New Directions for Network Verification

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Brief Summary of This Talk

- *Context*:
  - Proliferation of network verification tools.
  - Build on assumption that the network state is **immutable**.
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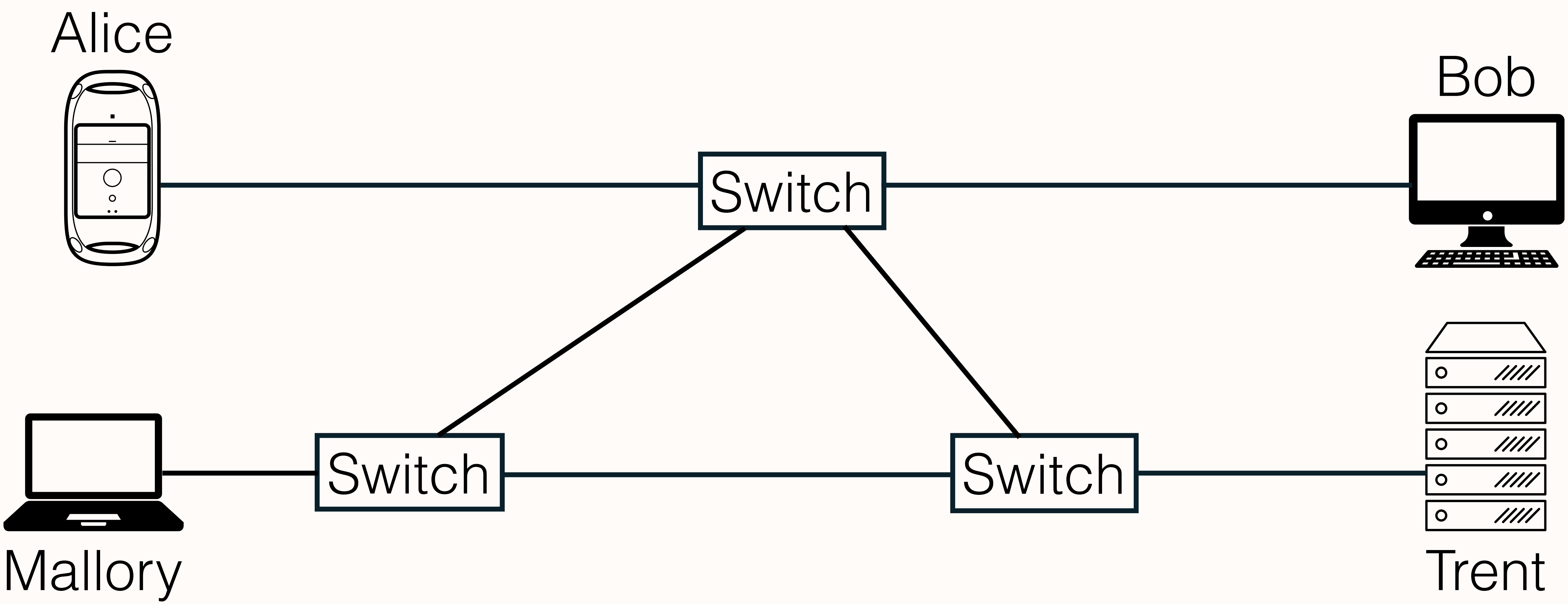
- *Context*:
  - Proliferation of network verification tools.
  - Build on assumption that the network state is **immutable**.
    - Immutable = Data packets do not change behavior of network
- *My point*:
  - Many network elements have **mutable state**
  - **Verifying mutable networks requires new techniques**
  - Two technical challenges: Modeling and Scaling

Outline

- **Background on networks.**
- Background on network verification.
- Verifying mutable networks.

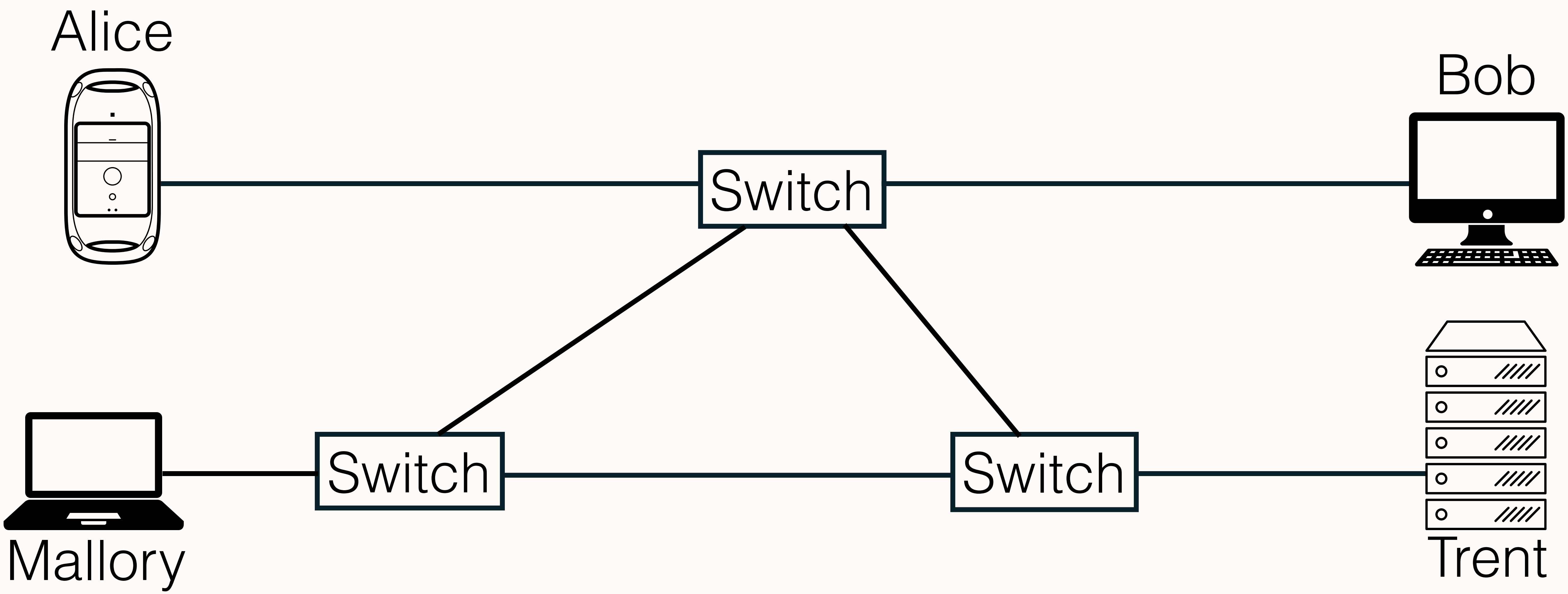
Classical Networking

Ted Stevens was right



- Networks provide end-to-end connectivity.
- Just contain host and switches.
- All interesting processing at the hosts.

Real Networks have Middleboxes!



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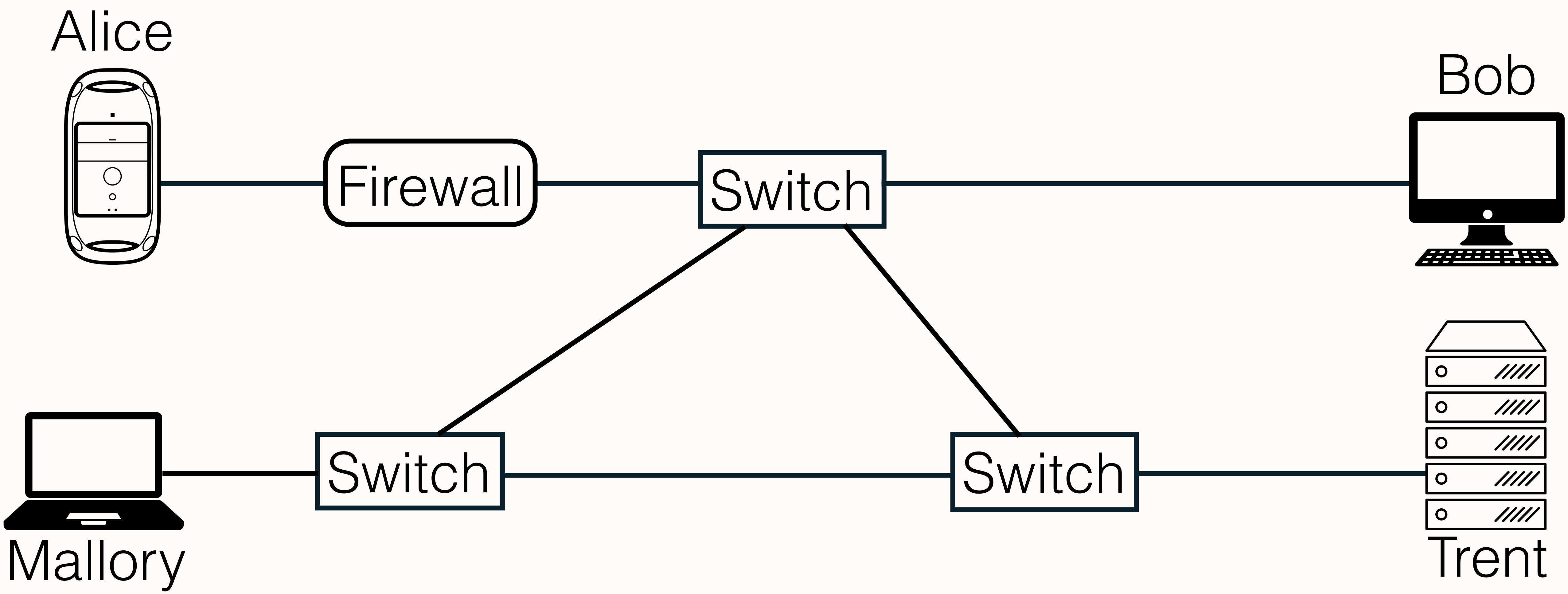

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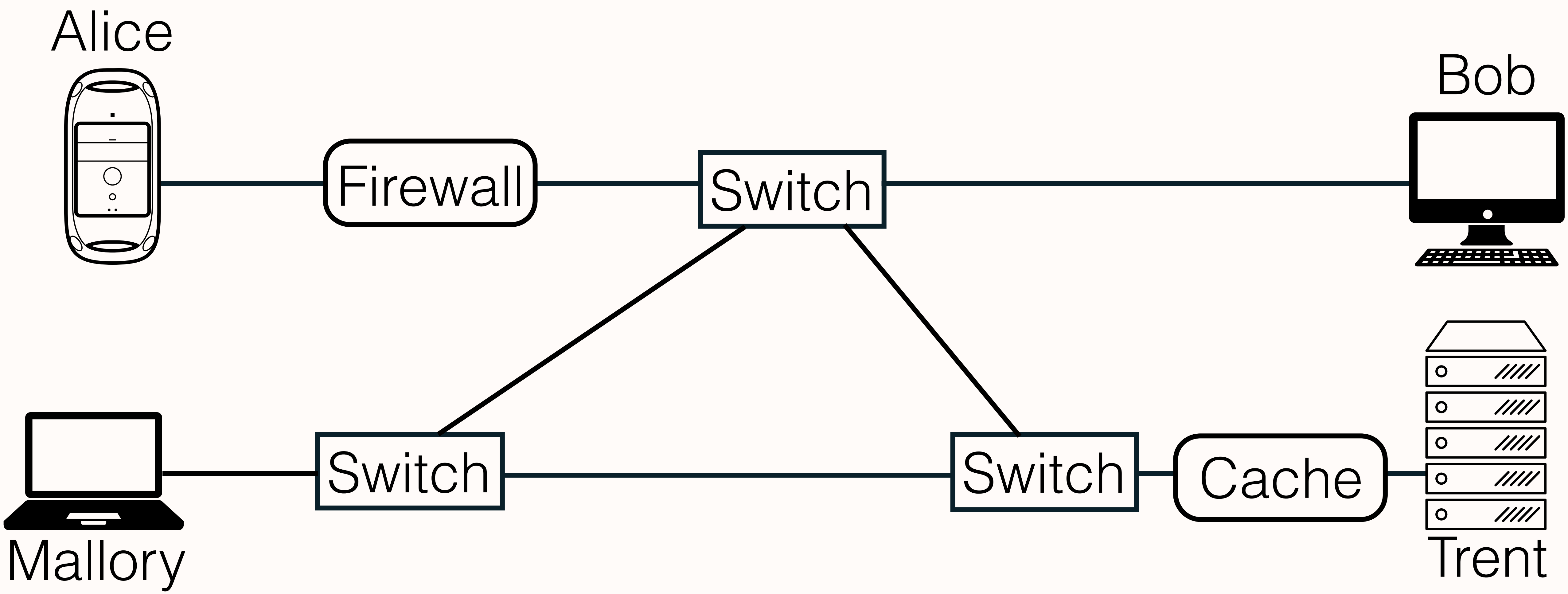

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- Performance (caches, load balancers,…).

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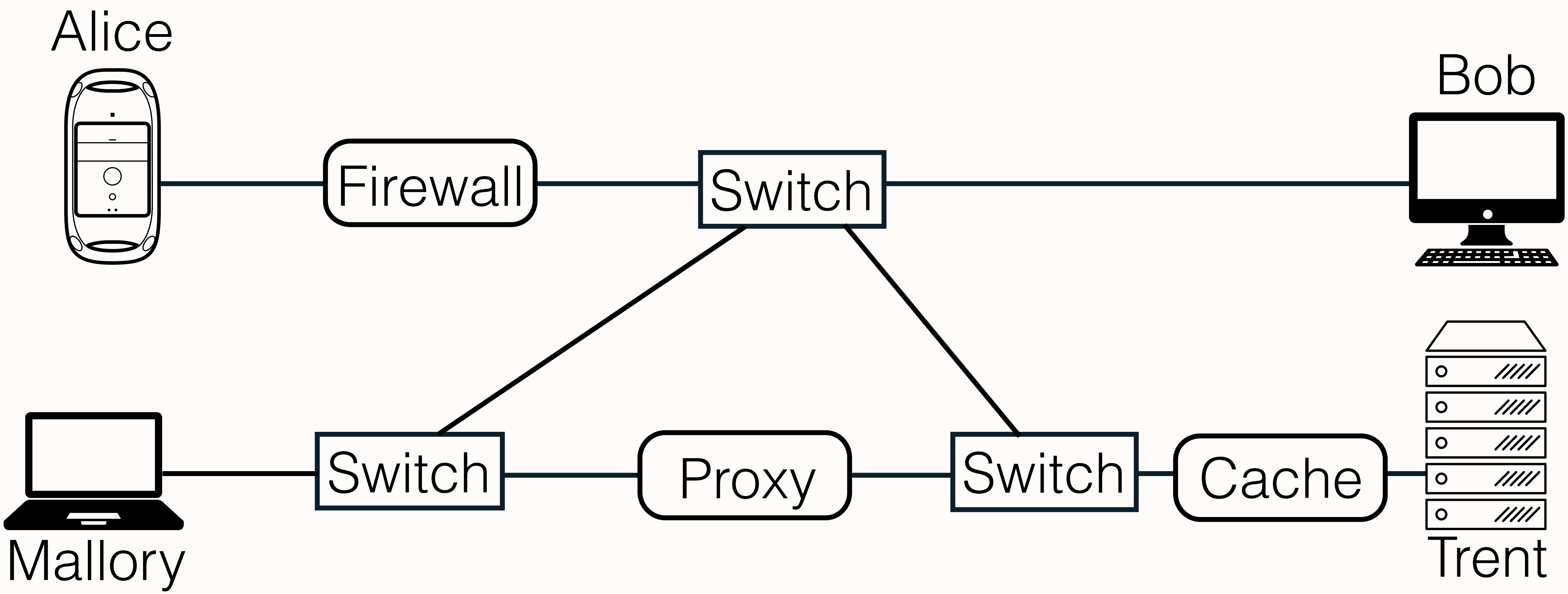

- Security (firewalls, IDSs,…).
- Performance (caches, load balancers,…).
- New functionality (proxies,…).

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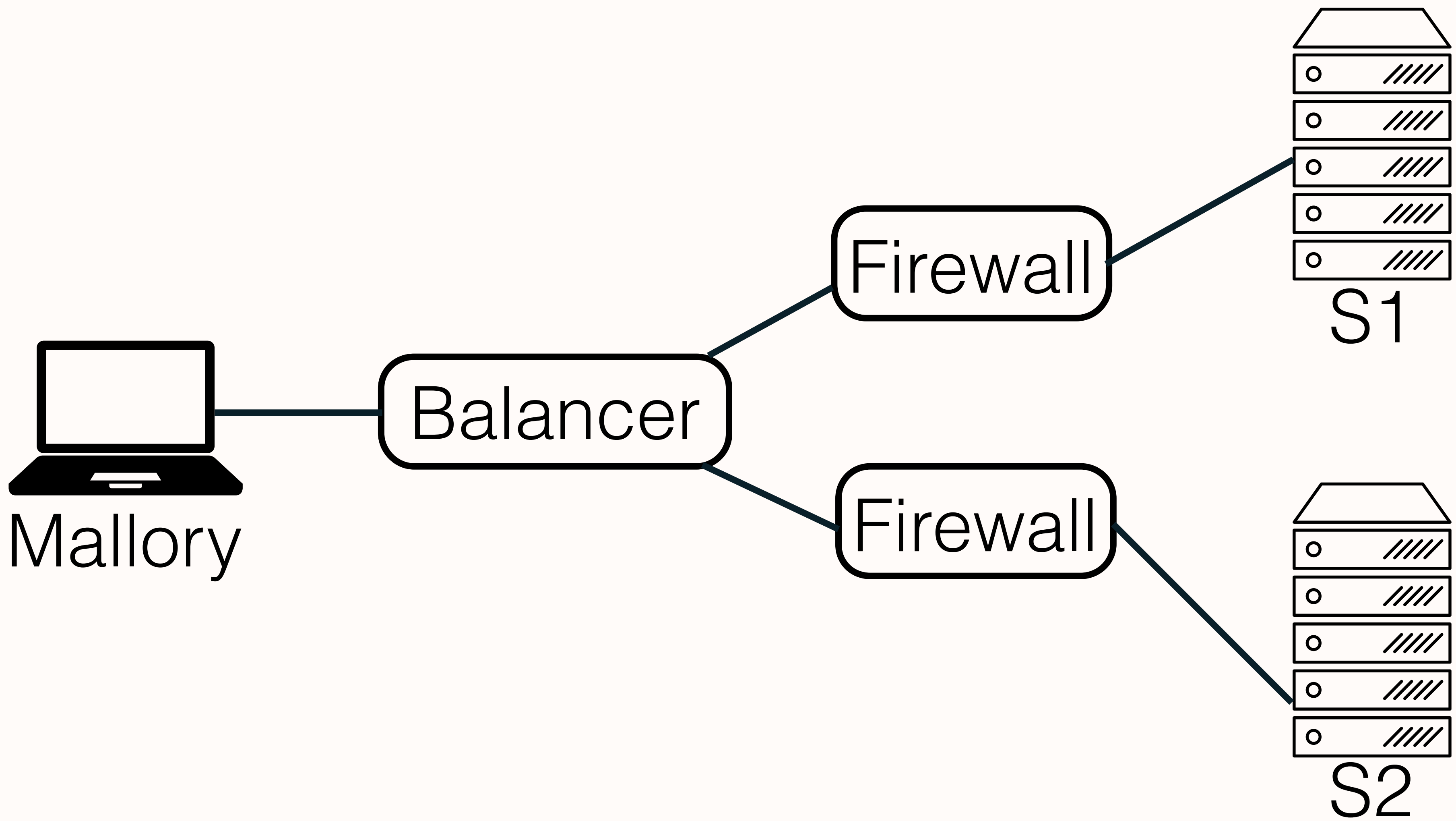
Reachability Invariants

- Focus on reachability invariants
  - Most important in practice, simple to state but already hard



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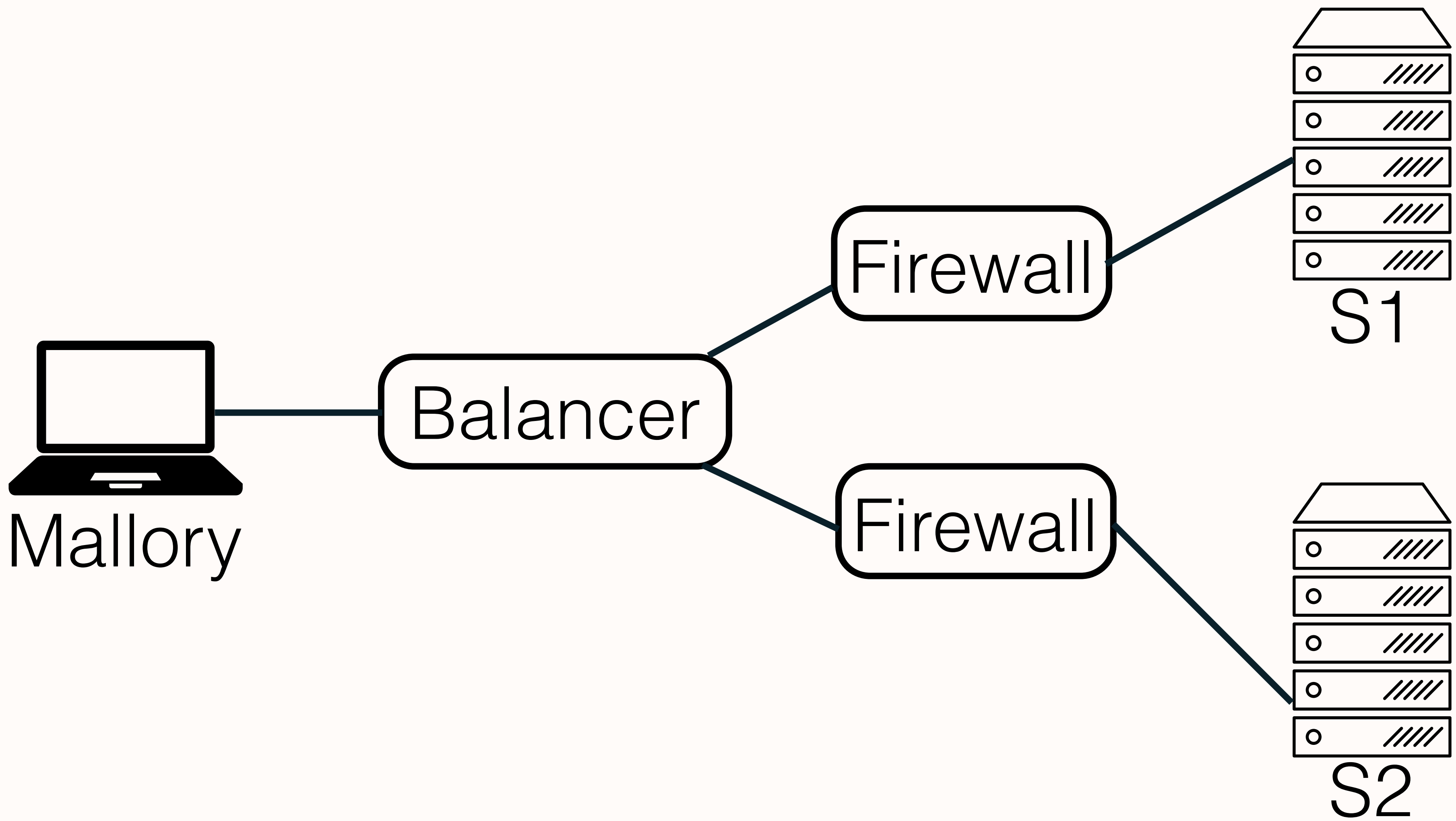

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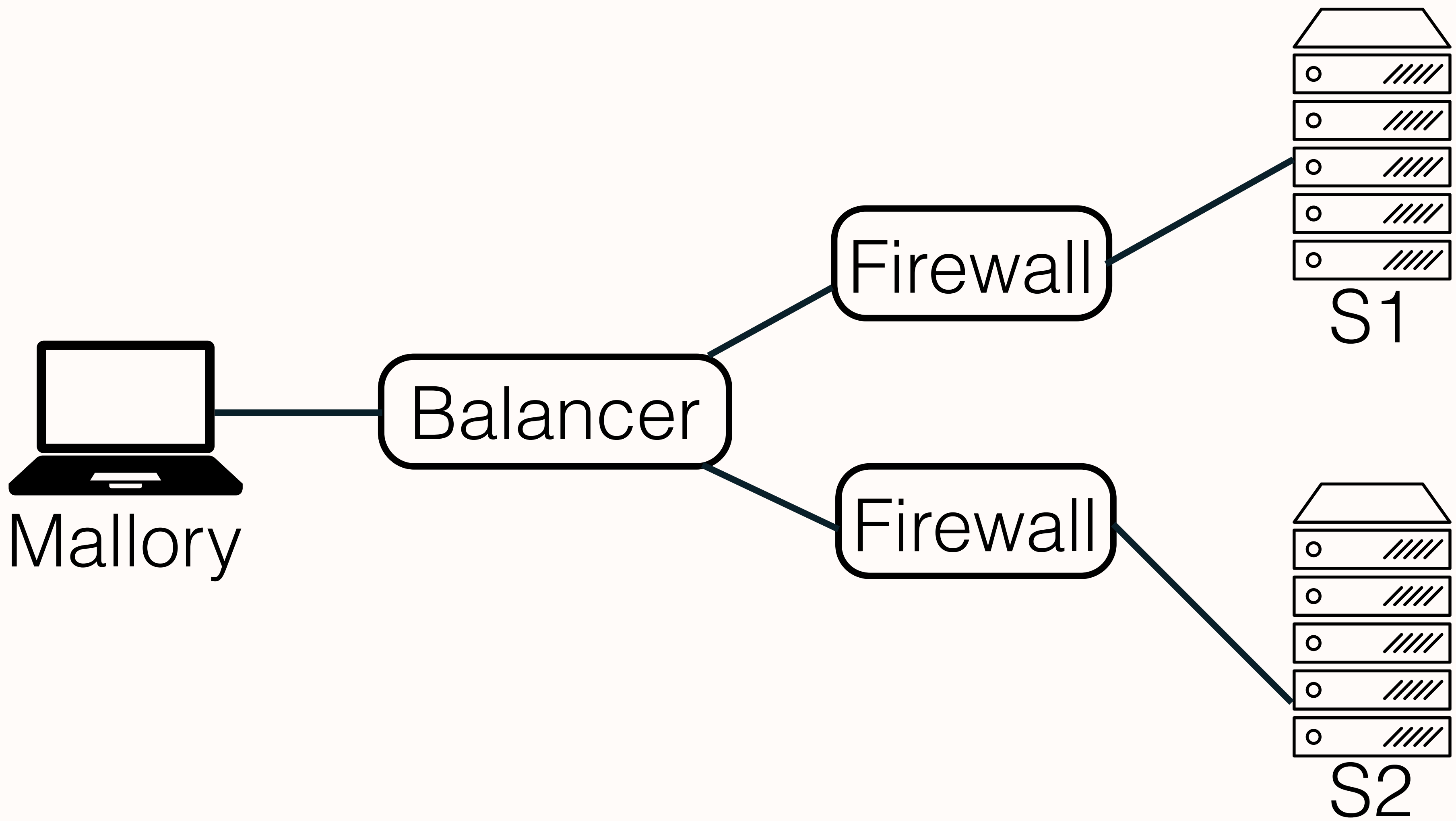

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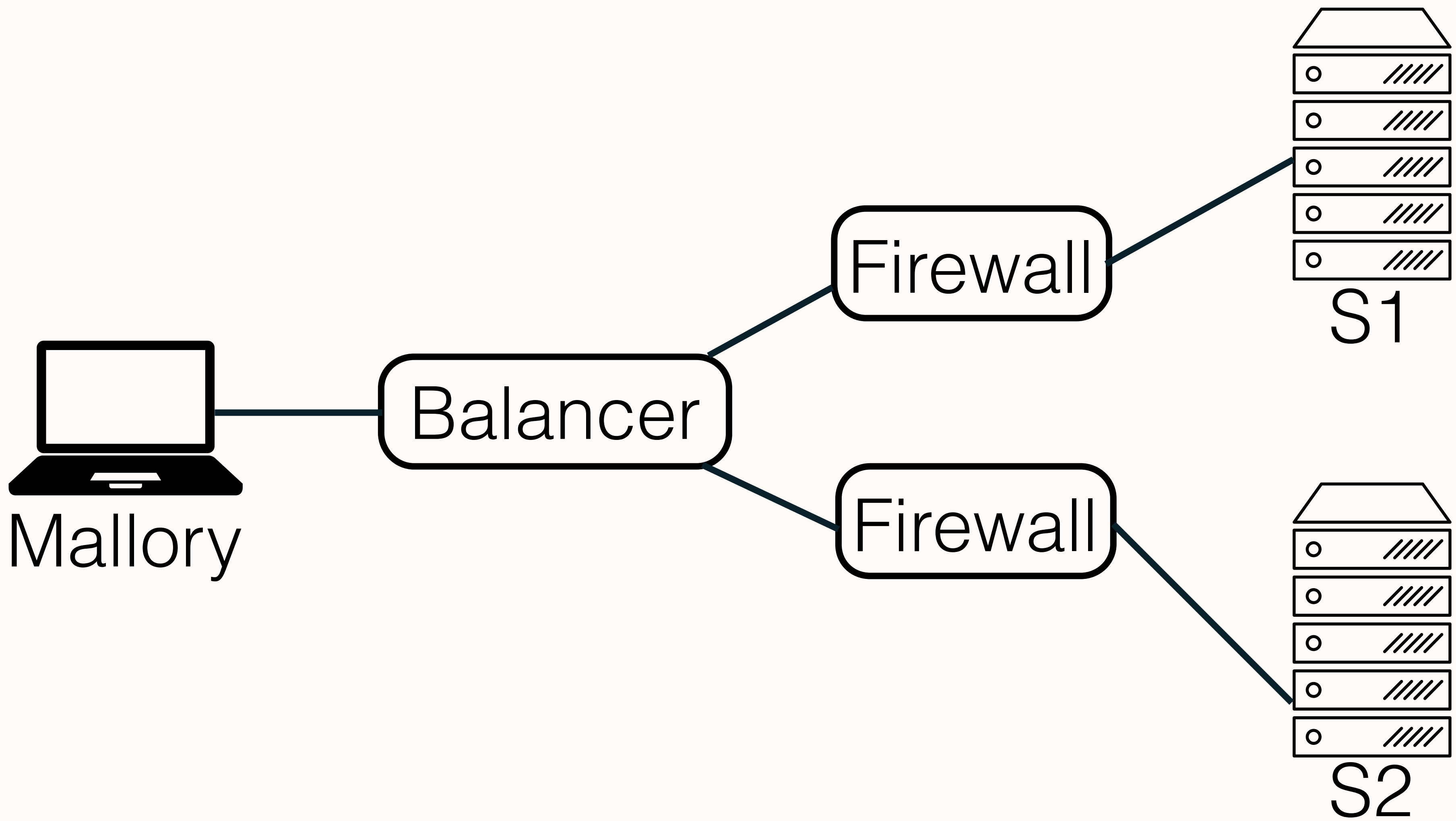

Can S2 receive packets from Mallory without a connection?

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  - Invariants should not depend on these details

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- Firewalls: Verify firewall configuration.

    Fang, Margrave, etc.

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Violated by many middleboxes

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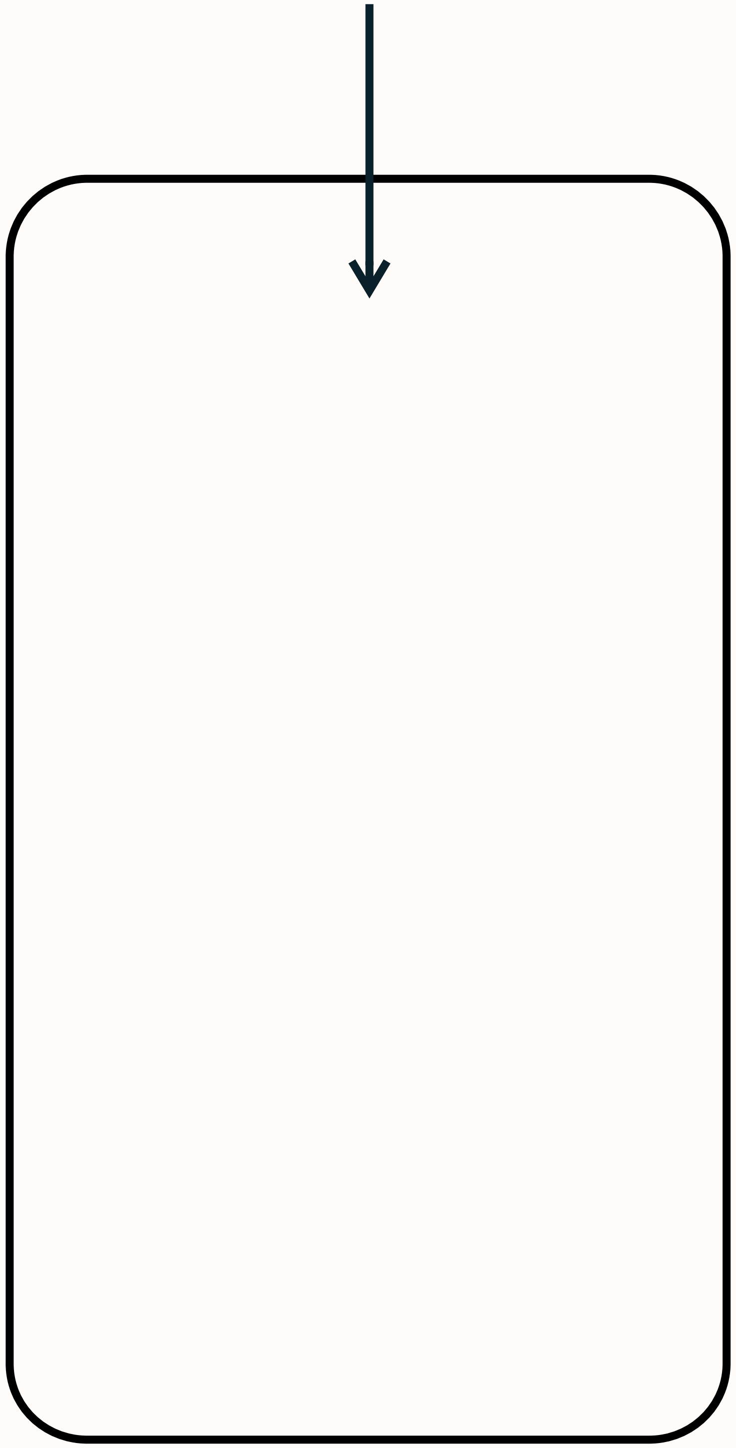
  - Large, proprietary code bases (Bro ~102K lines of code).
- Scalability is crucial
  - Networks contain several 1000 middleboxes or more.

Modeling Middleboxes



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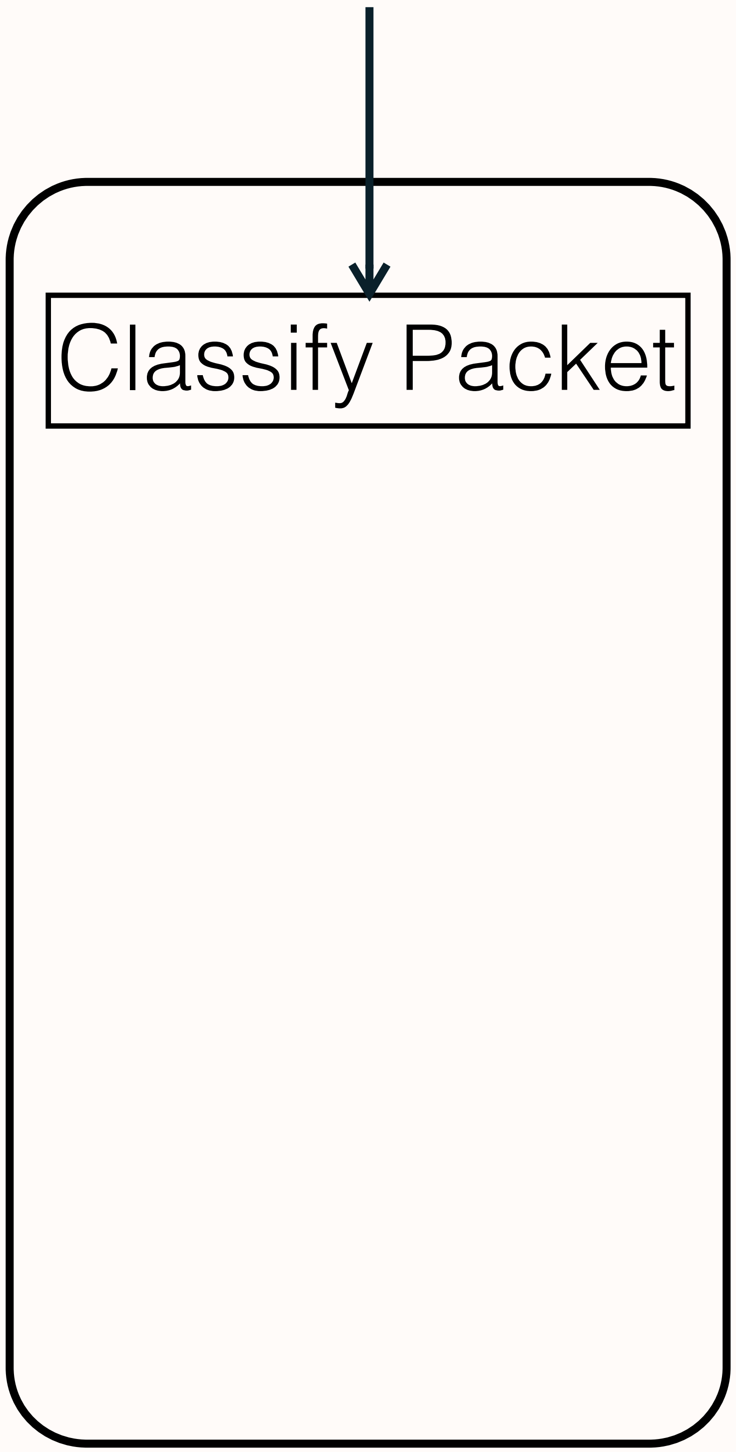

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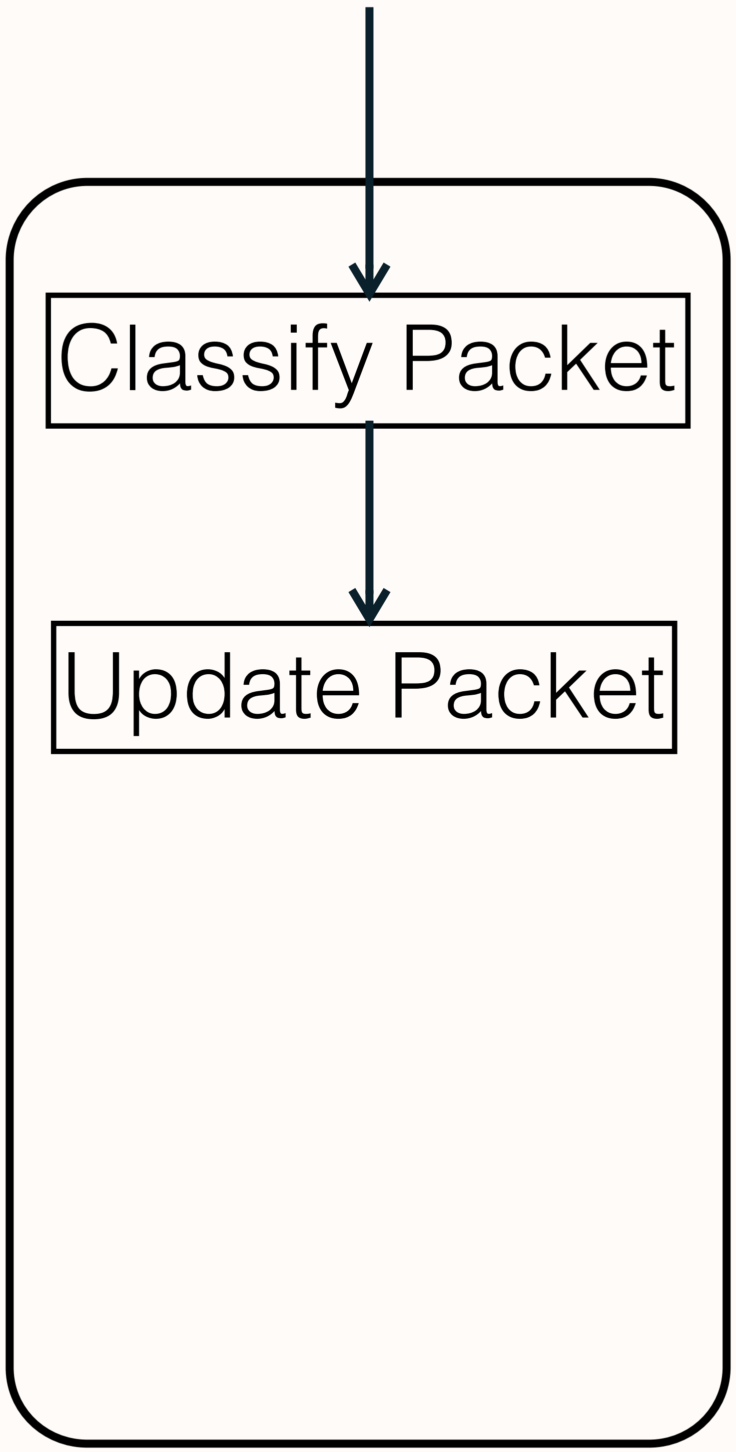

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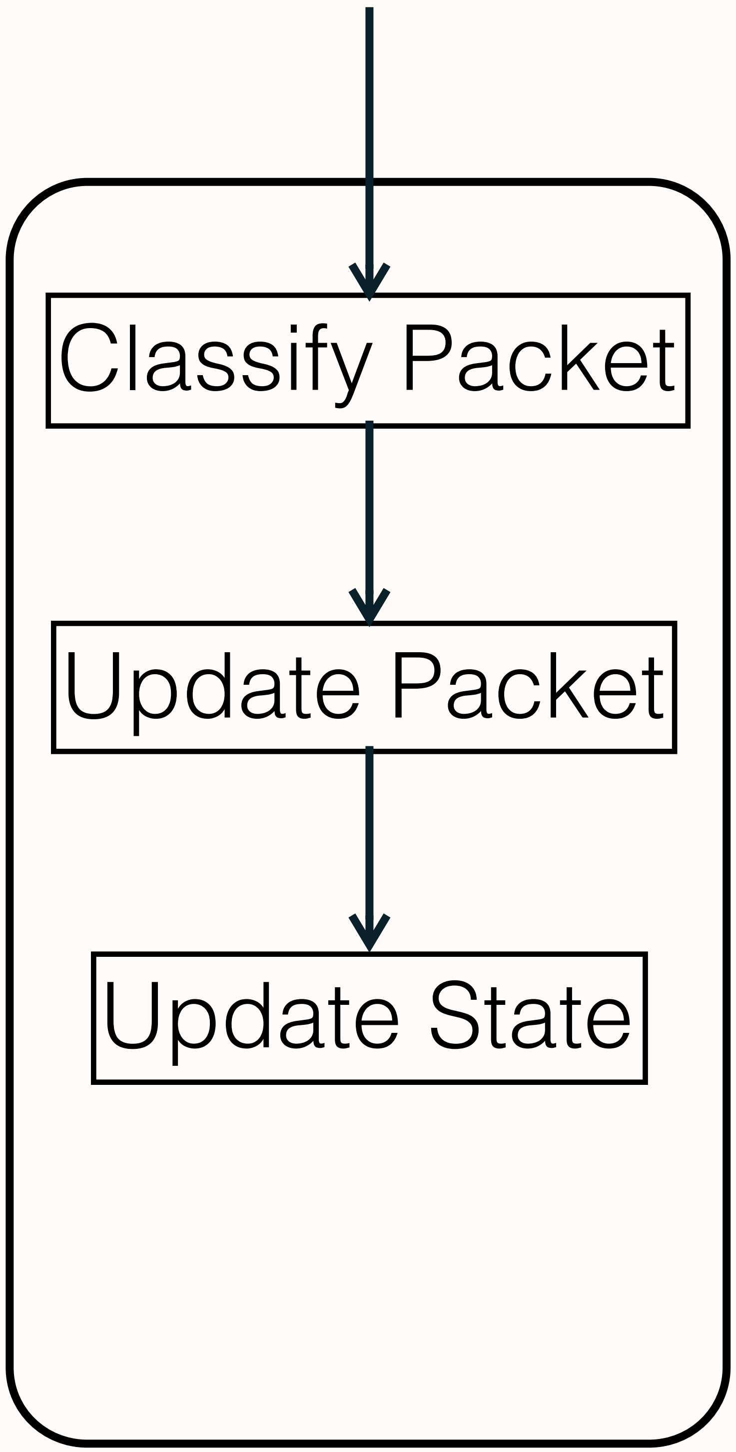

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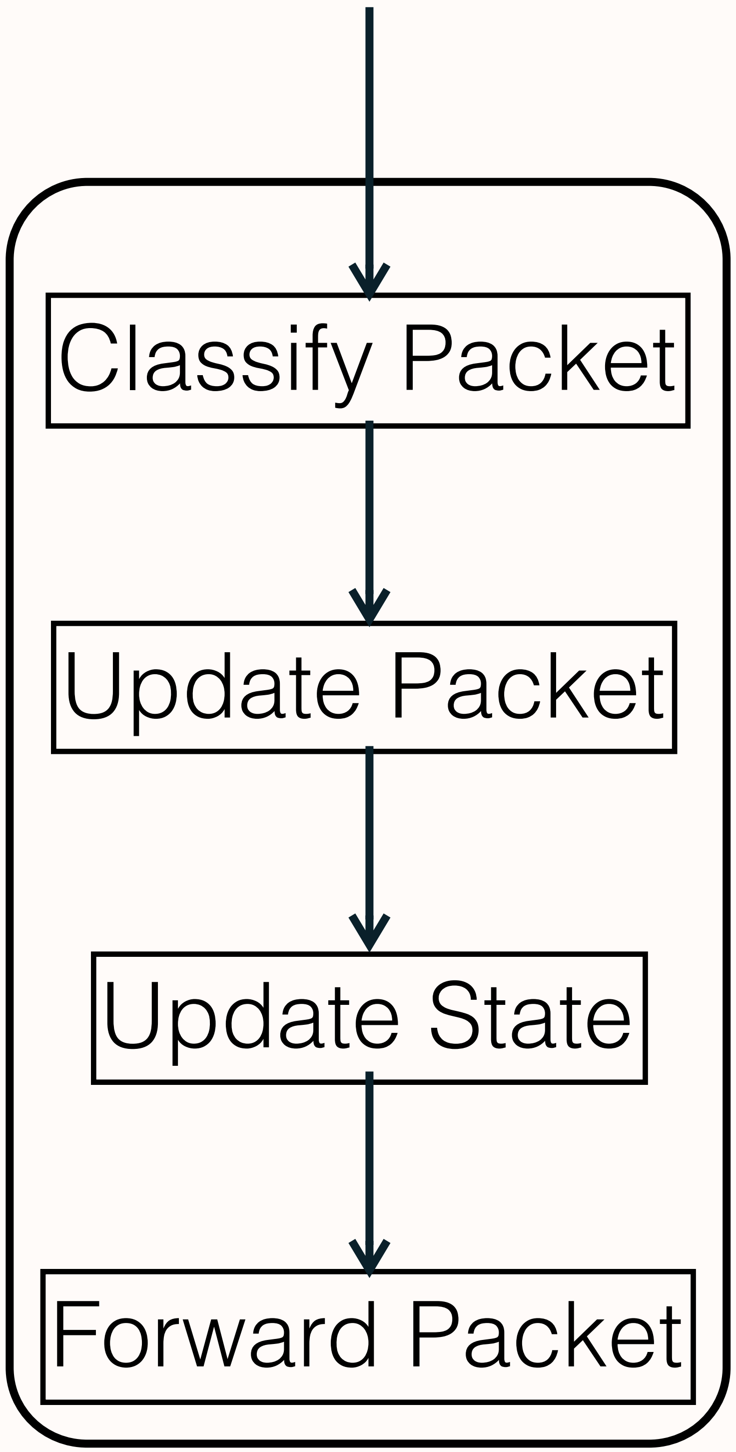

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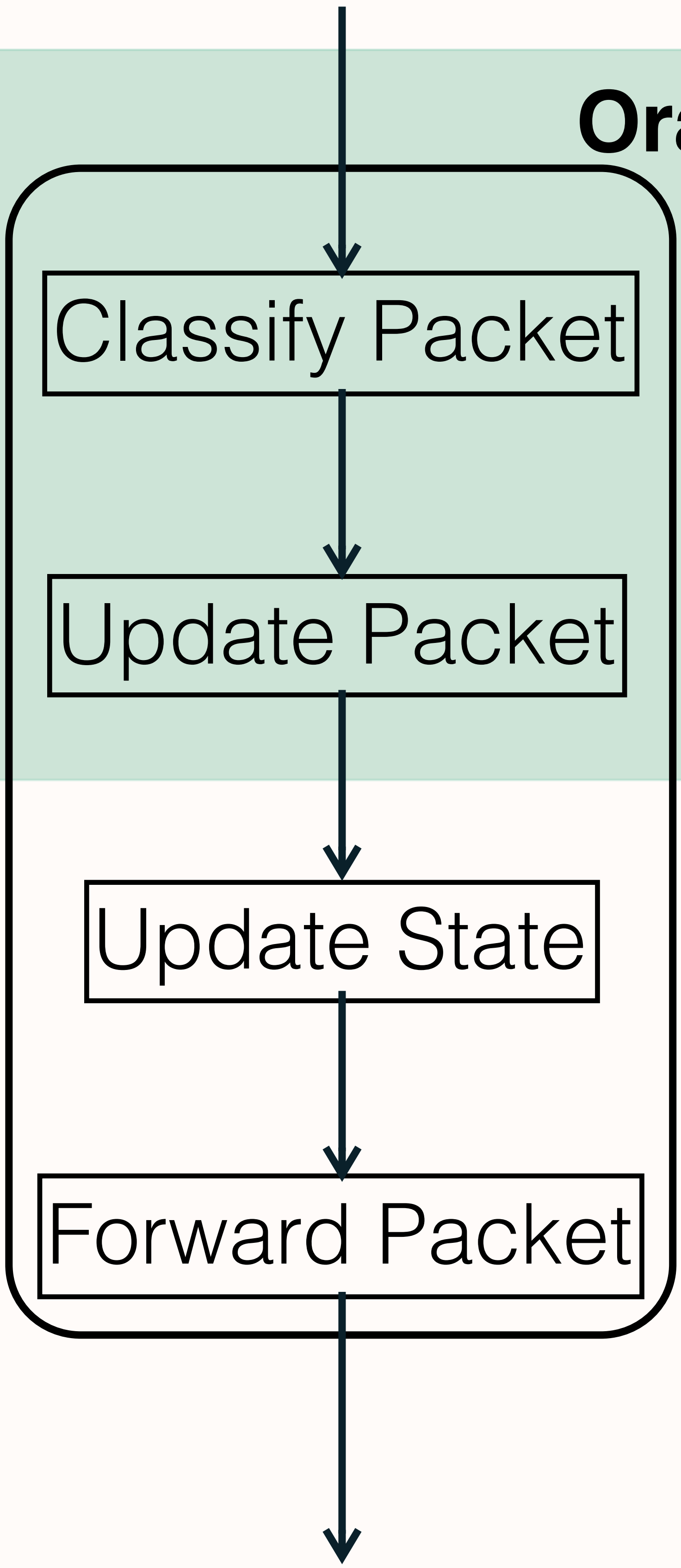

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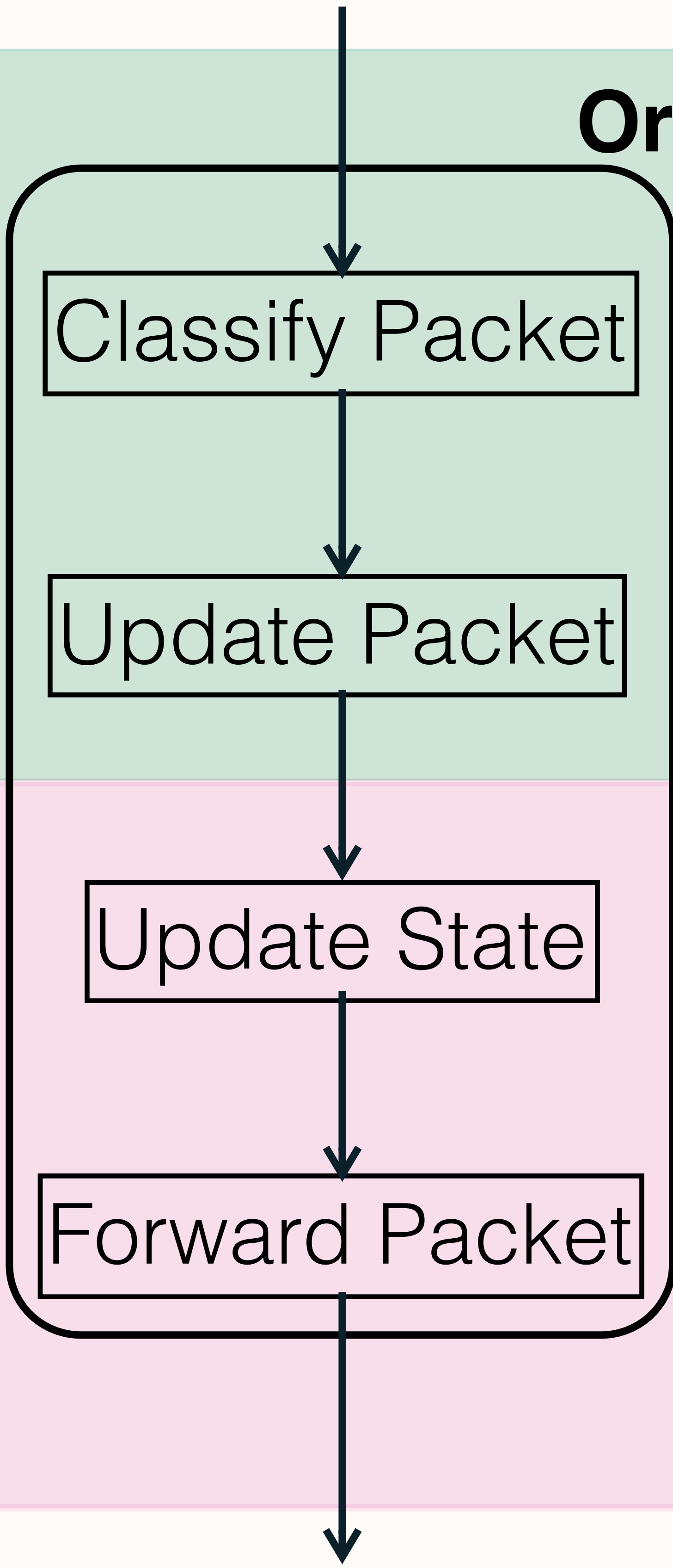

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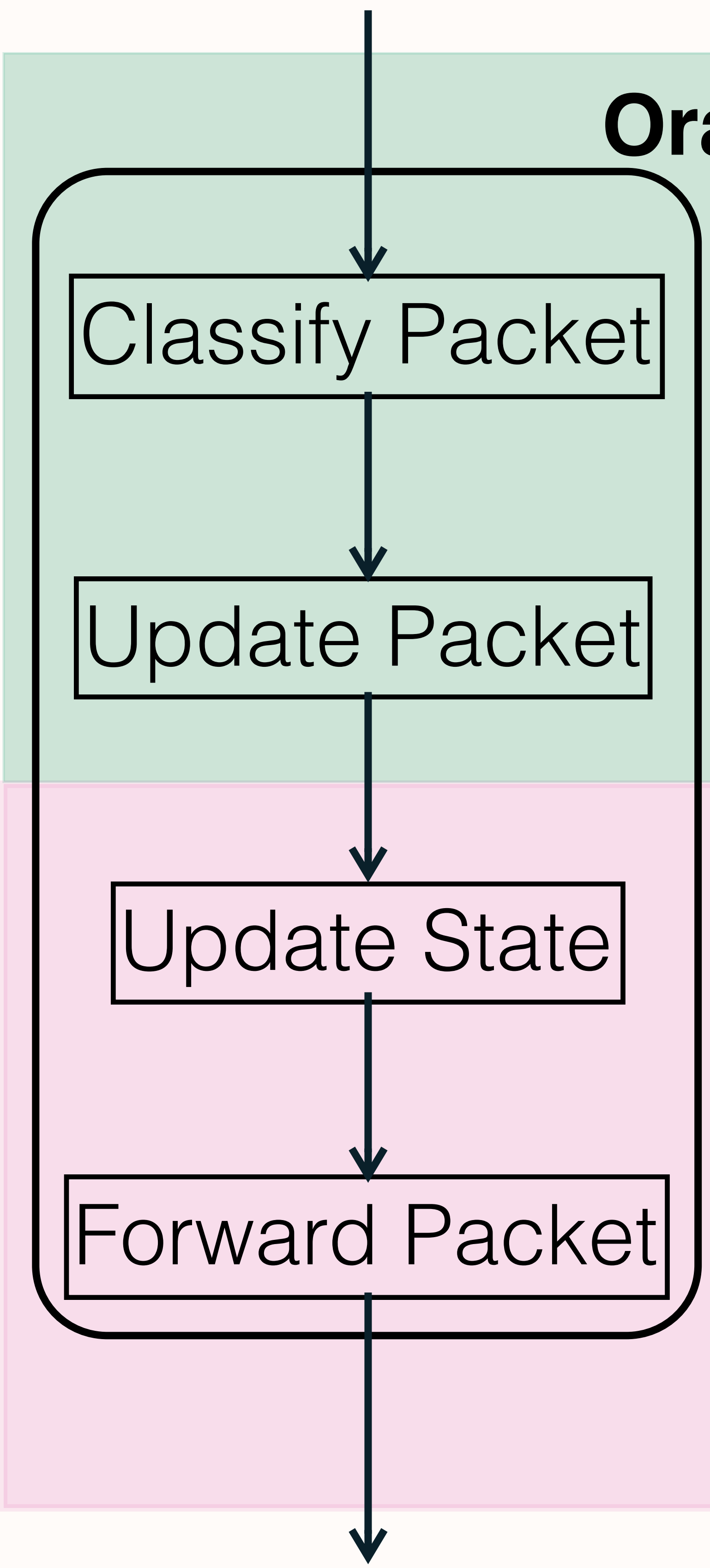

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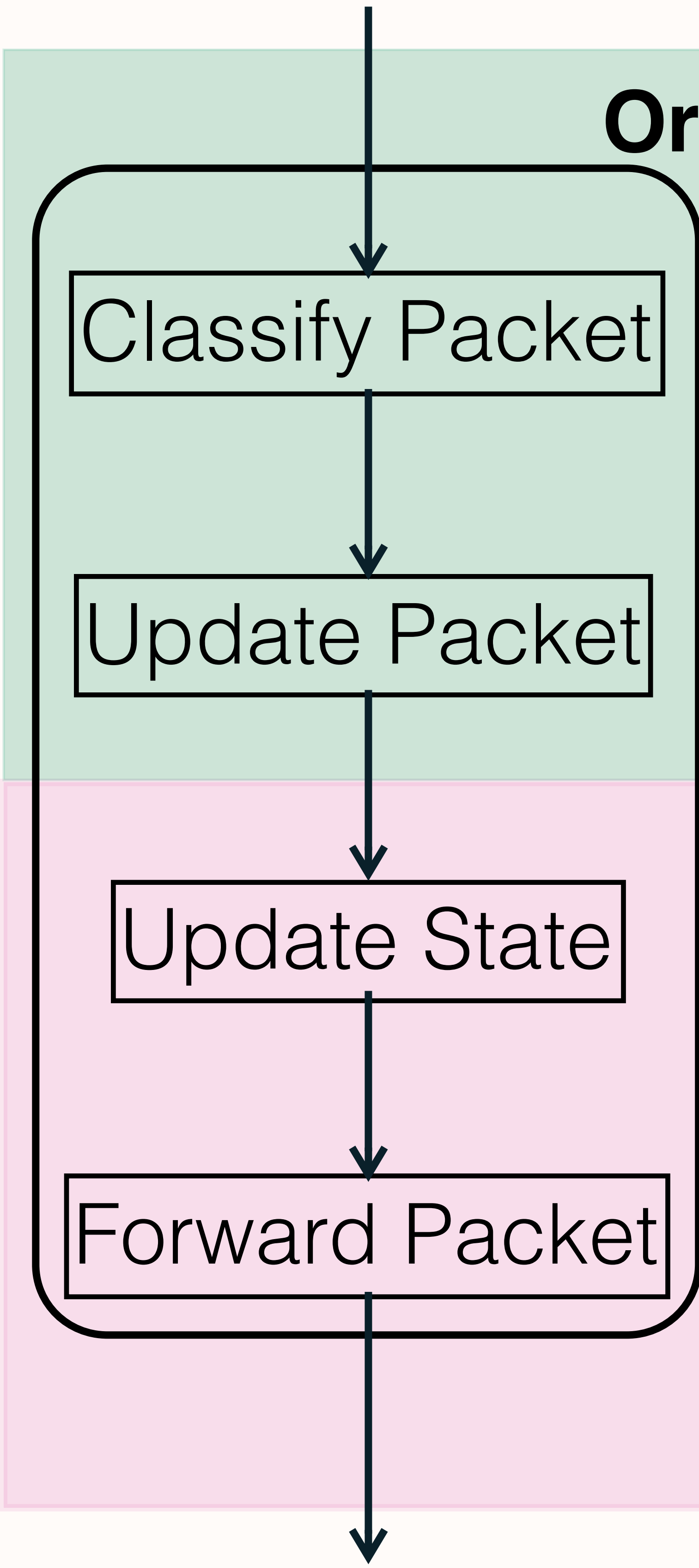

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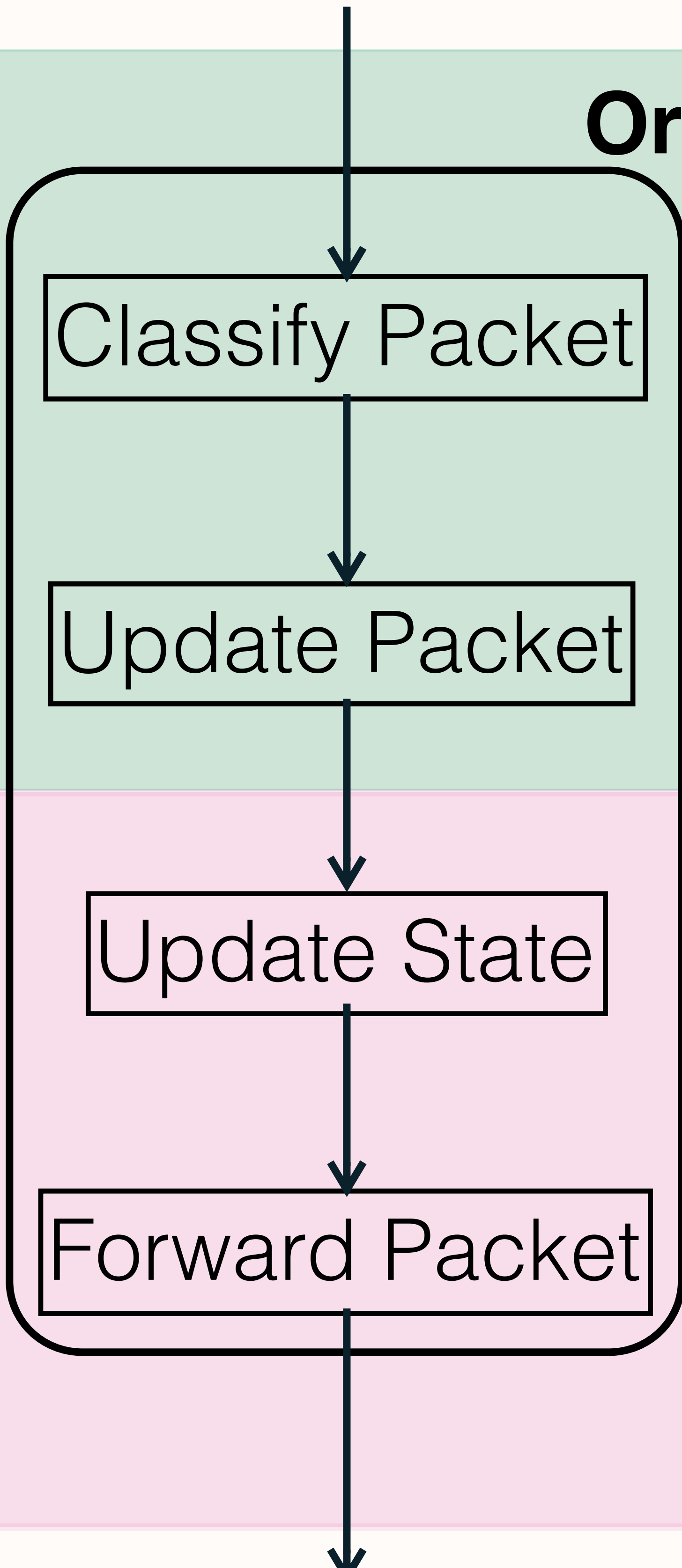

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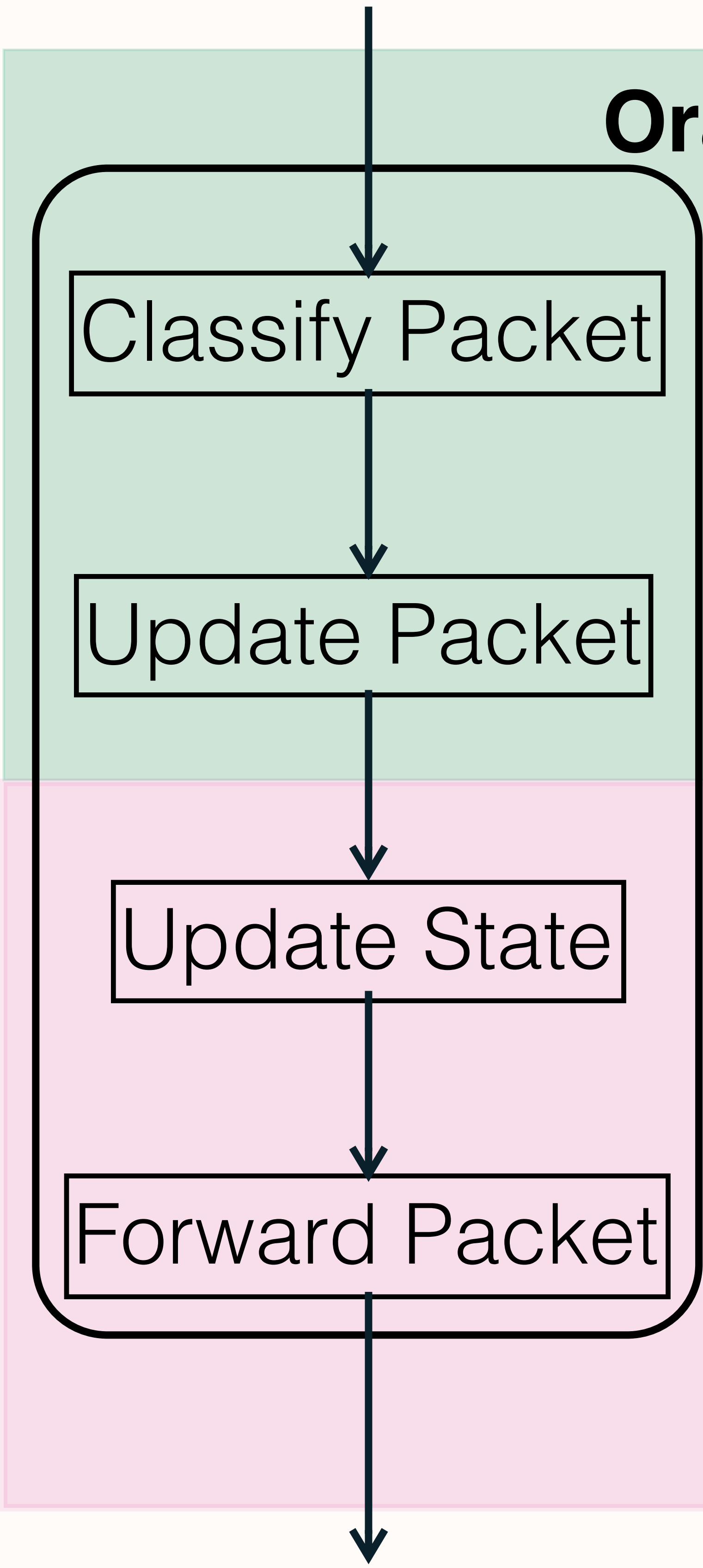

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See all packets in connection (flow).

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Is packet **infected**.

if (**infected**) {
    infected_connections.add(packet.flow)
}

if (**packet.flow** not in **infected_connections**) {
    forward (packet);
}

Forwarding Model: Specify Completely

Scaling Verification

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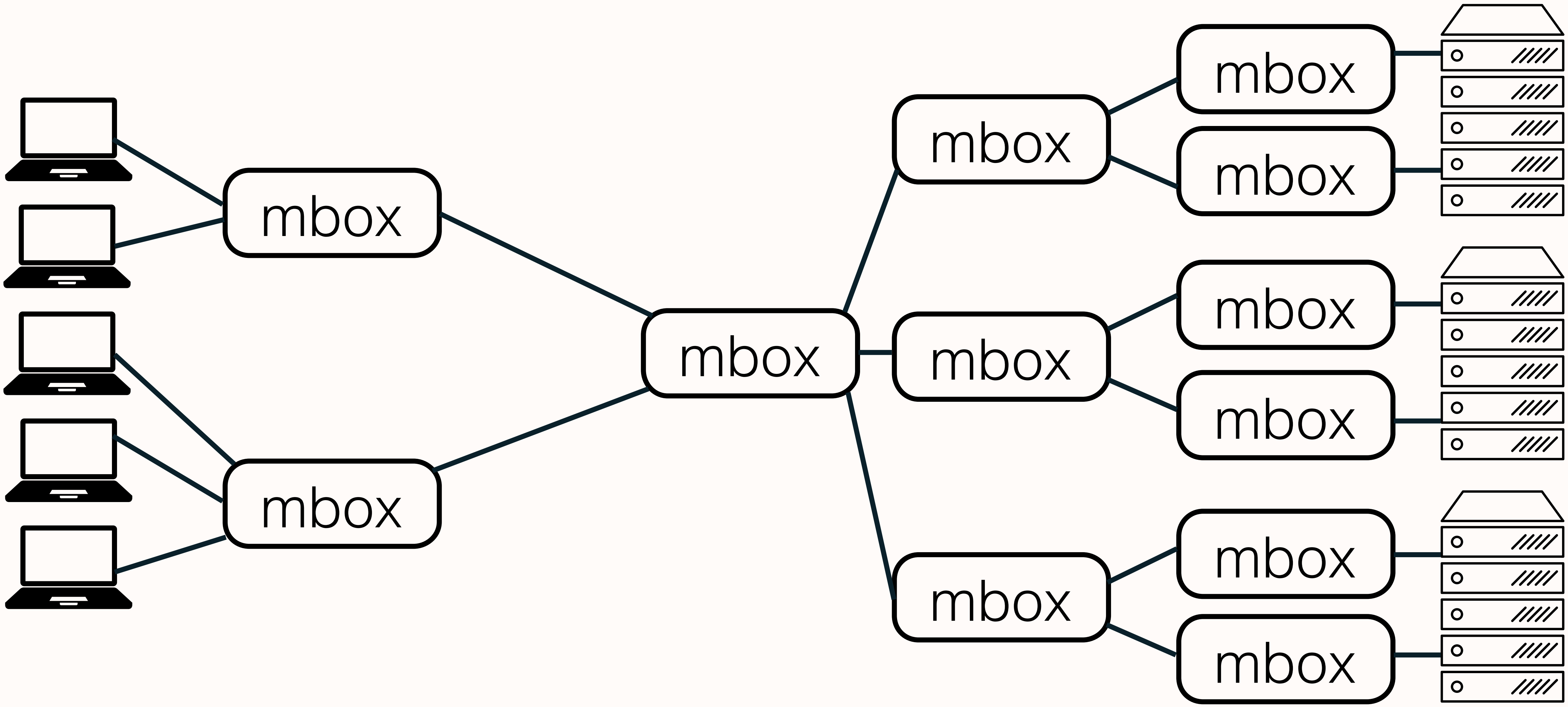
- This enables “compositional verification”
  - 30,000 middlebox networks verified in 5 minutes

Compositional Verification



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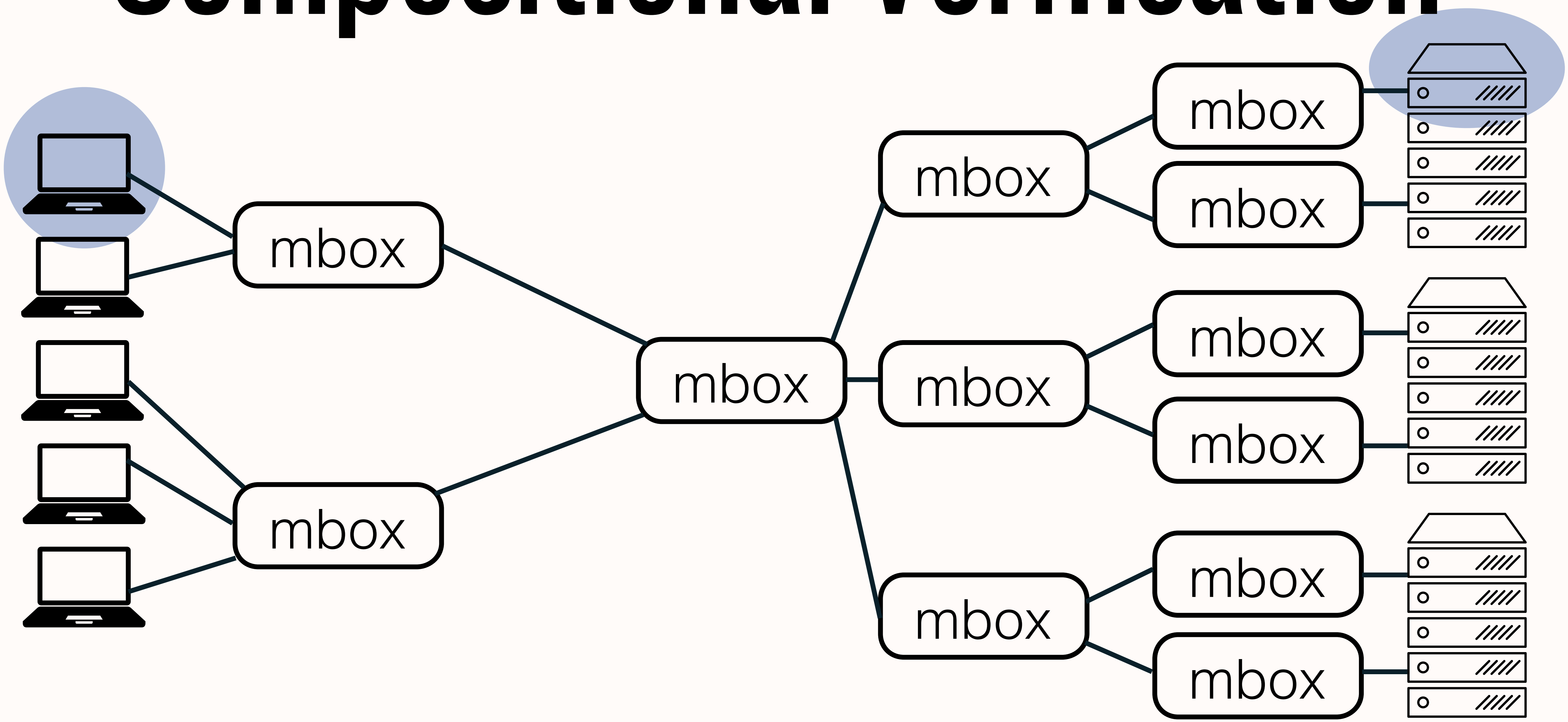

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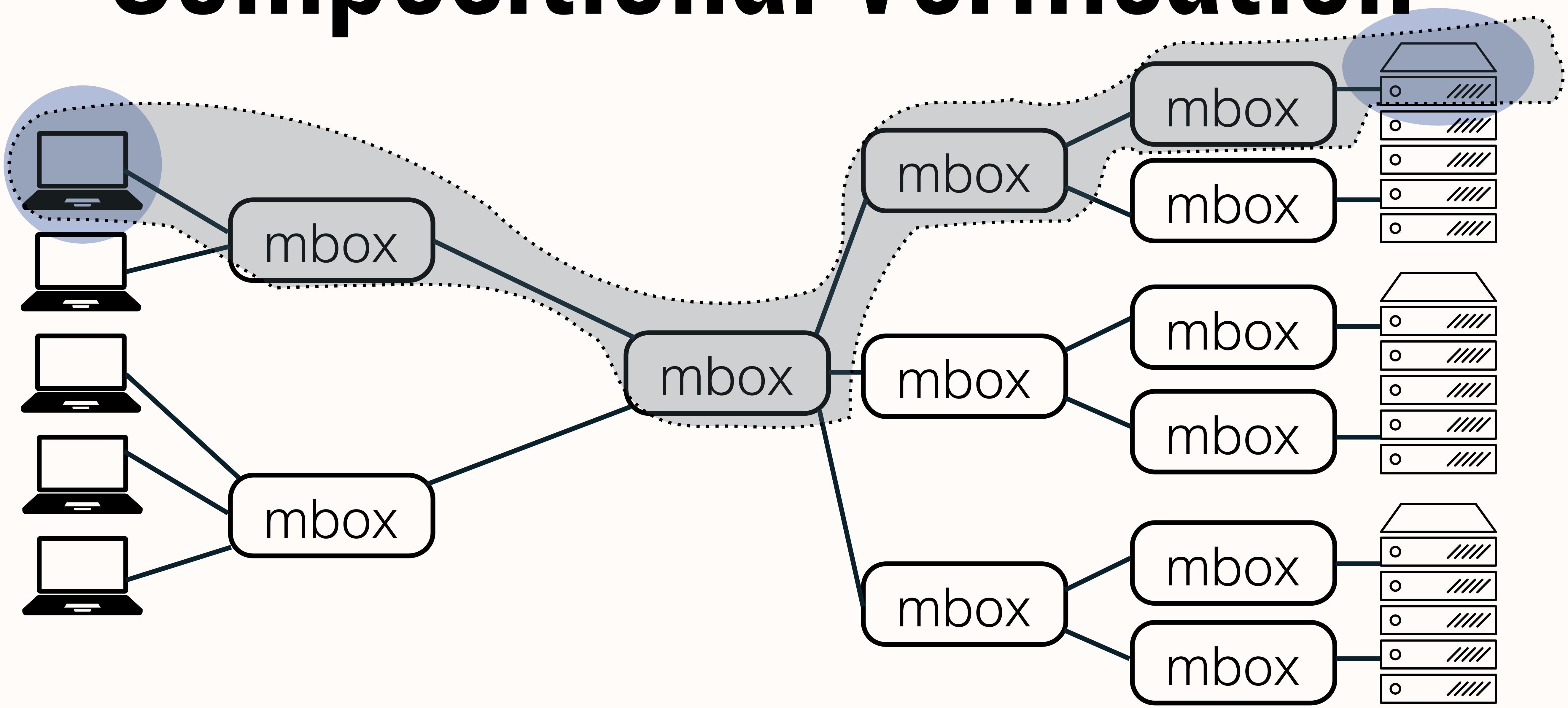

- Invariants talk about pairs of hosts.
  - When flow-parallel, need-only verify path.

Conclusion

- Real networks:
  - Contain mutable middleboxes.
  - Used to enforce rich connectivity invariants.

- Network verification needs to evolve to handle this.
- Several challenges
  - Right level of abstraction for specifying middleboxes.
  - Scalability, by leveraging compositional verification.
  - Future: Tractability of verification.

Backup

Does State Mutation Matter

- Do we even need to look at state evolution?
  - Check invariant for all possible states.
  - Approach used in tools like Margrave.
    - # of states is small (just whether connection established).
- False positives, some states may never occur.

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$conn(a \rightarrow b)$ Connection started by a to b.
Requires a to send packet to b, and b to respond

Can a packet from 'a' reach 'b'?