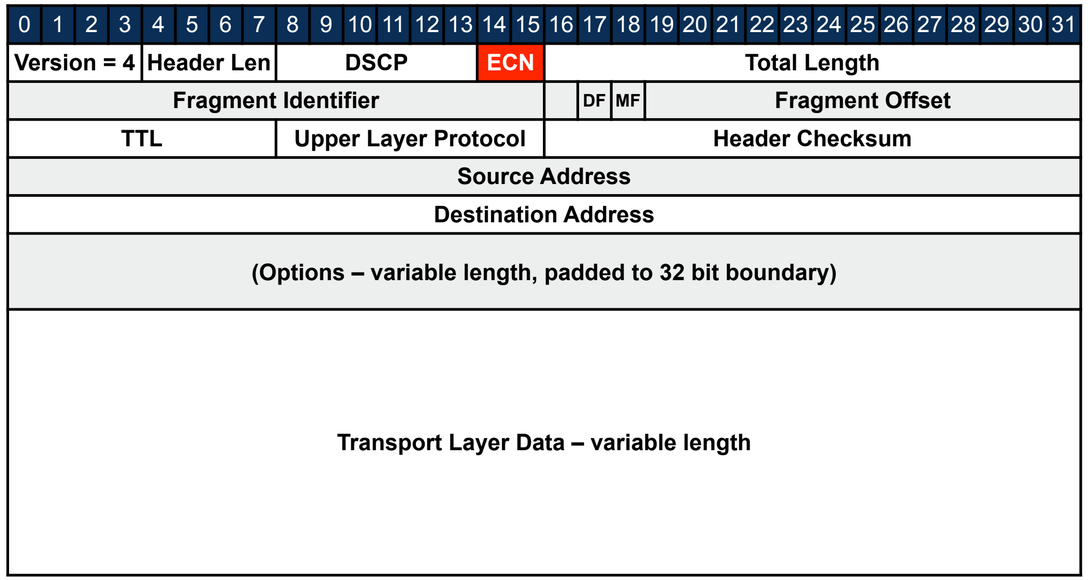
Explicit Congestion Notification (ECN)

- ECN for TCP and IP

Explicit Congestion Notification

- TCP has inferred congestion through measurement
  - TCP Reno and Cubic → packets lost when queues overflow
    - Problematic because it increases delay
    - Problematic because of non-congestive loss on wireless links
  - TCP Vegas → increase in delay as queues start to fill
    - Conceptually a good idea, but difficult to deploy when competing with TCP Reno and Cubic
- **Why not have the network tell TCP congestion is occurring?**
  - **E**xplicit **C**ongestion **N**otification (ECN) field in IP header
  - Tell TCP to slow down if it's overloading the network

ECN and IP



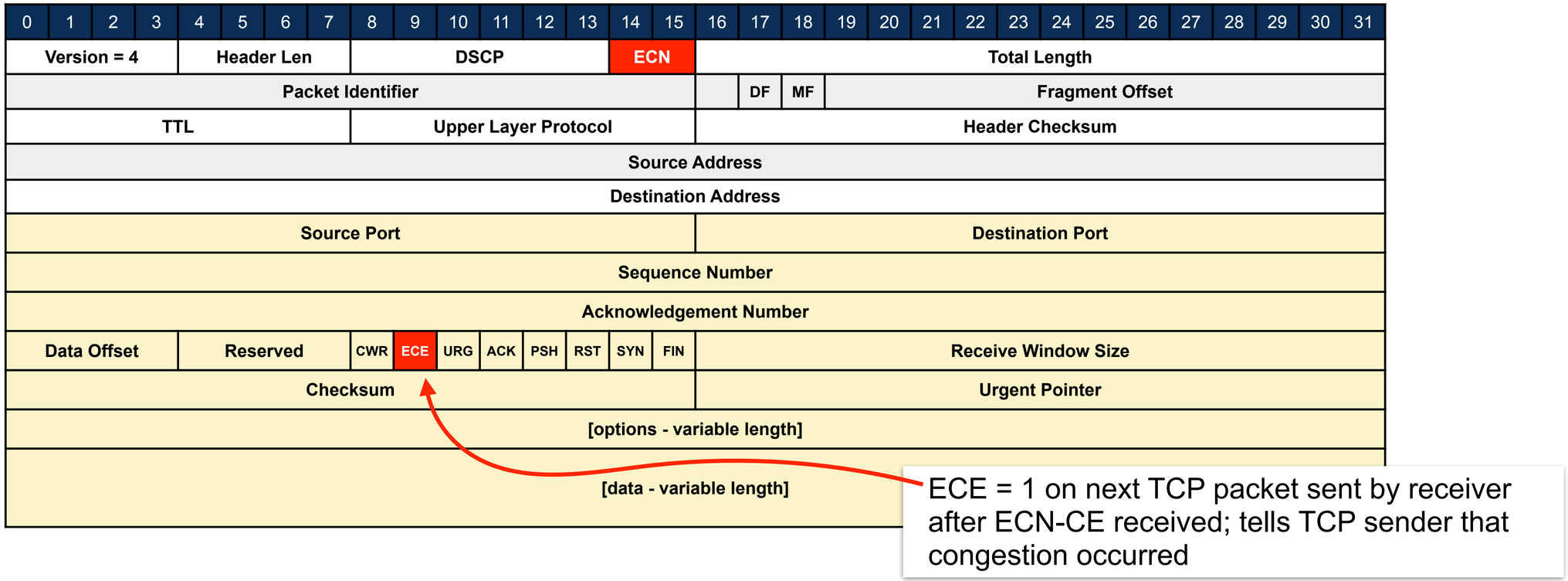
- Sender sets ECN bits on transmission:
  - 00 = Doesn't support ECN, 01 = ECN capable
- If congestion occurs, **congested router** sets ECN bits to 11 ("congestion experienced")
  - Indicates that a queue of packets for some link is getting full, but has not yet overflowed – **signal of congestion set by the network**
  - If the queue overflows, packets are dropped
- Cooperation between network and endpoints

K. Ramakrishnan, S. Floyd, and D. Black, "The Addition of Explicit Congestion Notification (ECN) to IP", IETF RFC 3168, September 2001. https://datatracker.ietf.org/doc/rfc3168/

Diagram shows IPv4, but ECN is also present in IPv6 and works the same

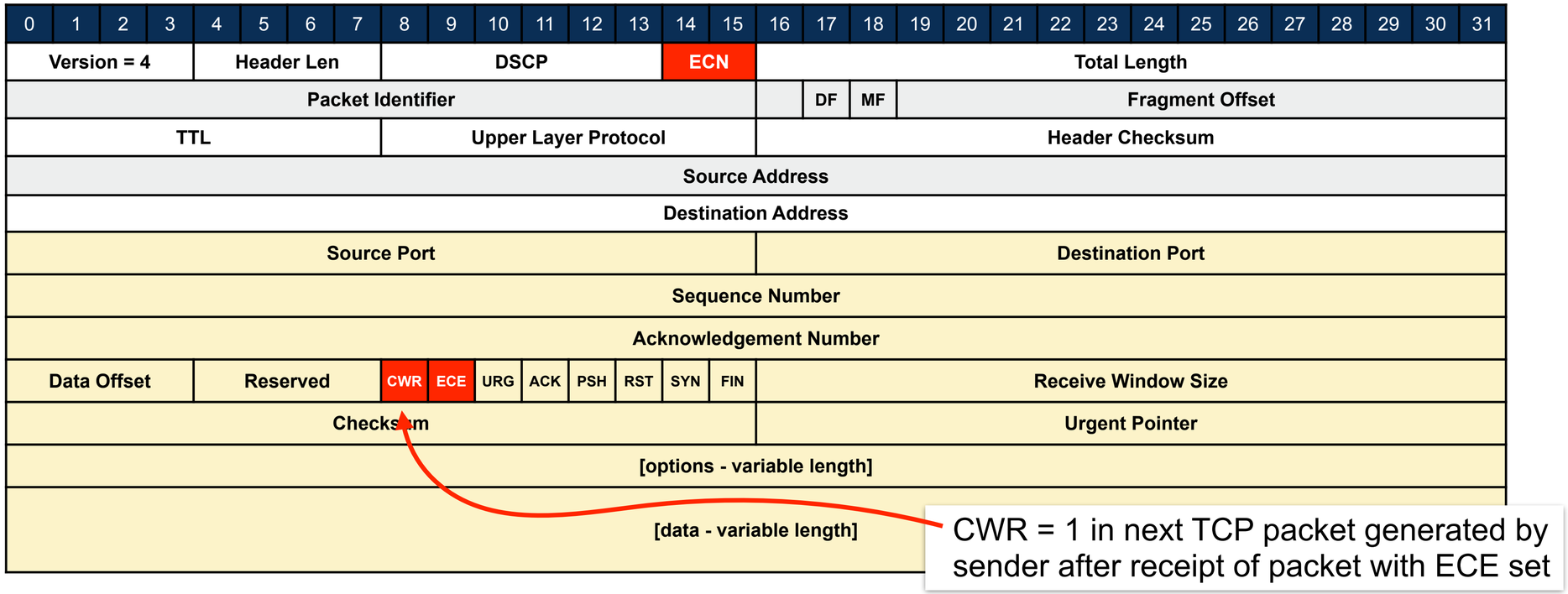
ECN and TCP (1/3)

- Receiver may get a TCP segment within an IP packet marked ECN Congestion Experienced (ECN-CE)
- ECN Echo (ECE) field in TCP header allow it to signal this back to the sender



ECN and TCP (2/3)

- Sender reduces congestion window on receiving acknowledgement with ECE = 1 **as if the packet had been lost**
- Sets CWR = 1 in next packet to inform network and receiver it has done so



ECN and TCP (3/3)

- ECN lets TCP react to congestion before packet loss occurs
  - Routers signal congestion **before** queues overflow
  - Independent of choice of TCP congestion control algorithm
  - Smaller queues → reduces latency, beneficial for video conferencing and gaming

- ECN extensions also exist in QUIC and RTP

ECN and TCP: Deployment

- TCP endpoints needed to be updated to support ECN → done
  - Endpoints now support ECN and **many** now enable ECN by default
    - ECN was widely implemented but disabled-by-default for many years, due to concerns that it wouldn't pass through firewalls
    - Apple forced firewalls to be fixed: iOS 9 enabled ECN for 5% of connection; iOS 10 for 50%; iOS 11 and later for all connections
- Most routers support ECN, relatively few enable it by default
  - Endpoints can react to ECN signals, but network is currently unlikely to provide them
  - Starting to change – e.g., recent DOCSIS cable modems enable ECN
  - Will take time, but latency reduced as ECN is enabled throughout the network

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