# Robust ECN Signaling with Nonces

David Ely, Neil Spring, David Wetherall,

Stefan Savage†, and Tom Anderson

University of Washington and †UC San Diego

IEEE ICNP, November, 2001

# ECN gives receivers power

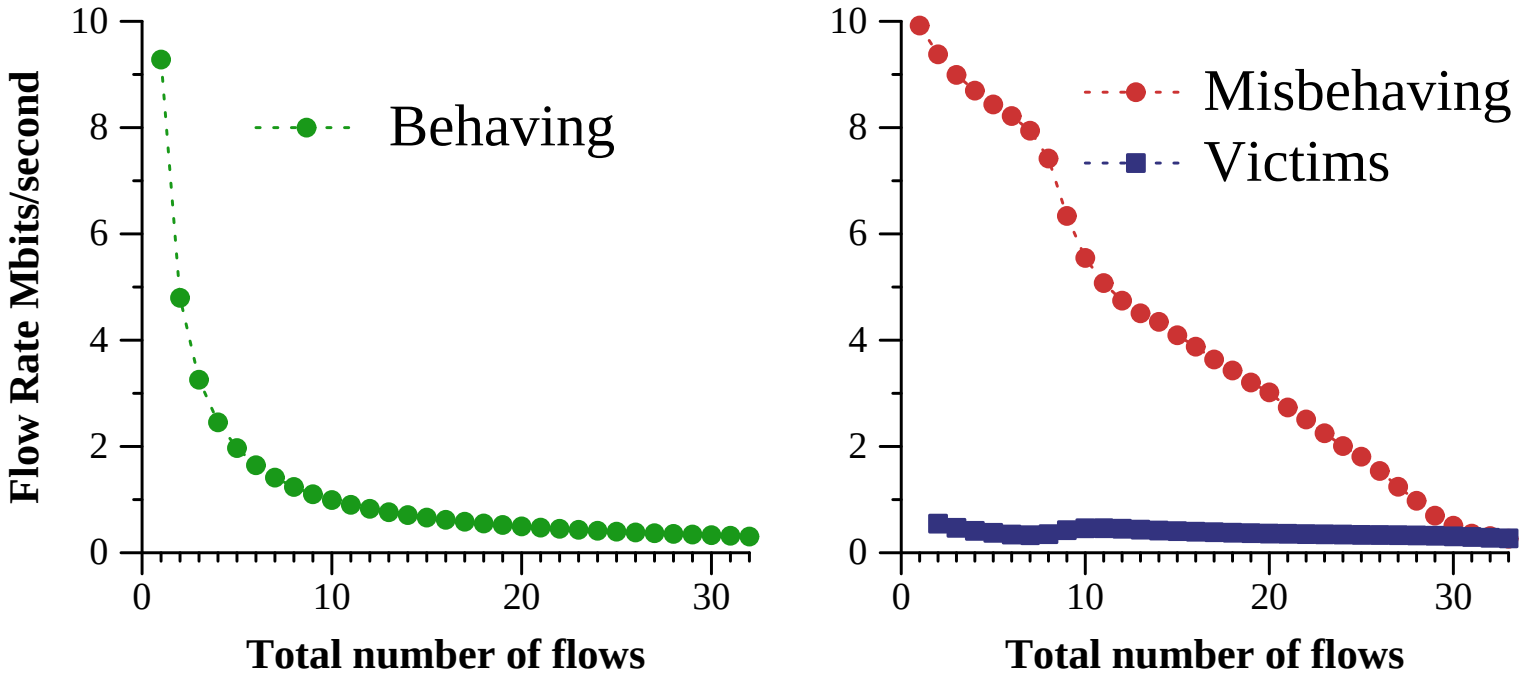
Old congestion signals:

- Receivers claim lost packets for reliable delivery.
- Senders slow down when retransmitting.

ECN congestion signals:

- Behaving receivers return Congestion Experienced (CE) as ECN Congestion Echo (ECE).
- Senders slow down when ECE seen.
- Greedy or buggy receivers have no incentive to set ECE.

# Misbehavior is dangerous




Receivers that conceal ECN signals:

- Get better performance: ● ≫ ●
- Reduce performance of competing Victims: ● ≪ ●

# The Challenge

Can we have both:

- The benefits of ECN, and
- Protection against misbehaving receivers?

Can we *detect* misbehavior?

Can we *discourage* misbehavior?

# Outline

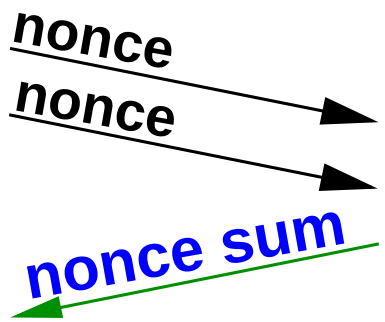
TODO: fix at last minute

- ECN-nonce basics
- Header bits: IP and TCP
- Walkthroughs: Normal and with misbehavior
- Endpoint state requirements
- Policy: giving the ECN-nonce teeth
- Short flows
- Conclusions

# Nonces revoke receiver power

Sender attaches random “nonce” using ECT field

Sum (parity) of nonces in ACKs




Correct nonce sum depends on unmarked packets.

Receiver’s sum legitimately incorrect when:

- ECT(0) or (1) removed by CE. $\rightarrow$ expect ECE.
- Retransmission lacks ECT $\rightarrow$ have retransmitted.

Sender can detect an misbehavior: claimed sum is wrong

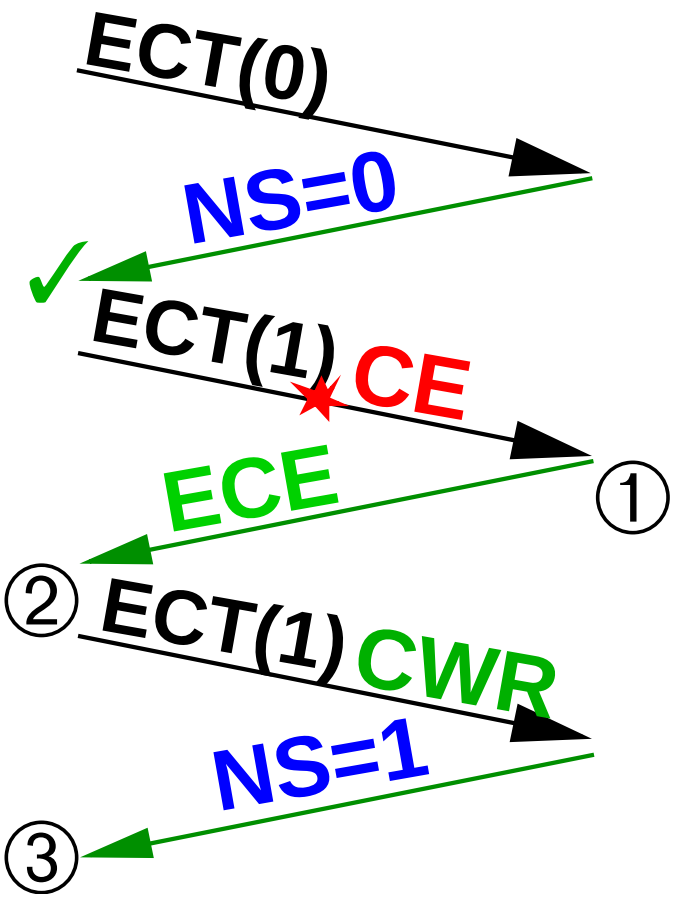
# ECN bits to code-points

| bits | RFC 2481 | RFC 3168 |
|---|---|---|
| 0 0 | not ECN capable | same |
| 0 1 | unused | ECT (1) |
| 1 0 | ECN-Capable Transport (ECT) | ECT (0) |
| 1 1 | Congestion Experienced | same |

**Transition to CE removes original ECT(0) or ECT(1).**

Use a flag bit in the TCP header to return Nonce Sum.

# ECN-Nonces with good receivers



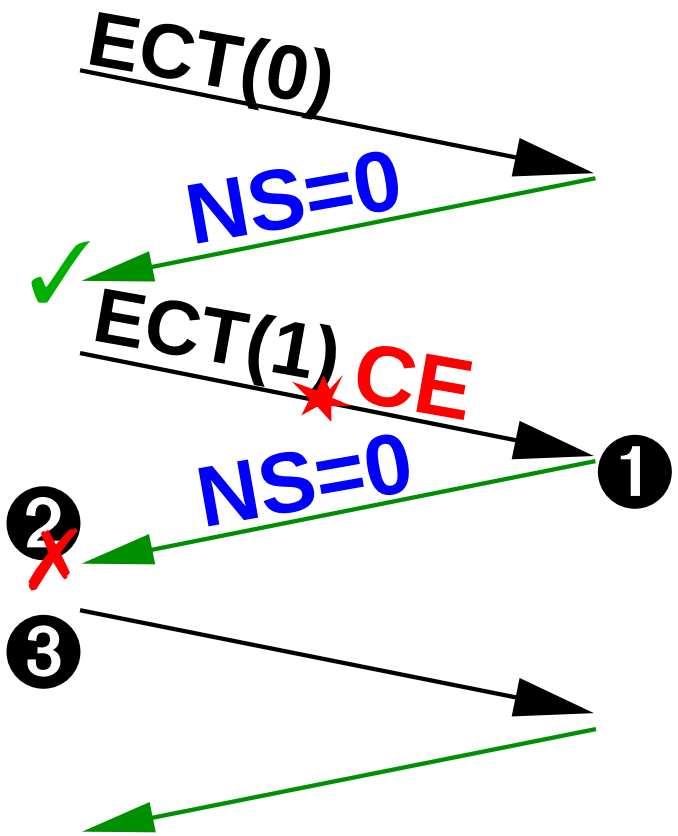

① ECN properly echoed

② Nonce sum (**NS**) ignored

③ Synch. **NS** after **CWR**:

Assume receiver is right.

# ECN-Nonces with a misbehaving receiver




❶ CE improperly hidden.

❷ Guessed **NS** is wrong.

❸ Sender disables ECN.

# State requirements

Senders store:

- Expected nonce sum for ack of each packet in retransmission buffer.
- The sequence number of the last CWR sent.
- A bit set when the expected nonce sum is wrong on Ack-of-CWR.

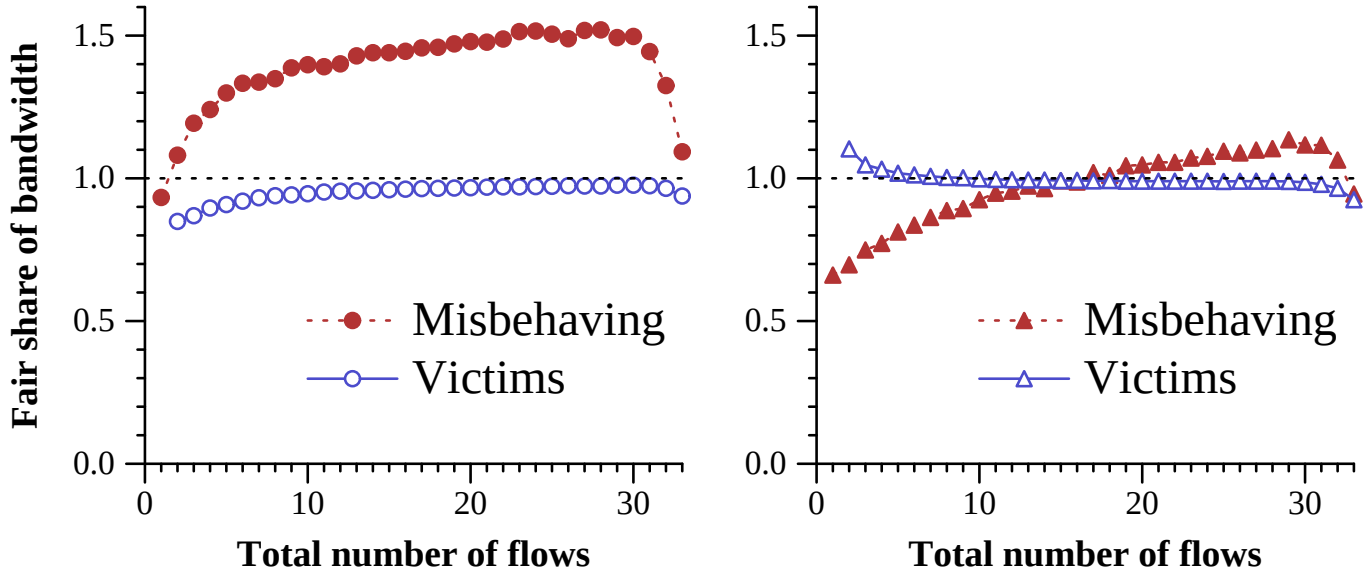
Receivers store:

- Nonce Sum to send in ACKs.
- Nonces of unacknowledged packets.

# Making detection sufficient (policy)

- Encourage nonce support
  - Preferred treatment
  - Non-ECN Optimizations
- Discourage misbehavior when detected:
  - Stop sending ECT
  - Reduce cwnd, ssthresh to 1.
  - Alternatives: RST, limit send window, blacklist

# Why cwnd = ssthresh = 1?



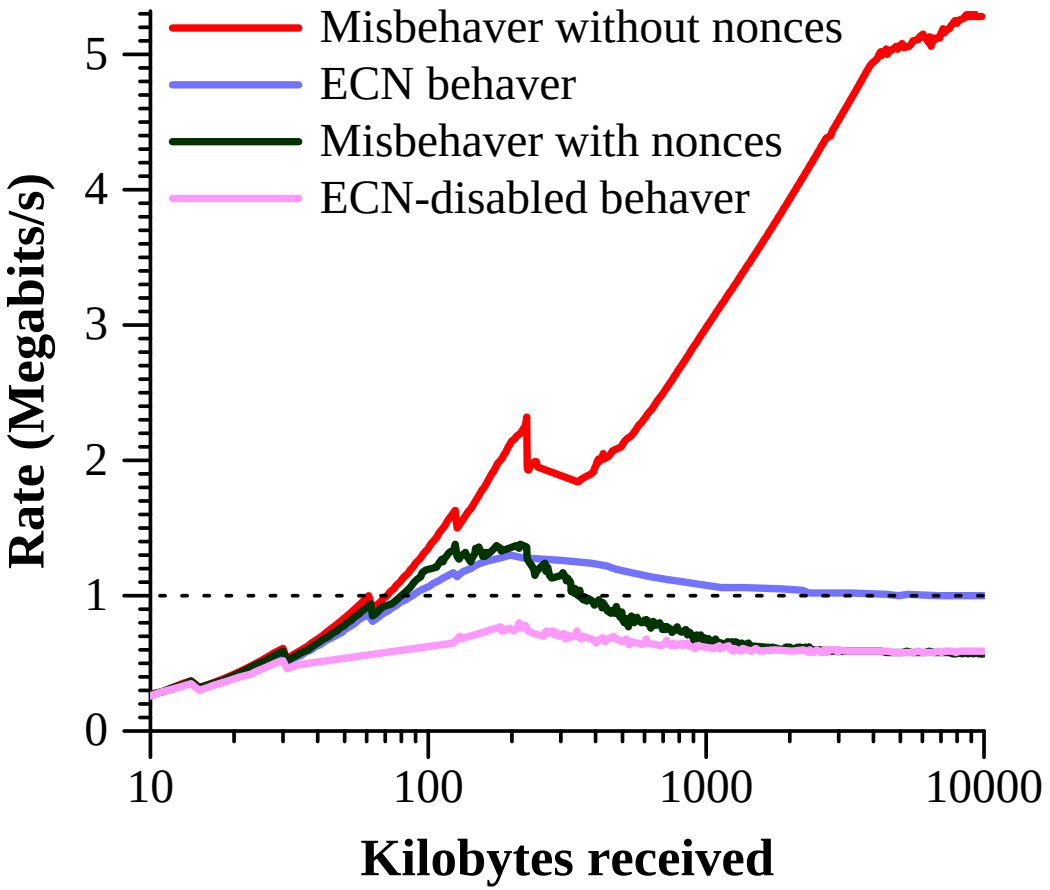

Shows long-term behavior: sender continues to set ECT.

cwnd /= 2 left an advantage that cwnd = 1 removed.

Stop sending ECT to be sure

# Misbehaving short flows

In-sequence data rate vs. flow length




- Misbehavior increasingly effective
- ECN converges
- ECN-nonce detects misbehavior quickly
- ECN disabled

ECN-nonce is effective: ● $\leq$ ●, and ● $\ll$ ●

# Conclusions

ECN-Nonce provides on-line detection of misbehavior.

- $1\frac{1}{2}$ header bits
- Cheap per-packet processing

Reacting to misbehavior can remove performance advantage:

- cwnd=1 makes 1-bit nonce sufficient
- Even for short flows.