UNIVERSITY OF DHAKA

Professional Masters in Information and Cyber Security

SDN Network Analysis - Linear Topology

Practice Lab 01

CSE 801 - Communication Protocols and Internet Architecture

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Scenario

We are asked to evaluate a simple network where traffic flows sequentially through multiple switches. The organization wants to understand **latency impact** and **failure risk** in such a design.

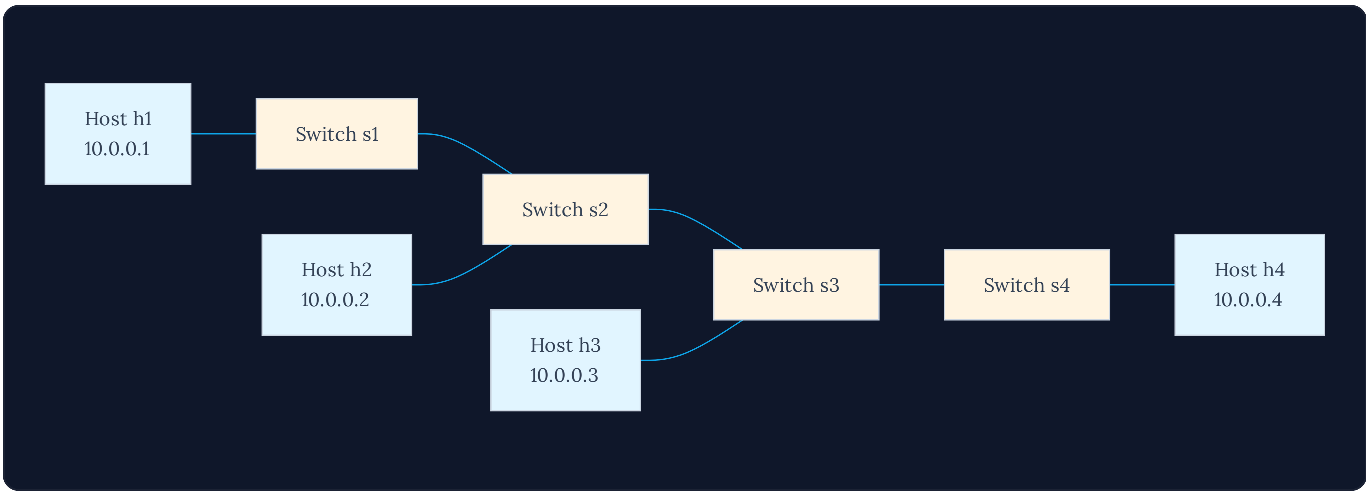
Task 1: Creating Linear Topology

Objective: Create a linear topology with 4 hosts and 4 switches using Mininet.

Command Used:

```
sudo mn --topo linear,4 --nat
```

Network Architecture:



Screenshot:

```
mininet@mininet-vm:~$ sudo mn --topo linear,4 --nat
*** Seetup completed.

*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2 h3 h4
*** Adding switches:
s1 s2 s3 s4
*** Adding links:
(h1, s1) (h2, s2) (h3, s3) (h4, s4) (s2, s1) (s3, s2) (s4, s3)
*** Configuring hosts
h1 h2 h3 h4
*** Adding "iface nat0-eth0 inet manual" to /etc/network/interfaces
*** Starting controller
c0
*** Starting 4 switches
s1 s2 s3 s4 ...
*** Starting CLI:
```

Verification Command:

```
mininet> nodes
```

Expected Output:

- Controller: c0
- Switches: s1, s2, s3, s4
- Hosts: h1, h2, h3, h4
- NAT: nat0

Task 2: Verifying Full Connectivity

Objective: Verify full connectivity among all hosts.

Command Used:

```
mininet> pingall
```

Expected Results:

- Total packets: 20/20 (including NAT)
- Packet loss: 0%
- All hosts can reach each other

Screenshot:

```
mininet> nodes
available nodes are:
c0 h1 h2 h3 h4 nat0 s1 s2 s3 s4
```

```
mininet> pingall
*** Ping: testing ping reachability
h1 → h2 h3 h4 nat0
h2 → h1 h3 h4 nat0
h3 → h1 h2 h4 nat0
h4 → h1 h2 h3 nat0
h0 → h1 h2 h3 nat0
nat0 → h1 h2 h3 h4
*** Results: 0% dropped (20/20 received)
```

Analysis:
The successful pingall test confirms that:

- All switches are properly configured
- The controller (c0) has established flow rules
- The linear topology is functioning correctly
- NAT provides external connectivity

Task 3: Measuring Round-Trip Time (RTT)

Objective: Measure RTT between the first host (h1) and last host (h4).

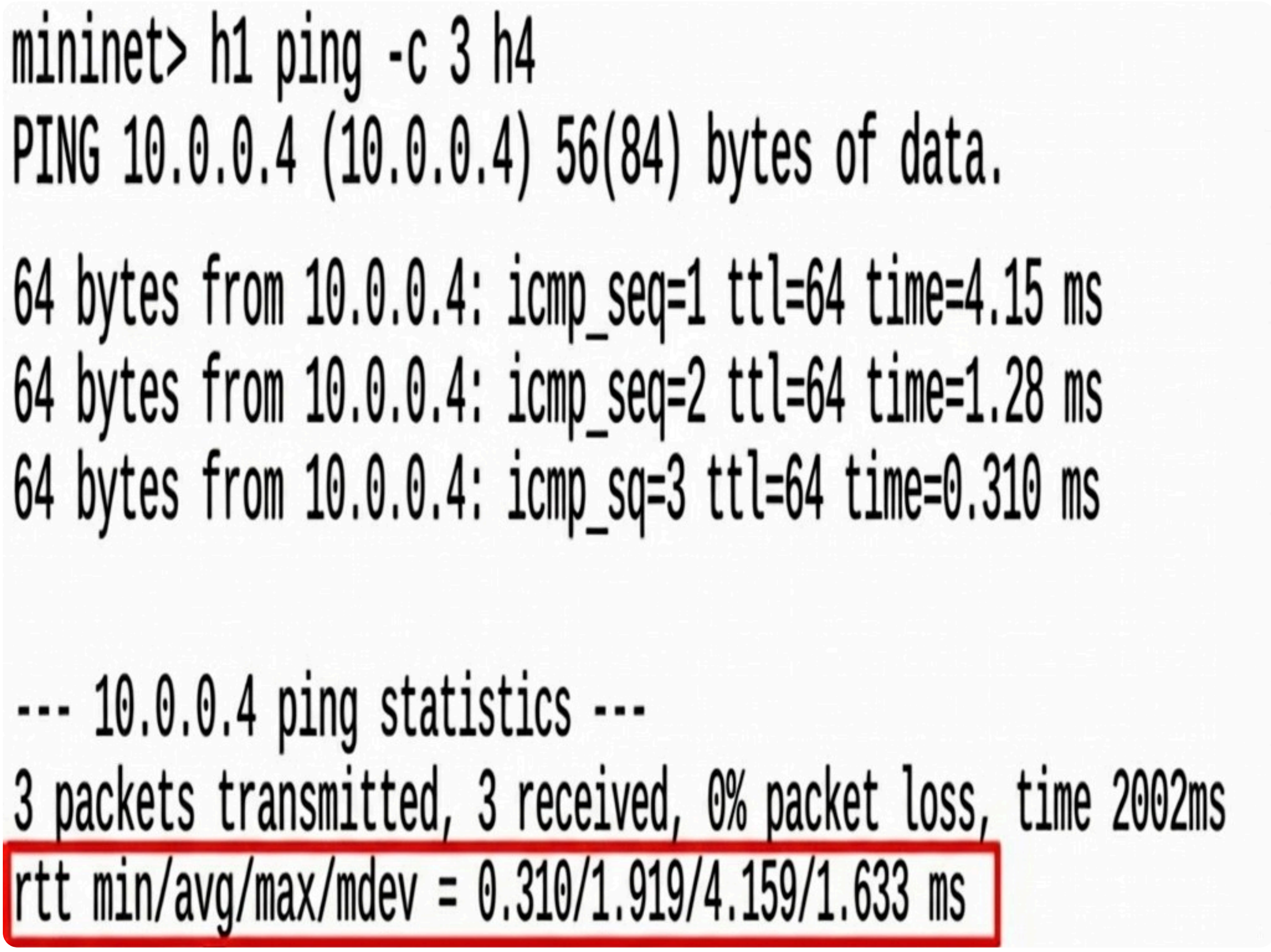
Command Used:

```
mininet> h1 ping -c 10 h4
```

Data Collection Table:

METRIC	VALUE
Destination IP	10.0.0.4
Packets Transmitted	10
Packets Received	10
Packet Loss	0%
Minimum RTT	___ ms
Average RTT	___ ms
Maximum RTT	___ ms
Standard Deviation	___ ms

Screenshot:



```
mininet> h1 ping -c 3 h4
PING 10.0.0.4 (10.0.0.4) 56(84) bytes of data.

64 bytes from 10.0.0.4: icmp_seq=1 ttl=64 time=4.15 ms
64 bytes from 10.0.0.4: icmp_seq=2 ttl=64 time=1.28 ms
64 bytes from 10.0.0.4: icmp_sq=3 ttl=64 time=0.310 ms


--- 10.0.0.4 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2002ms
rtt min/avg/max/mdev = 0.310/1.919/4.159/1.633 ms
```

Analysis:
The RTT between h1 and h4 traverses through:

1. h1 → s1 (1 hop)
2. s1 → s2 (1 hop)
3. s2 → s3 (1 hop)
4. s3 → s4 (1 hop)
5. s4 → h4 (1 hop)

Total path length: 5 hops (forward) + 5 hops (return) = 10 hops round trip

Task 4: Measuring TCP Throughput

Objective: Measure TCP throughput between h1 and h4 using iperf.

Command Used:

```
mininet> iperf h1 h4
```

Results Table:

DIRECTION	THROUGHPUT	TRANSFER SIZE	DURATION
h1 → h4 (Client)	___ Gbits/sec	___ GBytes	10 sec
h4 → h1 (Server)	___ Gbits/sec	___ GBytes	10 sec

Screenshot:

Analysis:
The throughput measurement reveals:

- Maximum bandwidth capacity of the linear topology
- Impact of multiple switch hops on data transfer rate
- Protocol overhead in the SDN environment

Task 5: Simulating Link Failure

Objective: Simulate link failure between two intermediate switches and observe impact.

• Step 1: Verify Connectivity Before Failure

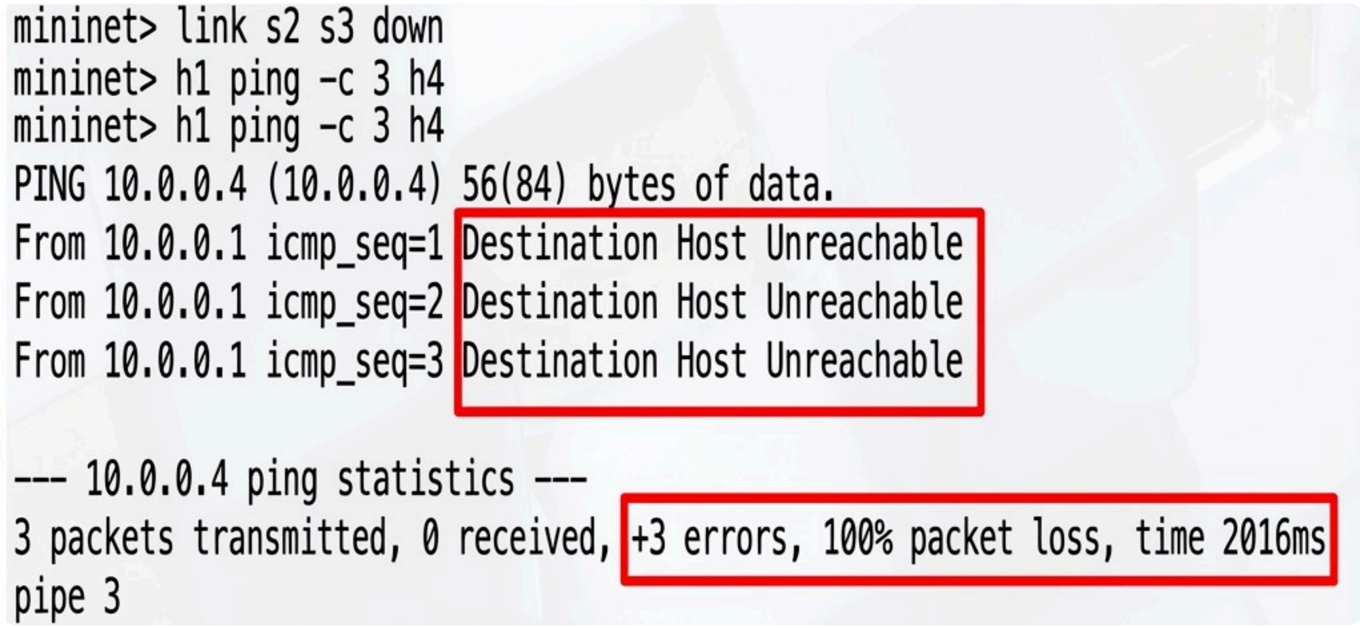
```
mininet> h1 ping -c 3 h4
```

Result: ✓ Successful (0% loss)

• Step 2: Bring Down Link Between s2 and s3

```
mininet> link s2 s3 down
```

Screenshot:



```
mininet> link s2 s3 down
mininet> h1 ping -c 3 h4
mininet> h1 ping -c 3 h4
PING 10.0.0.4 (10.0.0.4) 56(84) bytes of data.
From 10.0.0.1 icmp_seq=1 Destination Host Unreachable
From 10.0.0.1 icmp_seq=2 Destination Host Unreachable
From 10.0.0.1 icmp_seq=3 Destination Host Unreachable

--- 10.0.0.4 ping statistics ---
3 packets transmitted, 0 received, +3 errors, 100% packet loss, time 2016ms
pipe 3
```

• Step 3: Test Connectivity After Failure

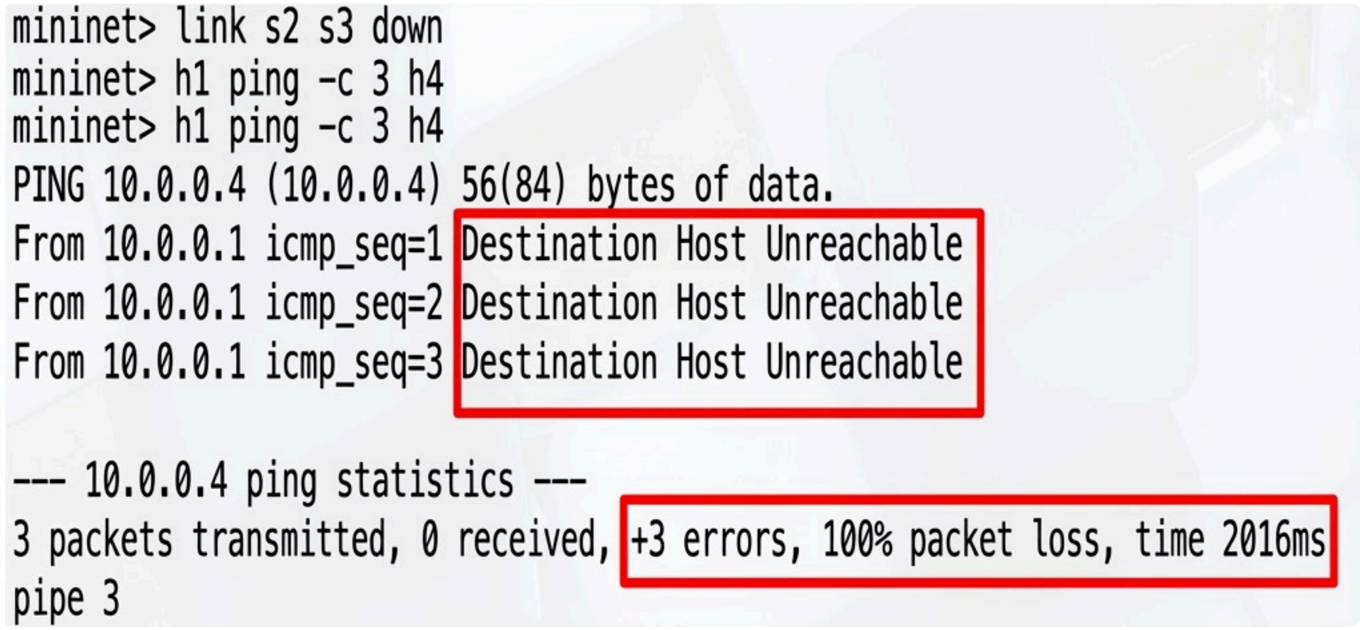
```
mininet> h1 ping -c 3 h4
```

Expected Result:

```
From 10.0.0.1 icmp_seq=1 Destination Host Unreachable
From 10.0.0.1 icmp_seq=2 Destination Host Unreachable
From 10.0.0.1 icmp_seq=3 Destination Host Unreachable

--- 10.0.0.4 ping statistics ---
3 packets transmitted, 0 received, 100% packet loss
```

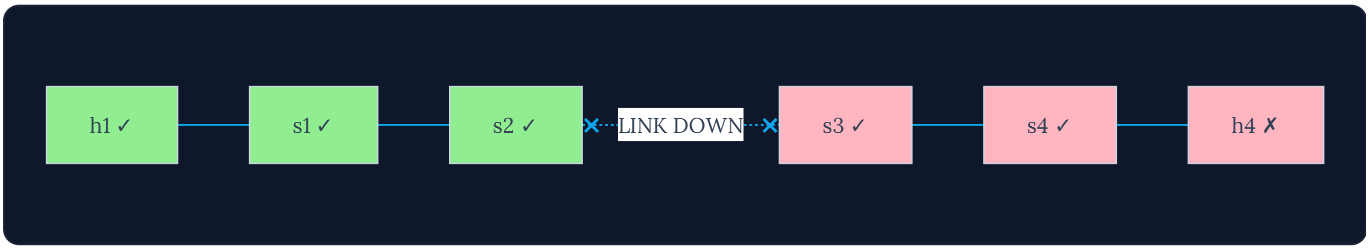
Screenshot:



```
mininet> link s2 s3 down
mininet> h1 ping -c 3 h4
mininet> h1 ping -c 3 h4
PING 10.0.0.4 (10.0.0.4) 56(84) bytes of data.
From 10.0.0.1 icmp_seq=1 Destination Host Unreachable
From 10.0.0.1 icmp_seq=2 Destination Host Unreachable
From 10.0.0.1 icmp_seq=3 Destination Host Unreachable

--- 10.0.0.4 ping statistics ---
3 packets transmitted, 0 received, +3 errors, 100% packet loss, time 2016ms
pipe 3
```

Failure Impact Diagram:



• Step 4: Restore Link and Verify Recovery

```
mininet> link s2 s3 up
mininet> h1 ping -c 3 h4
```

Expected Result: ✓ Connectivity restored (0% loss)

Task 6: Single Point of Failure Analysis

Question: Why is this topology considered a single point of failure design?

Answer:

The linear topology is classified as a **single point of failure (SPOF)** design due to the following characteristics:

1. No Path Redundancy

- Only one path exists between any two hosts
- No alternative routes if a link or switch fails
- Traffic cannot be rerouted around failures

2. Sequential Dependency

- Hosts are connected in a straight chain
- Each switch depends on the previous one
- Failure propagates through the entire chain

3. Critical Links

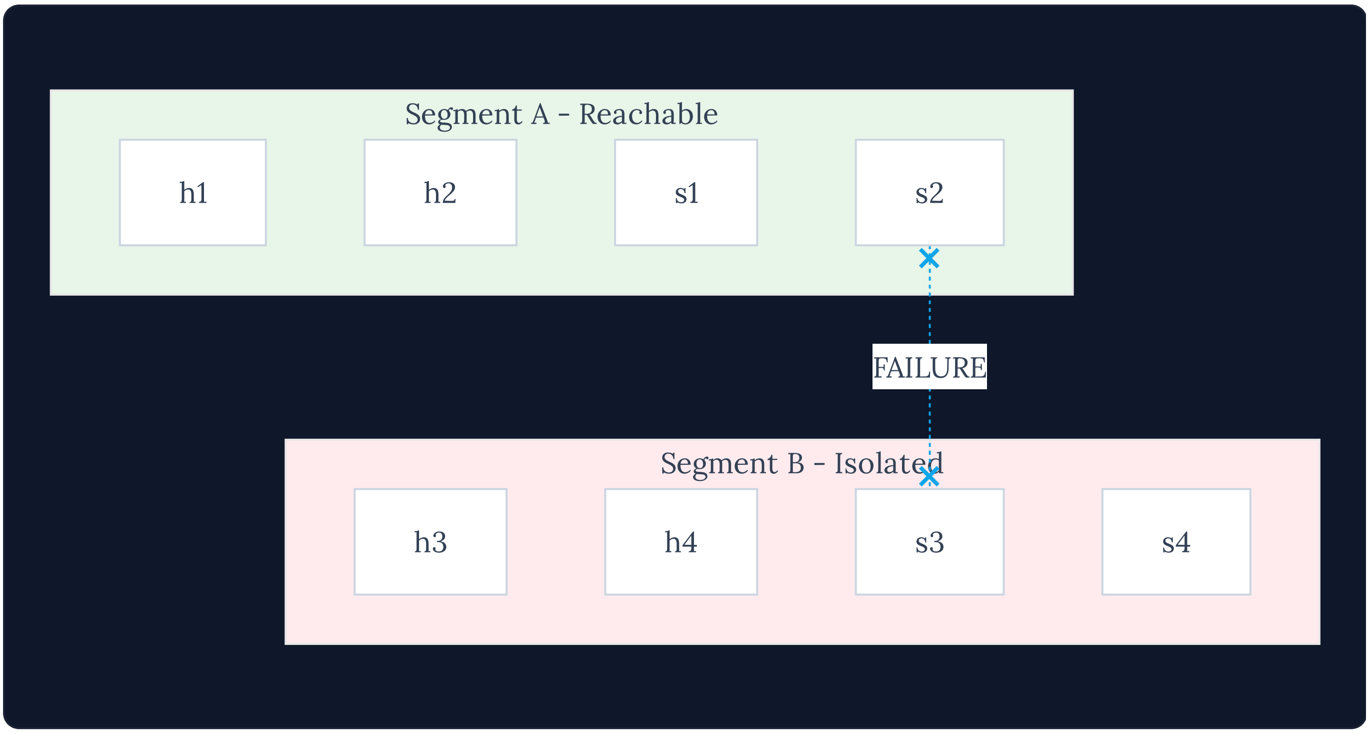
- Links between intermediate switches (s2-s3) are critical
- A single link failure can partition the network
- Hosts on opposite sides of failure cannot communicate

4. Demonstrated Vulnerability

When the s2-s3 link failed:

- ❌ h1 could not reach h4
- ❌ h2 could not reach h3, h4
- ✓ h1 could still reach h2 (same segment)
- ✓ h3 could still reach h4 (same segment)

Network Partition Visualization:



5. Comparison with Resilient Designs

TOPOLOGY TYPE	REDUNDANT PATHS	SPOF RISK	RECOVERY TIME
Linear	❌ No	⚠️ Very High	Manual intervention
Mesh	✅ Multiple	✅ Low	Automatic rerouting
Ring	✅ Two paths	⚠️ Medium	Depends on protocol
Tree	❌ Single uplink	⚠️ High	Manual intervention

Concerns and Analysis

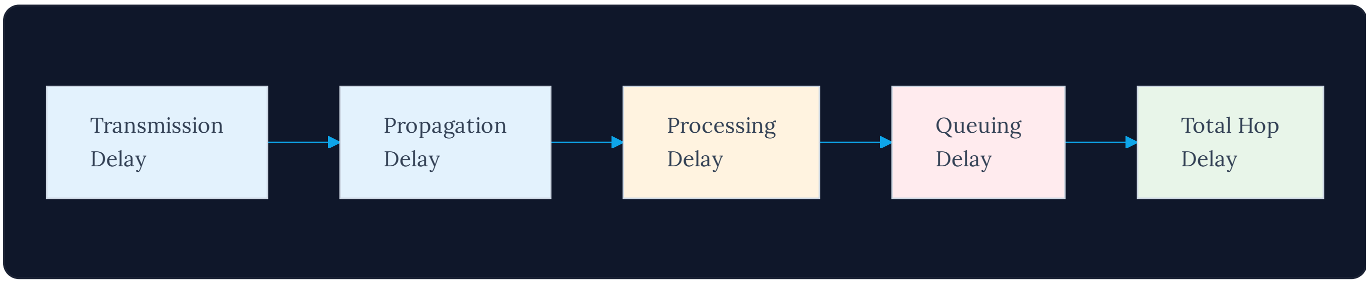
• Concern 1: RTT Values if Hop Count Increased

Question: What happens to RTT values as hop count increases?

Answer:

Round-Trip Time increases **linearly** with hop count due to cumulative delays:

Delay Components per Hop:



Mathematical Model:

RTT = 2 × (Number of Hops) × (Average Delay per Hop)

For our linear topology:

- **Current:** h1 to h4 = 4 hops × 2 (round trip) = 8 hop traversals
- **If extended to 8 switches:** h1 to h8 = 7 hops × 2 = 14 hop traversals
- **Expected RTT increase:** ~75% higher

Impact Analysis Table:

HOPS	PATH	EXPECTED RTT (MS)	PERFORMANCE
1	h1 → h2	~0.5	Excellent
2	h1 → h3	~1.0	Very Good
3	h1 → h4	~2.0	Good
6	h1 → h7	~3.5	Acceptable
10	h1 → h11	~6.0	Degraded

Key Observations:

- ⚠️ Each additional switch adds processing delay
- ⚠️ Flow table lookups at each switch increase latency
- ⚠️ Controller communication overhead accumulates
- ⚠️ Queuing delays increase with more hops

• Concern 2: Reachability Status with Single Link Failure

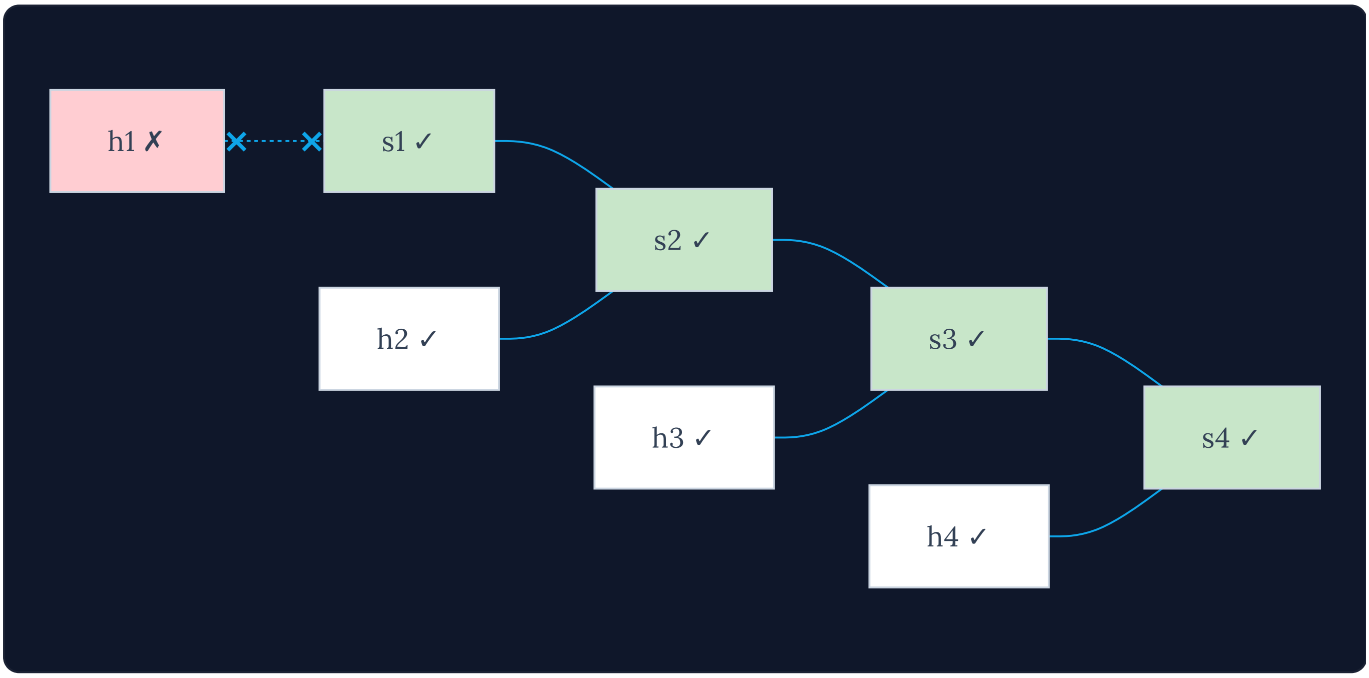
Question: What is the reachability status if a single link fails?

Answer:

A single link failure creates **network partitioning**, making some hosts unreachable from others.

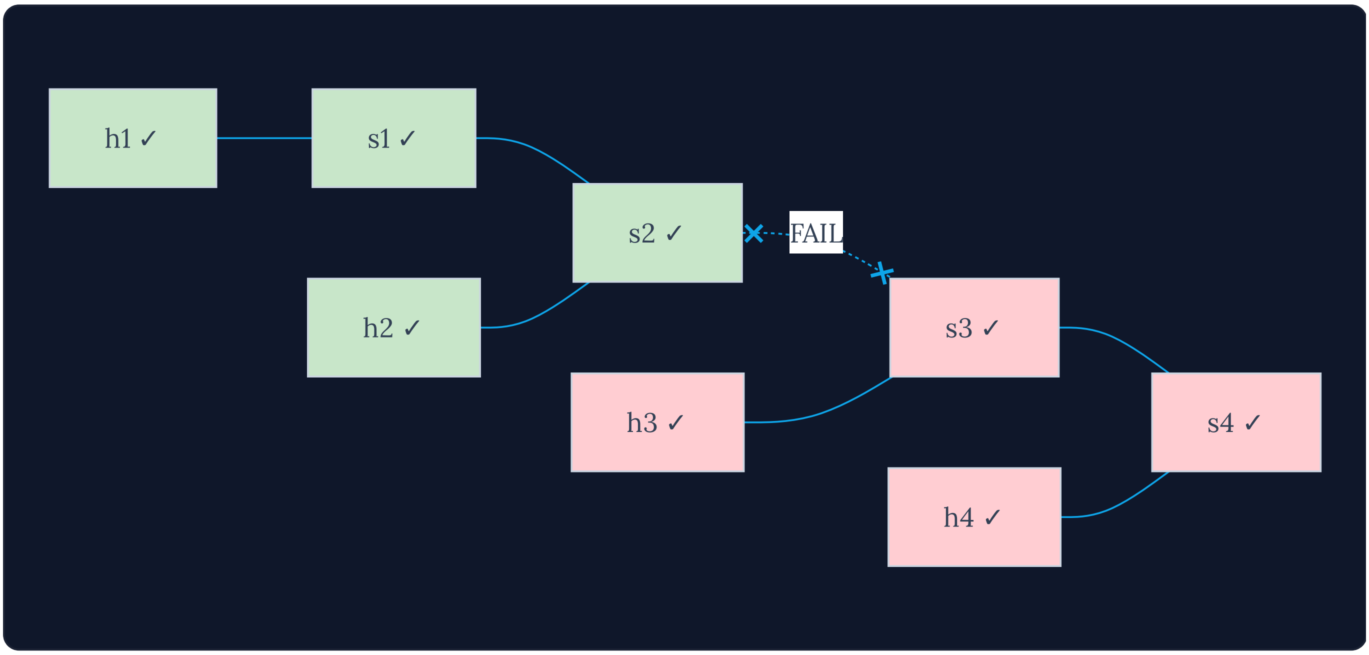
Failure Scenario Analysis:

Scenario A: Edge Link Failure (s1-h1)



Impact: Only h1 isolated (3 hosts remain connected)

Scenario B: Core Link Failure (s2-s3)



Impact: Network split into two segments (h1,h2 | h3,h4)

Reachability Matrix After Core Failure:

	H1	H2	H3	H4
h1	✓	✓	❌	❌
h2	✓	✓	❌	❌
h3	❌	❌	✓	✓
h4	❌	❌	✓	✓

Critical Findings:

- ❌ 50% of host-to-host paths become unavailable
- ❌ No automatic recovery mechanism
- ❌ Controller cannot establish alternate paths
- ⚠️ Manual intervention required to restore connectivity

Recommendations

Based on this analysis, the following improvements are recommended:

1. **Add Path Redundancy:** Implement mesh or ring topology for critical links
2. **Deploy Link Aggregation:** Use multiple physical links between switches
3. **Enable Rapid Failover:** Configure OpenFlow fast-failover groups
4. **Monitor Link Health:** Implement proactive monitoring and alerting
5. **Design for Fault Tolerance:** Avoid linear topologies in production environments

Conclusion

This lab demonstrated that linear topology, while simple to understand and implement, suffers from significant reliability issues. The single point of failure characteristic makes it unsuitable for production environments where high availability is required. The experiments clearly showed how a single link failure can partition the network and disrupt communication between hosts.

Key Takeaways:

- Linear topology has no redundancy
- Every link is a potential single point of failure
- RTT increases linearly with hop count
- Single link failures cause network partitioning
- Not recommended for production use

Appendix

• Useful Mininet Commands Reference

```
# Start linear topology
sudo mn --topo linear,4 --nat

# Test commands
mininet> pingall
mininet> iperf h1 h4
mininet> h1 ping -c 10 h2

# Link management
mininet> link s2 s3 down
mininet> link s2 s3 up

# Information commands
mininet> nodes
mininet> net
mininet> dump
```

End of Report