Transport Layer (1)

Networked Systems Architecture 3
Lecture 12

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Lecture Outline

- Role of the transport layer
- Transport layer functions
- Transport protocols in the Internet
  - TCP, UDP, DCCP, and SCTP
  - Deployment considerations

Role of the Transport Layer

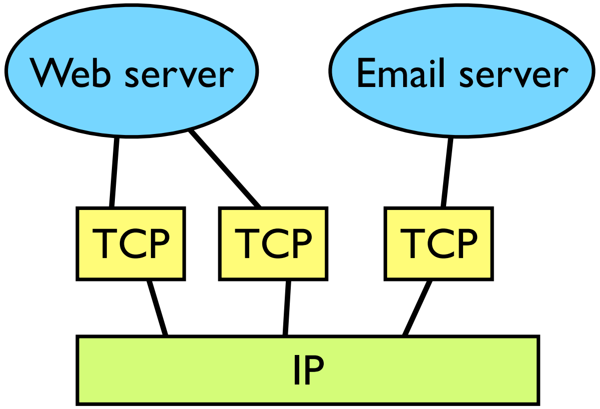
- Isolate upper layers from the network layer
  - Hide network complexity; make unreliable network appear reliable; enhance QoS of network layer
- Provide a useful, convenient, easy to use service
  - An easy to understand service model
  - An easy to use programming API
    - The Berkeley sockets API – very widely used by application programmers
    - Compare to network layer API – usually hidden in operating system internals

Transport Layer Functions

- Transport layer provides the following functions:
  - Addressing and multiplexing
  - Reliability
  - Framing
  - Congestion control
- Operates process-to-process, not host-to-host

Addressing and Multiplexing

- The network layer address identifies a host
- The transport layer address identifies a user process – a *service* – running on a host
- Provides a demultiplexing point
  - Each service has a unique transport layer address



Reliability

- Network layer *is* unreliable
  - Best effort packet switching in the Internet
  - But even nominally reliable circuits may fail
- Transport layer enhances the quality of service provided by the network, to match application needs
  - Appropriate *end-to-end* reliability

The End-to-End Argument

- Is it better to place functionality within the network or at the end points?
  - Only put functions that are absolutely necessary within the network, leave everything else to end systems
    - Example: put reliability in the transport layer, rather than the network
    - If the network is not guaranteed 100% reliable, the application will have to check the data anyway → don't check in the network, leave to the end-to-end transport protocol, where the check is visible to the application
  - One of the defining principles of the Internet

Transport Layer Reliability

- Different applications need different reliability
  - Email and file transfer → all data must arrive, in the order sent, but no strict timeliness requirement
  - Voice or streaming video → can tolerate a small amount of data loss, but requires timely delivery
- Implication for network architecture:
  - Network layer provides timely but unreliable service
  - Transport layer protocols add reliability, if needed

Framing

- Applications may wish to send structured data
- Transport layer responsible for maintaining the boundaries
  - Transport must *frame* the original data, if this is part of the service model

Congestion and Flow Control

- Transport layer controls the application sending rate
  - To match the rate at which network layer can deliver data – *congestion control*
  - To match the rate at which receiving application can process the data – *flow control*
- Must be performed end-to-end, since only end points know characteristics of entire path

Congestion and Flow Control

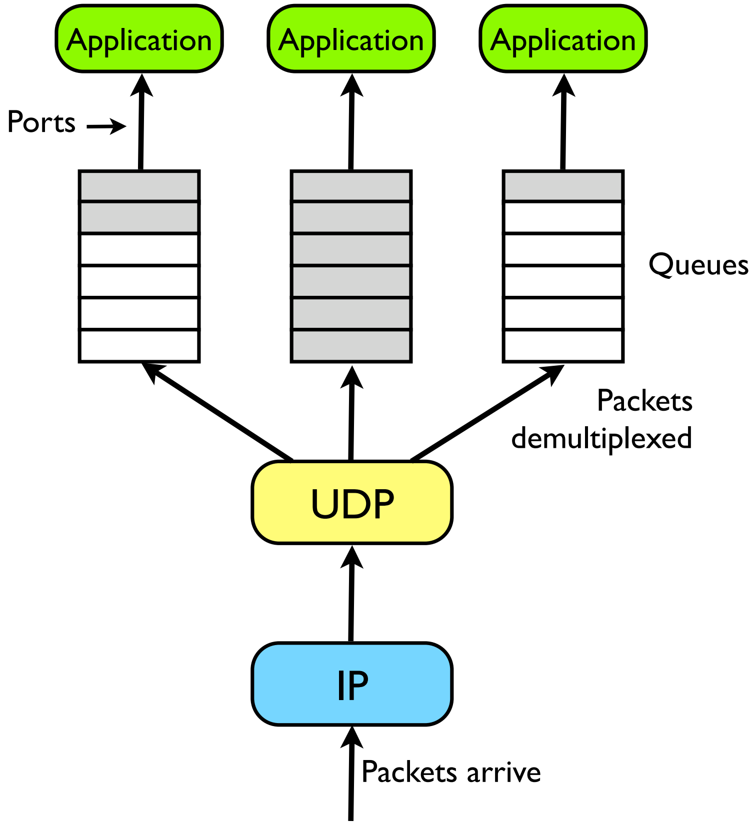
- Different applications have different needs for congestion control
  - Email and file transfer → *elastic* applications; faster is better, but don't care about actual sending rate
  - Voice or streaming video → *inelastic* applications; have minimum and maximum sending rates, and care about the actual sending rate
- Want range of congestion control algorithms at transport layer; within the network constraints

Internet Transport Protocols

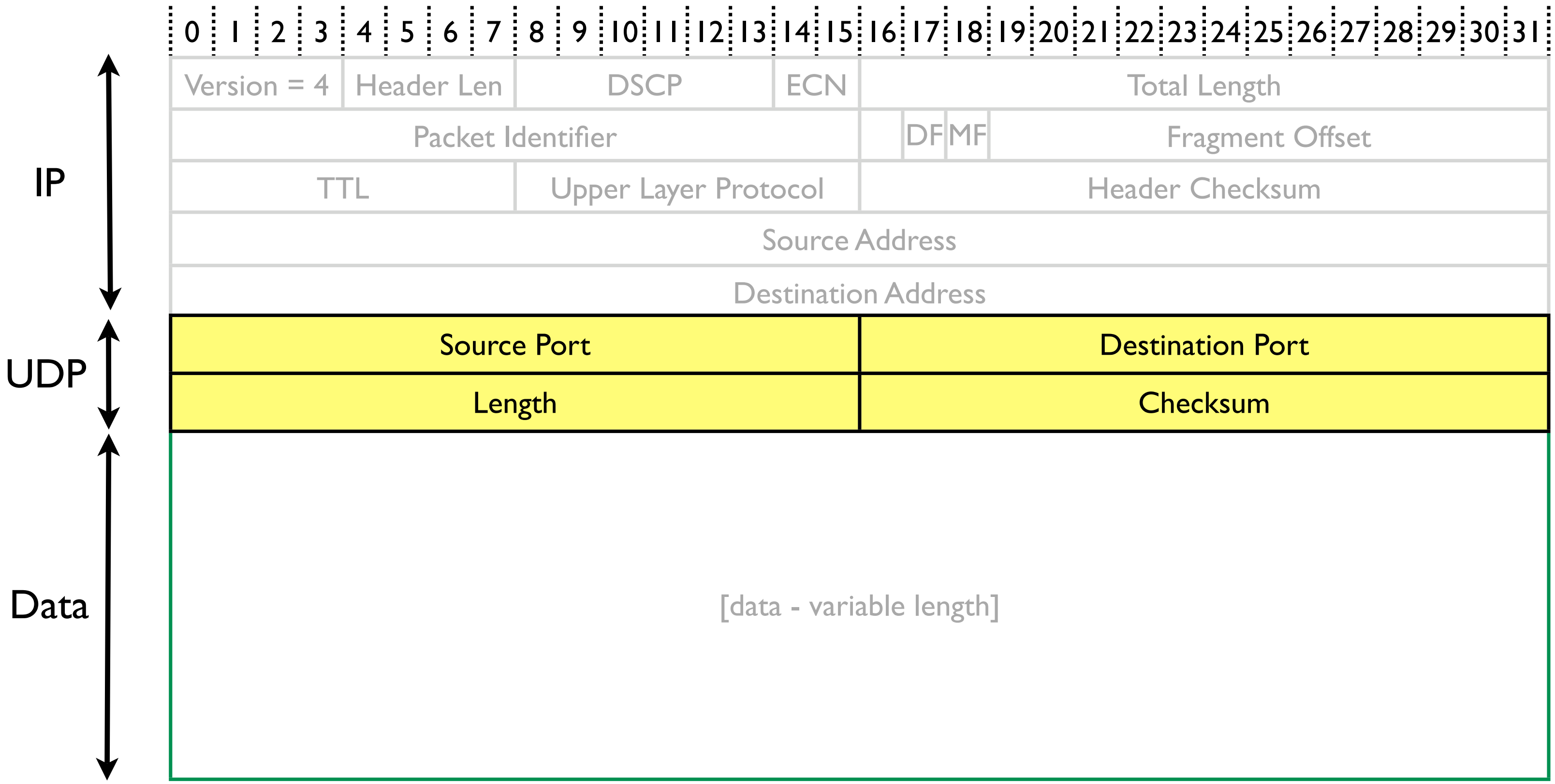
- The Internet Protocol provides a common base for various transports
  - User Datagram Protocol (UDP)
  - Transmission Control Protocol (TCP)
  - Datagram Congestion Control Protocol (DCCP)
  - Stream Control Transmission Protocol (SCTP)
- Each makes different design choices

UDP

- Simplest transport protocol
- Exposes raw IP service model to applications
  - Connectionless, best effort packet delivery: framed, but unreliable
  - No congestion control
- Adds a 16 bit *port* number to identify services



UDP Packet Format



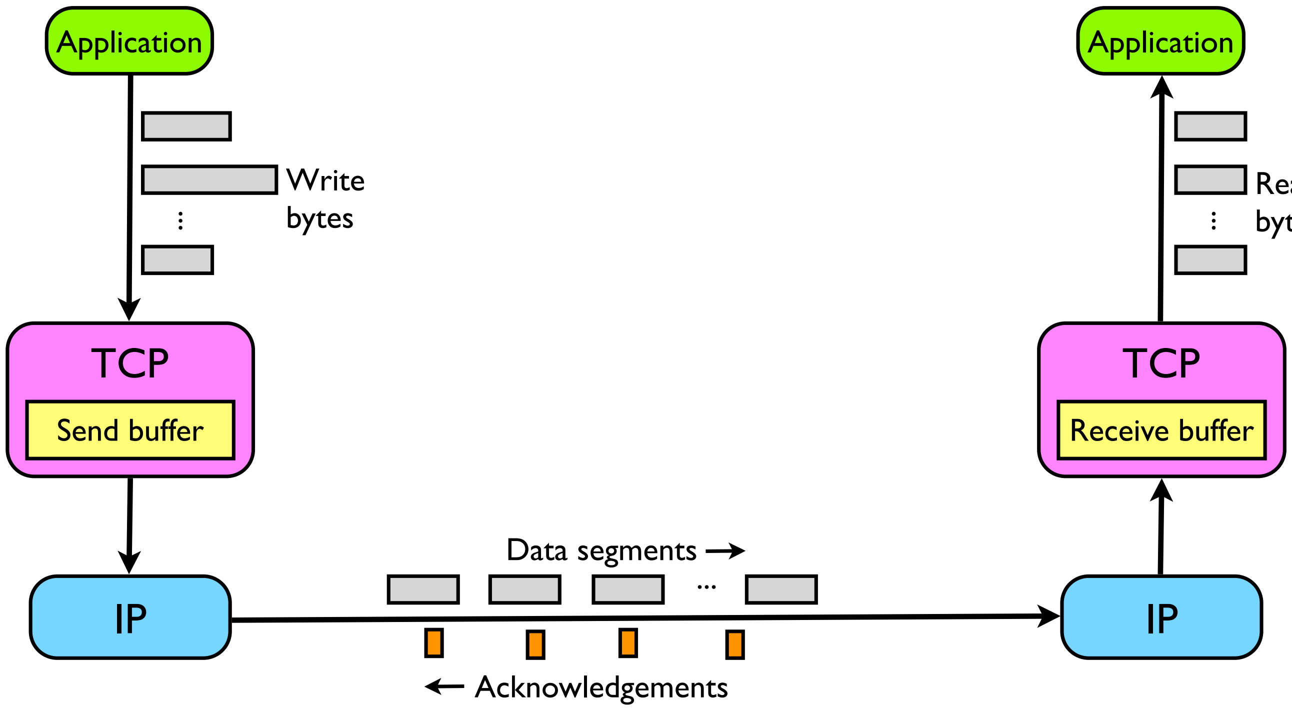
UDP Applications

- Useful for applications that prefer timeliness to reliability
  - Voice-over-IP
  - Streaming video
- Must be able to tolerate some loss of data
- Must be able to adapt to congestion in the application layer

TCP

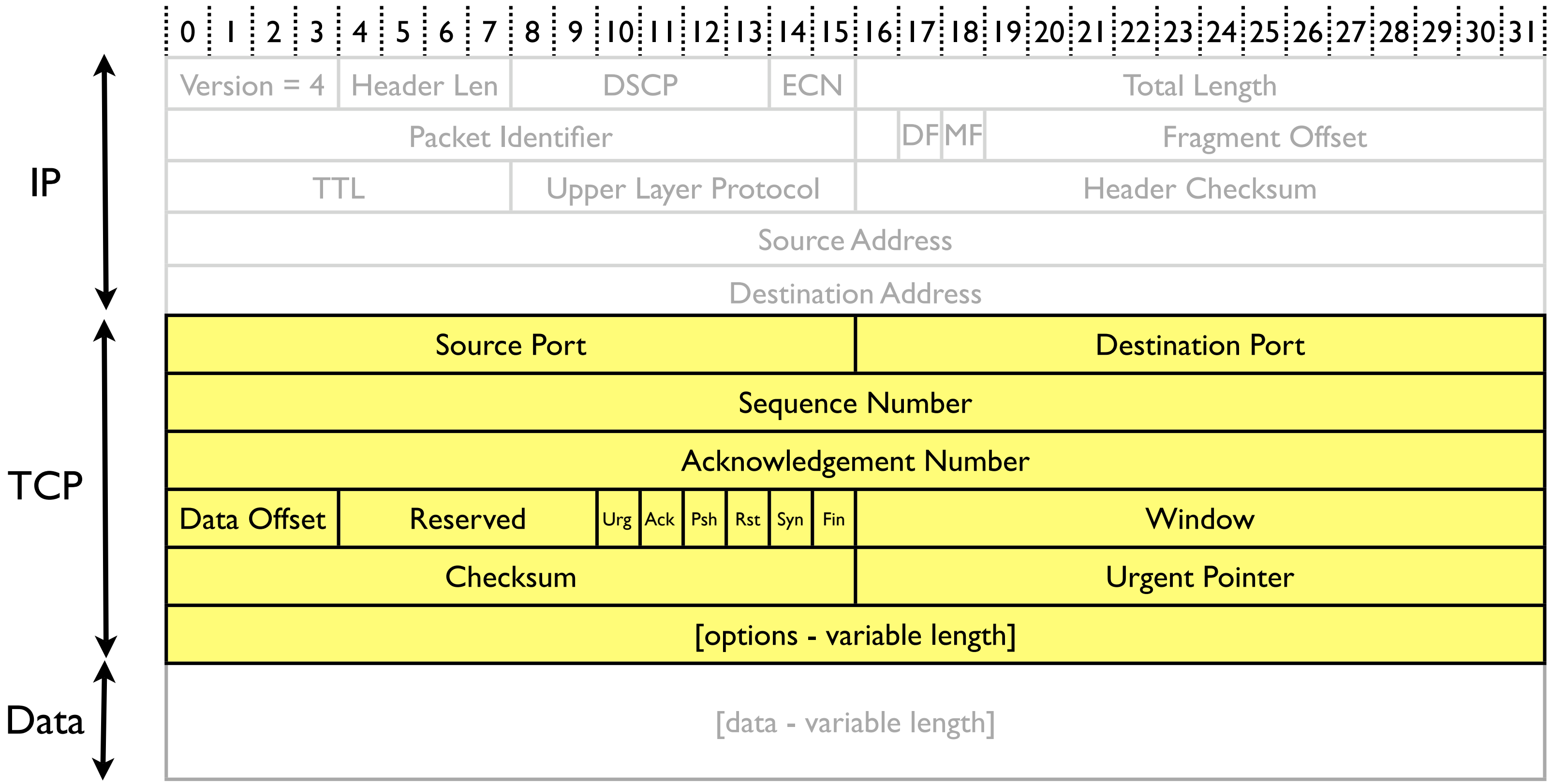
- Reliable byte stream protocol running over IP
  - Adds reliability
    - Packets contain sequence number to detect loss; any lost packets are retransmitted; data is delivered to higher-layers in order, without gaps
  - Adds congestion control – details in lecture 14
  - Adds 16 bit *port* number as a service identifier
  - Doesn't provide framing
    - Delivers an ordered byte stream, the application must impose structure

TCP



Application
Write
bytes
TCP
Send buffer
IP
Data segments
...
Acknowledgements
Application
Read
bytes
TCP
Receive buffer
IP

TCP Packet Format



TCP Applications

- Useful for applications that require reliable data delivery, and can tolerate some timing variation
  - File transfer and web downloads
  - Email
  - Instant messaging
- Default choice for most applications

TCP and UDP Ports

- TCP and UDP use a 16 bit port number to identify services
- Servers listen on *well known ports*
  - E.g. HTTP = 80, ssh = 22, jabber = 5269
  - http://www.iana.org/assignments/port-numbers
- Clients connect from an *ephemeral port*
  - Unused port, randomly allocated by operating system

Other Transport Protocols

- The IP network layer also supports two new transport protocols:
  - DCCP
  - SCTP
- Not widely used at this time, but potentially useful in future

DCCP

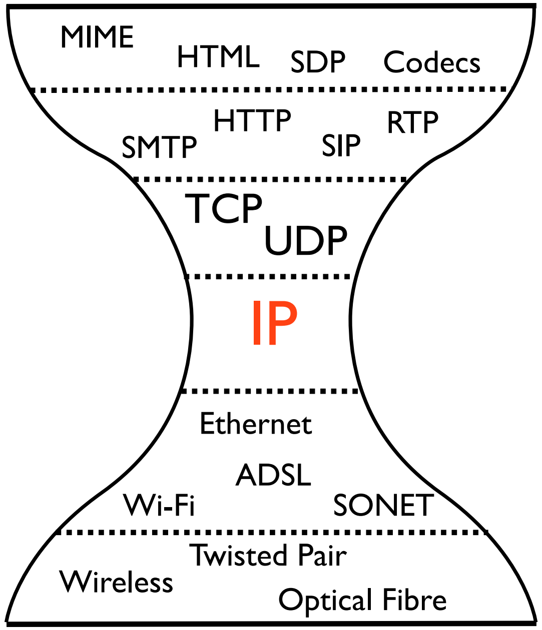
- Datagram Congestion Control Protocol
  - Unreliable, connection oriented, congestion controlled datagram service
    - "TCP without reliability" or "UDP with connections and congestion control"
    - Potentially easier for NAT boxes and firewalls than UDP
    - Congestion control algorithm ("CCID") negotiated at connection setup – range of algorithms supported
  - Adds 32 bit *service code* in addition to port number
- Use case: streaming multimedia and IPTV

SCTP

- Stream Control Transmission Protocol
  - Reliable datagram service, ordered per stream
  - Multiple streams within a single association
  - Multiple connection management
    - Fail-over from one IP address to another, for reliable multi-homing
  - TCP-like congestion control
- Use case: telephony signalling; "a better TCP"

Deployment Considerations

- IP is agnostic of the transport layer protocol
- But, firewalls perform "deep packet inspection" and look beyond the IP header to make policy decisions
  - The only secure policy is to disallow anything not understood
  - Implication: very difficult to deploy new transport protocols (i.e. DCCP and SCTP) in the Internet
  - Implication: limits future evolution of the network



Service Models

Protocol	Addressing	Reliable?	Framed?	Congestion Controlled?
UDP	16 bit port number	Unreliable packet delivery	Yes – uses explicit datagrams	No – handled by application layer
TCP	16 bit port number	Reliable ordered byte stream	No – handled by application layer	Yes – suitable for elastic applications
DCCP	16 bit port number plus service code	Unreliable packet stream	Yes – uses explicit datagrams	Yes – wide range of algorithms possible
SCTP	16 bit port number	Reliable ordered byte stream	Yes – explicit *chunk* boundaries	Yes – suitable for elastic applications

Questions?