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Transport Protocols
Recent developments

Stream Control Transmission Protocol (SCTP)

[RFC4960,2007]

Internet transport protocols

SCTP motivation

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- Why is SCTP needed given TCP and UDP are widely available?
- In 1998, an IETF working group (SIGTRAN) was formed to design a mechanism for reliably transporting call control signaling over the Internet.
- During SIGTRAN s work, two key problems surfaced in the use of TCP:
  - head-of-line blocking and lack of multihoming caused unacceptable delays in call signalling

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SCTP motivation

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- Reliability but no ordering

  "TCP provides both reliable data transfer and strict order of transmission delivery of data. Some applications need reliable transfer without sequence maintenance, while others would be satisfied with partial ordering of the data. In both of these cases, the head-of-line blocking offered by TCP causes unnecessary delay."

- Reliability but no stream-oriented

  "The stream-oriented nature of TCP is often an inconvenience. Applications must add their own record marking to delineate their messages, and must make explicit use of the push facility to ensure that a complete message is transferred in a reasonable time."

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SCTP motivation

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- More scalability and redundancy (multihoming)

"The limited scope of TCP sockets complicates the task of providing highly-available data transfer capability using multi-homed hosts."

- More robustness (to attacks)

"TCP is relatively vulnerable to denial-of-service attacks, such as SYN flood attacks."

"When compared to TCP, SCTP aims at enhancing transport performance and robustness"

Internet transport protocols

SCTP introduction

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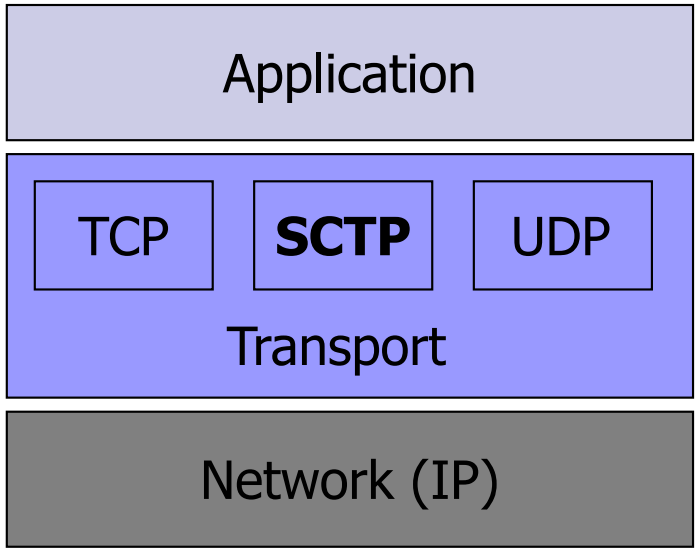
- SCTP Stream Control Transmission Protocol
  - Proposed IETF standard (RFC 4960, 2007)
  - Like TCP, it provides reliable, full-duplex, unicast transfers
  - Unlike TCP and UDP, it offers new delivery options that are particularly desirable for telephony signaling and multimedia applications



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SCTP goals

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- SCTP keeps TCP-like reliable retransmissions, congestion control, connection oriented, plus:
  - framing - preserve message boundaries
  - 4-way handshake - to reduce vulnerability to DoS attacks
  - multistreaming - up to 64k independent ordered streams
  - multihoming - instead of one IP address per endpoint a set of IP addresses per endpoint
    - SCTP uses multihoming for redundancy, not for load balancing!

Internet transport protocols

SCTP association

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- The combination of an SCTP port and an IP address defines an “SCTP Transport Address”
- An SCTP endpoint
  - an endpoint is the logical end of the SCTP transport protocol - a communicating party
  - may have MORE than one IP address but it always has one and only one port number.

endpoint = [10.1.4.2, 10.1.5.3 : 80]

- In SCTP, the communication relationship between two endpoints is called an association

association = { [10.1.61.11: 2223], [10.1.4.2,10.1.5.3 : 80]}

Internet transport protocols

SCTP framing

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- SCTP maintains message boundaries; an app message is maintained as one or more data chunks

The objective is to increase performance by removing blocking in the received data, either due to delay or loss

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SCTP framing

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- Decoupling of reliable and ordered delivery
  - allowing unordered delivery eliminates head-of-line blocking delay

TCP receiver buffer

Internet transport protocols

SCTP framing

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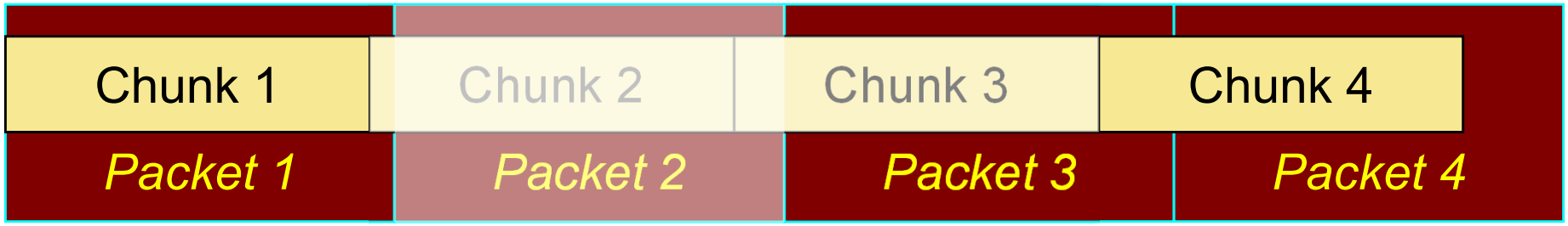
- Applications may want logical data units (“chunks“)
- Viewing data as a byte stream is inefficient



- If Packet 2 is lost, the other packets can be handled
- SCTP preserves Application Level Framing
  - each send/read is a “chunk“ (App. Data Unit)

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SCTP framing

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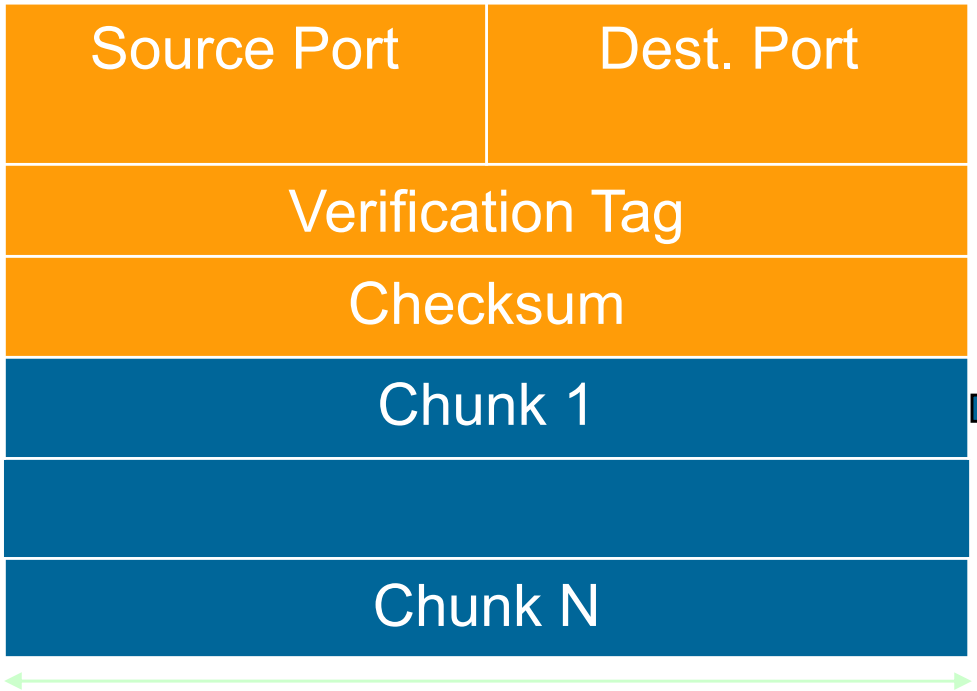

- SCTP PDU (max. 64 kbytes)
- SCTP may fragment user data according to minimum MTU

Examples of SCTP chunks:

0x00	DATA	User data
0x01	INIT	~ SYN
0x02	INIT-ACK	
0x03	SACK	Selective ACK
0x04	HEARTBEAT	Keep-alive message
0x05	HEARTBEAT-ACK	
0x07	SHUTDOWN	~FIN
0x08	SHUTDOWN-ACK	

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SCTP packets

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- Common header; three basic functions:
  - Source and destination ports, used together with the IP addresses and other state information to identify the *association* (connection)
  - Verification tag, random and negotiated at init
  - Checksum: CRC32 over the full SCTP packet
- followed by one or more chunks
  - chuncks are concatenated building blocks containing either control or data information
  - a chunk header identifies length, type, and any special flags
  - control chunks transfer information needed for association functionality and data chunks carry application layer data.
  - current RFC specifies: 14 different control chunks for the association establishment, termination, ACK, destination failure recovery, ECN, and error reporting
- report to RFC4960 for SCTP PDU details

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SCTP 4-way handshake

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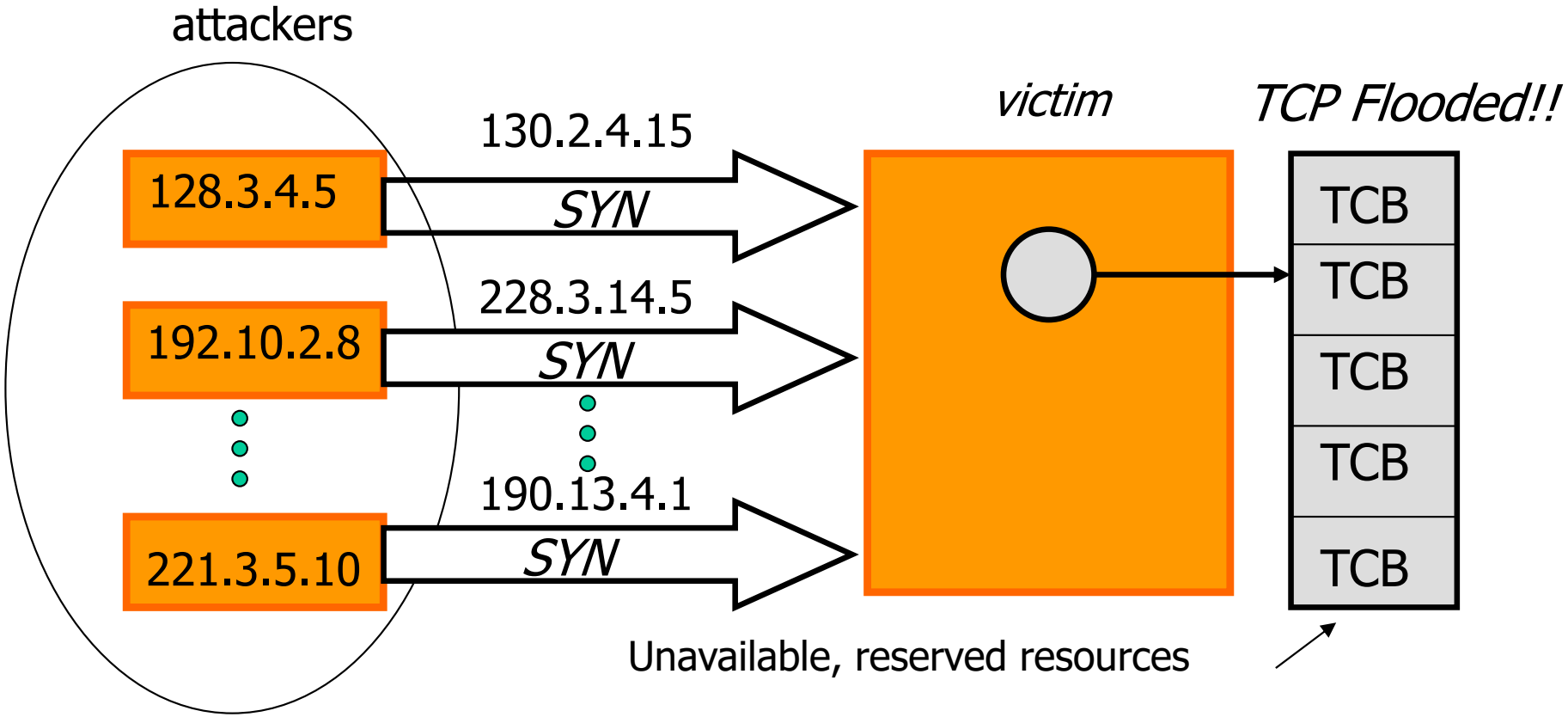
- SCTP improves protection against DoS attacks



There is no ACK in response to the SYN-ACK, hence connection remains half-open. Other genuine clients cannot open connections.

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SCTP – 4-way handshake

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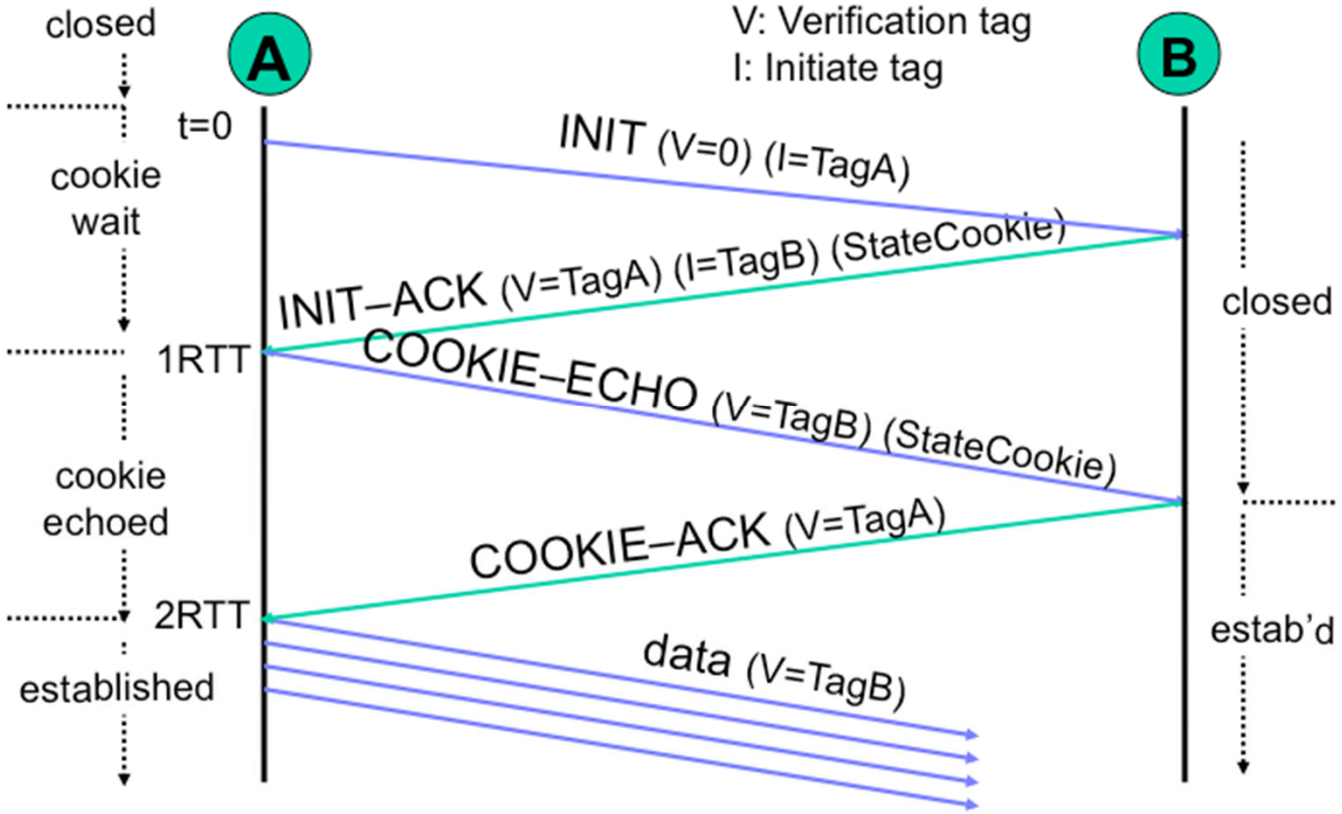

- Host A sends INIT chunk to Host B, Host B returns INIT-ACK containing a cookie w/ state information that only Host B can verify; 32 bits random verification tags; no memory allocated
- Host A replies with COOKIE-ECHO chunk; may contain A's first data.
- Host B checks validity of cookie; connection is established

Internet transport protocols

SCTP multistreaming

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- TCP provides transport for a single data stream
- SCTP allows multiple independent streams per association
- Examples:
  - in telephony signaling (SS7), it is only necessary to maintain sequencing of messages that affect, e.g., the same call). Other messages are only loosely correlated and can be delivered without having to maintain overall sequence integrity.
  - delivery of multimedia documents over a single session. Multi-streaming allows transport of multimedia components to be partially ordered rather than strictly ordered.

Internet transport protocols

SCTP multistreaming

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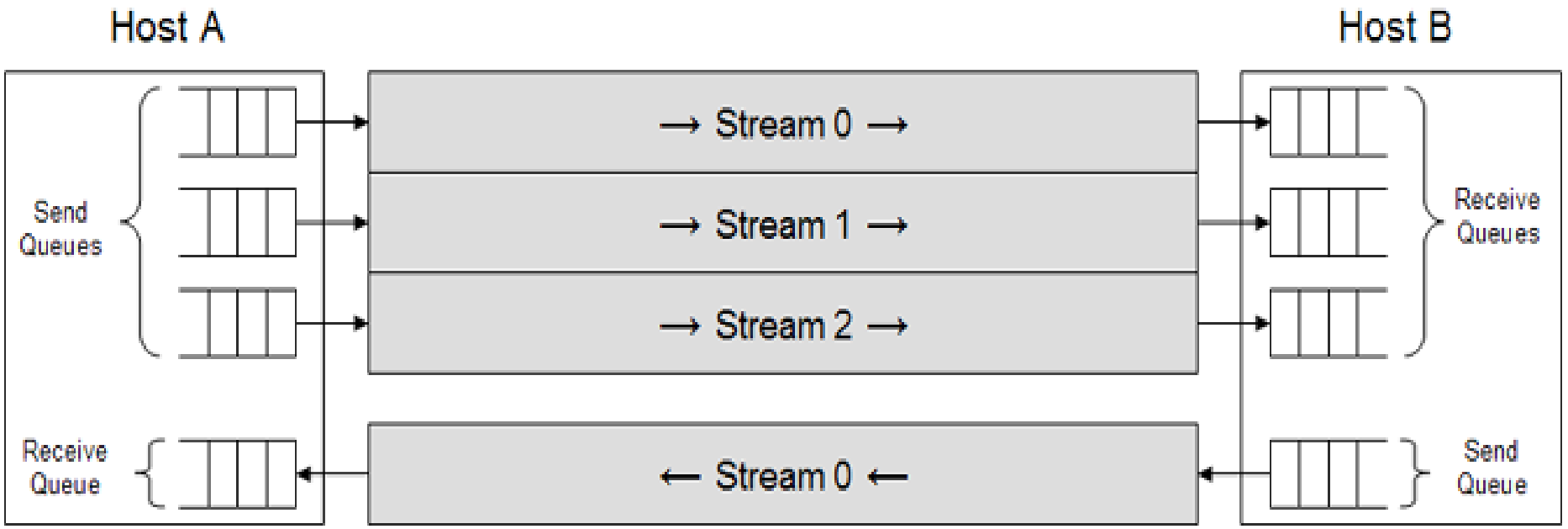

- Logical separation of data within an association
- Designed to prevent head-of-line blocking
- Can be used to deliver multiple objects of the same association
  - e.g.: objects within a webpage, multimedia streams (audio/video/text), files in an FTP *mget*

Internet transport protocols

SCTP multihoming

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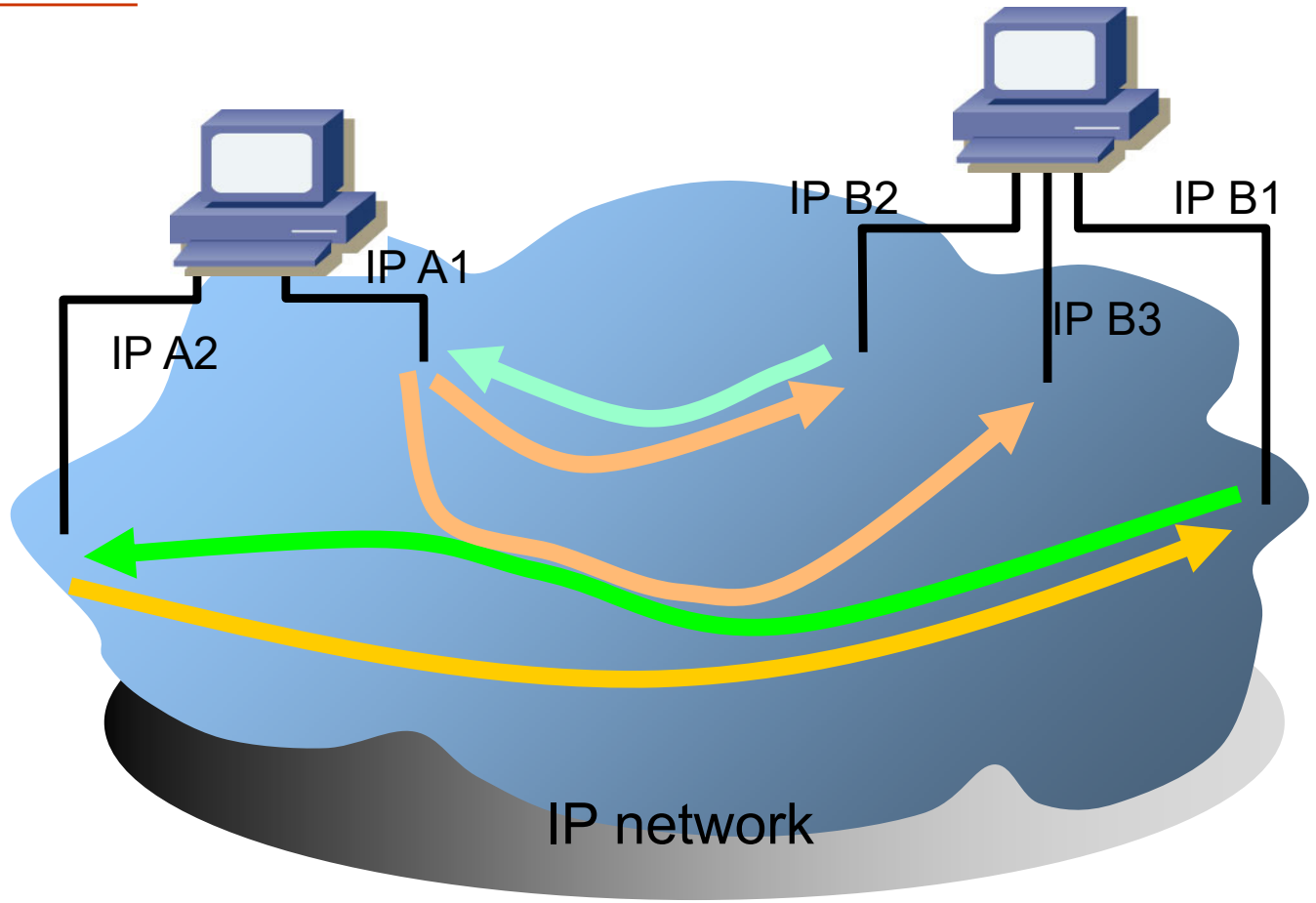

- SCTP is able to handle scenarios with multiple src/dst IP addresses (wired and wireless interfaces, multiple ISPs, etc.)

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SCTP multihoming

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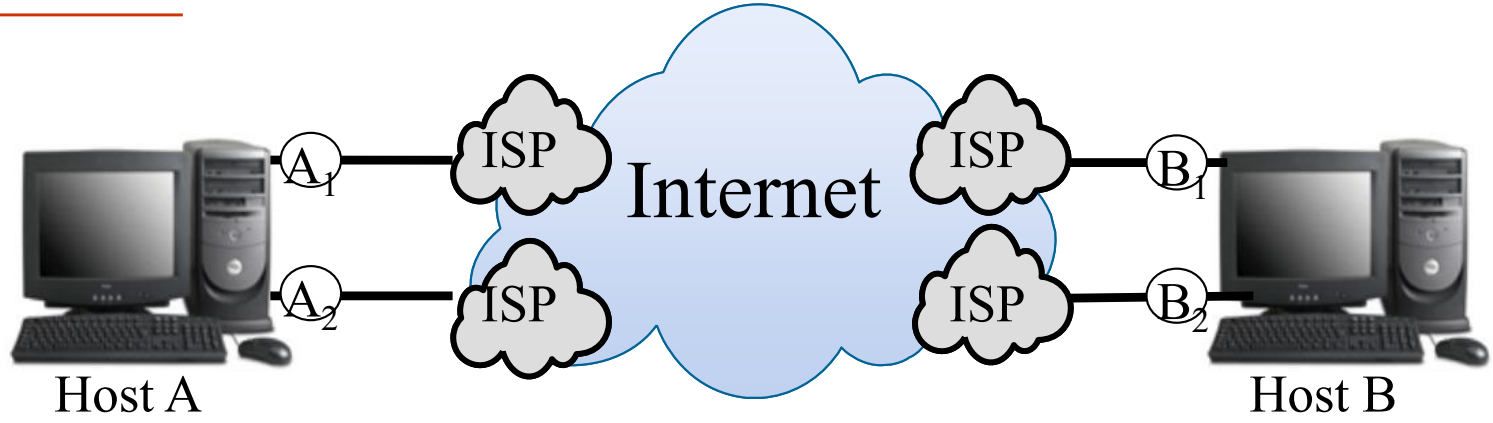

- Hosts pick 1 of 4 possible TCP connections:
  - $\{(A_1, B_1), (A_1, B_2), (A_2, B_1), (A_2, B_2)\}$
- Hosts use 1 SCTP association:
  - $(\{A_1,A_2\}, \{B_1,B_2\})$
  - Selectable “primary” destination
  - New data sent only to primary destination
  - Path status and reachability monitored (*heartbeats*)

Internet transport protocols
SCTP multihoming

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- TCP connection ⇔ SCTP association
  - 2 IP addresses, 2 port numbers ⇔ 2 sets of IP addresses, 2 port numbers
  - a common flow and congestion control mechanism is kept to reduce overhead
- Goal: robustness
  - automatically switch IP host addresses upon failure
  - eliminates effect of long routing reconvergence time

- TCP: no guarantee for “keepalive“ messages when connection idle
- SCTP monitors each destination's reachability via ACKs of
  - data chunks
  - heartbeat chunks

- SCTP uses multihoming for redundancy, not for load balancing!

Internet transport protocols

SCTP comparison to other protocols

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Services/Features	SCTP	TCP	UDP
Full-duplex data transmission	yes	yes	yes
Connection-oriented	yes	yes	no
Reliable data transfer	yes	yes	no
Partially reliable data transfer	optional	yes	no
Ordered data delivery	yes	yes	no
Unordered data delivery	yes	no	yes
Flow and Congestion Control	yes	yes	no
ECN support	yes	yes	no
Selective acks	yes	optional	no
Preservation of message boundaries	yes	no	yes
Path MTU Discovery	yes	yes	no
Application data fragmentation	yes	yes	no
Multistreaming	yes	no	no
Multihoming	yes	no	no
Protection against SYN flooding attack	yes	no	n/a
Half-closed connections	no	yes	n/a

Internet transport protocols

SCTP references

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- Current home: IETF TSVWG (Transport Services Working Group)
  - https://datatracker.ietf.org/wg/tsvwg/charter/
- Main RFC and info
  - SCTP - RFC 4960, IETF, September 2007
  - Sockets API Extensions for the Stream Control Transmission Protocol (SCTP), RFC 6458, Dec. 2011
- Implementations
  - AIX, FreeBSD (7.0 onwards), Linux, Mac OS X, QNX, Solaris, True64, IOS (Cisco), Microsoft Windows

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Eng. Serviços de Rede (ESR)

Transport Protocols
Recent developments

QUIC

A UDP-Based Multiplexed and Secure Transport

(short overview)

[RFC9000,2021]

Internet transport protocols

QUIC motivation

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- Need to provide fast delivery and rendering at app level
- QUIC aims to solve TCP drawbacks (already identified), having a similar SCTP motivation by allowing:
  - HOL blocking removal
  - multiplexing different streams
  - increased security
- proposed by Jim Roslink at Google in 2012, being integrated as a Chromium component, and supported by major browsers
- currently a proposed standard, RFC 9000, May 2021

Internet transport protocols
QUIC

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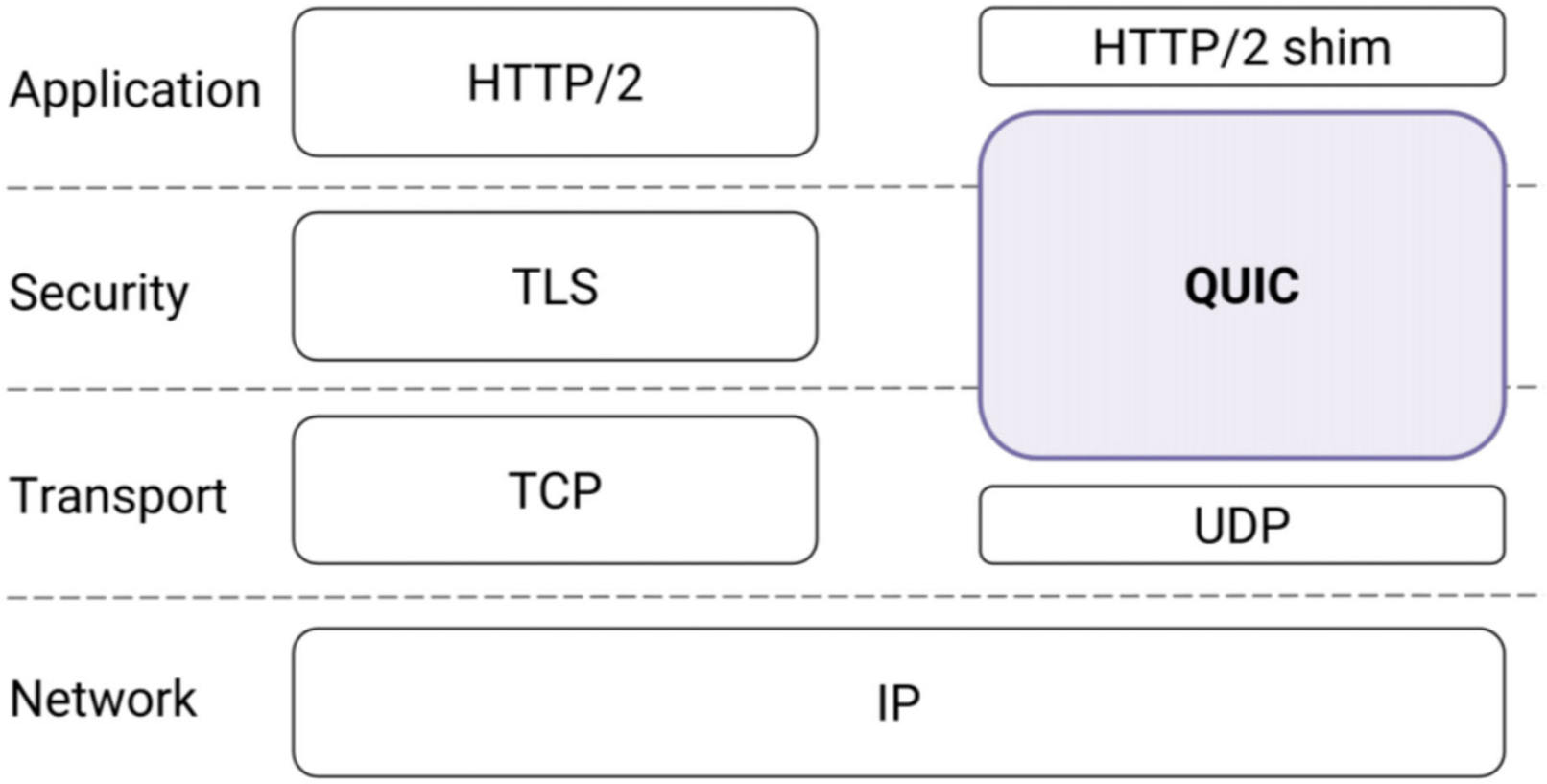

Figure 1: QUIC in the traditional HTTPS stack.

Internet transport protocols
QUIC

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- QUIC principles:
  - provides applications with flow-controlled streams for structured, communication, low-latency connection establishment, and network path migration.
  - includes security measures that ensure confidentiality, integrity, and availability based on TLS.
  - runs over TLS/UDP, implementing also congestion control.
  - is a connection-oriented protocol that creates a stateful interaction between a client and server.

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QUIC

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- QUIC operation:
  - handshaking combines negotiation of cryptographic and transport parameters (with low RTT concerns);
  - endpoints communicate exchanging QUIC packets;
  - packets contain frames, which carry control info and application data between endpoints;
  - app protocols send data over a QUIC connection via streams, which are ordered sequences of bytes.
  - streams can be bidirectional or unidirectional (only one endpoint can send data)

Internet transport protocols
QUIC

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- QUIC operation:
  - flow control relies on a credit-based scheme to limit stream creation and to bound the amount of data that can be sent.
  - provides the necessary feedback to implement reliable delivery and congestion control.
  - path migration, connections are not strictly bound to a single network path... a client may migrate to a new path if available (requires probing and path validation) (... e.g., endpoint with Wi-Fi and 4G access).

Internet transport protocols

QUIC info

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- IETF QUIC working group
  - https://quicwg.org
- Current implementations: https://github.com/quicwg/base-drafts/wiki/Implementations
- Additional Reading
  - Adam Langley, et al. The QUIC Transport Protocol: Design and Internet-Scale Deployment. In ACM SIGCOMM '17. ACM, New York, NY, USA, 183–196. DOI:https://doi.org/10.1145/3098822.3098842
  - RFC 9000, May 2021.
- Must have QUIC on radar in 2022... ☺