock situations.
- If the other end closes its receiver window, then also it keeps the window size information flowing.
- Whenever the sender receives an ACK from the receiver side with a zero window size, then it begins the persistent timer.
- In this situation, when the persistent timer goes off, then the sender transmits the special type of segment to the receiver.
- This special type of segment is commonly known as the probe segment and this special type of segment has only 1 byte of new data.

Persistent Timer

- The sequence number of this segment is never acknowledged.
- This sequence number is also not considered even when calculating the sequence number for the rest data.
- When the receiver transmits the response to the probe segment, then through this response the window size updates.
- If it is found that the updated window size is non-zero, then it represents that the data can be transmitted now.
- And if the size of the updated window is still found to be zero, then the persistent timer needs to be set again and this process continues till we get a non-zero window size.

Summary

Different types of timers are used by the TCP which are known as TCP timers.
TCP use timers to avoid excessive delays during communication.

- For dealing with the zero deadlock window problem, TCP used the persistent timer
- A long idle connection can be prevented using the keep-alive timer.
- For terminating the connection, TCP uses the time wait timer.
- For retransmission of lost segment, the time-out timer or the retransmission timer is used by the TCP.

User Datagram Protocol

User Datagram Protocol (UDP) is a connectionless, unreliable transport protocol.

Like TCP, UDP also provides process-to-process communication.

Unlike TCP, it does not provide flow control and error control mechanisms.

It is connectionless, therefore, it transfers data without establishing a connection.

User Datagram Protocol

The various features of UDP are:

It provides connectionless transport service.

It is unreliable.

It does not provide flow control and error control.

It is less complex and is simple than TCP, and easy to implement.

User datagrams (packets) are not numbered.

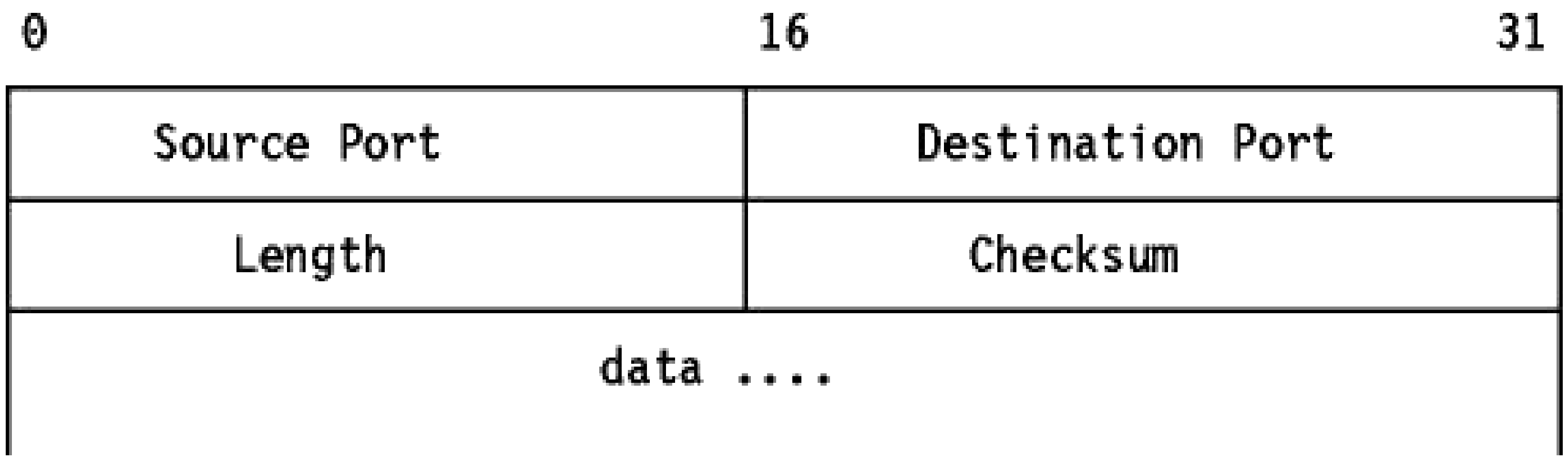
UDP Datagram

A datagram is the unit of data transferred between two processes.

Each UDP datagram consists of two parts:

- Header Part
- Data Part.

Format of UDP Datagram



UDP Datagram

Source Port:

It indicates the port number of source process. It is of 16 bits.

Destination Port:

This 16 bit field specifies the port number of destination process.

UDP Datagram

Length:

It specifies the total length of the user datagram (header + data). It is of 16 bits.

Checksum:

The contains the checksum, and is optional. It is also of 16 bits.