Transport Layer: UDP (User Datagram Protocol) Study-Ready Notes

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1 Introduction to Transport Layer

- Transport-layer services provide end-to-end communication between applications
- Key functions include multiplexing and demultiplexing
- Two main transport protocols: UDP (connectionless) and TCP (connection-oriented)
- Additional topics: reliable data transfer, congestion control principles

[Summary: The transport layer enables application-to-application communication across networks, with UDP providing lightweight connectionless service and TCP offering reliable connection-oriented service.]

2 UDP: User Datagram Protocol

2.1 Basic Characteristics

- "No frills," "bare bones" Internet transport protocol
- Best effort service segments may be:
 - Lost during transmission
 - Delivered out-of-order to application
- Connectionless no handshaking between UDP sender and receiver
- Each UDP segment handled independently of others

2.2 Why Use UDP?

- No connection establishment avoids RTT delay
- Simple no connection state maintained at sender or receiver
- Small header size minimal overhead
- No congestion control can transmit as fast as desired
- Robust can function even when network service is compromised

[Mnemonic: UDP = Uncomplicated, Direct, Prompt - emphasizes its simplicity and speed]

3 UDP Applications and Use Cases

3.1 Common UDP Applications

- Streaming multimedia apps loss tolerant, rate sensitive
- DNS (Domain Name System) quick name resolution
- SNMP (Simple Network Management Protocol) network monitoring
- HTTP/3 modern web protocol built on UDP

3.2 Reliability Over UDP

- If reliable transfer needed (e.g., HTTP/3):
 - Add reliability mechanisms at application layer
 - Implement congestion control at application layer
- Applications can customize reliability to their specific needs

4 UDP Protocol Specification [RFC 768]

4.1 Protocol Definition

- Standardized in RFC 768 (August 28, 1980)
- Provides datagram mode of packet-switched communication
- Assumes Internet Protocol (IP) as underlying protocol
- Transaction-oriented with minimal protocol mechanism

4.2 Service Guarantees

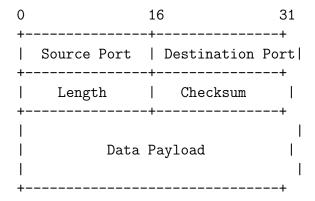
- No guaranteed delivery packets may be lost
- No duplicate protection may receive copies
- No ordered delivery out-of-order arrival possible
- Applications needing reliable streams should use TCP instead

5 UDP Segment Format

5.1 Header Structure

- 32-bit (4-byte) header followed by data payload
- Header fields:
 - Source Port (16 bits) sender's port number
 - **Destination Port** (16 bits) receiver's port number
 - Length (16 bits) total segment size in bytes (header + data)
 - Checksum (16 bits) error detection field

5.2 Format Visualization



[Concept Map: UDP Segment \rightarrow Header (Ports + Length + Checksum) + Data \rightarrow IP Packet \rightarrow Network Transmission]

6 UDP Transport Layer Actions

6.1 Sender Actions

- 1. Receives application-layer message
- 2. Determines UDP segment header field values
- 3. Creates UDP segment with header and data
- 4. Passes segment to IP layer for transmission

6.2 Receiver Actions

- 1. Receives segment from IP layer
- 2. Verifies UDP checksum header value

- 3. Extracts application-layer message from payload
- 4. Demultiplexes message to appropriate application via socket

6.3 SNMP Example

- SNMP client creates SNMP message
- UDP layer adds header and passes to IP
- SNMP server receives via IP, checks checksum, delivers to application

7 UDP Checksum Mechanism

7.1 Goal and Purpose

- Primary goal: Detect errors (flipped bits) in transmitted segments
- Provides basic data integrity verification
- Covers UDP header, data, and pseudo-IP header information

7.2 Sender Procedure

- 1. Treat UDP segment contents as sequence of 16-bit integers
- 2. Include UDP header fields and IP addresses in calculation
- 3. Compute one's complement sum of all 16-bit integers
- 4. Place resulting checksum value in UDP checksum field

7.3 Receiver Procedure

- 1. Compute checksum of received segment using same method
- 2. Compare computed checksum with received checksum field
- 3. Not equal: Error detected segment may be corrupted
- 4. Equal: No error detected (but errors still possible due to checksum limitations)

8 Internet Checksum: Detailed Example

8.1 Calculation Process

- Add two 16-bit integers using one's complement arithmetic
- Example:
 - First number: 1110 0110 0110 0110 (binary)
 - Second number: 1101 0101 0101 0101 (binary)
 - Sum: 1101 1101 1101 1011 (with carry)
- Wraparound: Carry from most significant bit added back to result

8.2 Mathematical Representation

8.3 Checksum Weaknesses

- Limited error detection capability
- May not detect certain error patterns (e.g., swapped bytes)
- Example: Even when numbers change due to bit flips, checksum may remain unchanged
- Not cryptographically secure easy to forge

[Summary: UDP checksum provides basic error detection using one's complement addition, but has limitations and cannot guarantee complete data integrity.]

9 Comprehensive UDP Summary

9.1 Protocol Characteristics

- "No frills" protocol with minimal overhead
- Segments may be lost or delivered out-of-order
- Best effort service: "send and hope for the best"

9.2 UDP Advantages

- No setup/handshaking required (avoids RTT delay)
- Can function when network conditions are poor
- Provides basic error detection via checksum
- Enables application-specific reliability implementations

9.3 Modern Applications

- Foundation for HTTP/3 and other modern protocols
- Allows building customized transport functionality
- Ideal for applications preferring timeliness over reliability

[Mnemonic: UDP Benefits = FAST - Fast setup, Application control, Simple, Timely delivery]

10 Study Questions

10.1 Conceptual Questions

- 1. Compare and contrast UDP and TCP in terms of reliability, connection establishment, and overhead.
- 2. Explain why streaming applications often prefer UDP over TCP.
- 3. Describe the UDP checksum calculation process and its limitations.
- 4. What are the advantages of implementing reliability at the application layer rather than using TCP?

10.2 Technical Problems

- 1. Calculate the UDP checksum for a segment with source port 5200, destination port 53, length 32 bytes, and data "Hello".
- 2. Explain what happens when a UDP receiver detects a checksum error.
- 3. Design an application-layer protocol that adds reliability to UDP for file transfer.

10.3 Real-World Applications

- 1. Research and explain why HTTP/3 uses UDP instead of TCP.
- 2. Identify three real-world applications that use UDP and explain why it's appropriate for each.
- 3. Analyze the trade-offs between using raw UDP vs. building custom reliability vs. using TCP.

[Concept Map: Transport Layer \rightarrow UDP vs TCP \rightarrow UDP: Connectionless + Best Effort + Applications (DNS, Streaming) + Checksum \rightarrow Modern Uses (HTTP/3)]