

Setup

The simulation is run with three nodes in a network:

- Initiator: Initiates a TCP handshake.
- Responder: Sets up the connection.
- Router: Forwards packets.

Place **tcp-ecn-example.cpp** in the **scratch/** directory and run:

```
./ns3 run "scratch/tcp-ecn-example"
```

Optional flags:

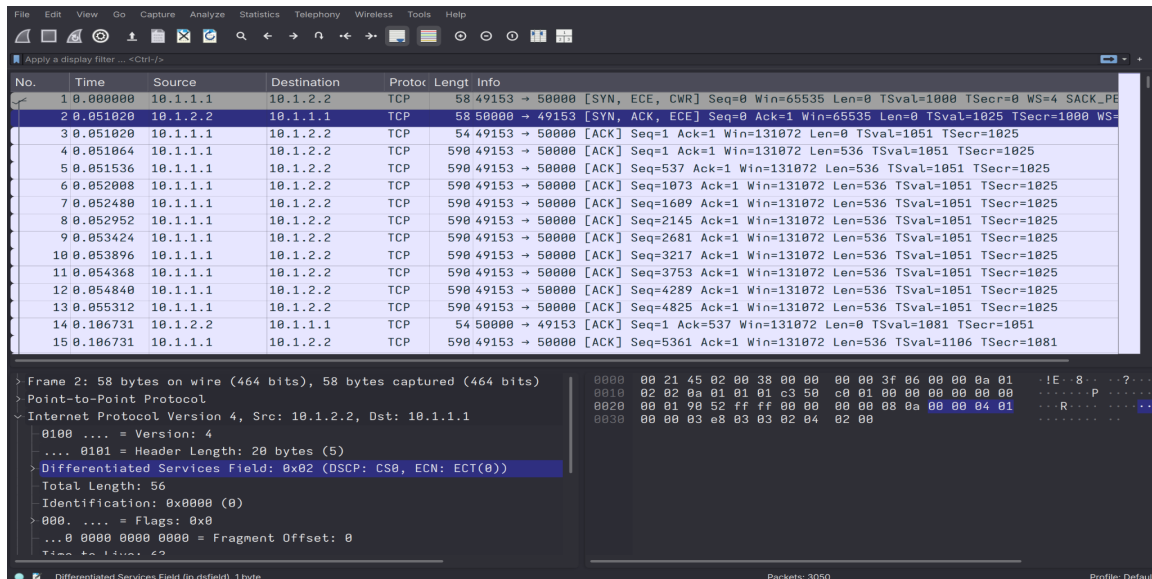
- **--dropFirst**: Drop the first SYN-ACK packet.
- **--markSynAck**: CE-mark the first ECN-enabled SYN-ACK.
- **--dropAll**: Drop all SYN-ACK packets.

Examples:

```
./ns3 run "scratch/tcp-ecn-example --dropFirst"
./ns3 run "scratch/tcp-ecn-example --markSynAck"
./ns3 run "scratch/tcp-ecn-example --markSynAck --dropFirst"
./ns3 run "scratch/tcp-ecn-example --markSynAck --dropAll"
```

Results

1. Default Run



Observation: The SYN-ACK is ECN-enabled (ECT(0)), handshake succeeds, followed by data transmission.

2. Drop First SYN-ACK (--dropFirst)

The screenshot shows a Wireshark capture of a TCP connection. The packet list shows a SYN packet (No. 1) and a SYN-ACK packet (No. 2) which was dropped. A retransmitted SYN packet (No. 3) is followed by an ACK packet (No. 4). The packet details for the ACK packet show the sequence number 1 and acknowledgment number 1. The packet bytes show the ACK flag set and the acknowledgment number 1.

No.	Time	Source	Destination	Protoc	Length	Info
1	0.000000	10.1.1.1	10.1.2.2	TCP	58	49153 → 50000 [SYN, ECE, CWR] Seq=0 Win=65535 Len=0 TSval=1000 TSecr=0 WS=4 SACK_PERM=0
2	0.051020	10.1.2.2	10.1.1.1	TCP	58	50000 → 49153 [SYN, ACK, ECE] Seq=0 Ack=1 Win=65535 Len=0 TSval=1025 TSecr=1000 WS=4 SACK_PERM=0
3	0.051020	10.1.2.2	10.1.1.1	TCP	58	[TCP Retransmission] 50000 → 49153 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 TSval=1025 TSecr=1000
4	0.051020	10.1.1.1	10.1.2.2	TCP	54	49153 → 50000 [ACK] Seq=1 Ack=1 Win=131072 Len=0 TSval=4051 TSecr=4025
5	0.051064	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=1 Ack=1 Win=131072 Len=536 TSval=4051 TSecr=4025
6	0.051536	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=537 Ack=1 Win=131072 Len=536 TSval=4051 TSecr=4025
7	0.052008	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=1073 Ack=1 Win=131072 Len=536 TSval=4051 TSecr=4025
8	0.052480	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=1609 Ack=1 Win=131072 Len=536 TSval=4051 TSecr=4025
9	0.052952	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=2145 Ack=1 Win=131072 Len=536 TSval=4051 TSecr=4025
10	0.053424	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=2681 Ack=1 Win=131072 Len=536 TSval=4051 TSecr=4025
11	0.053896	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=3217 Ack=1 Win=131072 Len=536 TSval=4051 TSecr=4025
12	0.054368	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=3753 Ack=1 Win=131072 Len=536 TSval=4051 TSecr=4025
13	0.054840	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=4289 Ack=1 Win=131072 Len=536 TSval=4051 TSecr=4025
14	0.055312	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=4825 Ack=1 Win=131072 Len=536 TSval=4051 TSecr=4025
15	0.106731	10.1.2.2	10.1.1.1	TCP	54	50000 → 49153 [ACK] Seq=1 Ack=537 Win=131072 Len=0 TSval=4081 TSecr=4051

[Conversation completeness: Complete, WITH_DATA (31)]

[TCP Segment Len: 0]

Sequence Number: 0 (relative sequence number)

Sequence Number (raw): 0

[Next Sequence Number: 1 (relative sequence number)]

Acknowledgment Number: 1 (relative ack number)

Acknowledgment number (raw): 1

1001 = Header Length: 36 bytes (9)

Flags: 0x012 (SYN, ACK)

Window: 65535

Packet 2097

Observation: First SYN-ACK dropped triggers retransmission; second SYN-ACK unmarked, data flows after handshake.

3. CE-Mark First SYN-ACK (--markSynAck)

The screenshot shows a Wireshark capture of a TCP connection. The packet list shows a SYN packet (No. 1) and a SYN-ACK packet (No. 2) which is CE-marked. A retransmitted SYN packet (No. 3) is followed by an ACK packet (No. 4). The packet details for the ACK packet show the sequence number 1 and acknowledgment number 2. The packet bytes show the ACK flag set and the acknowledgment number 2.

No.	Time	Source	Destination	Protoc	Length	Info
1	0.000000	10.1.1.1	10.1.2.2	TCP	58	49153 → 50000 [SYN, ECE, CWR] Seq=0 Win=65535 Len=0 TSval=1000 TSecr=0 WS=4 SACK_PERM=0
2	0.051020	10.1.2.2	10.1.1.1	TCP	58	50000 → 49153 [SYN, ACK, ECE] Seq=0 Ack=1 Win=65535 Len=0 TSval=1025 TSecr=1000 WS=4 SACK_PERM=0
3	0.051020	10.1.1.1	10.1.2.2	TCP	54	49153 → 50000 [ACK, ECE] Seq=1 Ack=1 Win=131072 Len=0 TSval=1051 TSecr=1025
4	0.102006	10.1.2.2	10.1.1.1	TCP	58	[TCP Port numbers reused] 50000 → 49153 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 TSval=1025 TSecr=1000
5	0.102006	10.1.1.1	10.1.2.2	TCP	54	49153 → 50000 [ACK] Seq=1 Ack=1 Win=32768 Len=0 TSval=1102 TSecr=1076
6	0.102049	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=1 Ack=1 Win=32768 Len=536 TSval=1102 TSecr=1076
7	0.102521	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=537 Ack=1 Win=32768 Len=536 TSval=1102 TSecr=1076
8	0.102993	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=1073 Ack=1 Win=32768 Len=536 TSval=1102 TSecr=1076
9	0.103465	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=1609 Ack=1 Win=32768 Len=536 TSval=1102 TSecr=1076
10	0.103937	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=2145 Ack=1 Win=32768 Len=536 TSval=1102 TSecr=1076
11	0.104409	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=2681 Ack=1 Win=32768 Len=536 TSval=1102 TSecr=1076
12	0.104881	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=3217 Ack=1 Win=32768 Len=536 TSval=1102 TSecr=1076
13	0.105353	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=3753 Ack=1 Win=32768 Len=536 TSval=1102 TSecr=1076
14	0.105825	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=4289 Ack=1 Win=32768 Len=536 TSval=1102 TSecr=1076
15	0.106297	10.1.1.1	10.1.2.2	TCP	598	49153 → 50000 [ACK] Seq=4825 Ack=1 Win=32768 Len=536 TSval=1102 TSecr=1076

[Conversation completeness: Incomplete (30)]

[TCP Segment Len: 0]

Sequence Number: 0 (relative sequence number)

Sequence Number (raw): 1

[Next Sequence Number: 1 (relative sequence number)]

Acknowledgment Number: 1 (relative ack number)

Acknowledgment number (raw): 2

1001 = Header Length: 36 bytes (9)

Flags: 0x012 (SYN, ACK)

Window: 65535

Packet 3036

Observation: First SYN-ACK is CE-marked; initiator sends ECE-ACK; congestion window reduced (Win=32768).

4. CE-Mark + Drop First SYN-ACK (--markSynAck --dropFirst)

No.	Time	Source	Destination	Protoc	Length	Info
1	0.000000	10.1.1.1	10.1.2.2	TCP	58	49153 → 50000 [SYN, ECE, CWR] Seq=0 Win=65535 Len=0 TSval=1000 TSecr=0 WS=4 SACK_PERM
2	0.051020	10.1.1.2	10.1.1.1	TCP	58	50000 → 49153 [SYN, ACK, ECE] Seq=0 Ack=1 Win=65535 Len=0 TSval=1025 TSecr=1000 WS=4 SACK_PERM
3	0.051020	10.1.1.1	10.1.2.2	TCP	54	49153 → 50000 [ACK, ECE] Seq=1 Ack=1 Win=131072 Len=0 TSval=1051 TSecr=1025
4	0.102006	10.1.2.2	10.1.1.1	TCP	58	[TCP Port numbers reused] 50000 → 49153 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 TSval=1000 TSecr=1025
5	3.102006	10.1.2.2	10.1.1.1	TCP	58	[TCP Retransmission] 50000 → 49153 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 TSval=1000 TSecr=1025
6	3.102006	10.1.1.1	10.1.2.2	TCP	54	49153 → 50000 [ACK] Seq=1 Ack=1 Win=32768 Len=0 TSval=4102 TSecr=4076
7	3.102049	10.1.1.1	10.1.2.2	TCP	590	49153 → 50000 [ACK] Seq=537 Ack=1 Win=32768 Len=536 TSval=4102 TSecr=4076
8	3.102521	10.1.1.1	10.1.2.2	TCP	590	49153 → 50000 [ACK] Seq=1609 Ack=1 Win=32768 Len=536 TSval=4102 TSecr=4076
9	3.102993	10.1.1.1	10.1.2.2	TCP	590	49153 → 50000 [ACK] Seq=2145 Ack=1 Win=32768 Len=536 TSval=4102 TSecr=4076
10	3.103465	10.1.1.1	10.1.2.2	TCP	590	49153 → 50000 [ACK] Seq=2681 Ack=1 Win=32768 Len=536 TSval=4102 TSecr=4076
11	3.103937	10.1.1.1	10.1.2.2	TCP	590	49153 → 50000 [ACK] Seq=3217 Ack=1 Win=32768 Len=536 TSval=4102 TSecr=4076
12	3.104409	10.1.1.1	10.1.2.2	TCP	590	49153 → 50000 [ACK] Seq=3753 Ack=1 Win=32768 Len=536 TSval=4102 TSecr=4076
13	3.104881	10.1.1.1	10.1.2.2	TCP	590	49153 → 50000 [ACK] Seq=4289 Ack=1 Win=32768 Len=536 TSval=4102 TSecr=4076
14	3.105353	10.1.1.1	10.1.2.2	TCP	590	49153 → 50000 [ACK] Seq=4829 Ack=1 Win=32768 Len=536 TSval=4102 TSecr=4076
15	3.105825	10.1.1.1	10.1.2.2	TCP	590	49153 → 50000 [ACK] Seq=537 Ack=1 Win=32768 Len=536 TSval=4102 TSecr=4076

[TCP Segment Len: 0]		0000 00 21 45 00 00 38 00 02 00 00 3f 06 00 00 0a 01	..IE..8.. ..@..
Sequence Number: 0 (relative sequence number)		0010 02 02 0a 01 01 01 c3 50 c0 01 00 00 01 00 00	...P....
Sequence Number (raw): 1		0020 00 02 90 12 ff ff 00 00 00 00 08 0a 00 00 0f ecP.....
[Next Sequence Number: 1 (relative sequence number)]		0030 00 00 04 1b 03 03 02 04 02 00
Acknowledgment Number: 1 (relative ack number)			
Acknowledgment number (raw): 2			
1001 = Header Length: 36 bytes (9)			
> Flags: 0x012 (SYN, ACK)			
Window: 65535			
[Calculated window size: 65535]			
Checksum: 0x0000 [unverified]			

Observation: First CE-marked SYN-ACK acknowledged with ECE-ACK; subsequent non-ECT SYN-ACKs dropped.

5. CE-Mark + Drop All SYN-ACKs (--markSynAck --dropAll)

No.	Time	Source	Destination	Protoc	Length	Info
1	0.000000	10.1.1.1	10.1.2.2	TCP	58	49153 → 50000 [SYN, ECE, CWR] Seq=0 Win=65535 Len=0 TSval=1000 TSecr=0 WS=4 SACK_PERM
2	0.051020	10.1.1.2	10.1.1.1	TCP	58	50000 → 49153 [SYN, ACK, ECE] Seq=0 Ack=1 Win=65535 Len=0 TSval=1025 TSecr=1000 WS=4 SACK_PERM
3	0.051020	10.1.1.1	10.1.2.2	TCP	54	49153 → 50000 [ACK, ECE] Seq=1 Ack=1 Win=131072 Len=0 TSval=1051 TSecr=1025
4	0.102006	10.1.2.2	10.1.1.1	TCP	58	[TCP Port numbers reused] 50000 → 49153 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 TSval=1000 TSecr=1025
5	3.102006	10.1.2.2	10.1.1.1	TCP	58	[TCP Retransmission] 50000 → 49153 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 TSval=1000 TSecr=1025
6	8.000000	10.1.1.1	10.1.2.2	TCP	54	49153 → 50000 [RST] Seq=0 Win=32768 Len=0 TSval=9000 TSecr=4076

Acknowledgment Number: 1 (relative ack number)		0000 00 21 45 00 00 34 00 01 00 00 40 06 00 00 0a 01	..IE..4.. ..@..
Acknowledgment number (raw): 1		0010 01 01 0a 01 02 02 c0 01 c3 50 00 00 00 01 00 00	...P....
1000 = Header Length: 32 bytes (8)		0020 00 01 00 50 00 00 00 00 00 00 08 08 0a 00 00 04 1bP.....
> Flags: 0x050 (ACK, ECE)		0030 00 00 04 01 00 00
Window: 32768			
[Calculated window size: 131072]			
[Window size scaling factor: 4]			
Checksum: 0x0000 [unverified]			
[Checksum Status: Unverified]			
Urgent Pointer: 0			
Options (12 bytes): Timestamp, End of Option List (EOO), End of O			

Observation: First CE-marked SYN-ACK triggers ECE-ACK; all subsequent SYN-ACKs dropped, handshake fails upon retransmission limit.