QUIC Loss Detection

draft-ietf-quic-recovery-19

TCPM @ IETF 104, March 2019

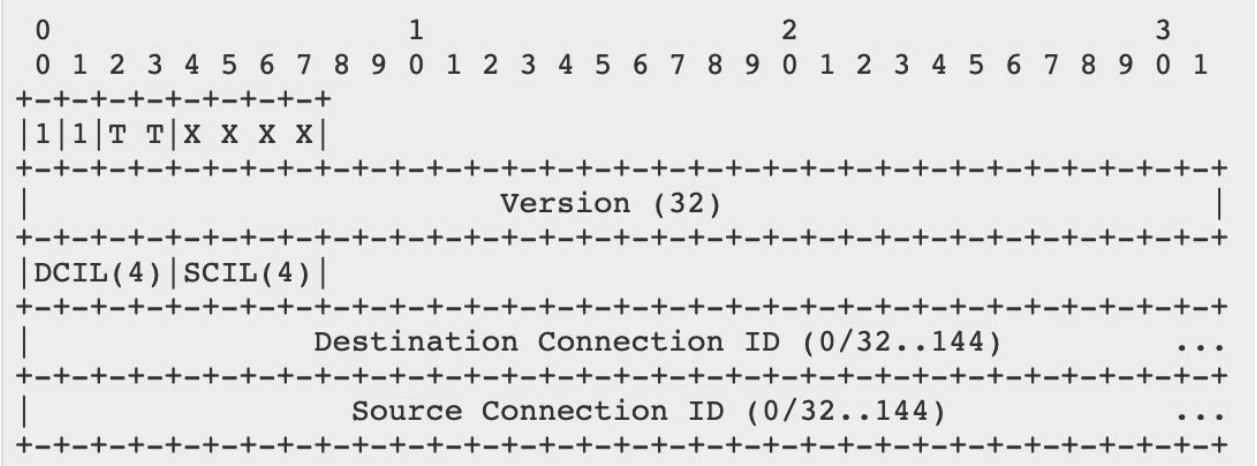
QUIC Packet Format

Long header

Short header

QUIC Packet Format

Long header



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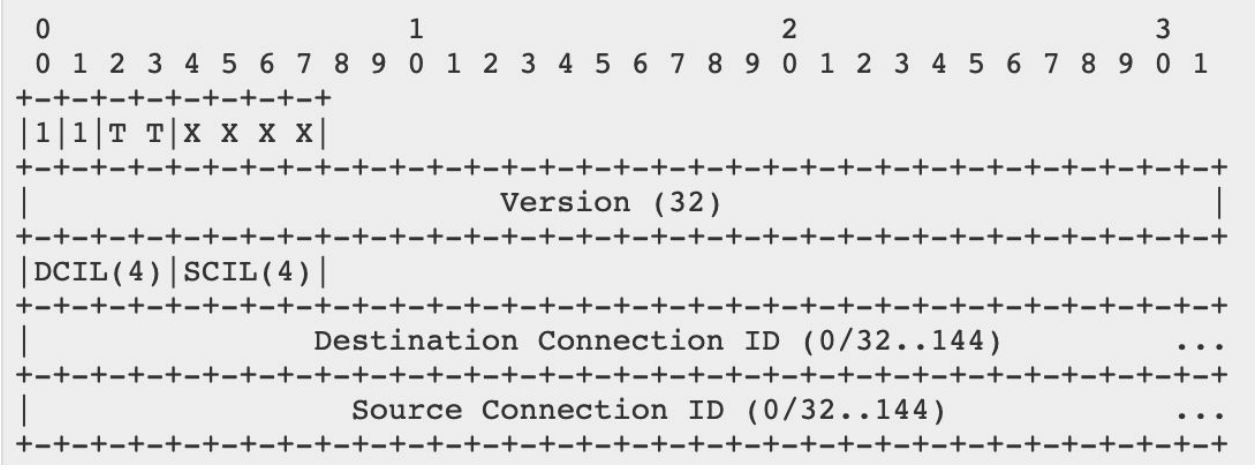

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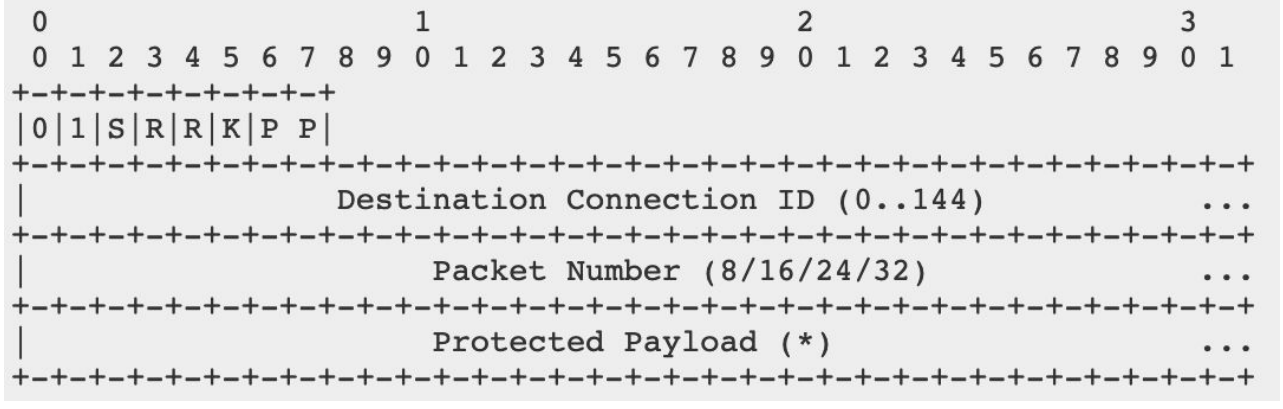
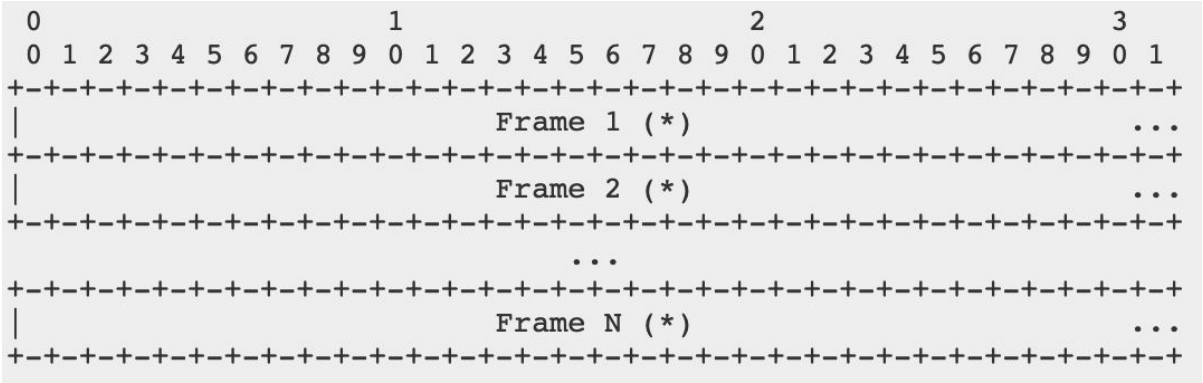
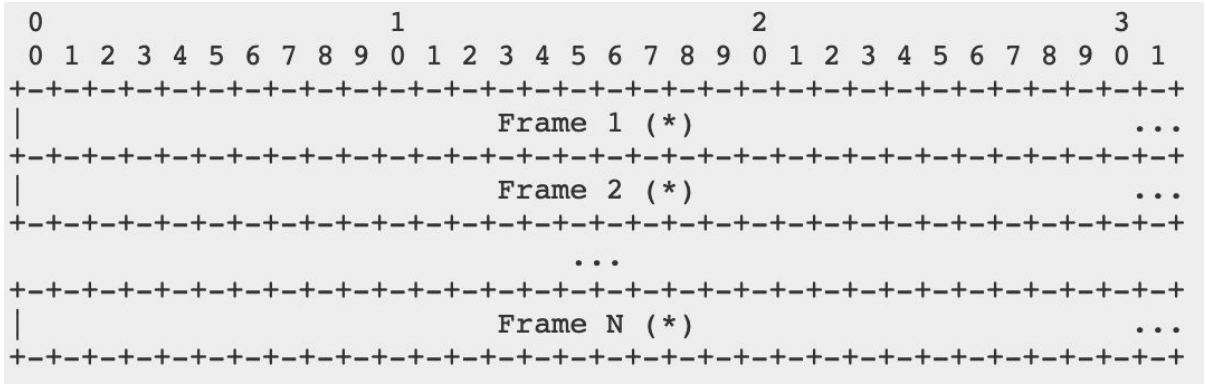


Frames


0 1 2 3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
Frame 1 (*)
...
Frame 2 (*)
...
...
Frame N (*)
...

Frames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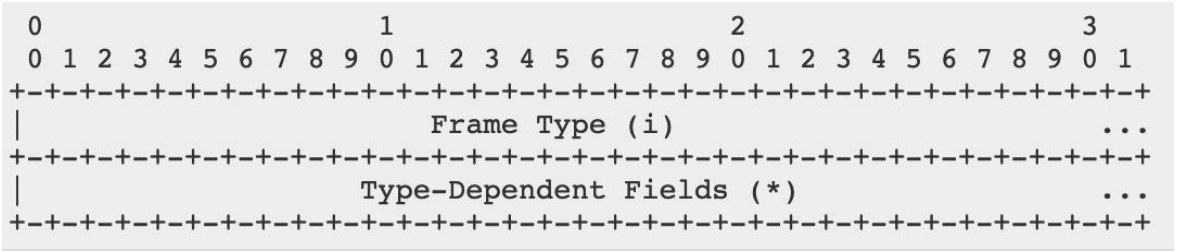
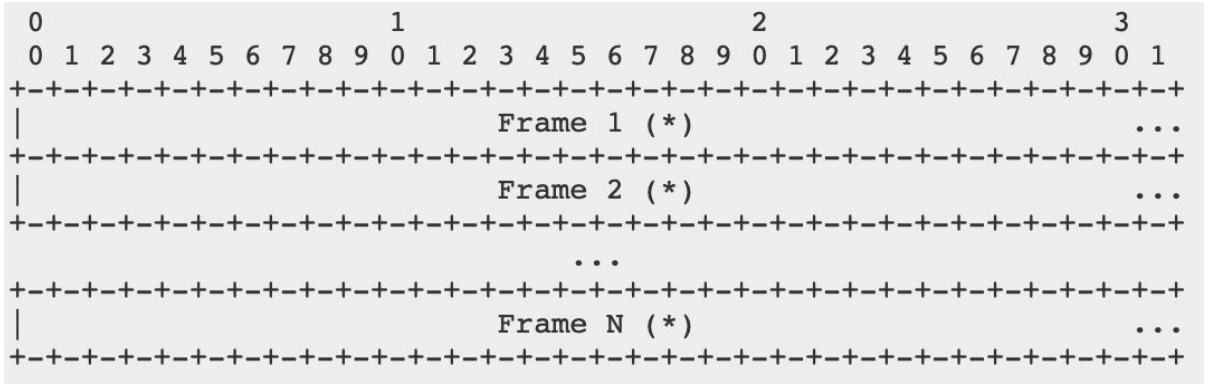
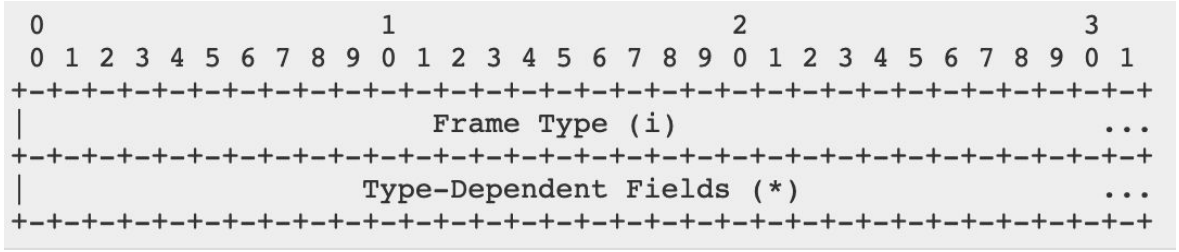
Frame 2 (*)
...
Frame N (*)


0 1 2 3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
Frame Type (i)
Type-Dependent Fields (*)

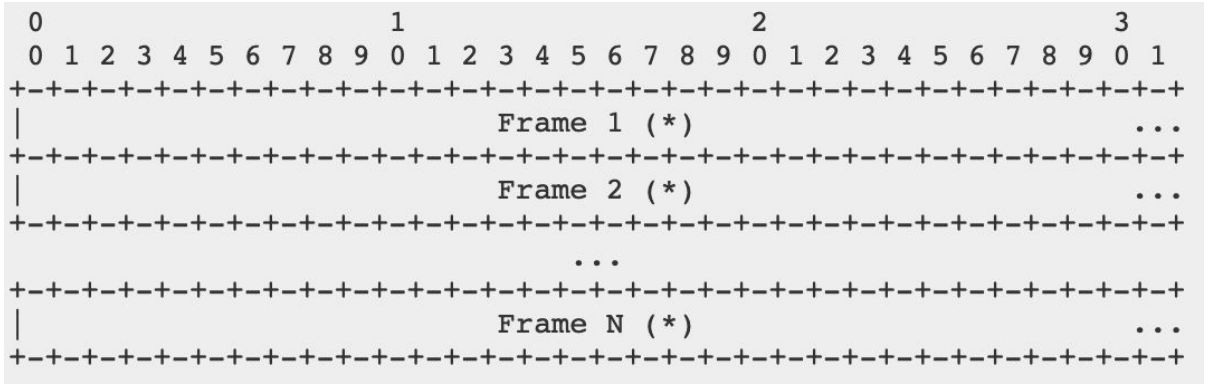
Frames

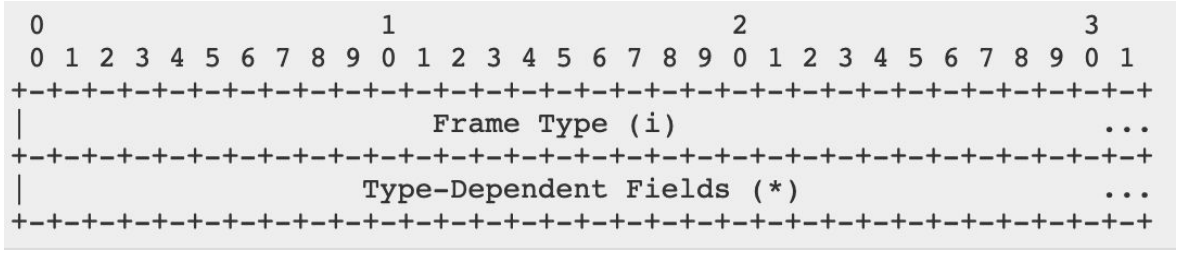




Type Value	Frame Type Name
0x00	PADDING
0x01	PING
0x02 - 0x03	ACK
0x04	RESET_STREAM
0x05	STOP_SENDING
0x06	CRYPTO
0x07	NEW_TOKEN
0x08 - 0x0f	STREAM
0x10	MAX_DATA
0x11	MAX_STREAM_DATA
0x12 - 0x13	MAX_STREAMS
0x14	DATA_BLOCKED
0x15	STREAM_DATA_BLOCKED
0x16 - 0x17	STREAMS_BLOCKED
0x18	NEW_CONNECTION_ID
0x19	RETIRE_CONNECTION_ID
0x1a	PATH_CHALLENGE
0x1b	PATH_RESPONSE
0x1c - 0x1d	CONNECTION_CLOSE

Frames





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0x1a	PATH_CHALLENGE
0x1b	PATH_RESPONSE
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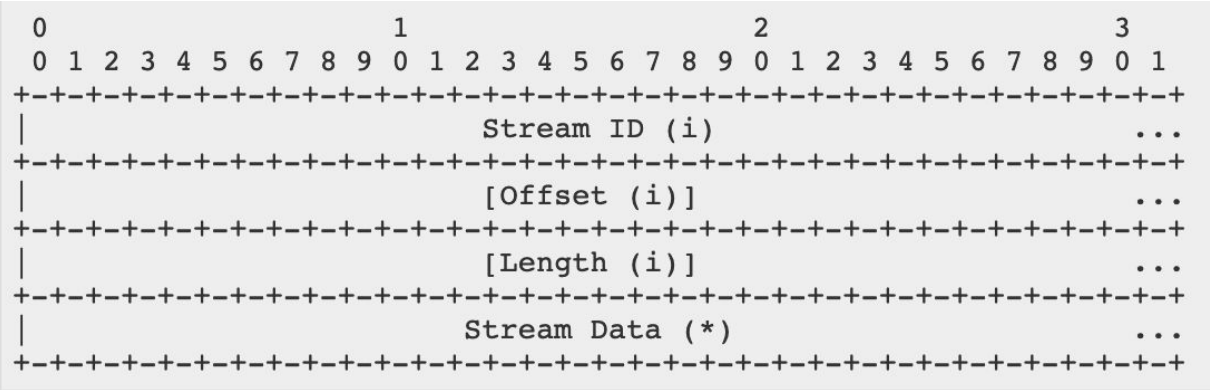
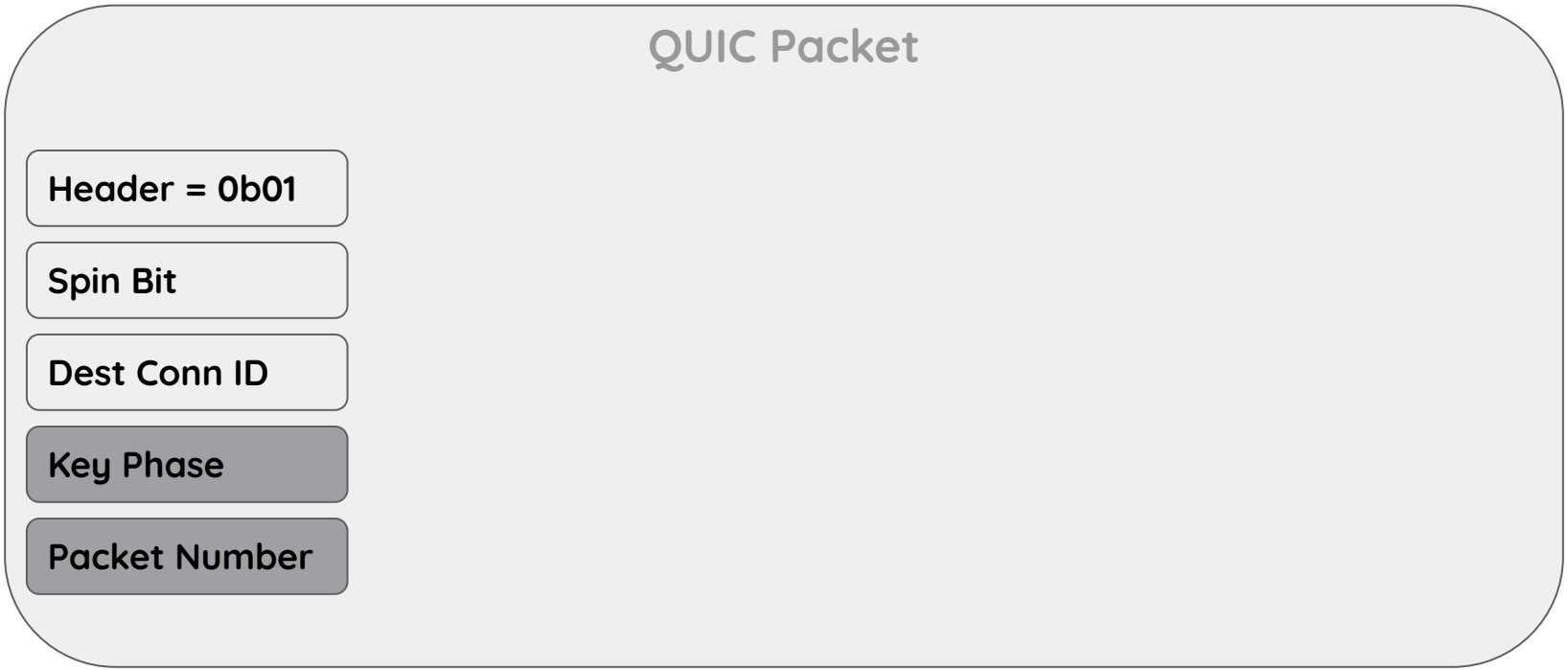
STREAM Frame



QUIC Packetization: Example



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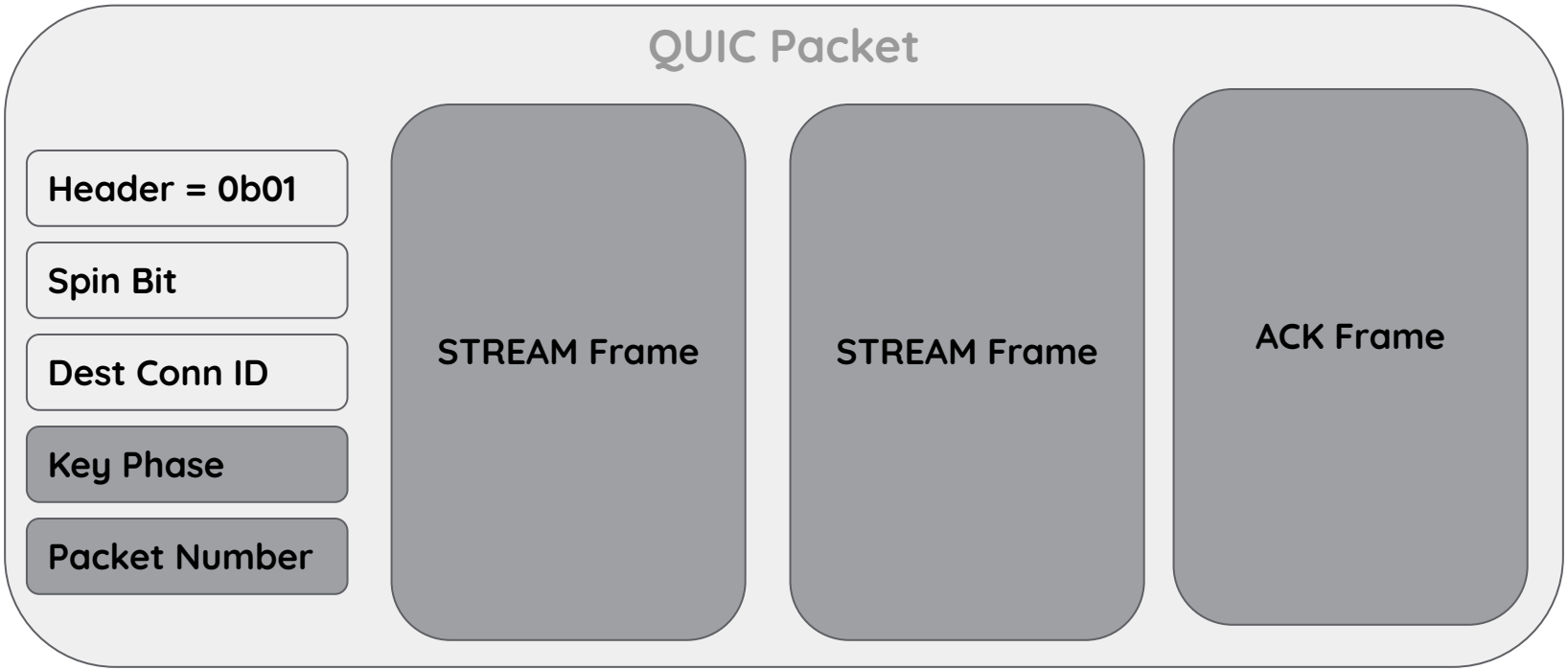

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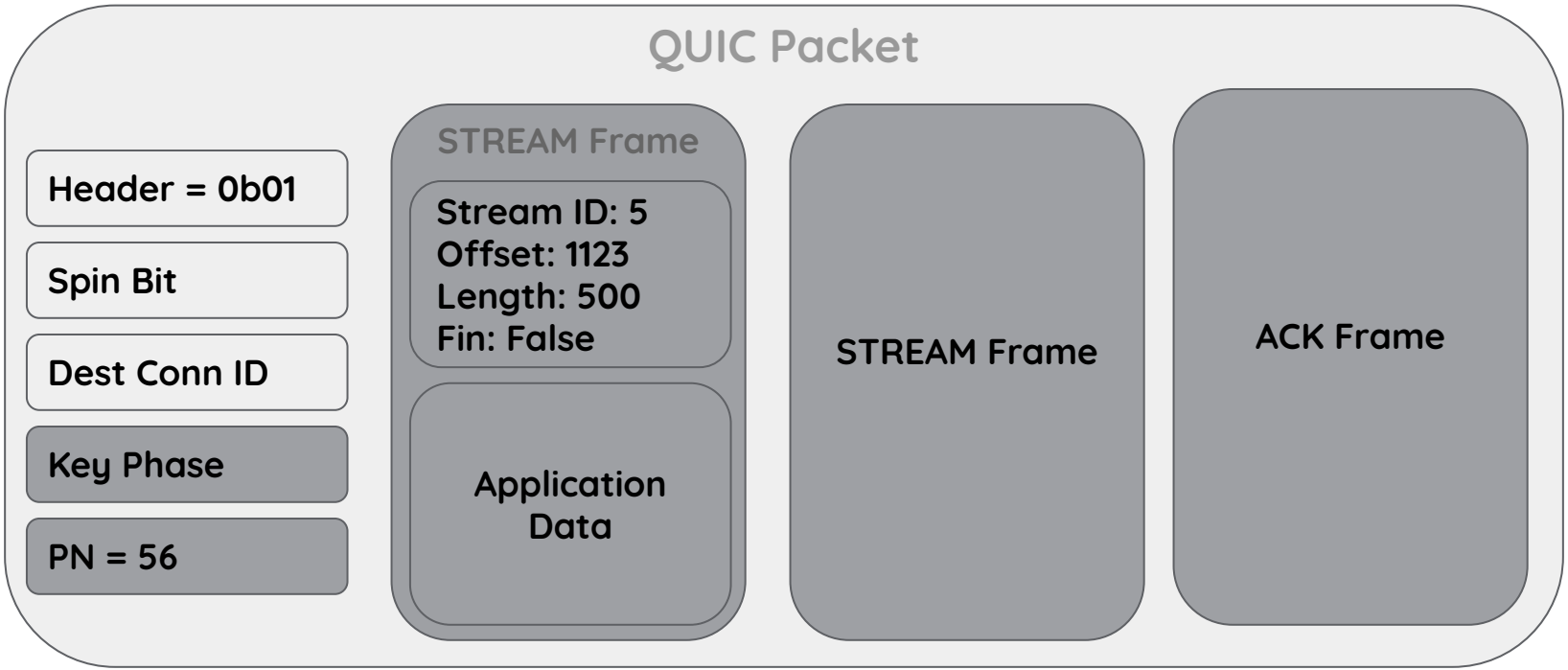

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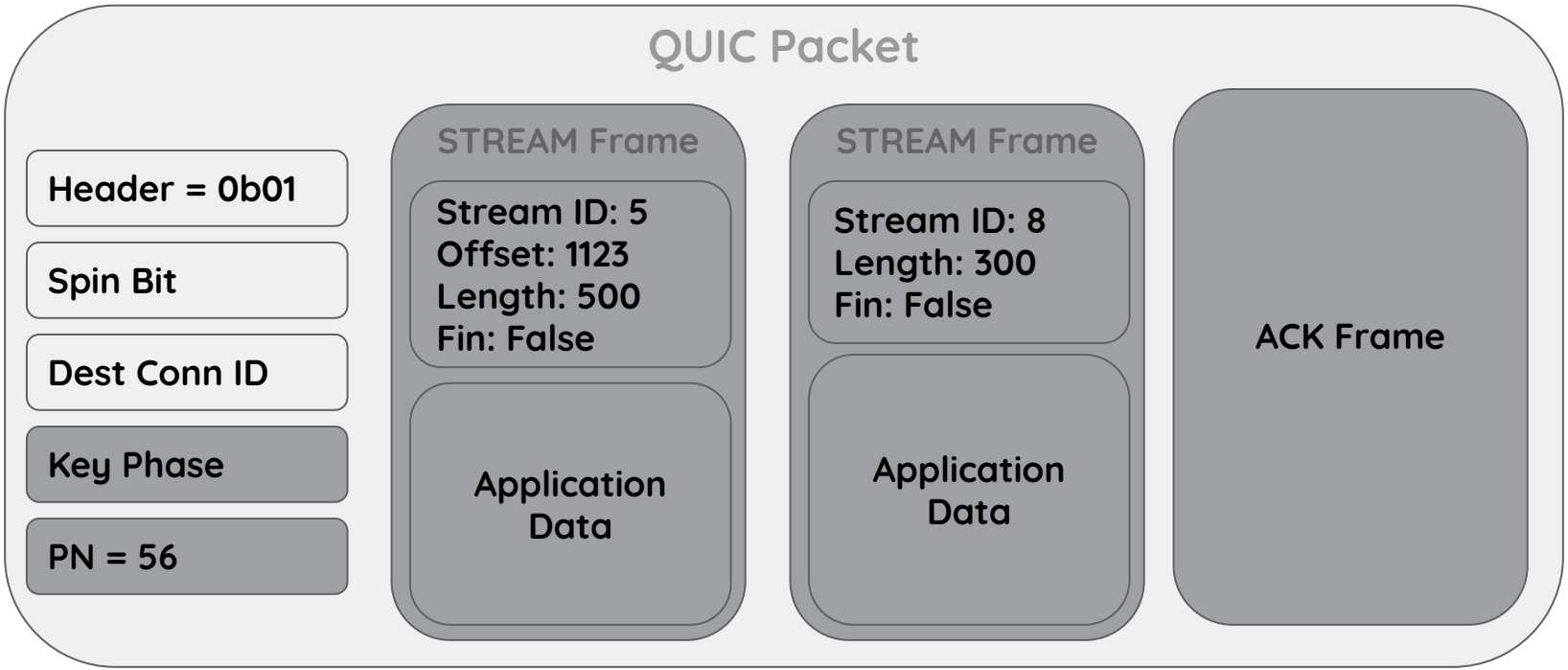
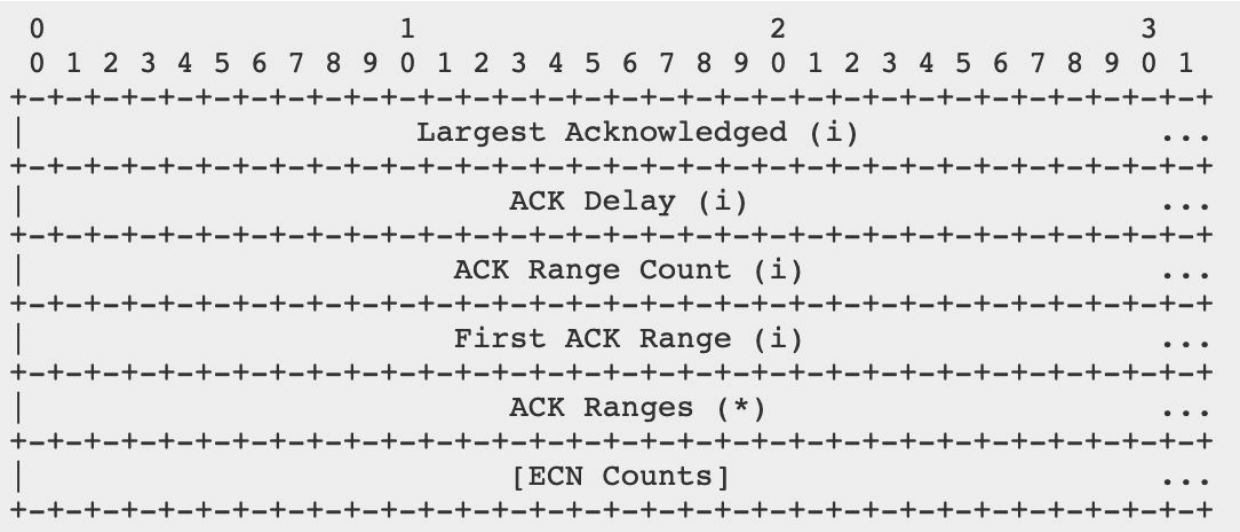
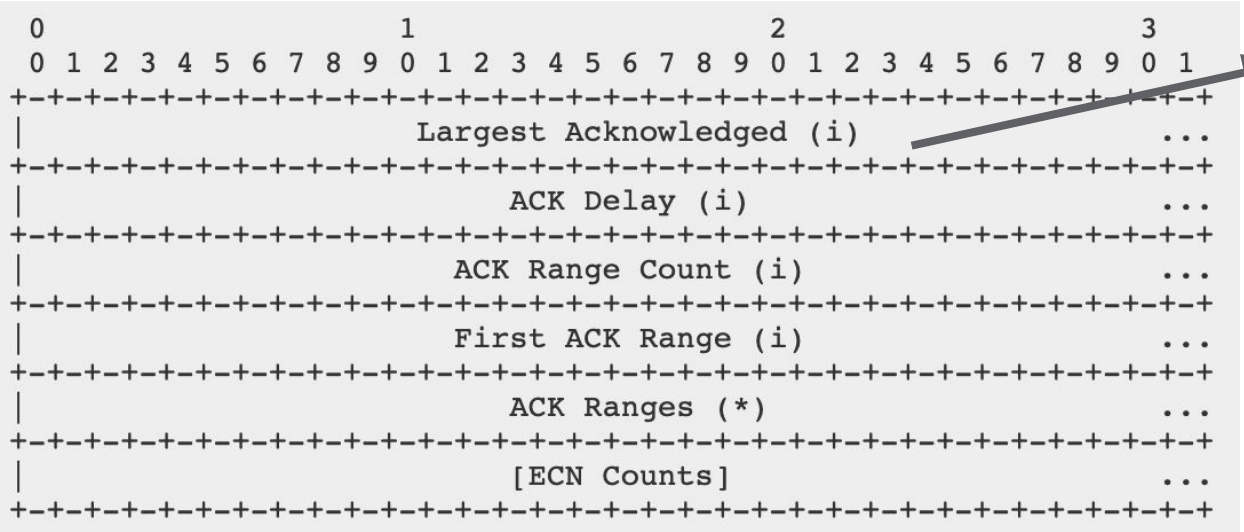


ACK Frame

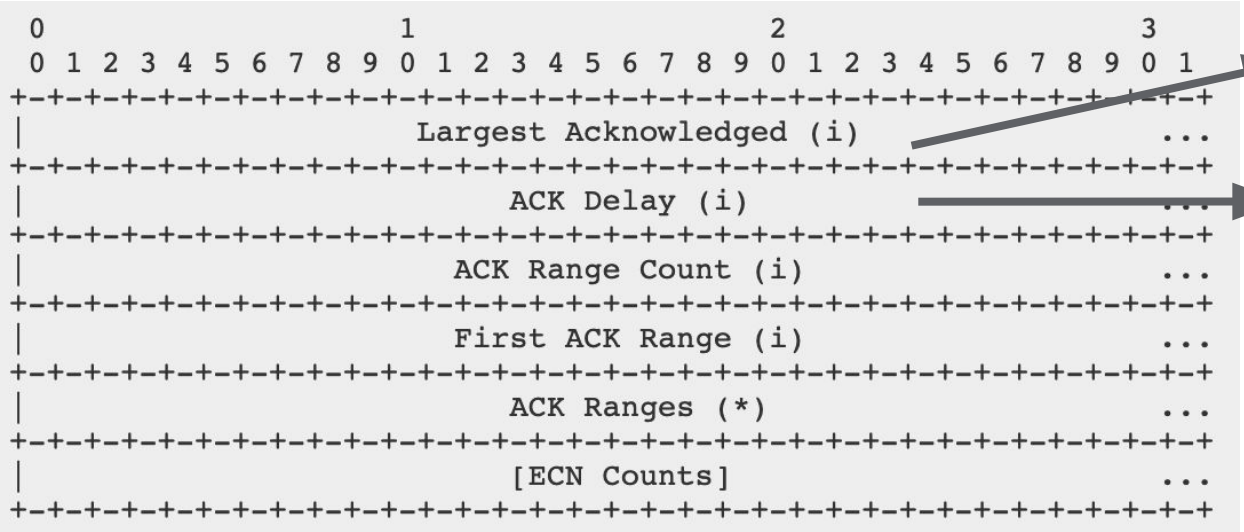

0 1 2 3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
Largest Acknowledged (i) ...
ACK Delay (i) ...
ACK Range Count (i) ...
First ACK Range (i) ...
ACK Ranges (*) ...
[ECN Counts] ...

ACK Frame



Highest Packet Number seen so far

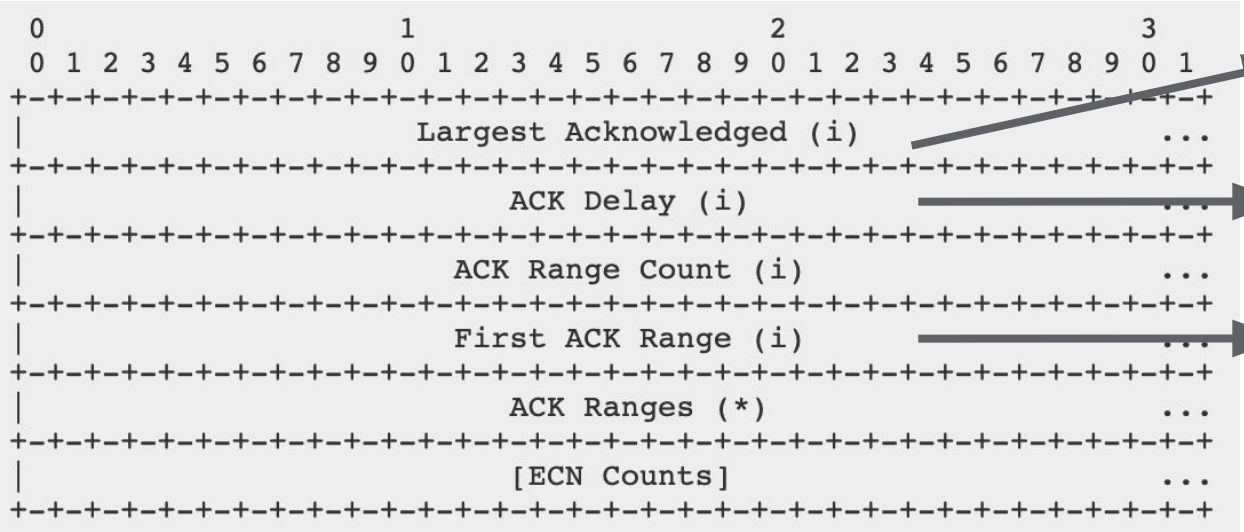
ACK Frame



Highest Packet Number seen so far

Time since Largest Acked was received

ACK Frame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First ACK Range (i) ...
ACK Ranges (*) ...
[ECN Counts] ...
Highest Packet Number seen so far
Time since Largest Acked was received
Contiguous from Largest Acked

QUIC Packetization: Ack Example

Packets received: 1 … 125

Time since largest received: 25ms

represented as a shifted value (default 3, negotiable)

25ms = 3125us << 3

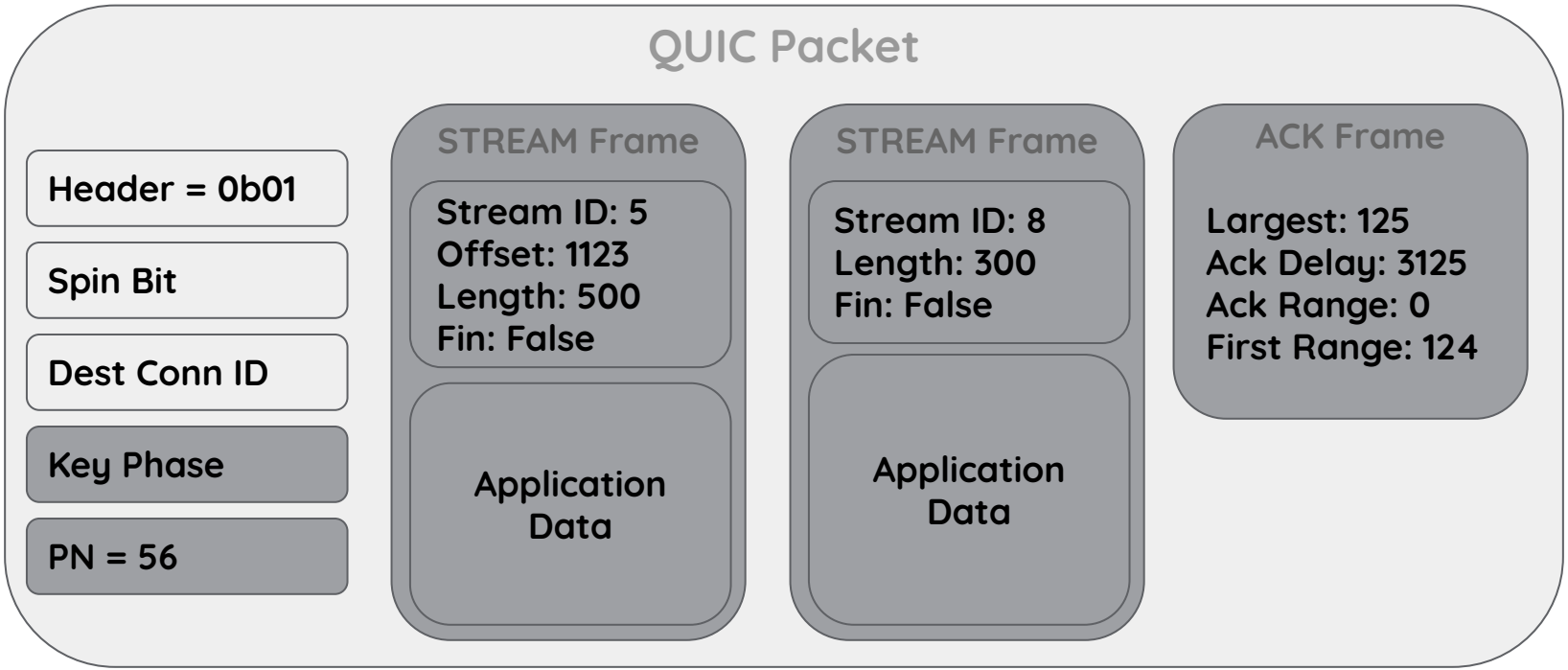
ACK fields

Largest packet received so far: 125

First Ack Range: 124

Ack Range Count: 0

QUIC Packetization: Example



QUIC Packetization: Ack Example

Packets received: 1 … 125, 130
Time since largest received: 0ms

ACK fields

Largest packet received so far: 130
First Ack Range: 0
Gap #1: 126 - 129
Ack Range #1: 1 - 125

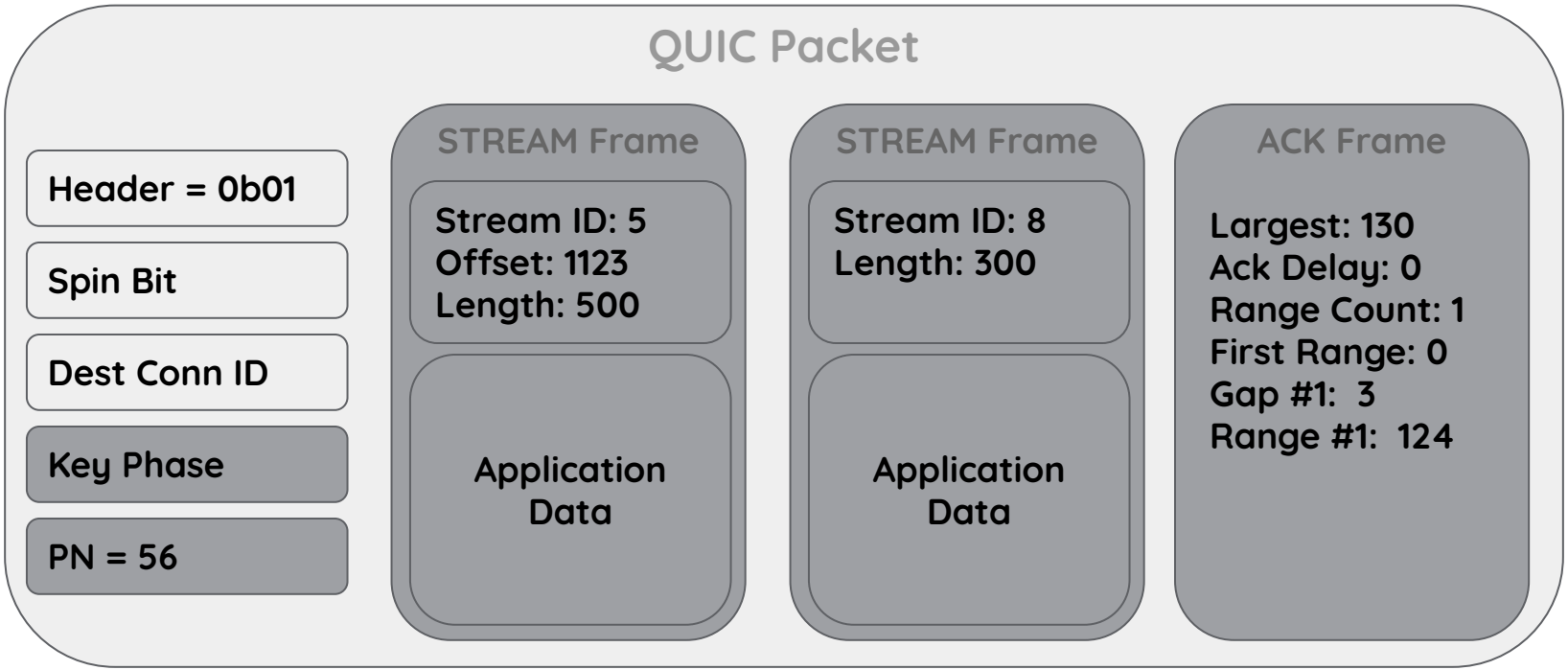
QUIC Packetization: Ack Example

Packets received: 1 … 125, 130
Time since largest received: 0ms

ACK fields

Largest packet received so far: 130
First Ack Range: 0
Gap #1: 126 - 129 (encoded as 3)
Ack Range #1: 1 - 125 (encoded as 124)

QUIC Packetization: Example



QUIC Packetization: Loss Example

Packet 56 dropped

QUIC Packetization: Loss Example

Packet 56 dropped

Also, Stream 8 was reset

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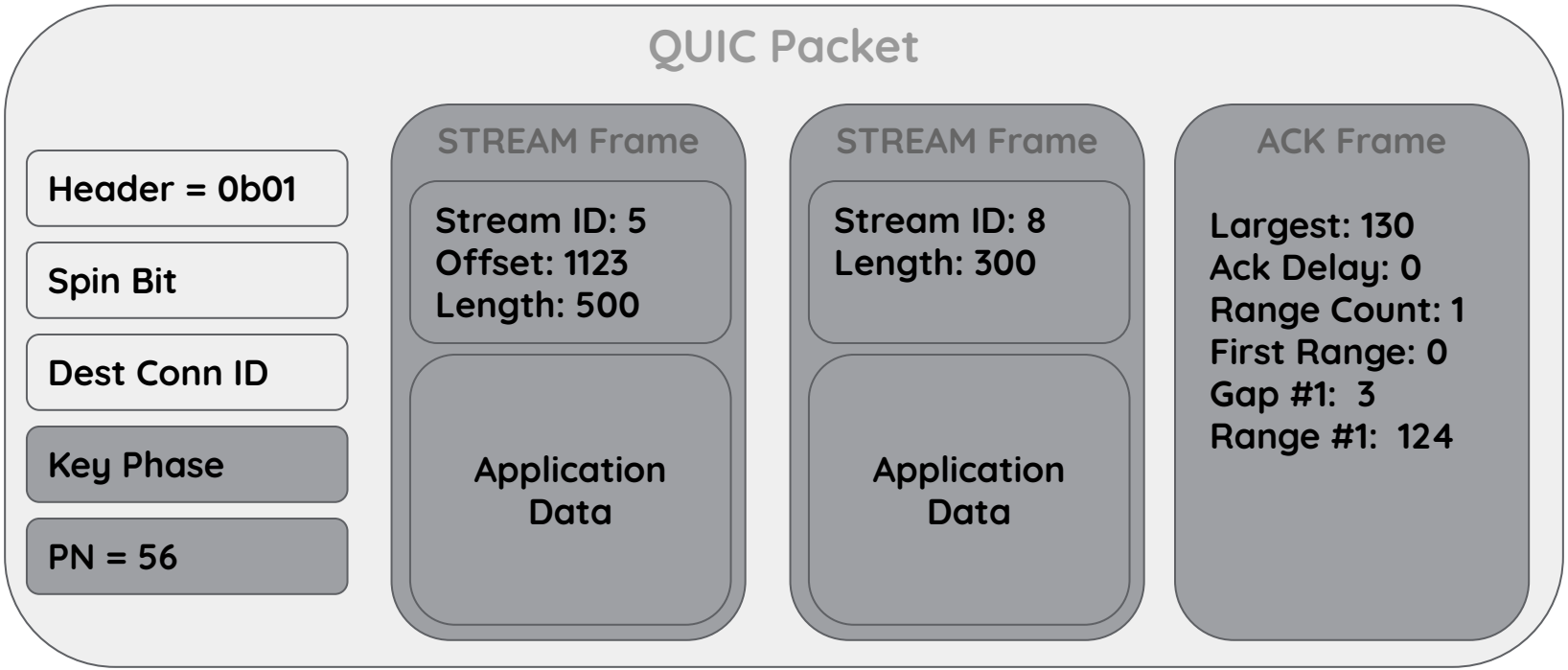
Also, Stream 8 was reset

QUIC loss detection marks packet 56 as lost

let’s say last packet sent was packet number 74

QUIC Packetization: Example



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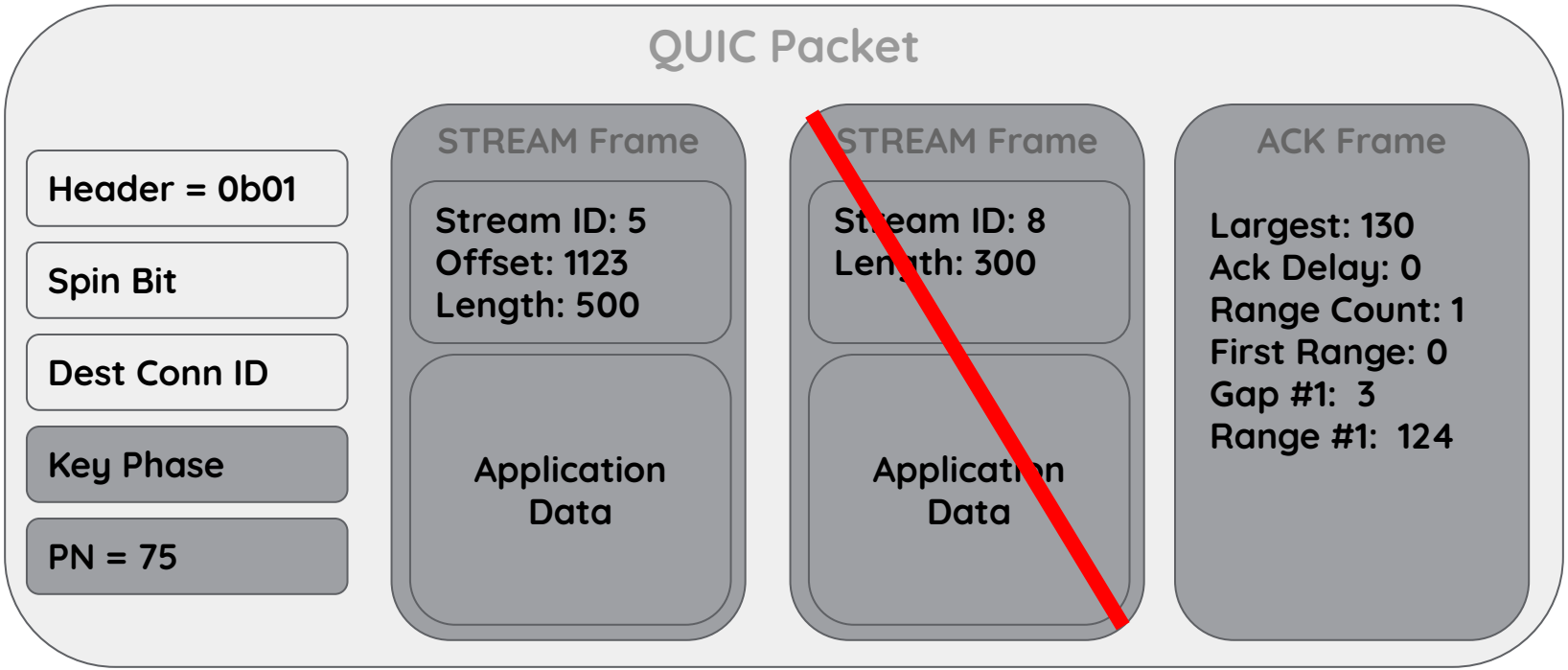

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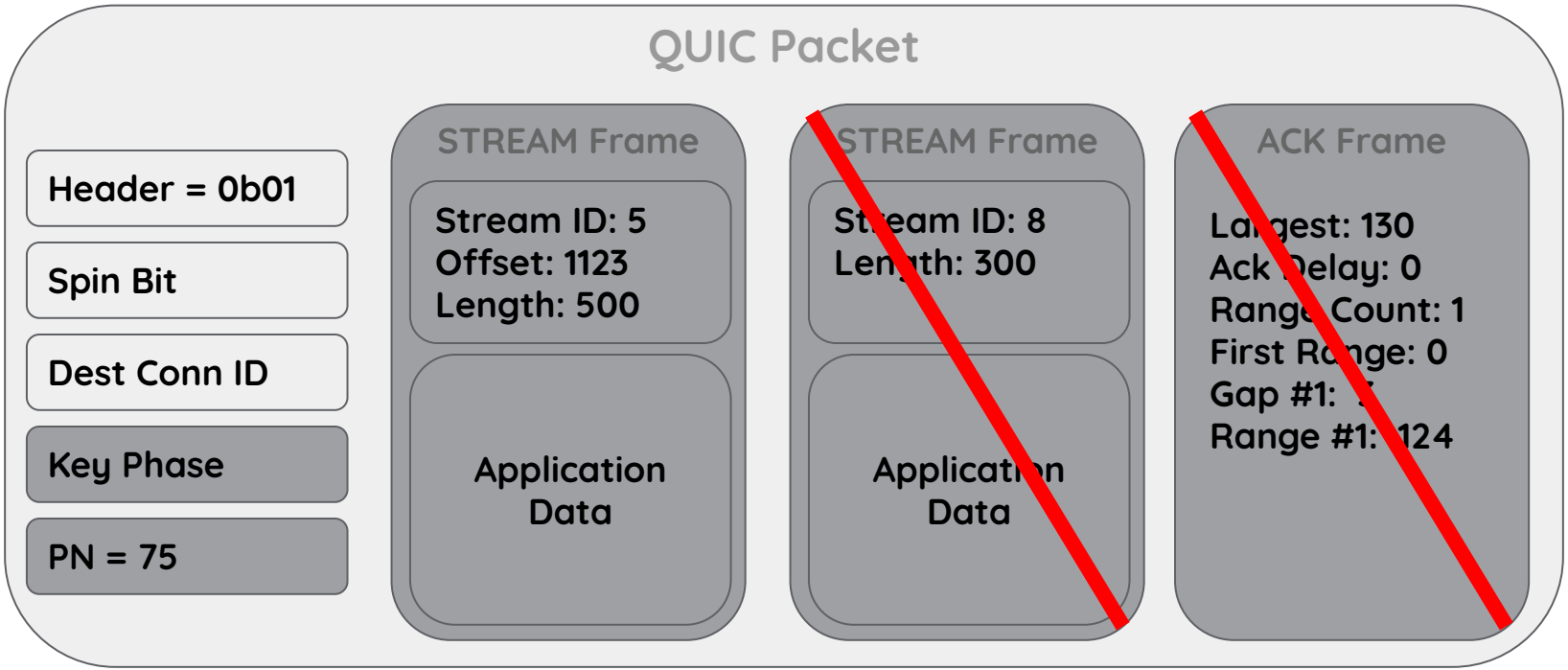

QUIC Loss Recovery

Packet numbers represent transmission order

stream IDs and offsets used for delivery order

monotonically increasing 62-bit packet numbers

(caveat: multiple PN spaces during connection setup)

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Packet numbers represent transmission order

stream IDs and offsets used for delivery order
monotonically increasing 62-bit packet numbers
(caveat: multiple PN spaces during connection setup)

Packets are containers

carry a mix of various types of frames

Retransmissions are not automatically high priority

depends on relative stream priority
application-dependent

Generating ACK frames

SHOULD ACK every other packet

subject to 25ms delayed ack timer

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SHOULD ACK immediately if:

Received packet number != largest received + 1

CE codepoint received

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MAY process more packets before ACK

allows less frequent acking

QUIC Loss Detection

Loss detection only when ACK frame received

that newly acks a packet

use both packet and time thresholds

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Packet threshold

reordering >= 3 packets

Time threshold

reordering >= 1 packet AND

time > 9/8 * max(SRTT, latest_RTT)

No ACKs received: Probe Timeout

Probe Timeout (PTO) triggers packet(s) when no ACK

on PTO, send 1 or 2 probe packets (new or old data)

restarted when new ACK-eliciting packet (tail) sent

exponential backoff (pto *= 2)

pto = smoothed_rtt + max(4*rttvar, kGranularity) + max_ack_delay

Timeout does not necessarily mean packet loss

exception: if no data to send, mark outstanding as lost

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No ACKs received: Persistent Congestion

When all packets are lost over a long-enough time

(smoothed_rtt + 4 * rttvar + max_ack_delay) *
(2 ^ kPersistentCongestionThreshold - 1)

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Collapse congestion window to min_cwnd

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When all packets are lost over a long-enough time

(smoothed_rtt + 4 * rttvar + max_ack_delay) *
(2 ^ kPersistentCongestionThreshold - 1)

Collapse congestion window to min_cwnd

Default kPersistentCongestionThreshold = 2

same as 2 TLPs followed by an RTO

Tooling

In-network packet tracing

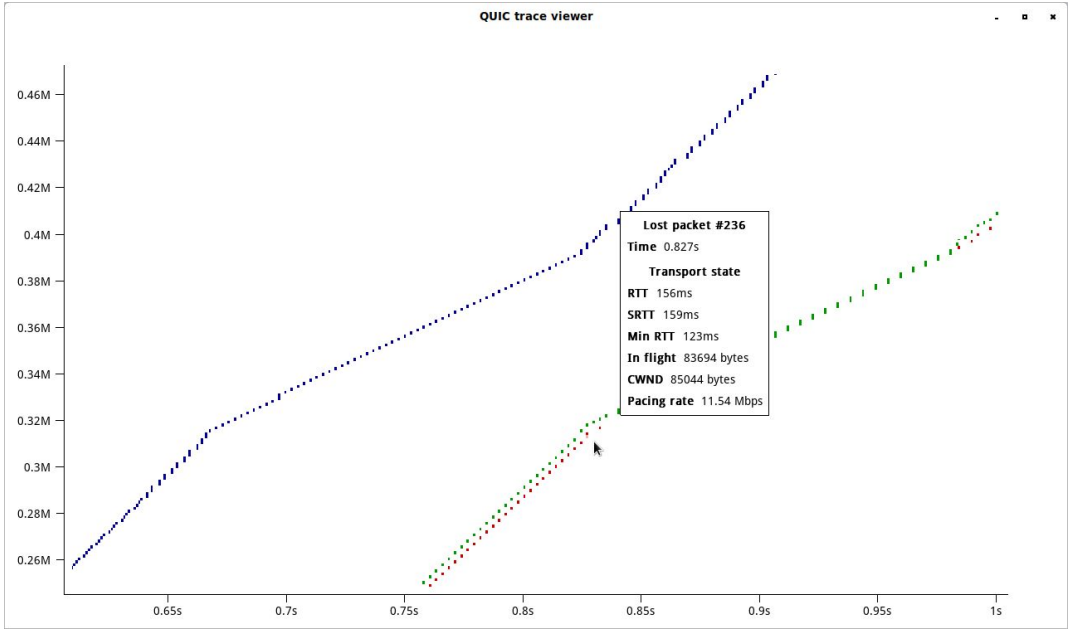
- Wireshark dissector available
- This isn't enough. Why?

Endpoint-based packet tracing

- Log packet and frame details at endpoint
- (also log other transport info, such as cwnd)
- quic-trace
- QUICvis

Tooling: quic-trace

Written by Victor Vasiliev et al (Google)
Available at https://github.com/google/quic-trace
Input: protobuf or JSON



Tooling: QUICvis

Written by Robin Marx et al
Available at https://quic.edm.uhasselt.be/
Input: JSON