IP Data Plane

CPSC 433/533, Spring 2021

Anurag Khandelwal

BGP: Errata

- **Rules for route selection in priority order**

Priority	Rule	Remarks
1	LOCAL PREF	Pick highest LOCAL PREF
2	ASPATH	Pick shortest ASPATH length
3	eBGP > iBGP	Did AS learn route via eBGP (preferred) or iBGP?
4	Hot Potato	Lowest IGP cost to next hop (egress router)
5	MED	Lowest MED Preferred
6	Router ID	Smallest next-hop router's IP address as tie-breaker

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- **Today & next class: the data plane**
  - What data packets look like at the IP layer
  - How routers forward these IP packets

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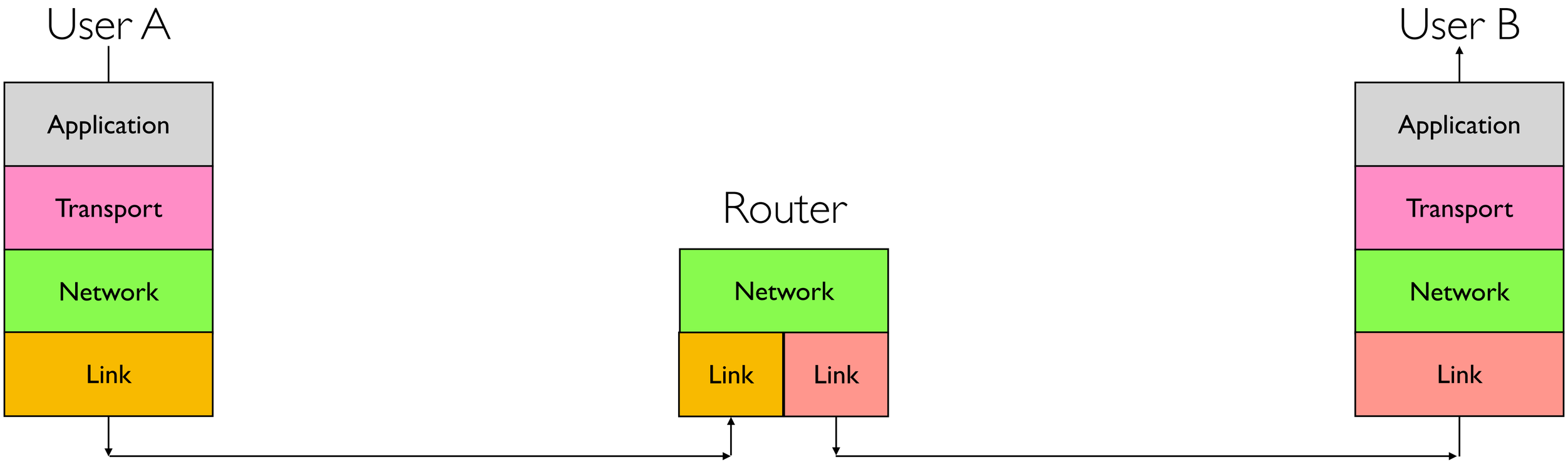

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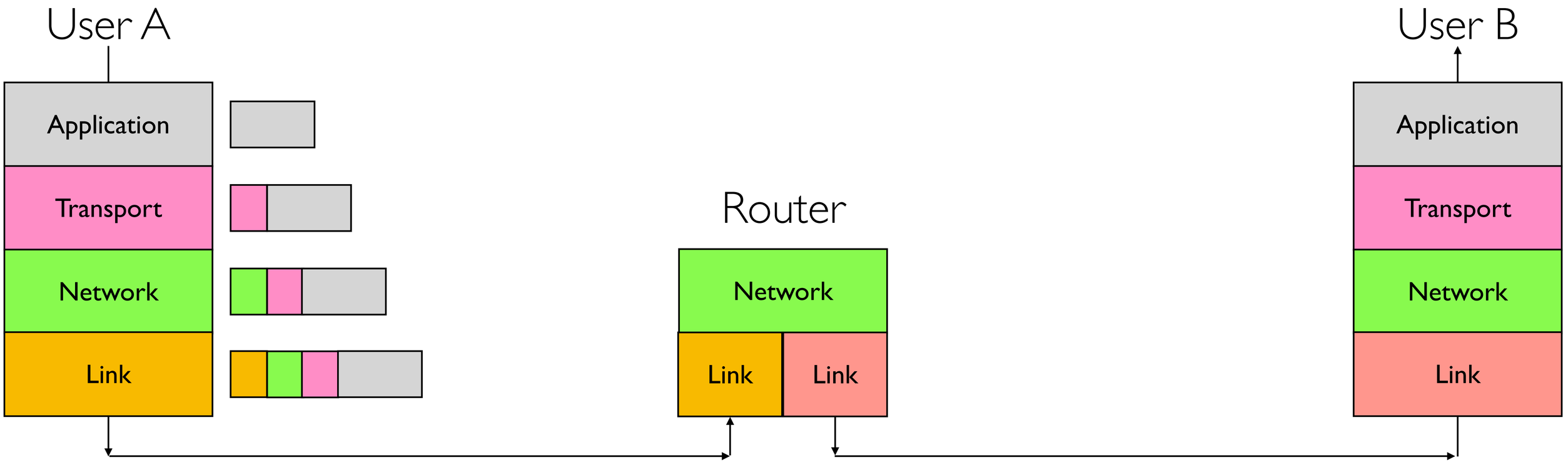

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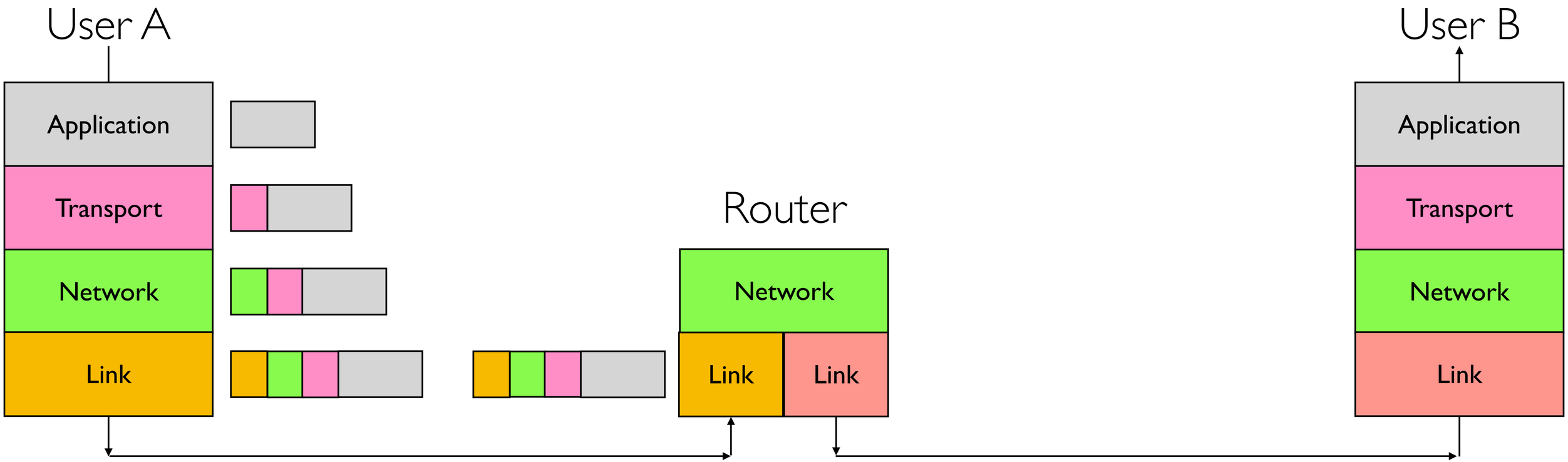

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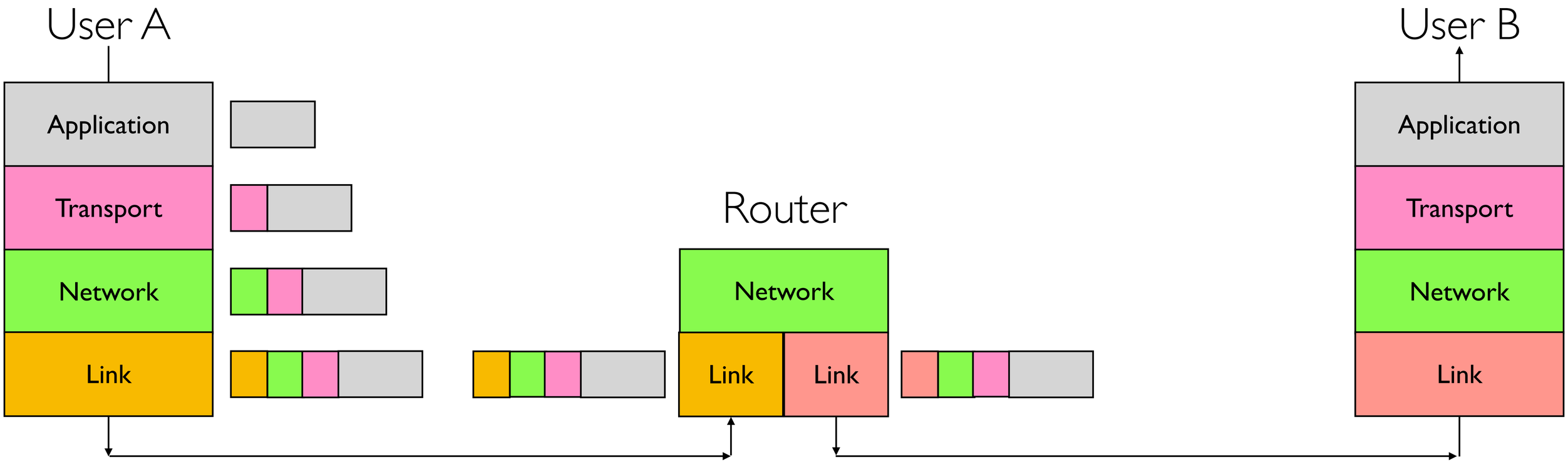

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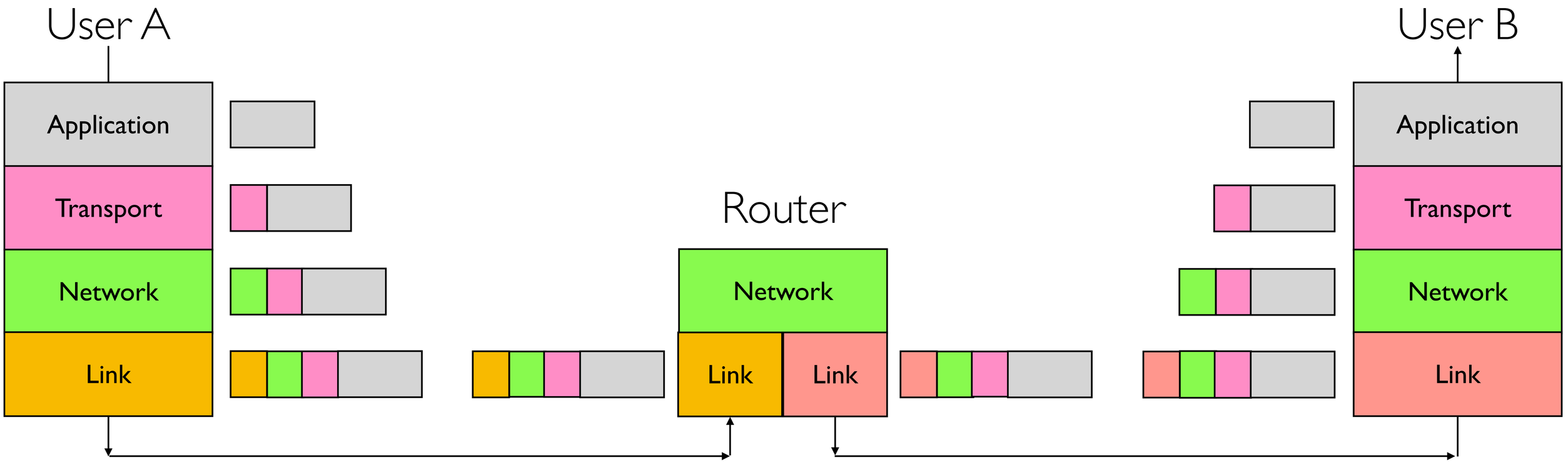

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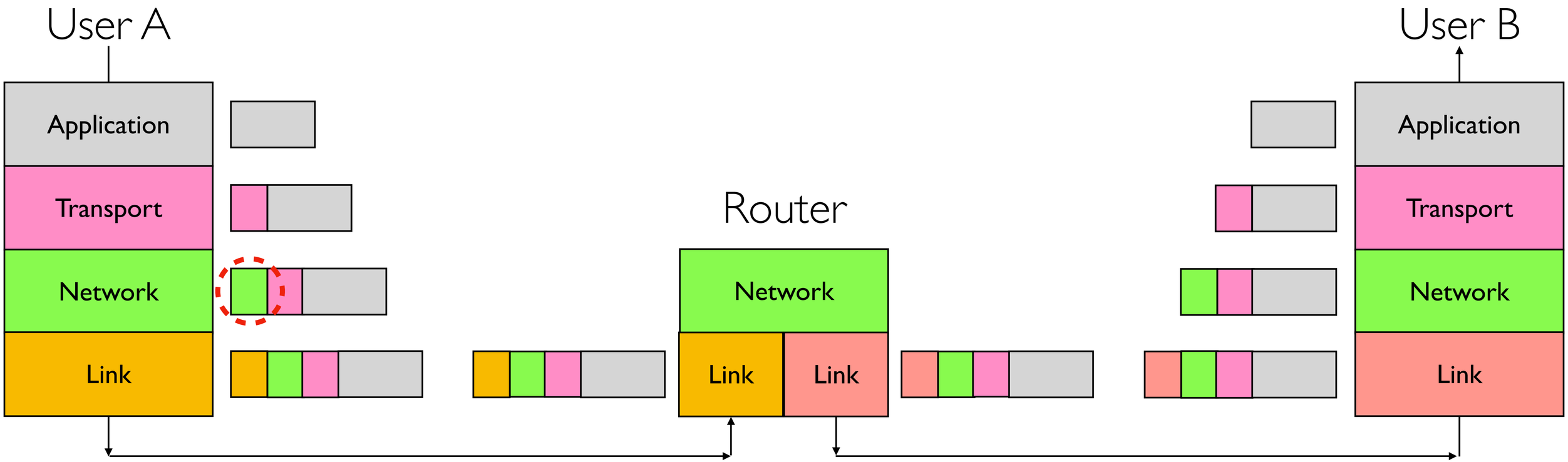

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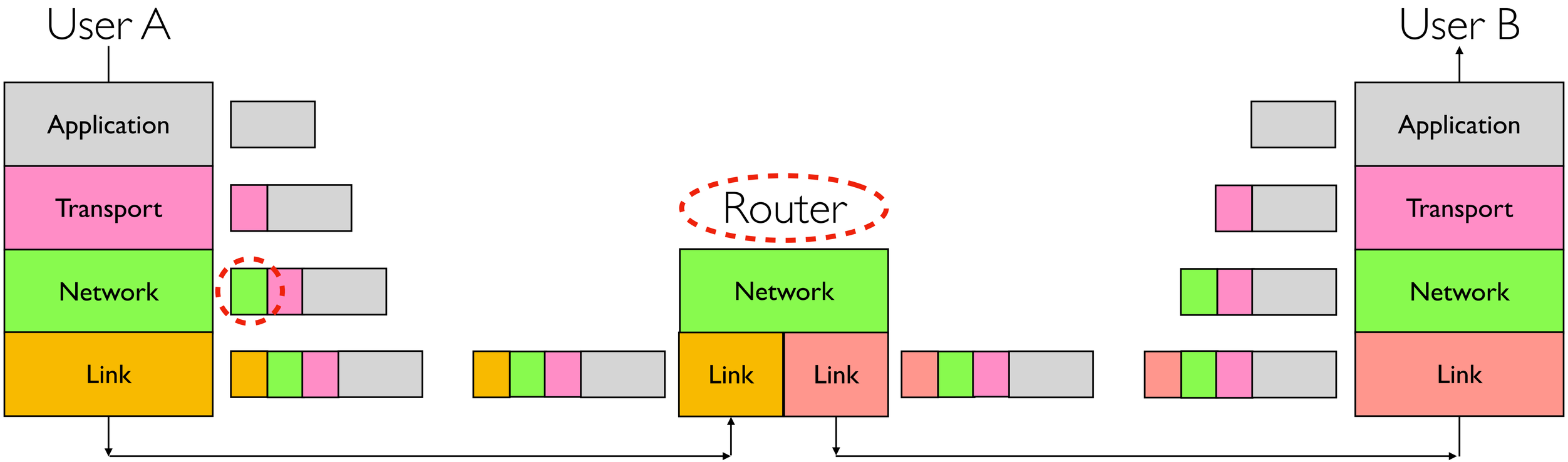

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- **IP packet contains a header and payload**
  - Payload is opaque to the network
  - Header is what we care about

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- **Header reflects information needed for basic tasks**

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  - Typically "5" (for a 20-byte IPv4 header)
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- **Total Length (16 bits)**
  - Number of bytes in the packet
  - Maximum size is 65536 (2^16 - 1)
  - … though underlying links may impose smaller limits

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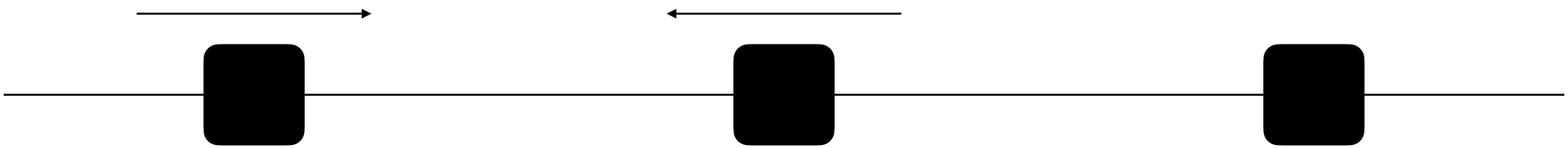

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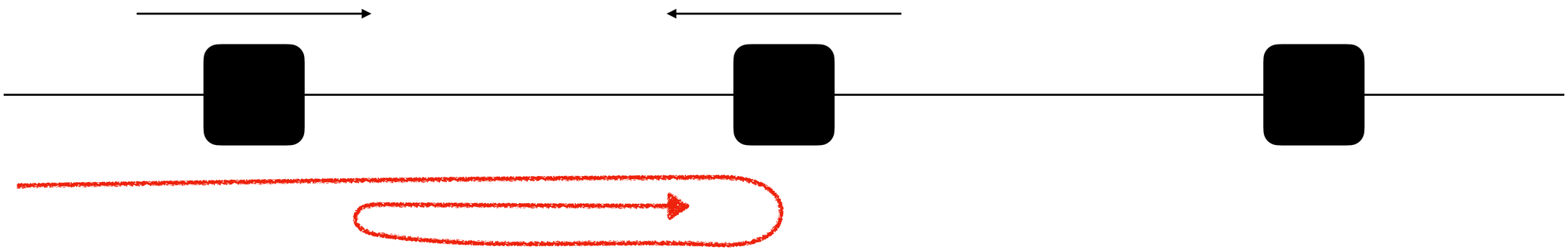

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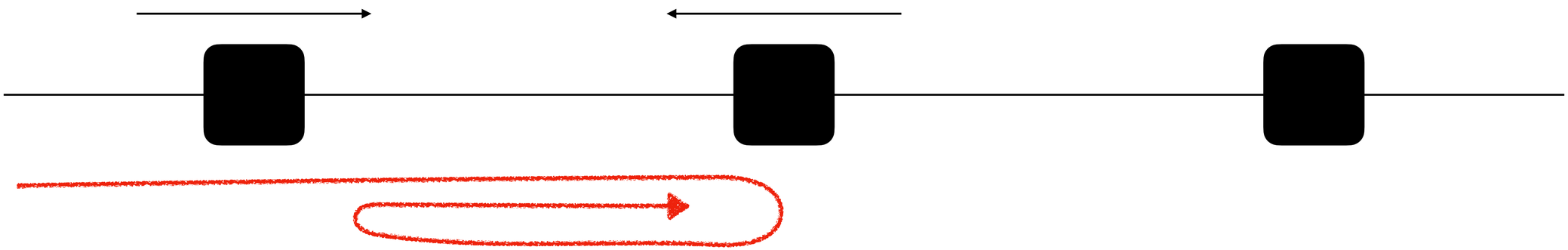

- **Time-To-Live (TTL) field (8 bits)**
  - Decremented at each hop, packet discarded if TTL reaches 0
  - … and "time exceeded" message sent to the source
    - *Basis for traceroute!*

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- **If not correct, router discards packet**
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- **Checksum recalculated at every router**
  - *Why?*
  - *Why only header?*

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- ***Will return to fragmentation shortly…***

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Special Handling

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- **"Type-of-Service" (ToS) (8 bits)**
  - Allow packets to be treated differently based on needs
    - e.g., low delay audio, high bandwidth data transfer, etc.
  - Has been redefined several times
  - Now called "Differentiated Services Code Point (DSCP)"
  - No general use…

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- **Examples of options**
  - Record route
  - Strict Source Route
  - Loose Source Route
  - …

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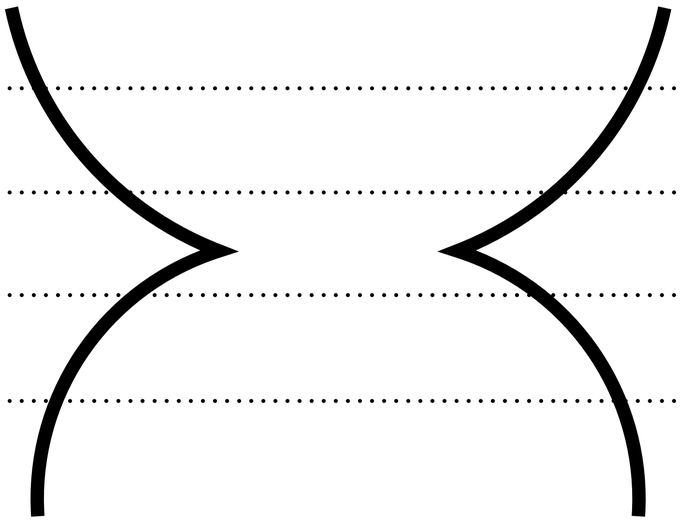

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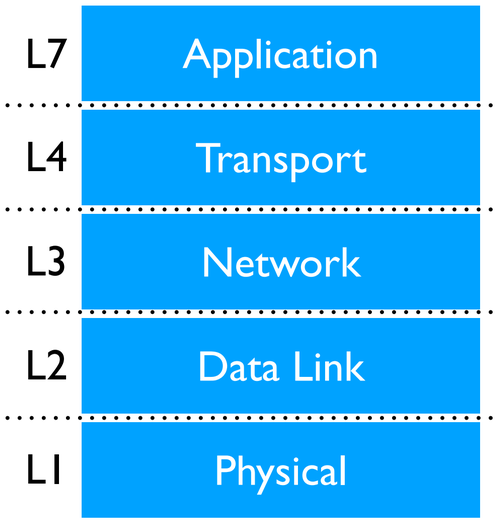

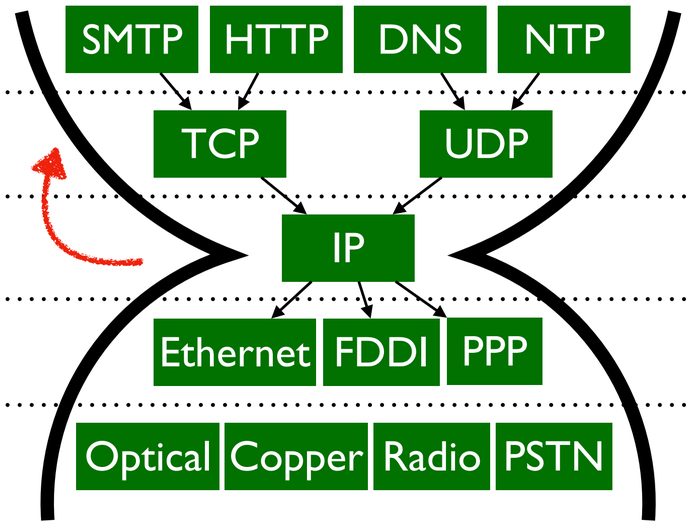

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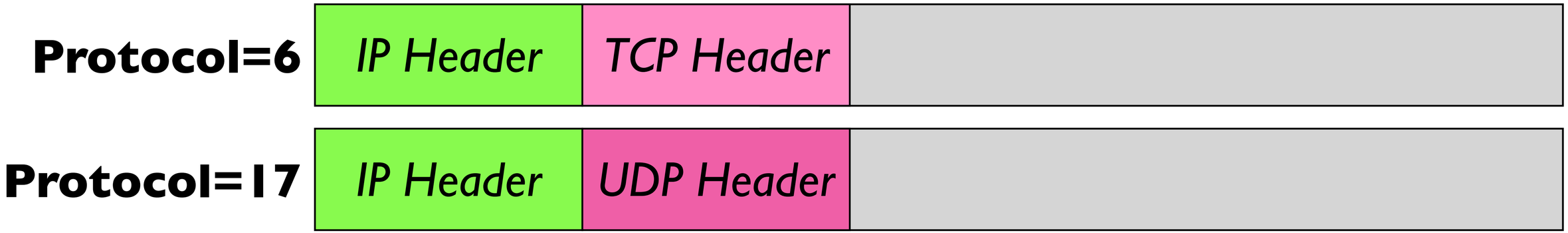

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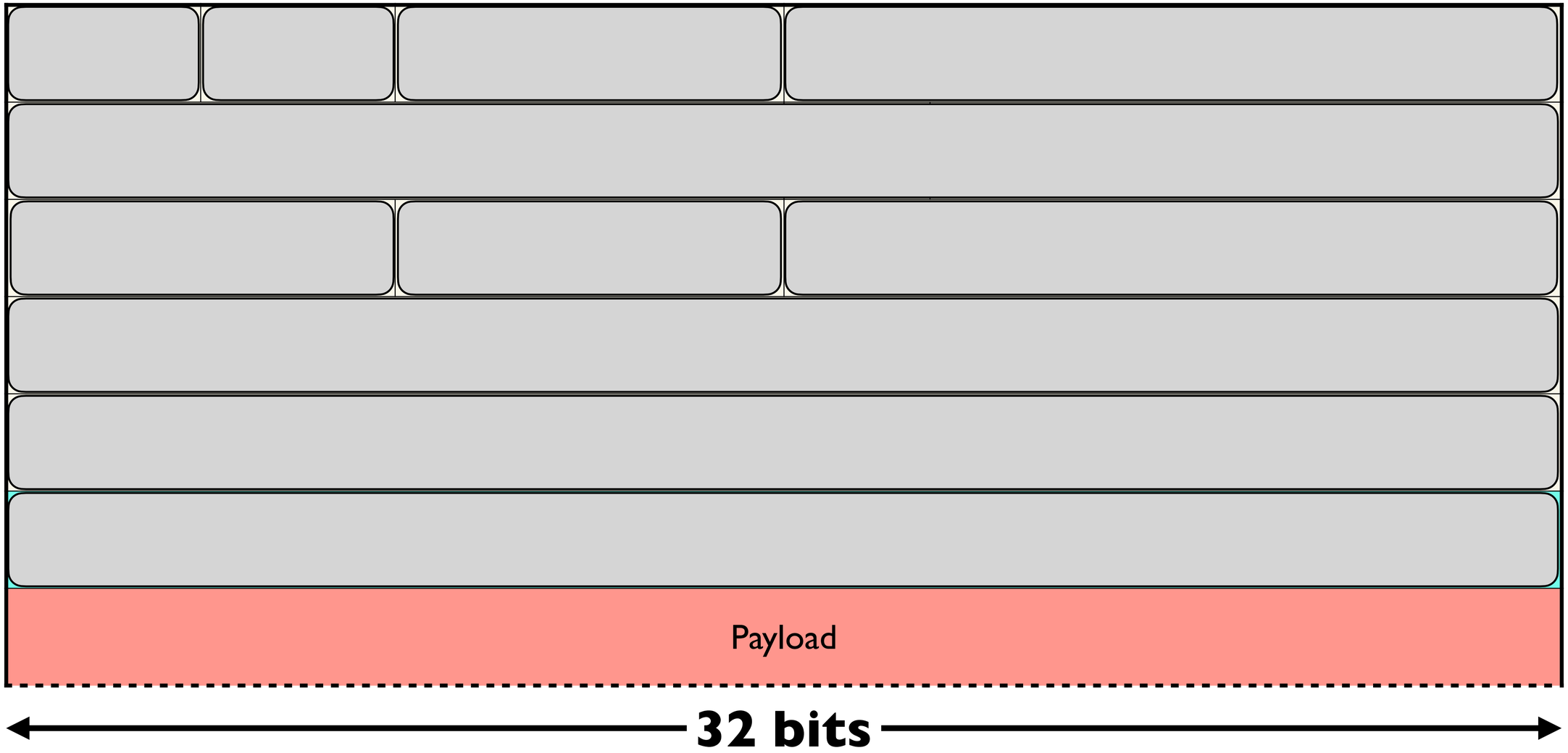

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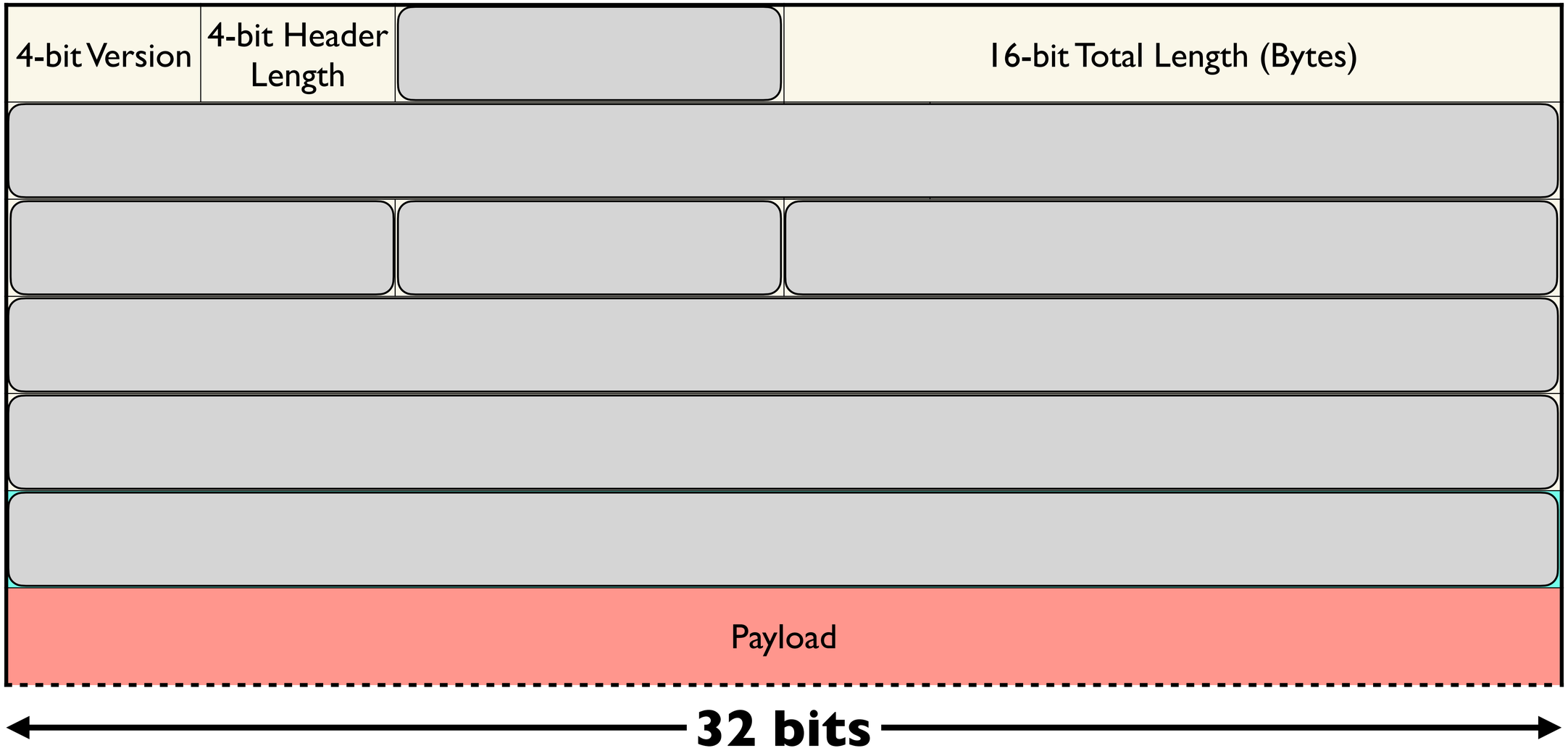

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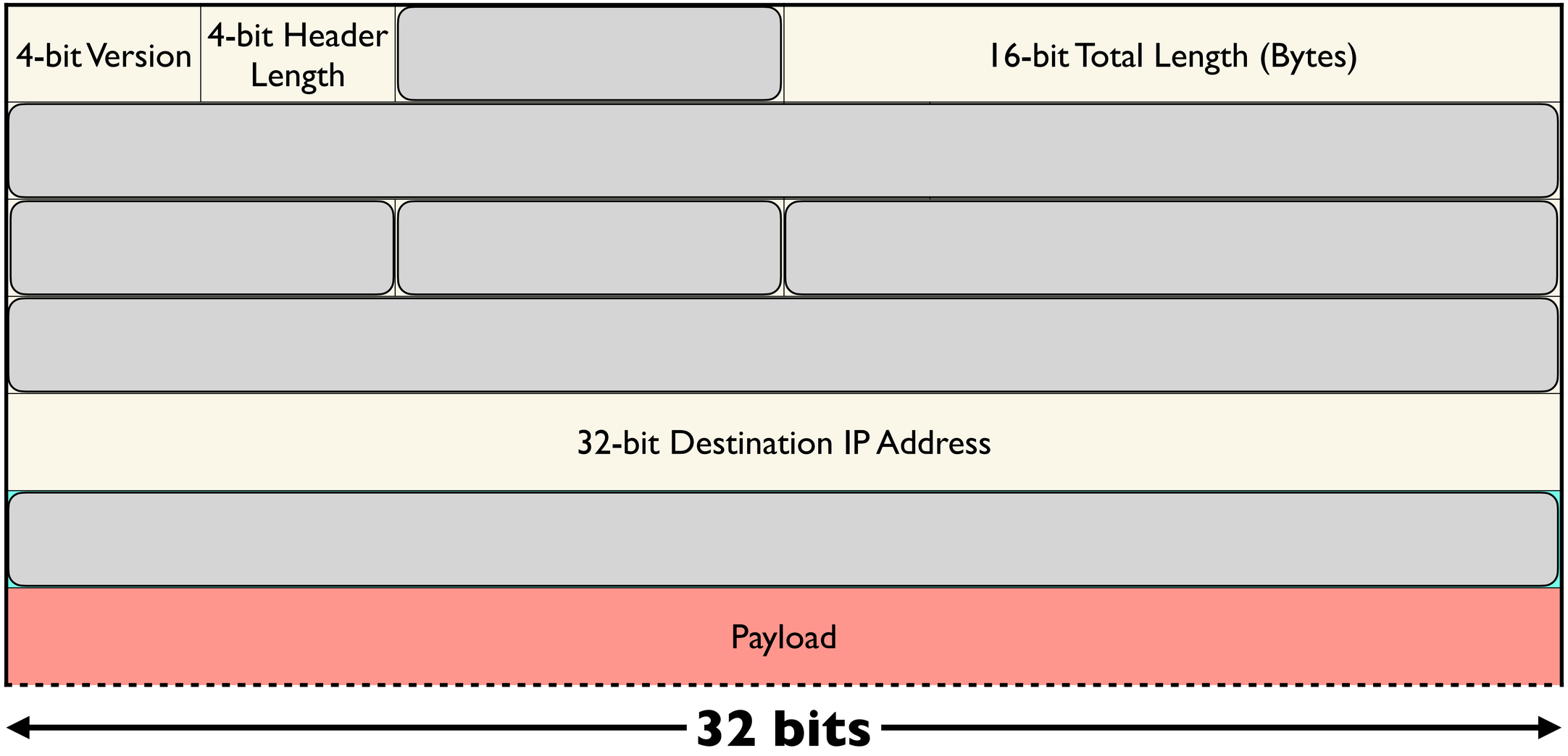

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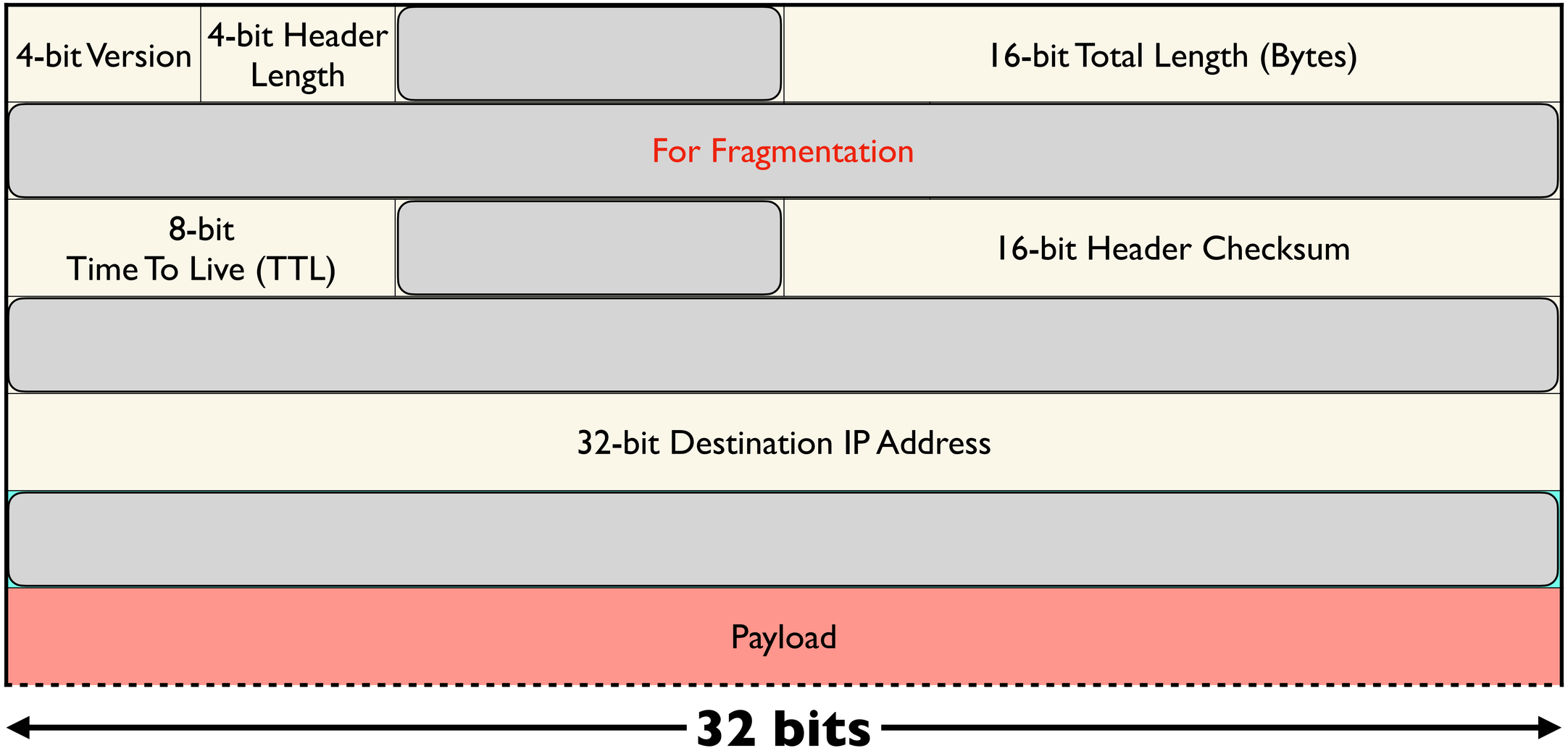

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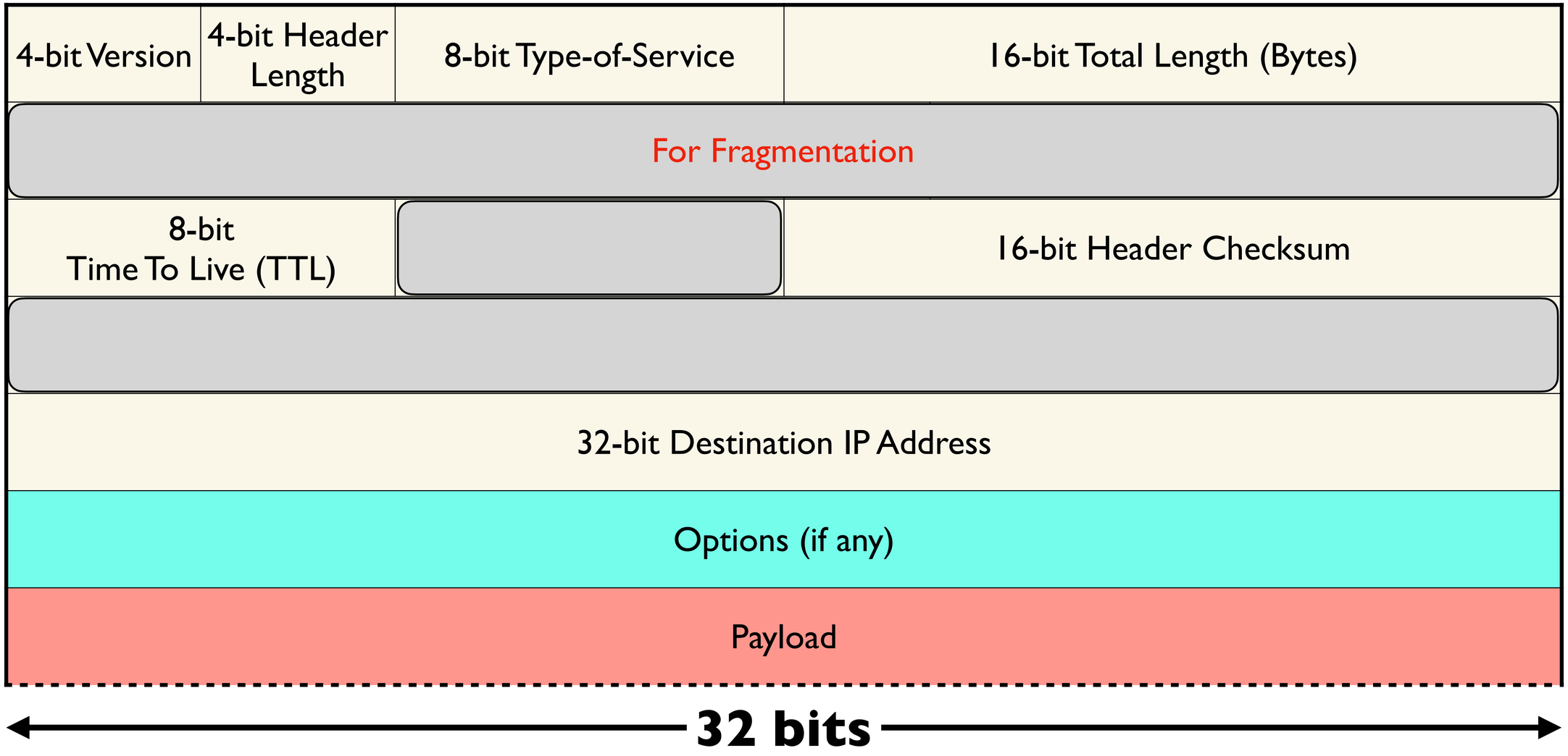

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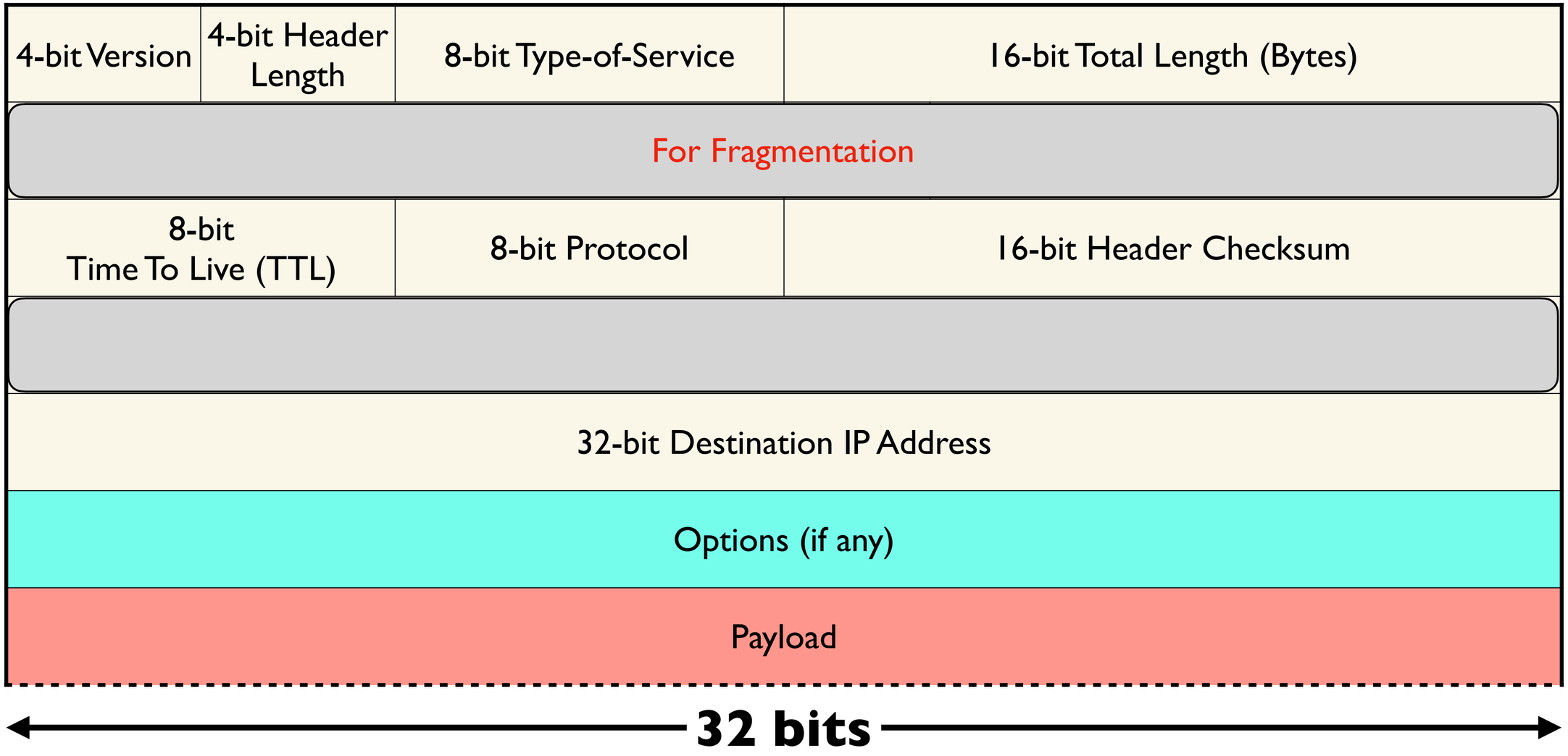

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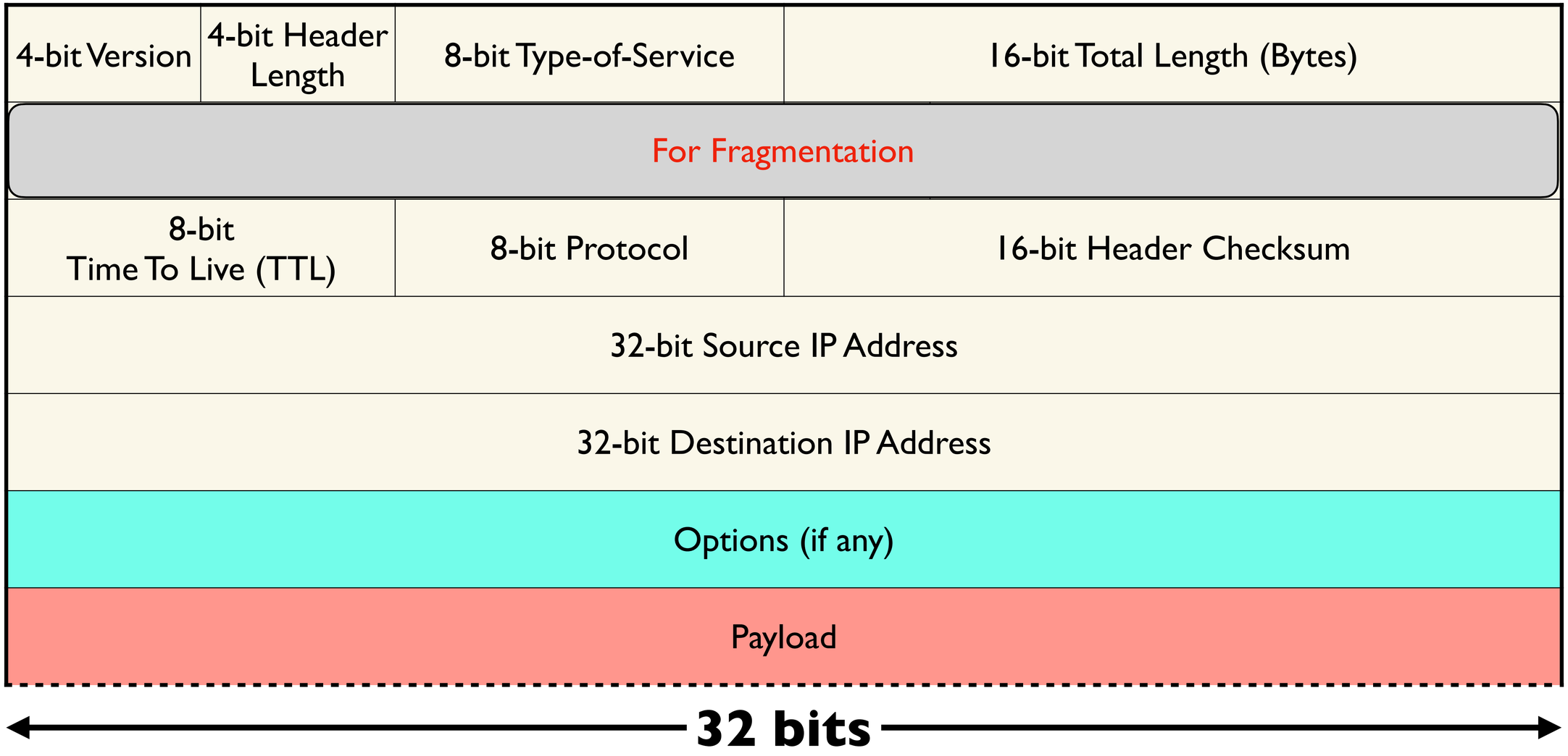

A Closer Look at Fragmentation

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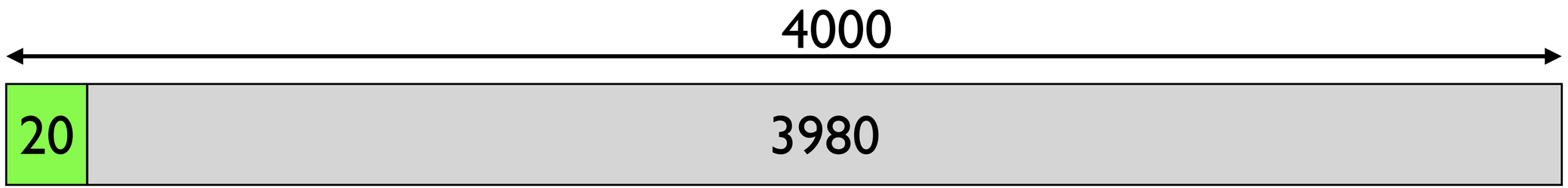

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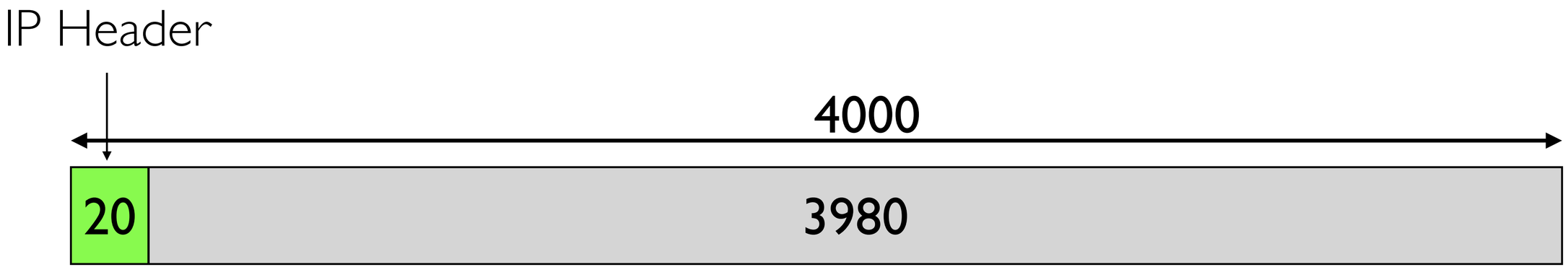

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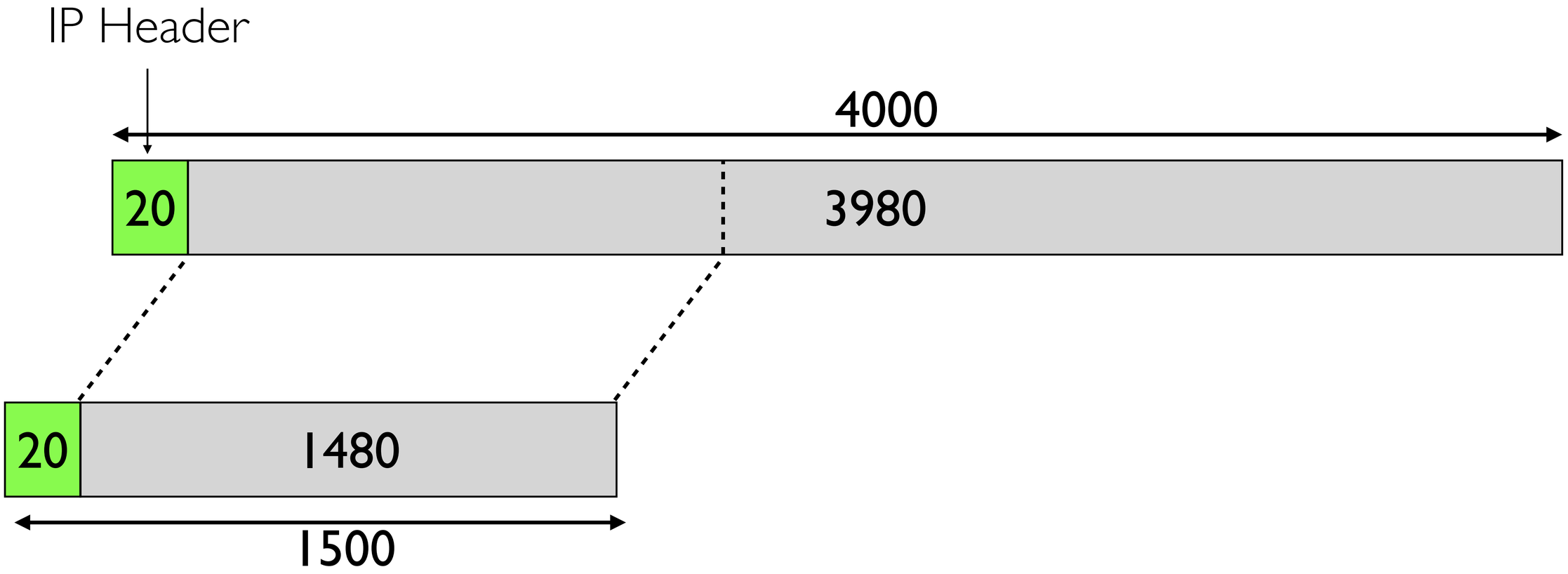

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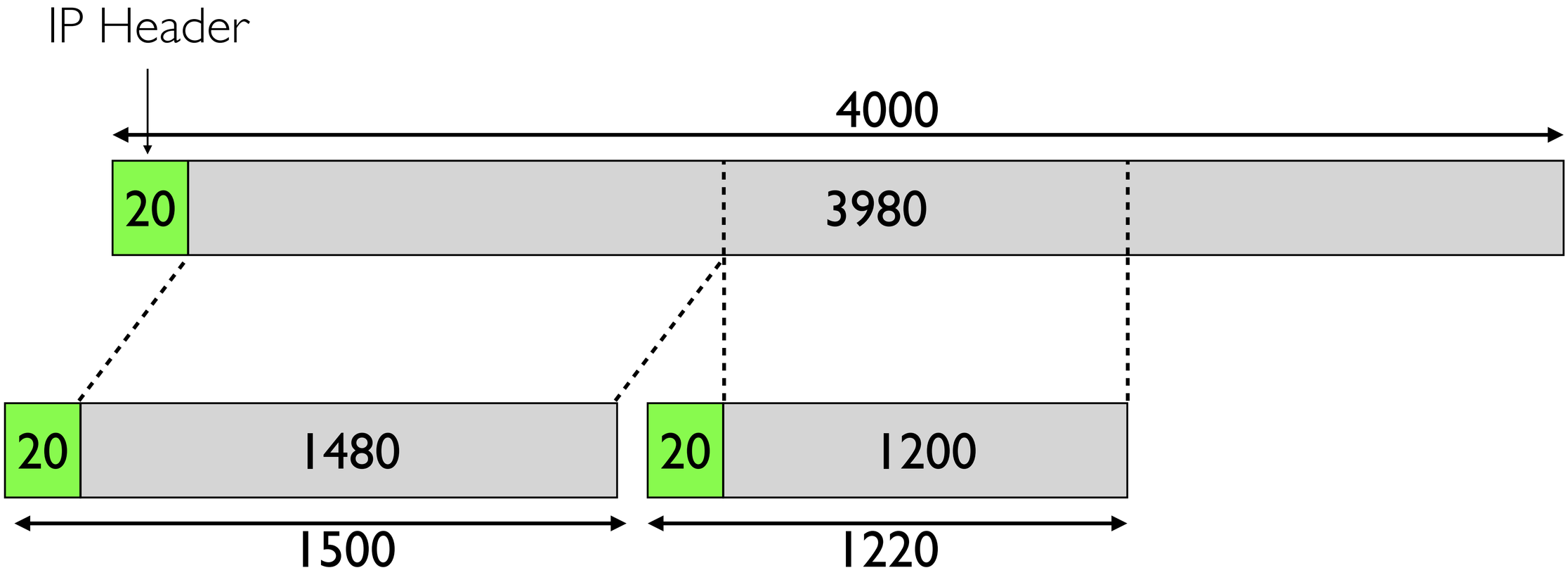

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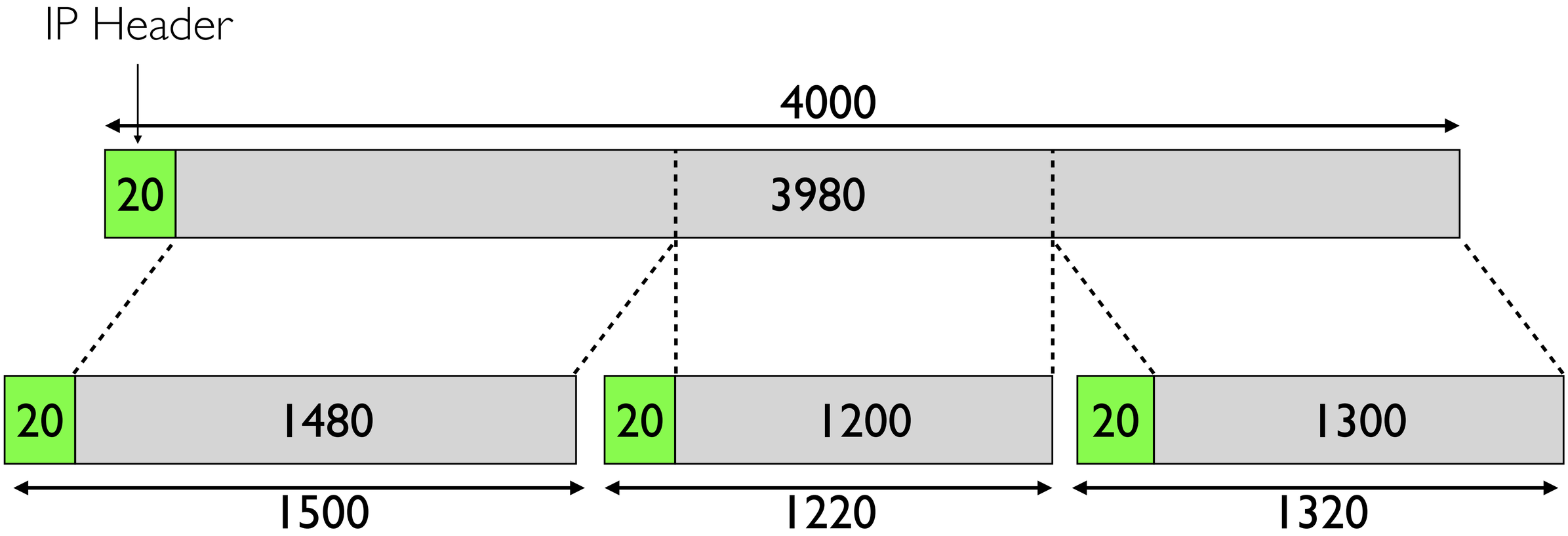

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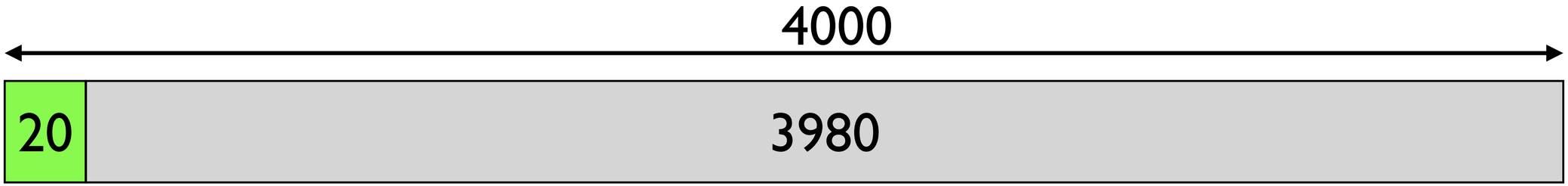

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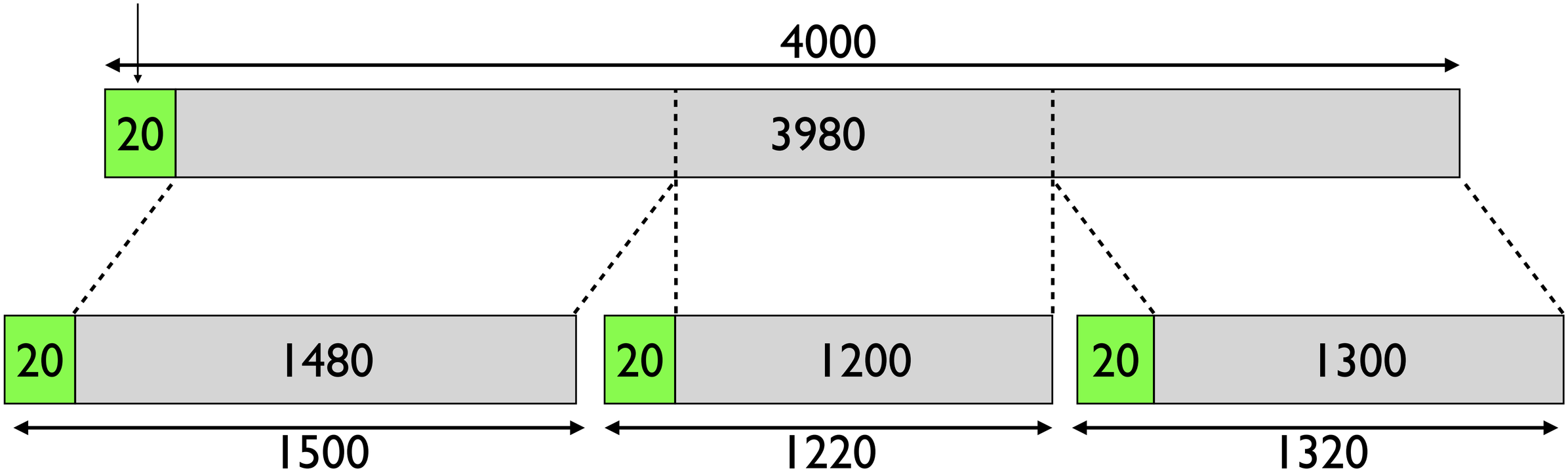

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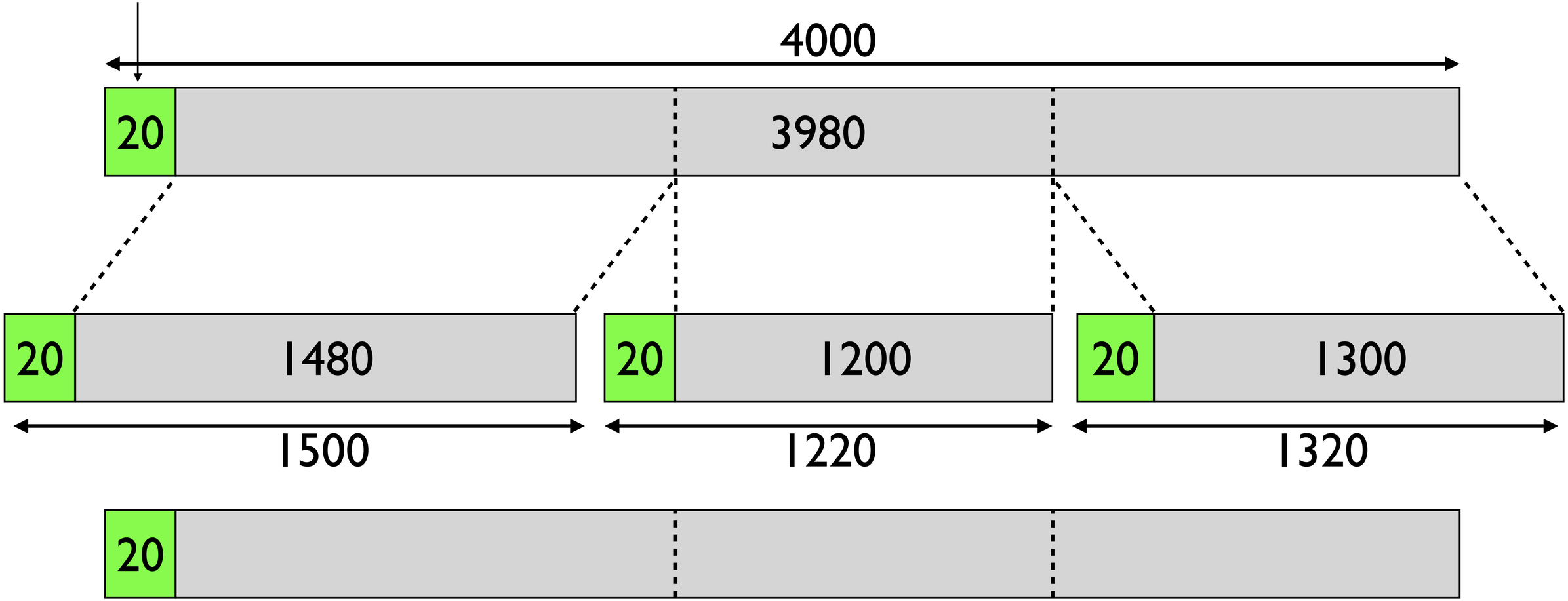

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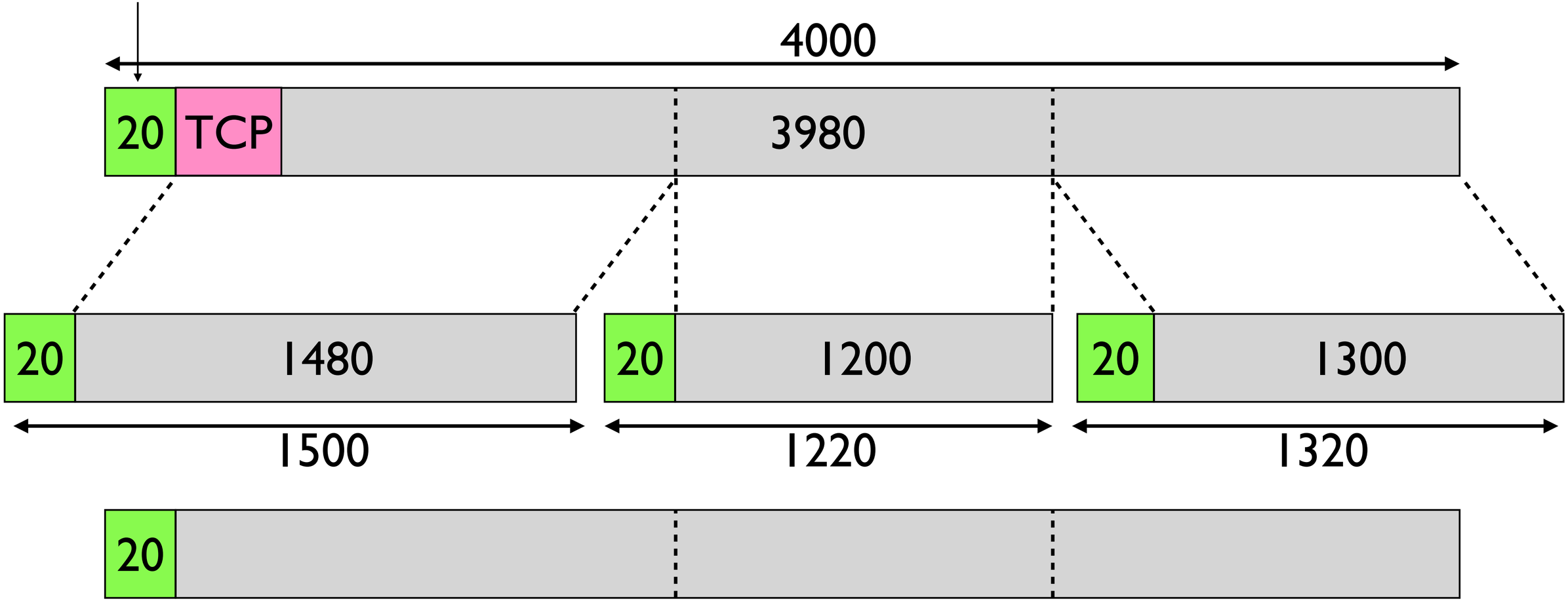

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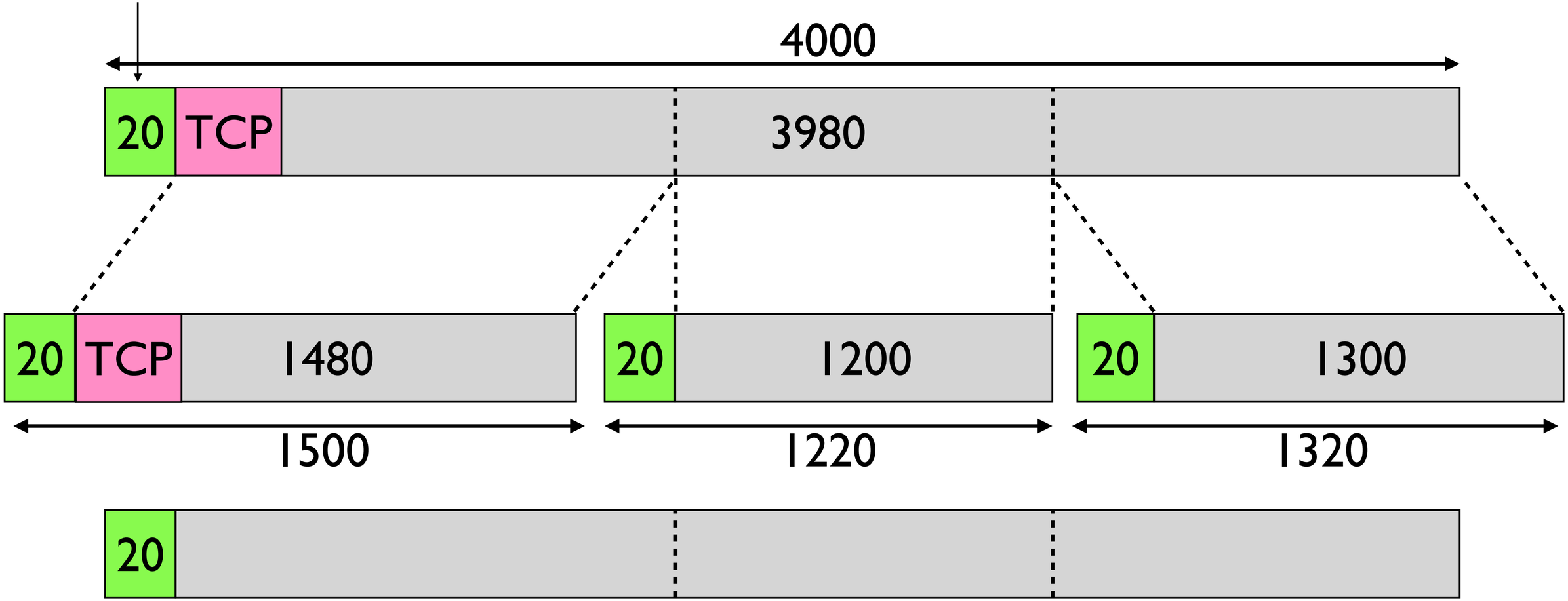

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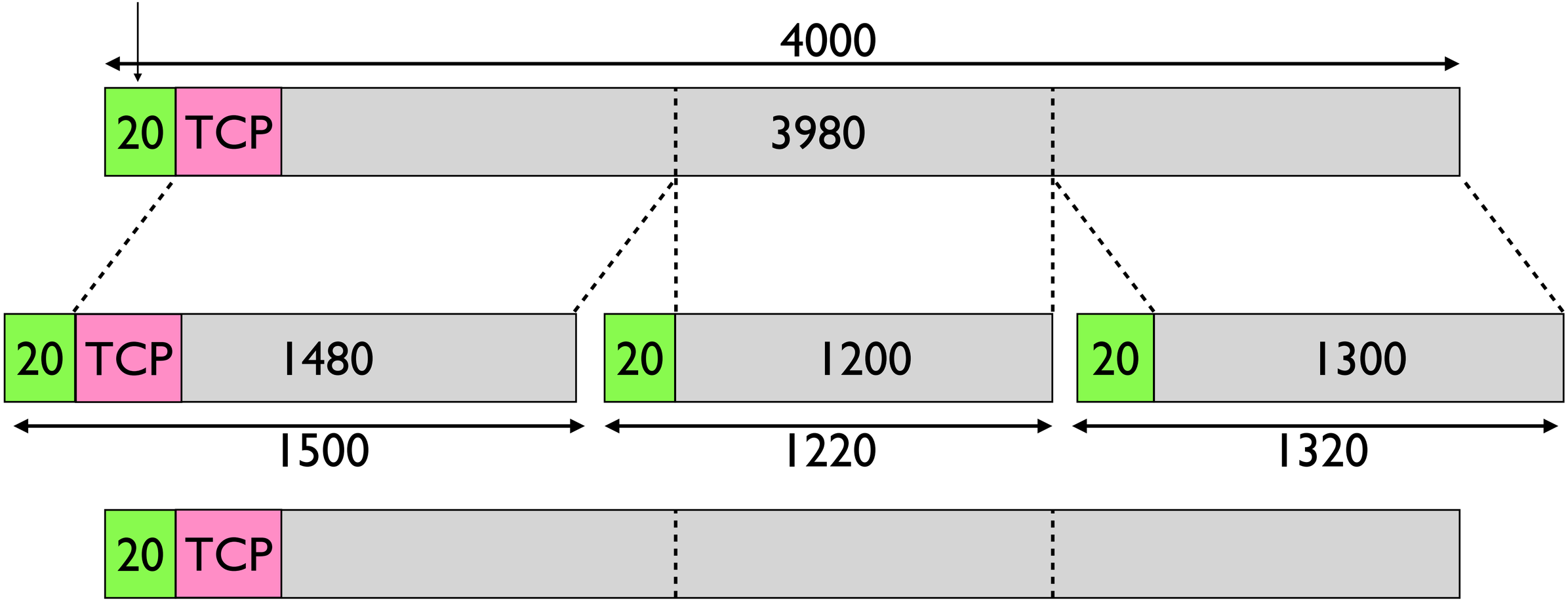

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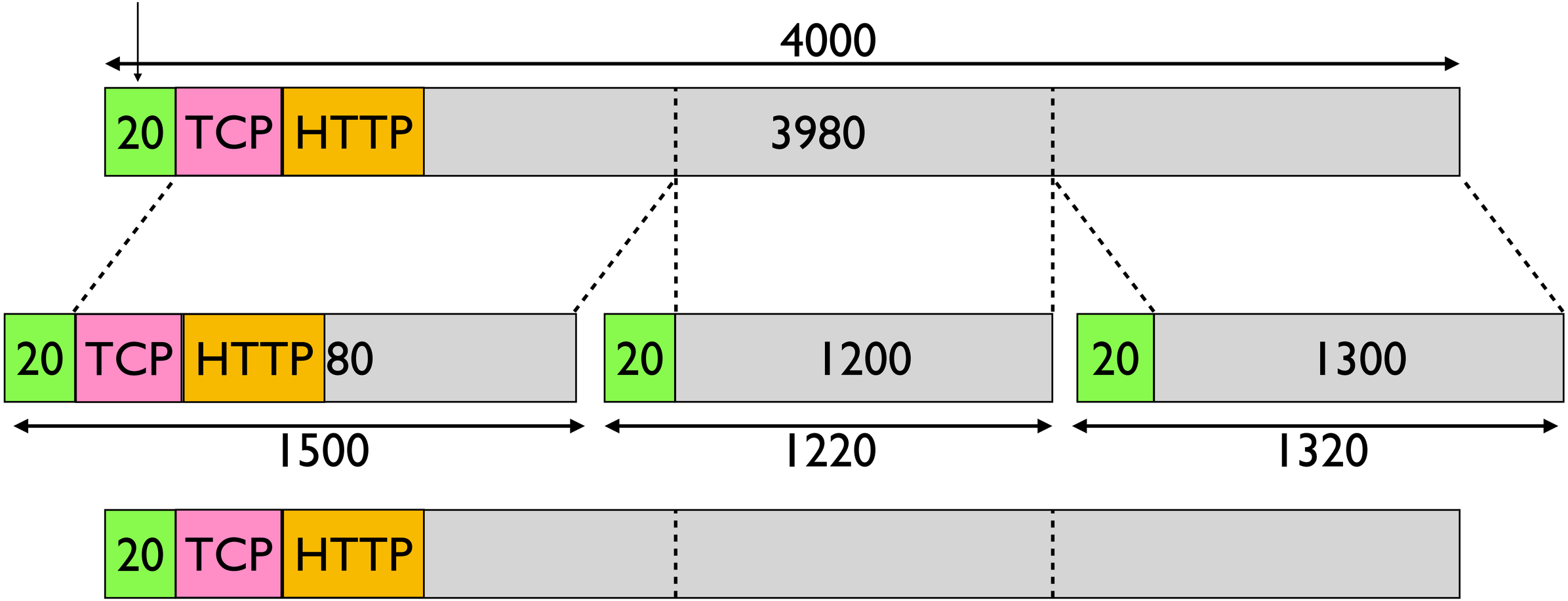

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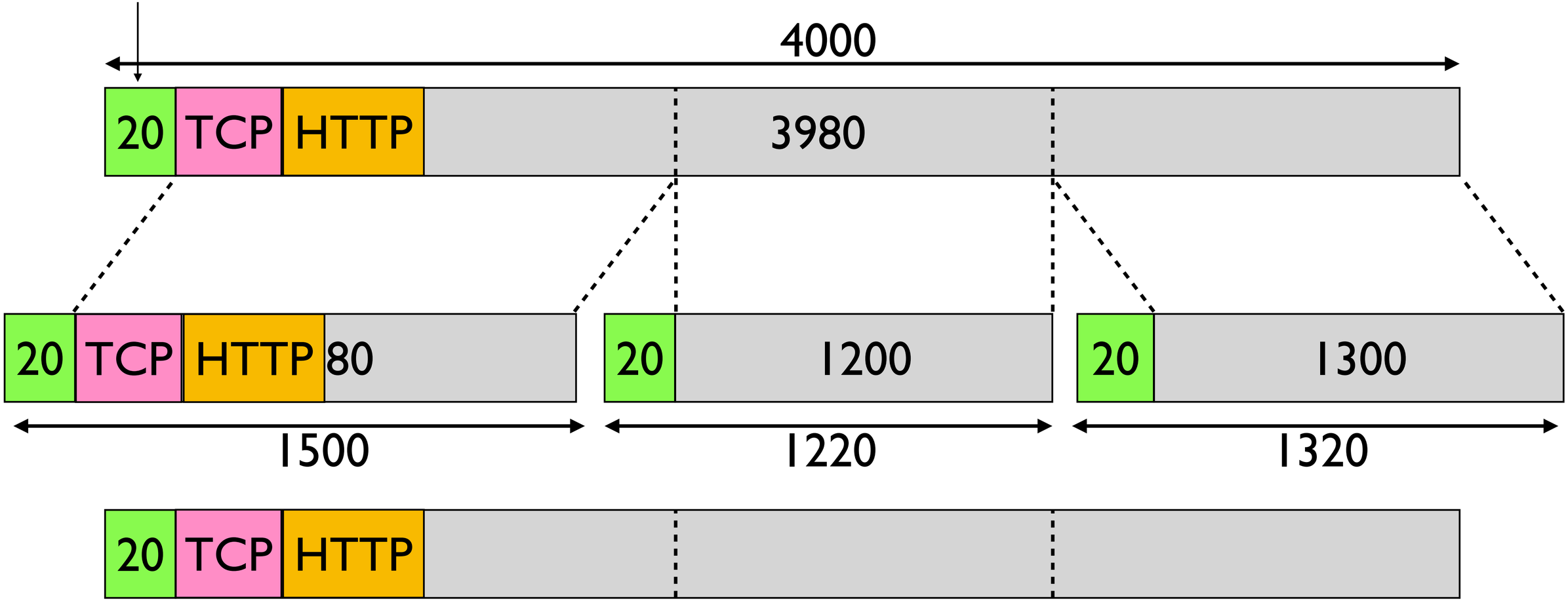

Must reassemble before sending the packet to higher layers!

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- **How to handle out-of-order or lost fragments?**
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  - Need a ***max sequence number*** or ***flag***

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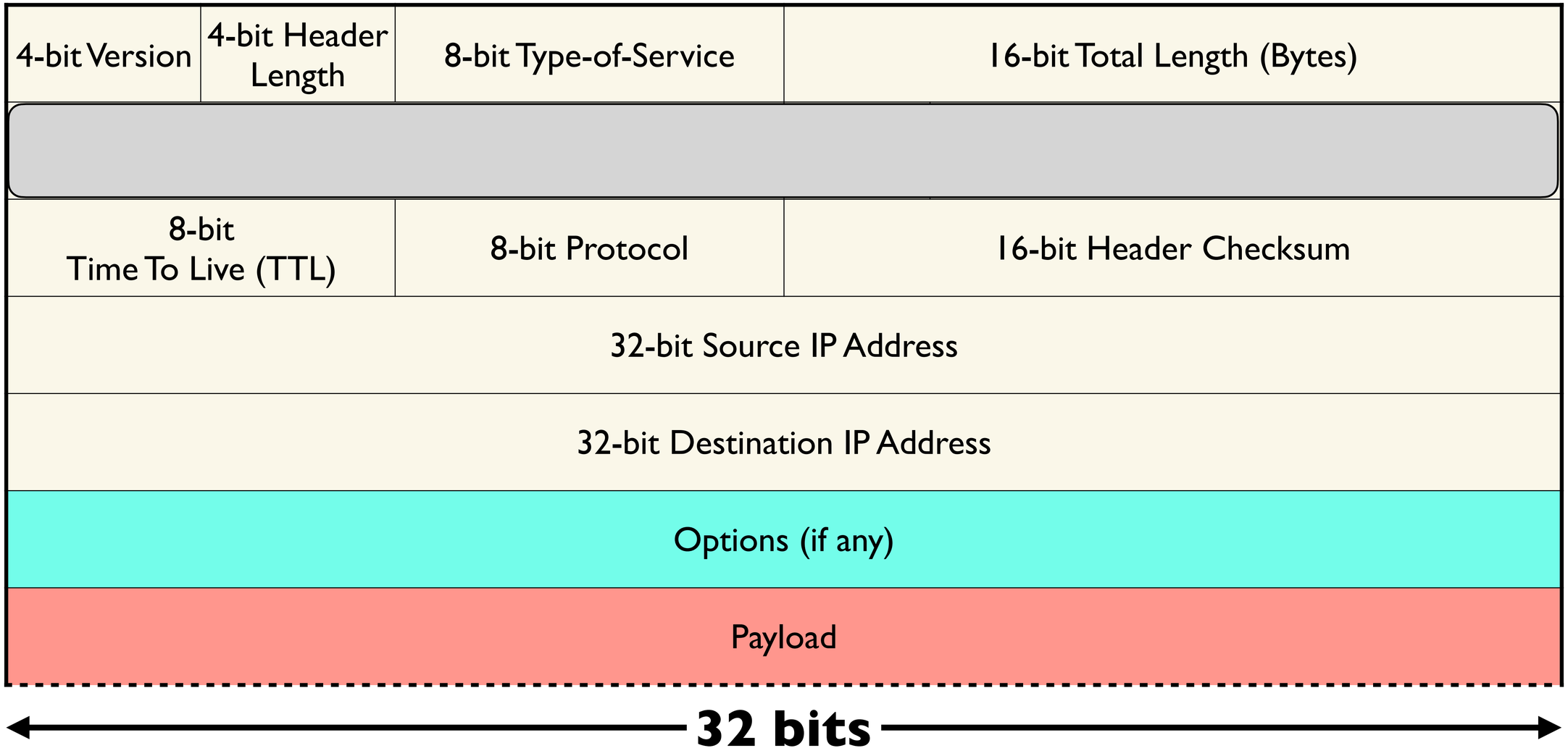
  - **R**eserved: ignore
  - **D**F: don't fragment
    - May trigger error message back to sender
  - **M**F: more fragments coming

IP Packet Structure



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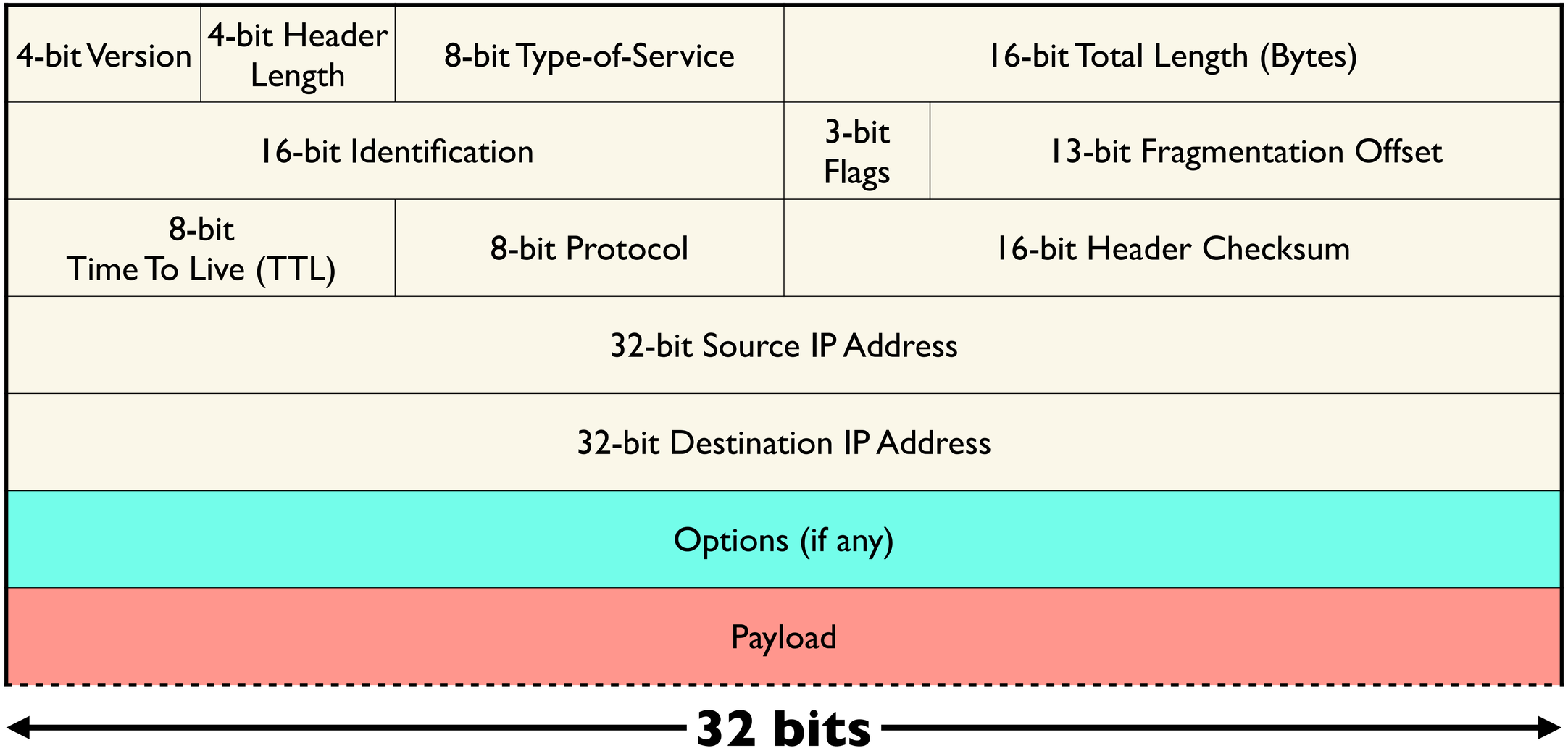

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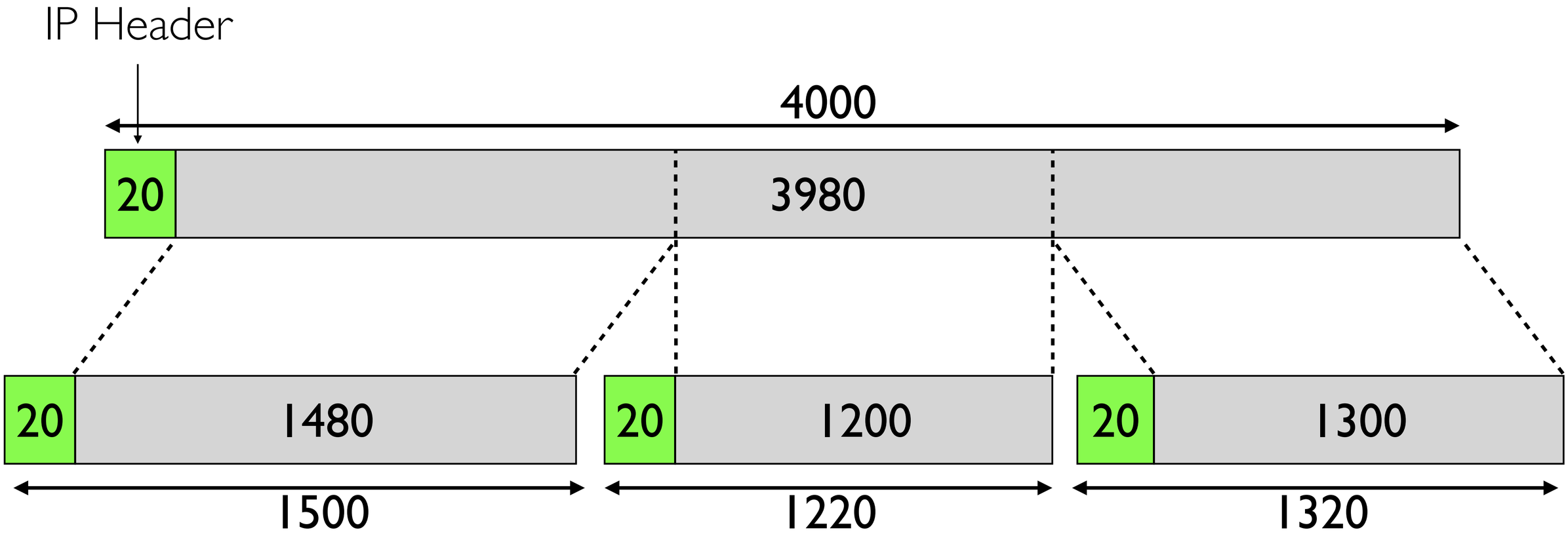

Example of Fragmentation (Contd.)

- **4000B packet from host 1.2.3.4 to 5.6.7.8 traverses link with MTU 1500B**

Version 4	Header Length 5	Type-of-Service 0	Total Length (Bytes): 4000	
Identification: 56273			R/D/M 0/0/0	Fragmentation Offset: 0
Time To Live (TTL) 127		Protocol 6	Checksum: 44019	
Source IP Address: 1.2.3.4				
Destination IP Address: 5.6.7.8				

Example of Fragmentation (Contd.)

- **Possible first piece:**

<table>
<tr><td>Version
4</td><td>Header Length
5</td><td>Type-of-Service
0</td><td colspan="2">Total Length (Bytes): 1500</td></tr>
<tr><td colspan="3">Identification: 56273</td><td>R/D/M
0/0/1</td><td>Fragmentation Offset: 0</td></tr>
<tr><td colspan="2">Time To Live (TTL)
127</td><td>Protocol
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Example of Fragmentation (Contd.)

- **Possible second piece (Fragment#1 covered 1480 bytes)**

Version 4	Header Length 5	Type-of-Service 0	Total Length (Bytes): 1220	
Identification: 56273			R/D/M 0/0/1	Fragmentation Offset: 185 (185 * 8 = 1480)
Time To Live (TTL) 127		Protocol 6	Checksum: yyy	
Source IP Address: 1.2.3.4				
Destination IP Address: 5.6.7.8				

Example of Fragmentation (Contd.)

- **Possible third piece (Fragment#1&2 covered 1480+1200=2680 bytes)**

<table>
<tr><td>Version
4</td><td>Header Length
5</td><td>Type-of-Service
0</td><td colspan="2">Total Length (Bytes): 1320</td></tr>
<tr><td colspan="3">Identification: 56273</td><td>R/D/M
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(335 * 8 = 2680)</td></tr>
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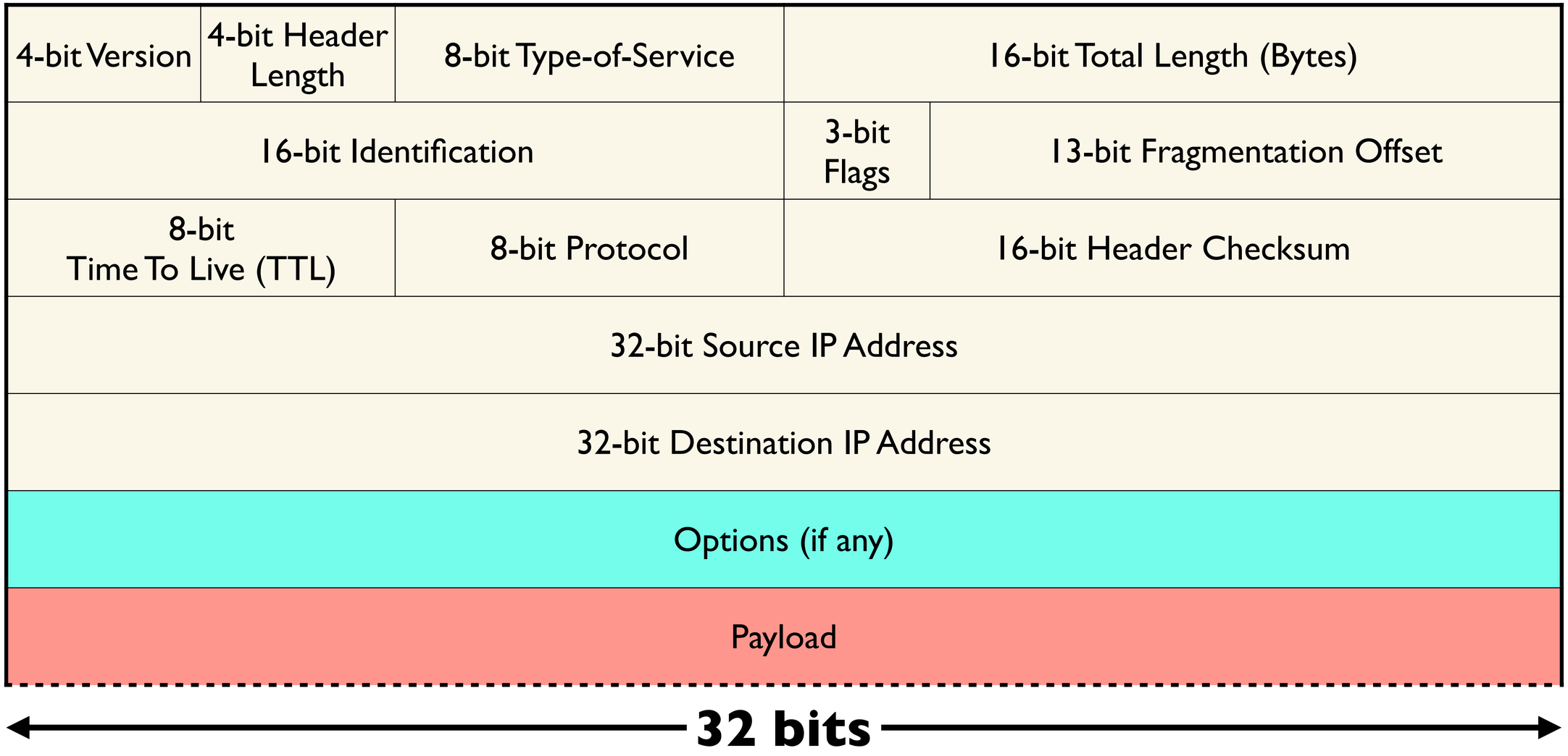
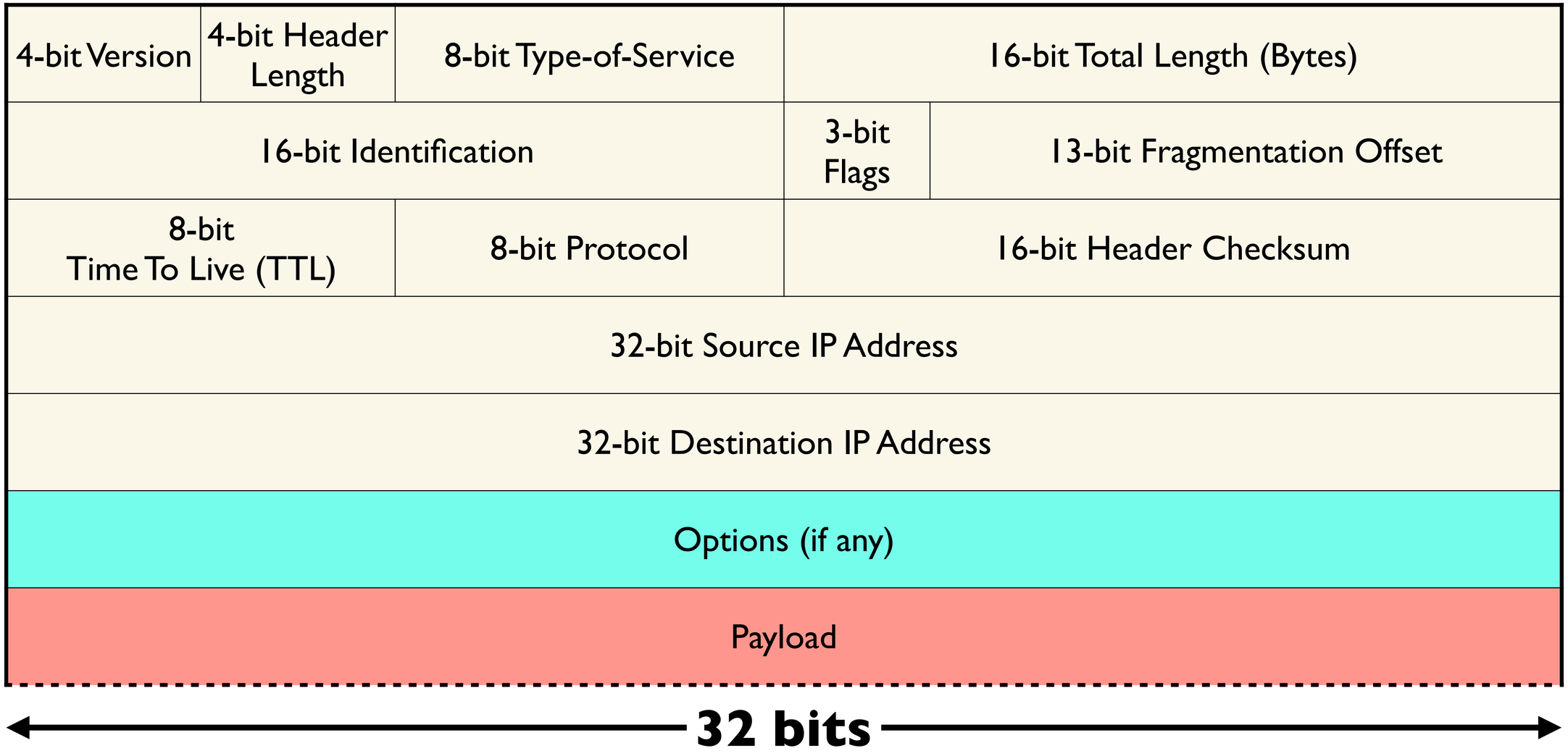


Quick Security Analysis of IP Header

IP Packet Structure



IP Address Integrity

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- **Source address should be the sending host**
  - … but who's checking?
  - You could send packets with any source you want…
  - Why is checking hard?

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- **Or: as a way to bother the spoofed host**
  - Spoofed host is wrongly blamed
  - Spoofed host may receive return traffic from the receiver

More Security Implications

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- **IP Options**
  - Misuse: e.g., **Source Route** lets sender control path taken through network - say sidestep security monitoring
  - IP options often processed in router's *slow path:* attacker can try to overload routers
  - Firewalls often configured to **drop** packets with options

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- **Monitor must remember previous fragments**
  - But that costs **state**, which is another vector of attack

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Let’s take a quick look at the IPv6 header…

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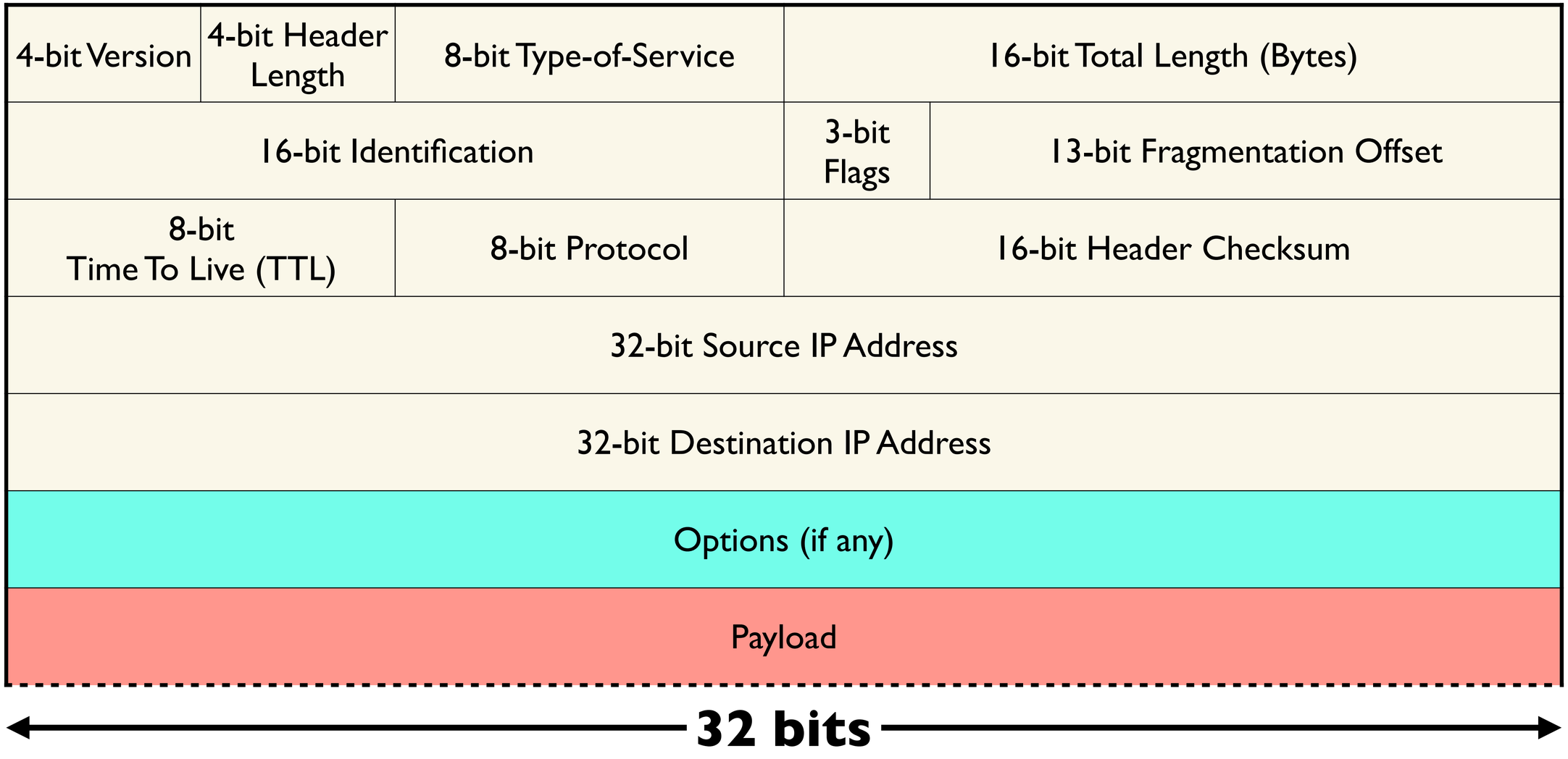
- **Result is an elegant, if unambitious, protocol**

What "clean up" would you do?



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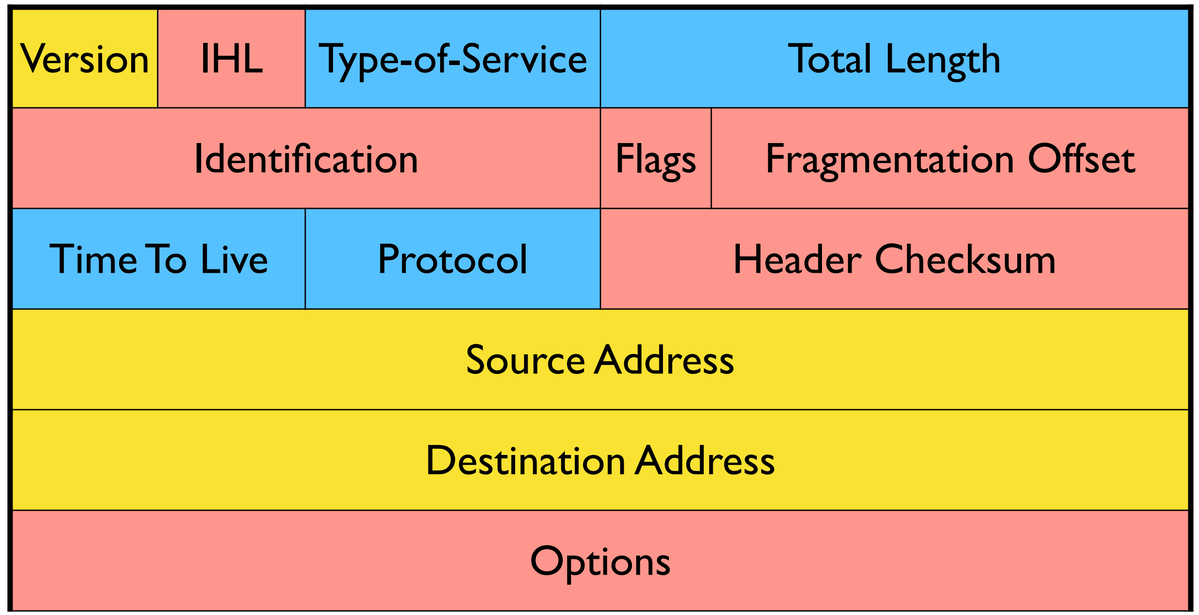
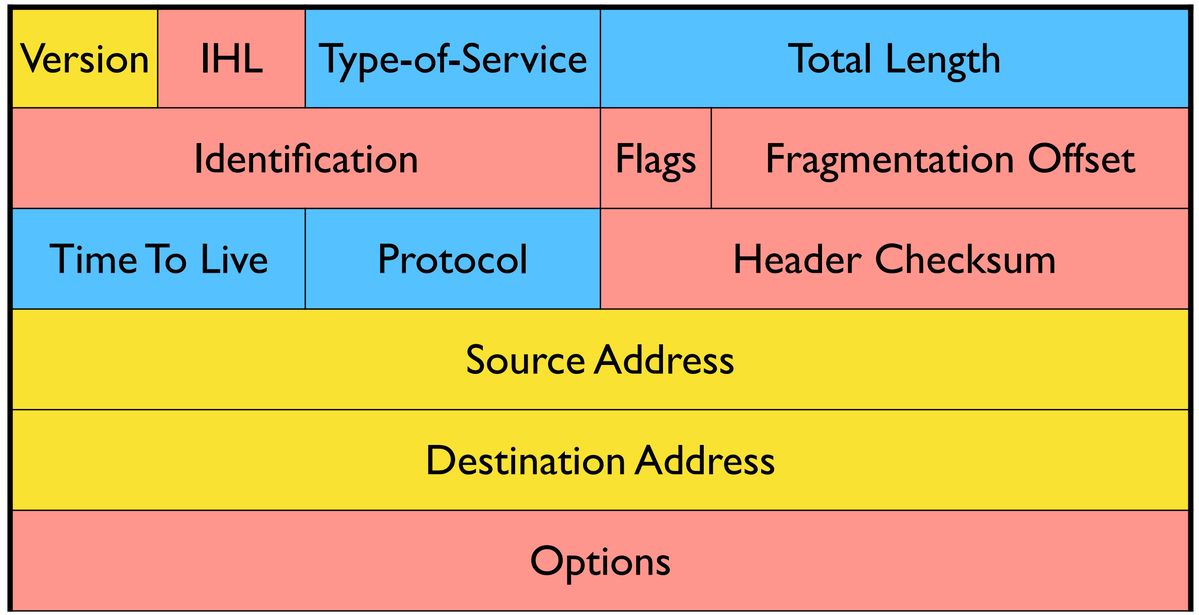
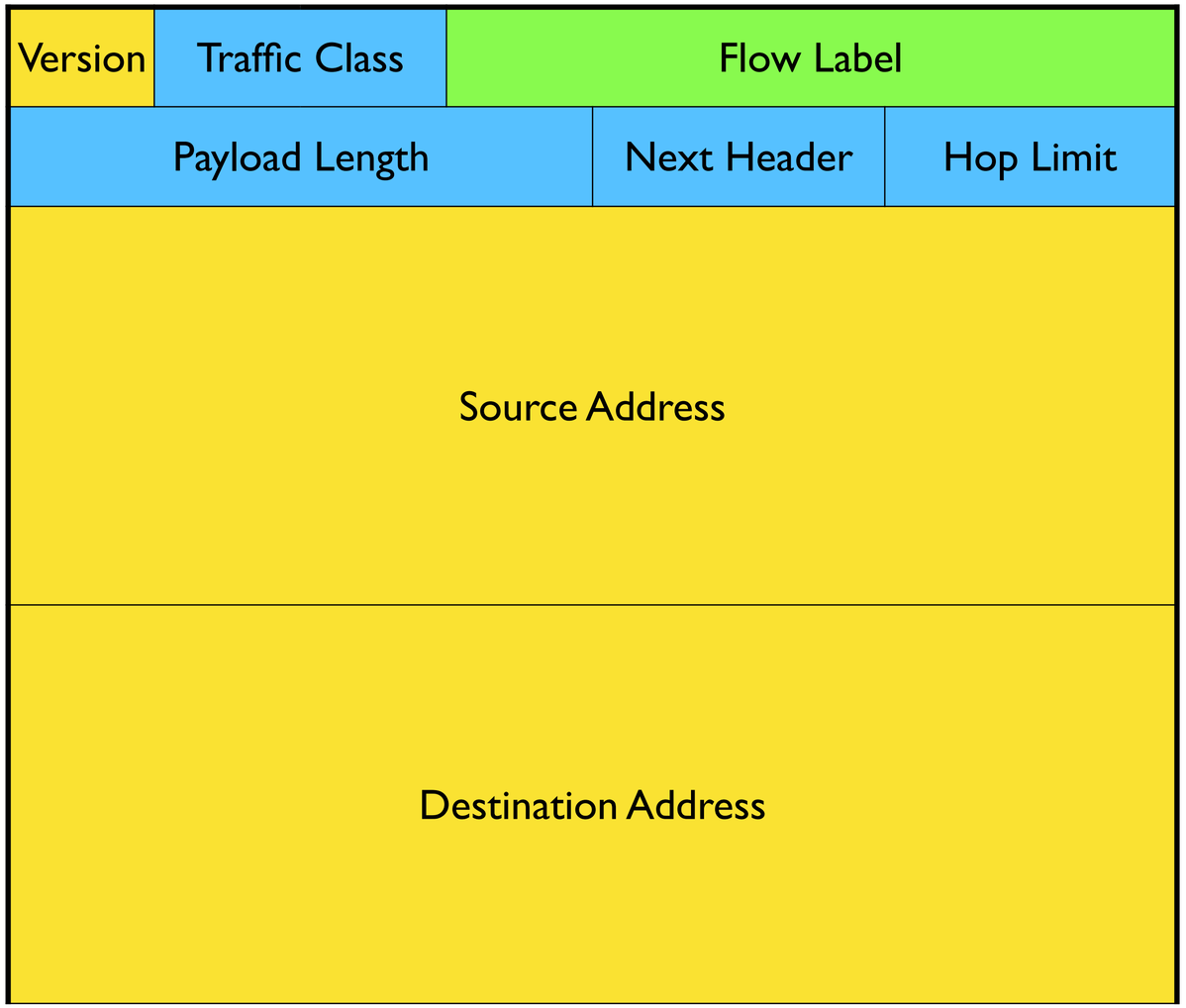


IPv4 and IPv6 Header Comparison





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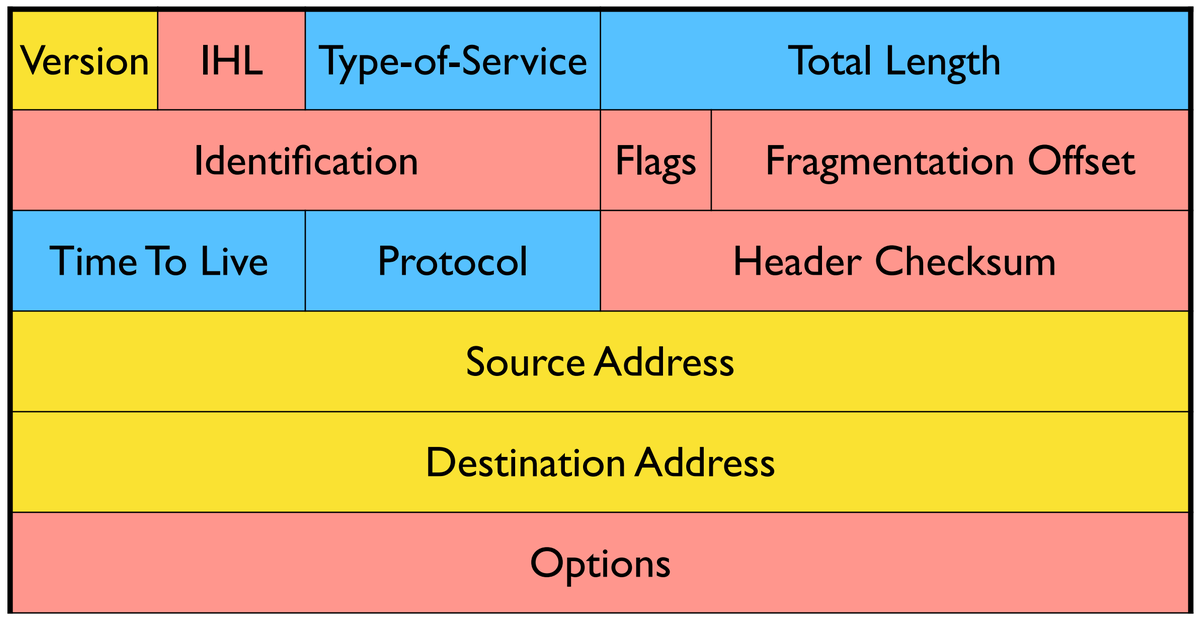

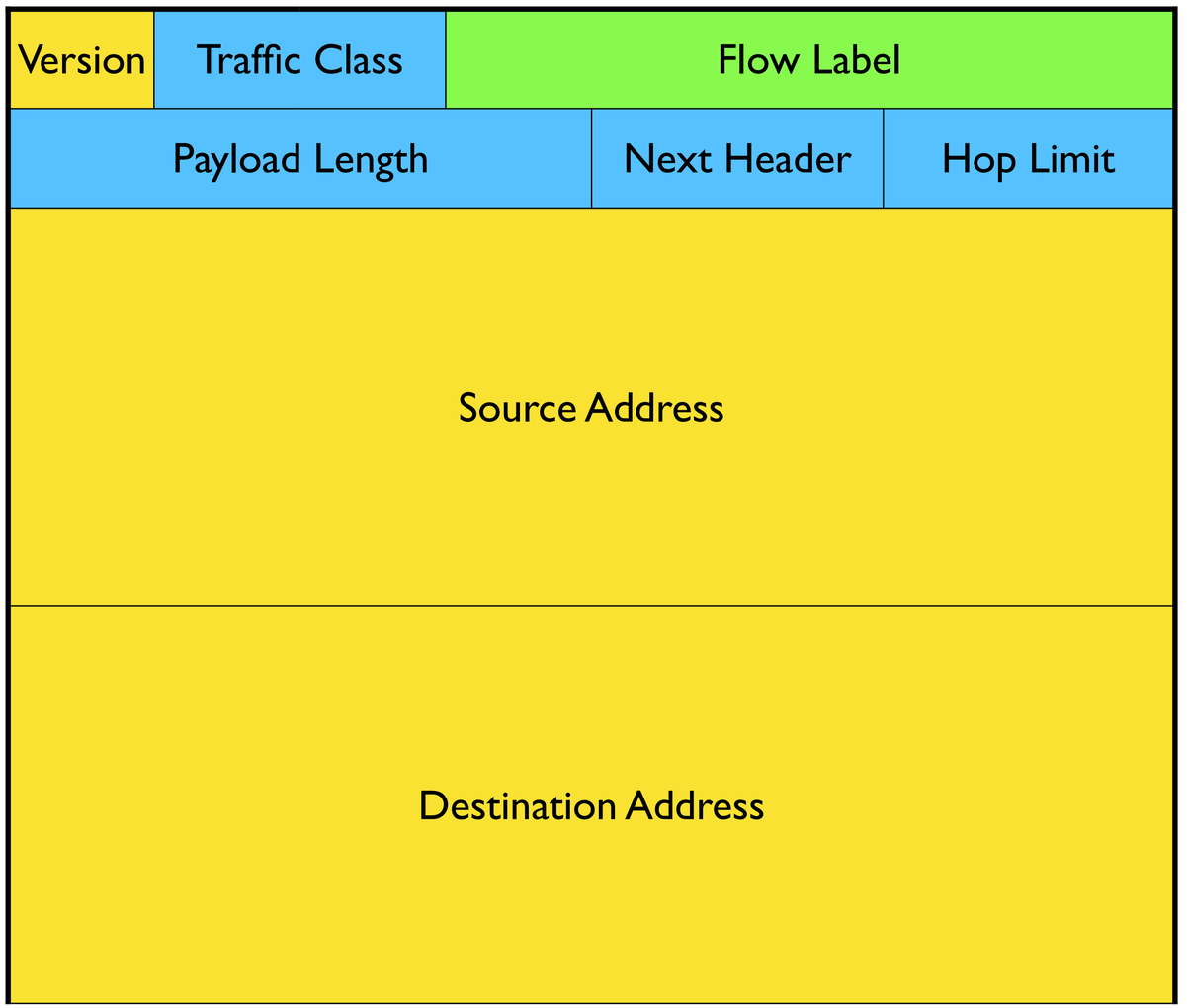

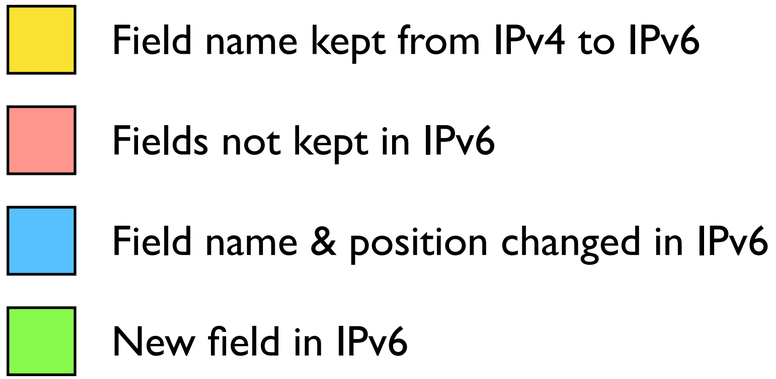

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- **Provide general flow label for packet**
  - Not tied to semantics
  - Provides great flexibility

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