

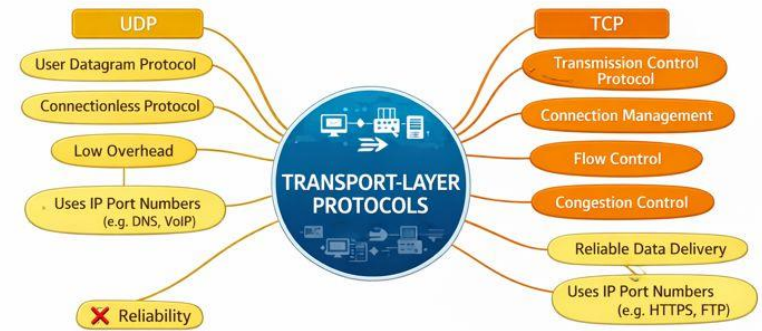
23ITT204 - COMPUTER NETWORK

UNIT 2 - TRANSPORT LAYER

CONGESTION CONTROL

Congestion Control in the Transport Layer

Managing network traffic flow to ensure optimal performance and reliability



Why Congestion Control Matters



The Network Traffic Jam Problem

Network congestion occurs when too much data floods the network simultaneously, creating a digital traffic jam that causes delays, packet loss, and potentially complete network collapse.

Congestion control acts as the intelligent traffic management system, ensuring smooth data flow across networks while maintaining fairness among all users.



Maximize Throughput

Optimize data transmission rates without overwhelming the network



Minimize Delay

Reduce latency and packet loss for responsive communications



Ensure Fairness

Distribute bandwidth equitably across all network users

TCP's Congestion Control Mechanisms

TCP employs a sophisticated three-phase approach to manage network congestion dynamically, adapting to changing network conditions in real-time.

01

Slow Start Phase

The congestion window (cwnd) grows exponentially with each successful round-trip time (RTT), rapidly probing available network capacity.

- Initial cwnd starts at 1 segment
- Doubles with each RTT: $1 \rightarrow 2 \rightarrow 4 \rightarrow 8 \rightarrow 16$ segments
- Continues until reaching slow start threshold (ssthresh)

02

Congestion Avoidance

After reaching the threshold, TCP switches to conservative linear growth, adding just 1 segment per RTT to prevent network overload.

- Gradual increase maintains stability
- Balances throughput with safety
- Continues until congestion detected

03

Congestion Detection & Recovery

TCP responds to congestion signals by reducing transmission rate through multiplicative decrease and adjusting thresholds.

- **Timeout event:** cwnd reset to 1, slow start restarts
- **Triple duplicate ACKs:** cwnd set to ssthresh, fast recovery initiated
- ssthresh updated to half of current cwnd

Impact & Importance of Congestion Control Today

Congestion control remains the invisible foundation enabling the modern Internet to function reliably at massive scale, supporting billions of devices and countless applications worldwide.



Network Stability

Prevents catastrophic network collapse despite millions of concurrent data flows competing for bandwidth, maintaining Internet stability 24/7.



Bandwidth Efficiency

Optimizes network resource utilization by reducing unnecessary retransmissions and minimizing latency across all connections.




Fair Resource Sharing

Ensures no single user or application monopolizes network resources, maintaining equitable access for all participants.



Modern Applications

Serves as the critical foundation for cloud services, video streaming, real-time communications, and IoT applications that define our digital lives.

 **Looking Forward:** Continuous research evolves TCP variants and alternative protocols to meet ever-growing network demands, adapting congestion control for 5G, satellite networks, and emerging technologies.