Abstractions for Network Update

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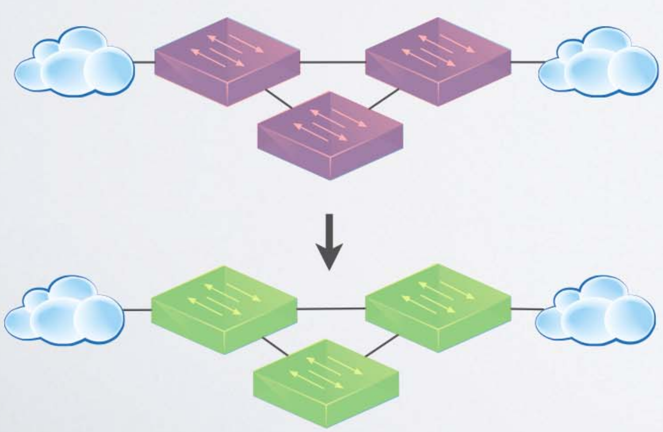
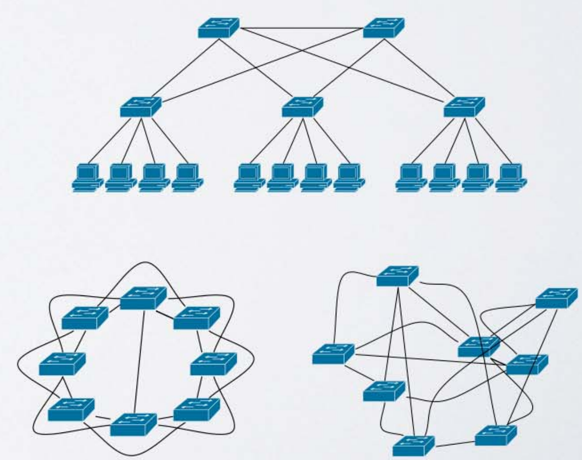
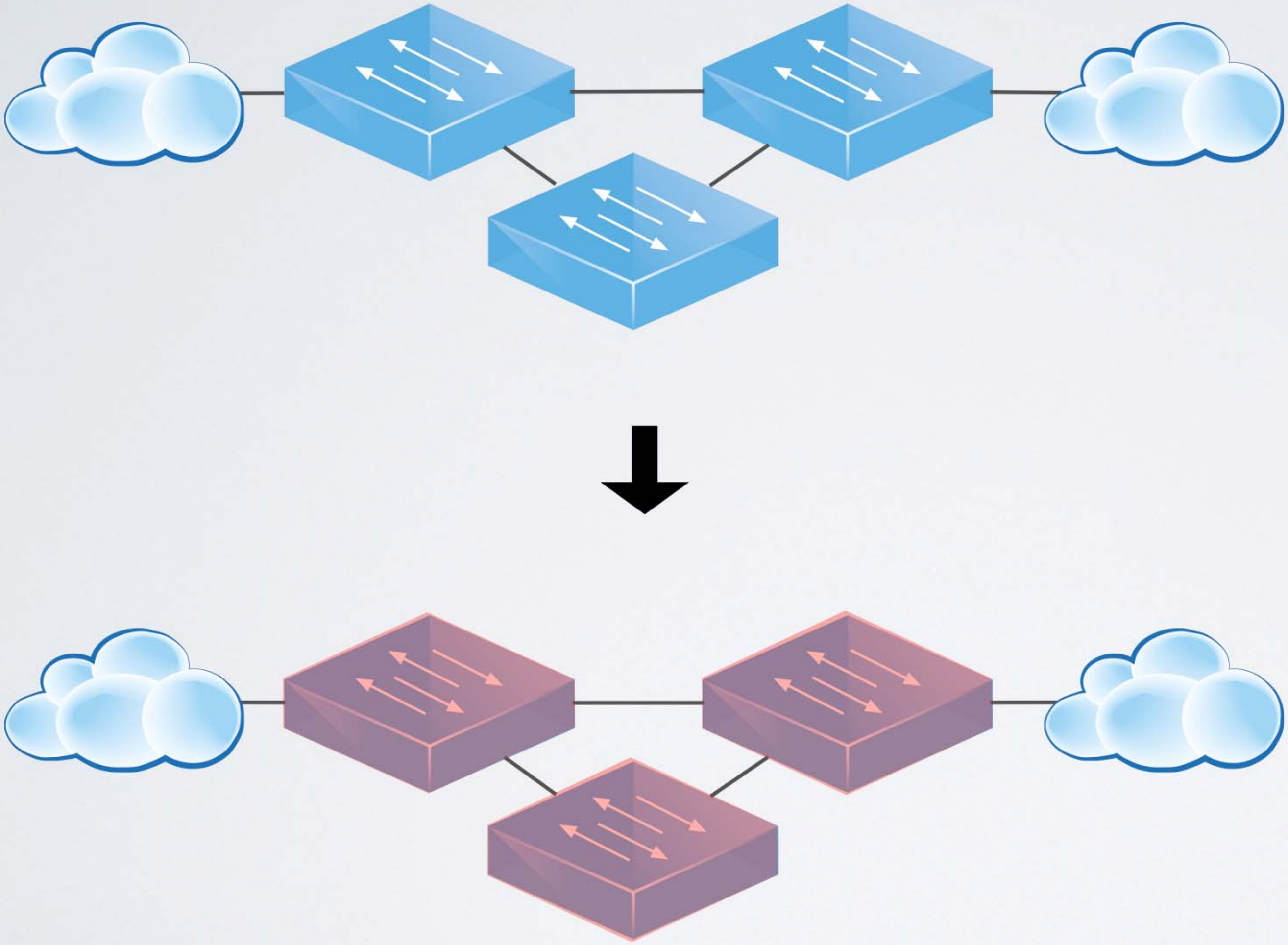




Updates Happen



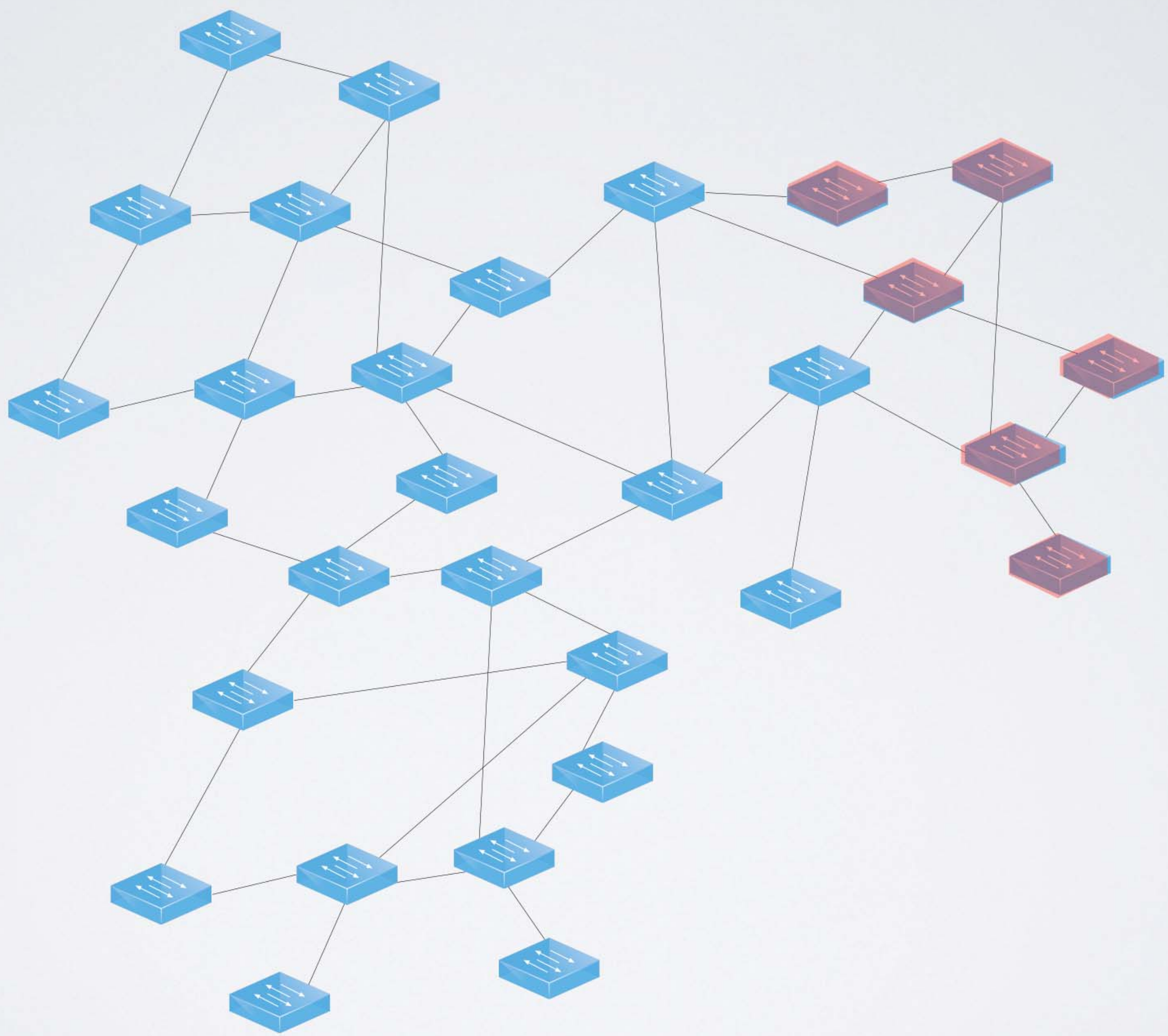
Network Updates

- Maintenance
- Failures
- ACL Updates

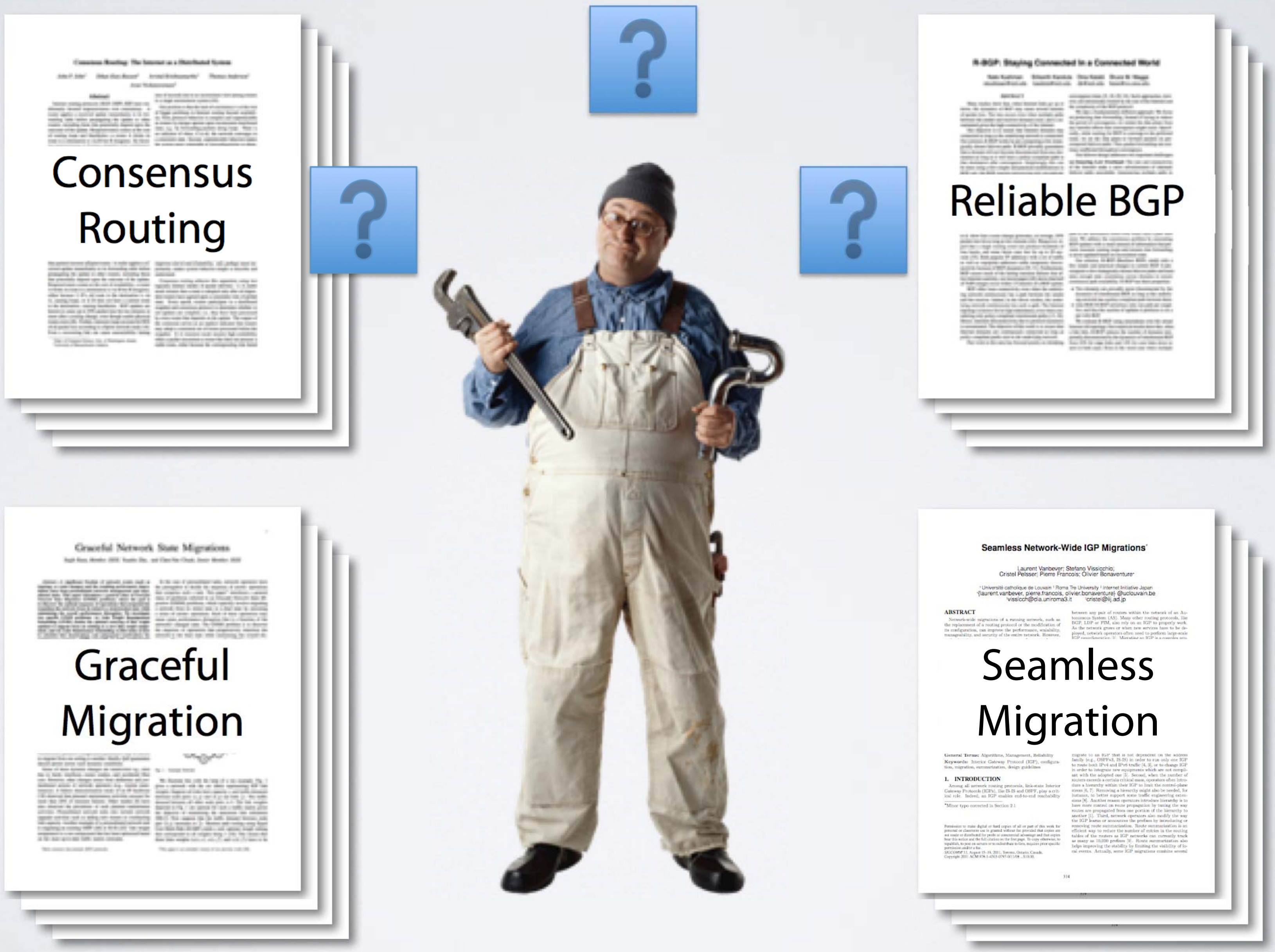
Desired Invariants

- No black-holes
- No loops
- No security violations

Network Updates Are Hard



Prior Work


Consensus Routing
Reliable BGP
Graceful Migration
Seamless Migration

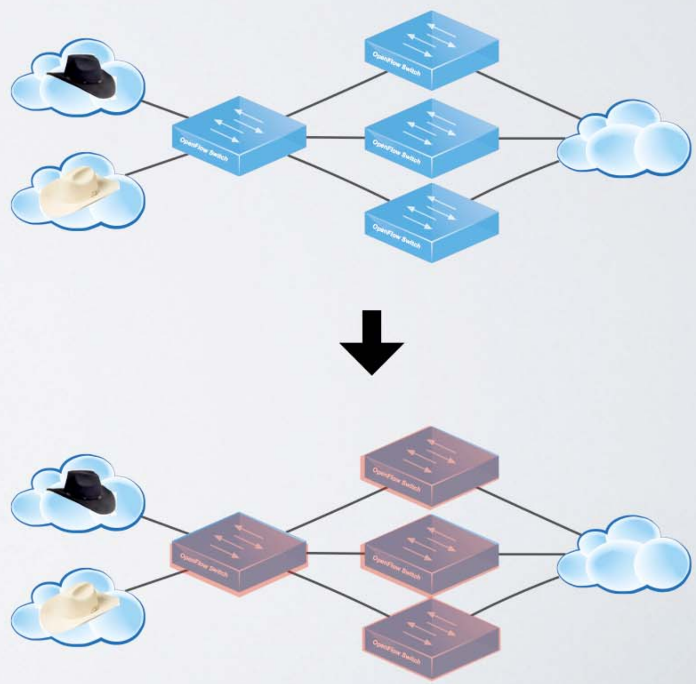
Network Update Abstractions

Goal

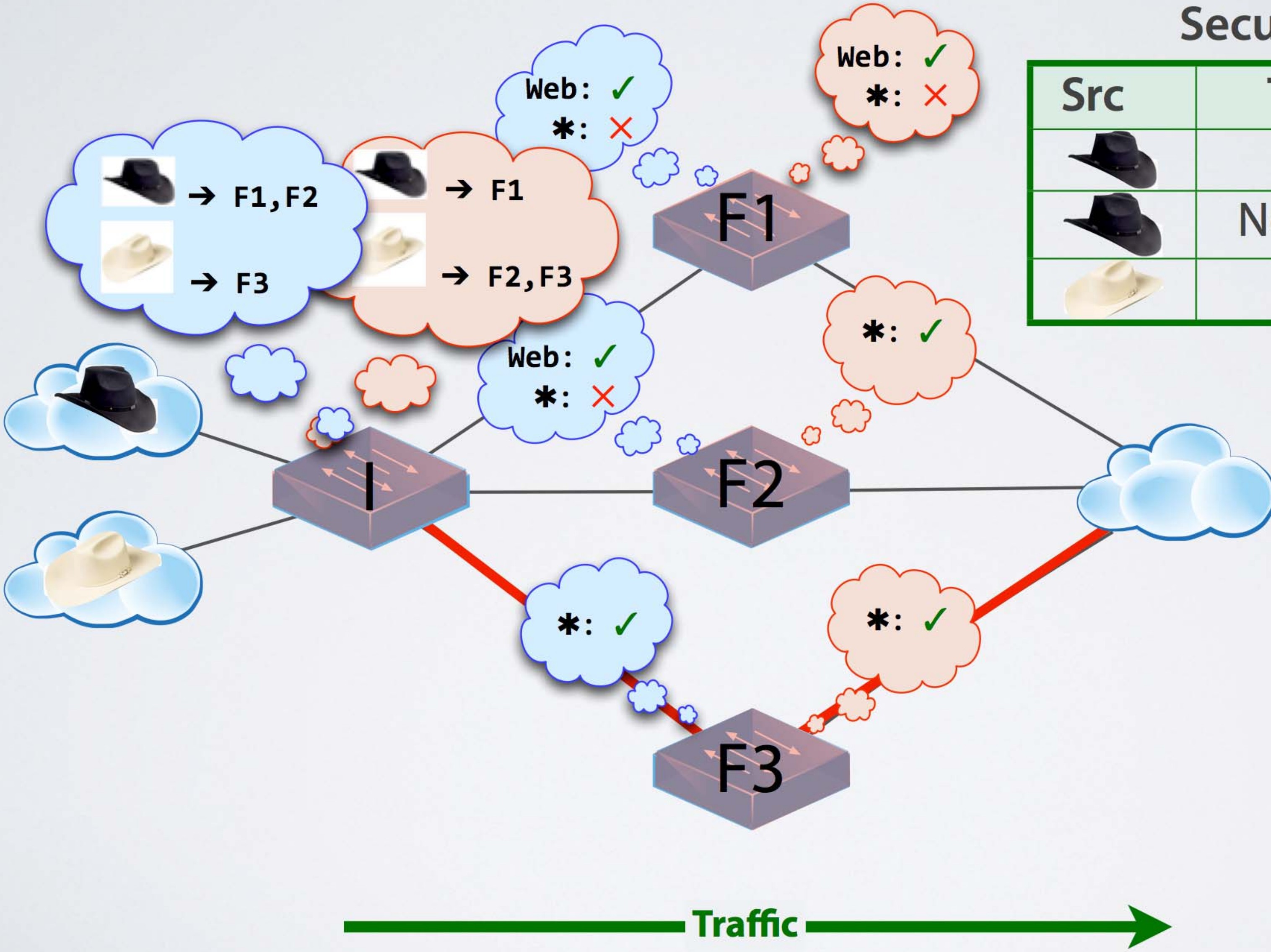
- Tools for whole network update

Our Approach

- Develop update abstractions
- Endow them with strong semantics
- Engineer efficient implementations



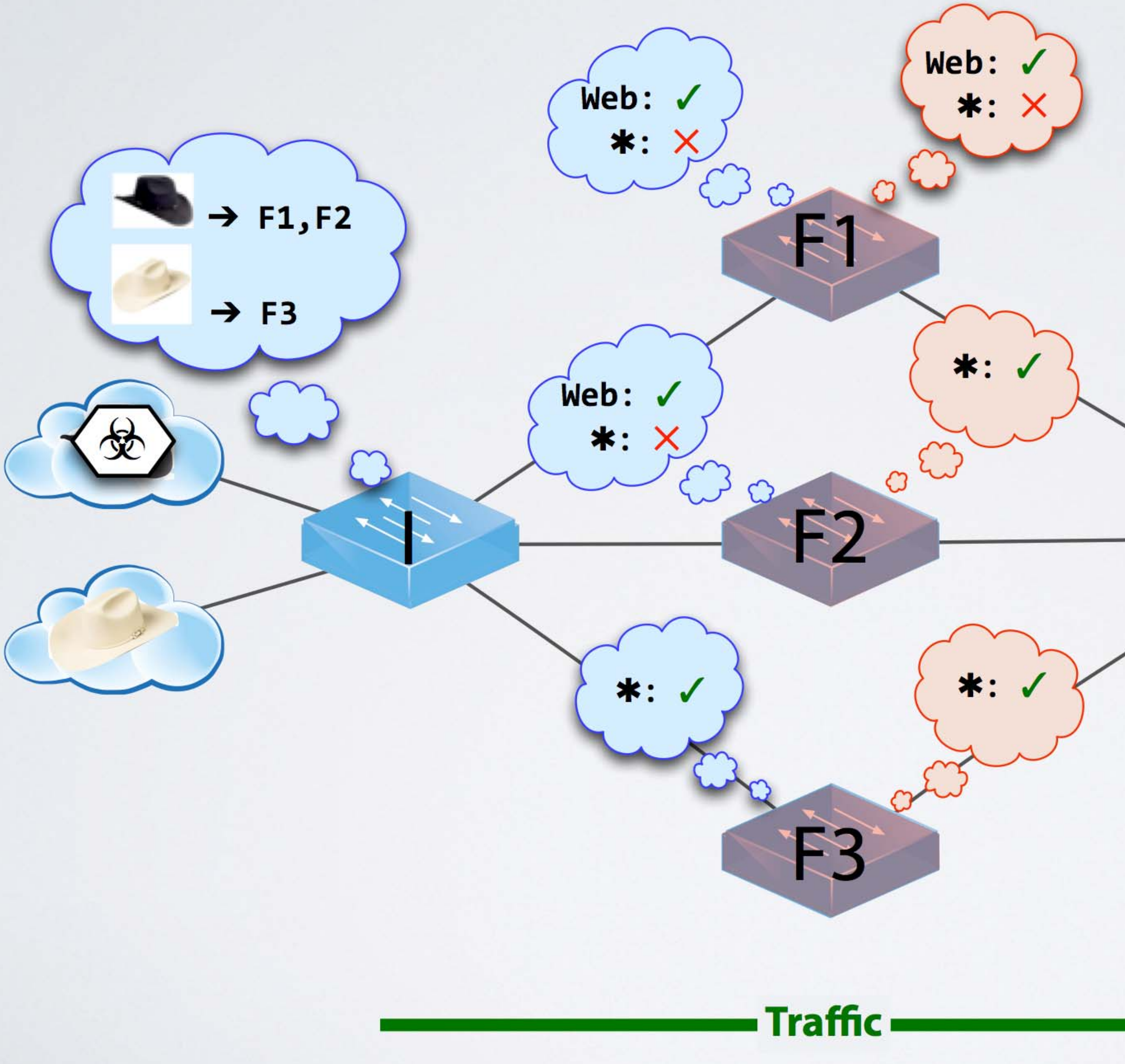
Example: Distributed Access Control



Security Policy

Src	Traffic	Action
	Web	Allow
	Non-web	Drop
	Any	Allow

Naive Update



Security Policy

Src	Traffic	Action
	Web	Allow
	Non-web	Drop
	Any	Allow

Order

F1

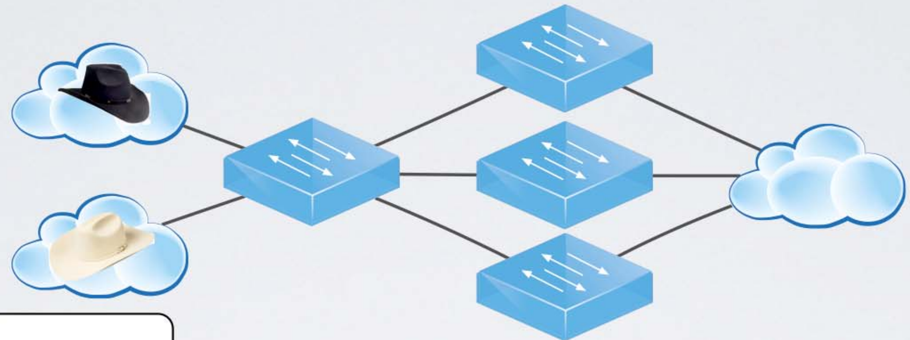
F2

F3

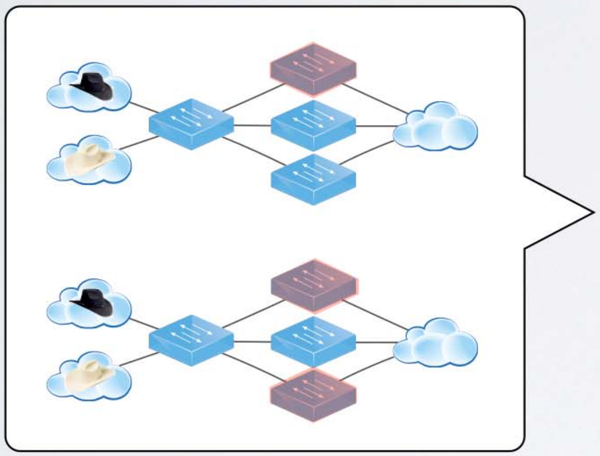
I

Use an Abstraction!

Security Policy

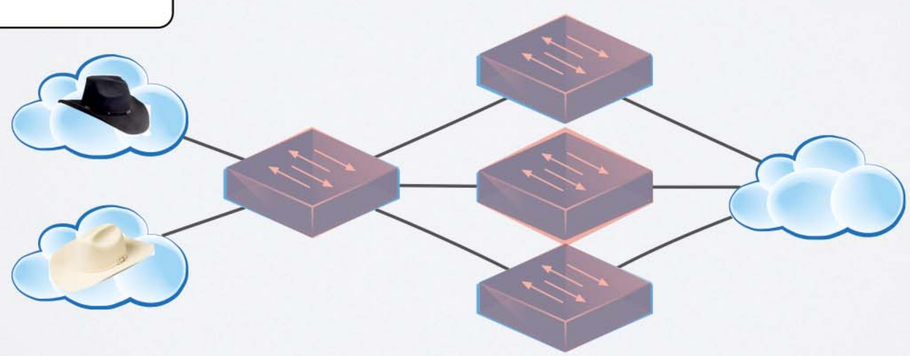


✓



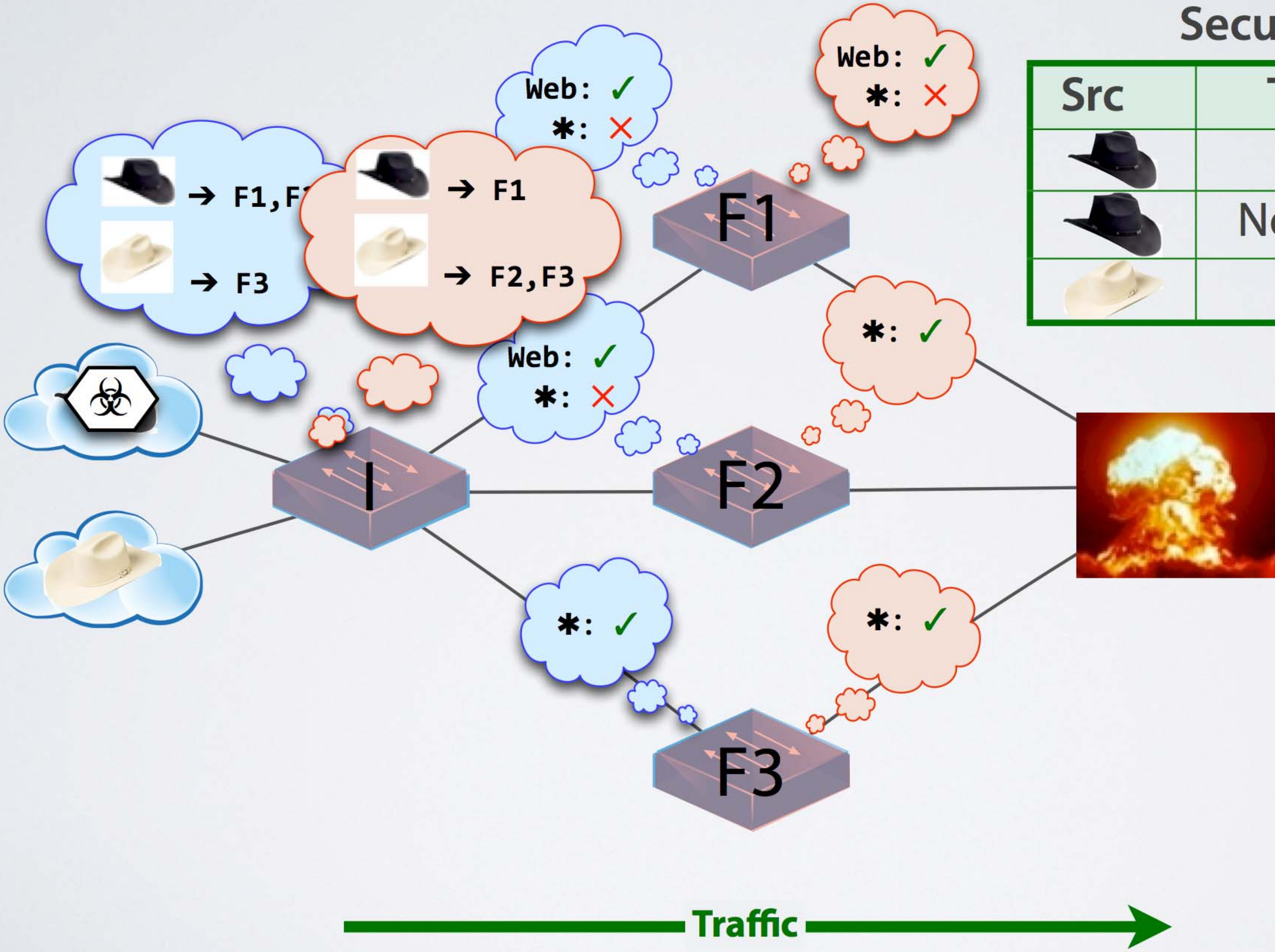
UPDATE

✓



✓

Atomic Update?



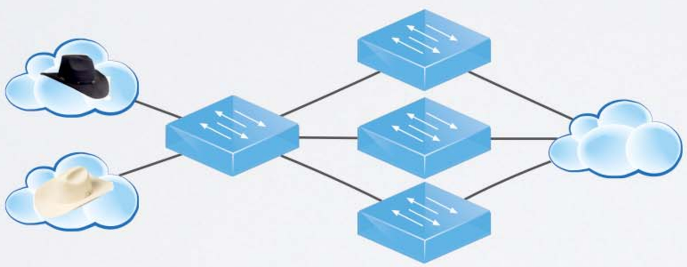
Security Policy

Src	Traffic	Action
(black hat)	Web	Allow
(black hat)	Non-web	Drop
(white hat)	Any	Allow

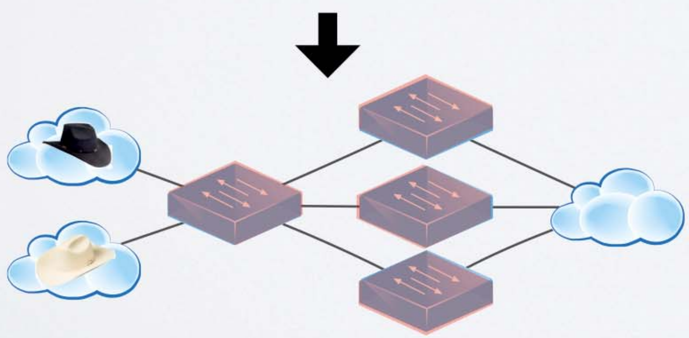
Per-Packet Consistent Updates

Per-Packet Consistent Update
Each packet processed with old or new configuration, but not a mixture of the two.

Obeys policy:



Obeys policy:



Security Policy

Src	Traffic	Action
	Web	Allow
	Non-web	Drop
	Any	Allow

Universal Property Preservation

Theorem: Per-packet consistent updates preserve all trace properties.

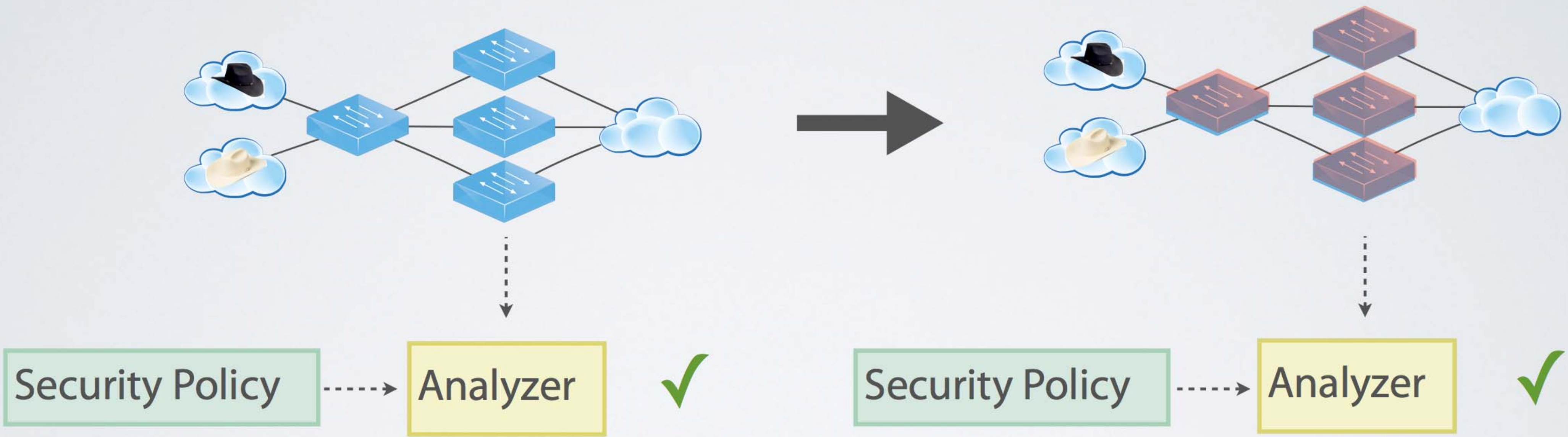
Trace Property
Any property of a *single* packet's path through the network.

Examples of Trace Properties:
Loop freedom, access control, waypointing ...

Trace Property Verification Tools:
Anteater , Header Space Analysis, ConfigChecker ...

Formal Verification

Corollary: To check an invariant, verify the old and new configurations.



Verification Tools

- Anteater [SIGCOMM '11]
- Header Space Analysis [NSDI '12]
- ConfigChecker [ICNP '09]

MECHANISMS

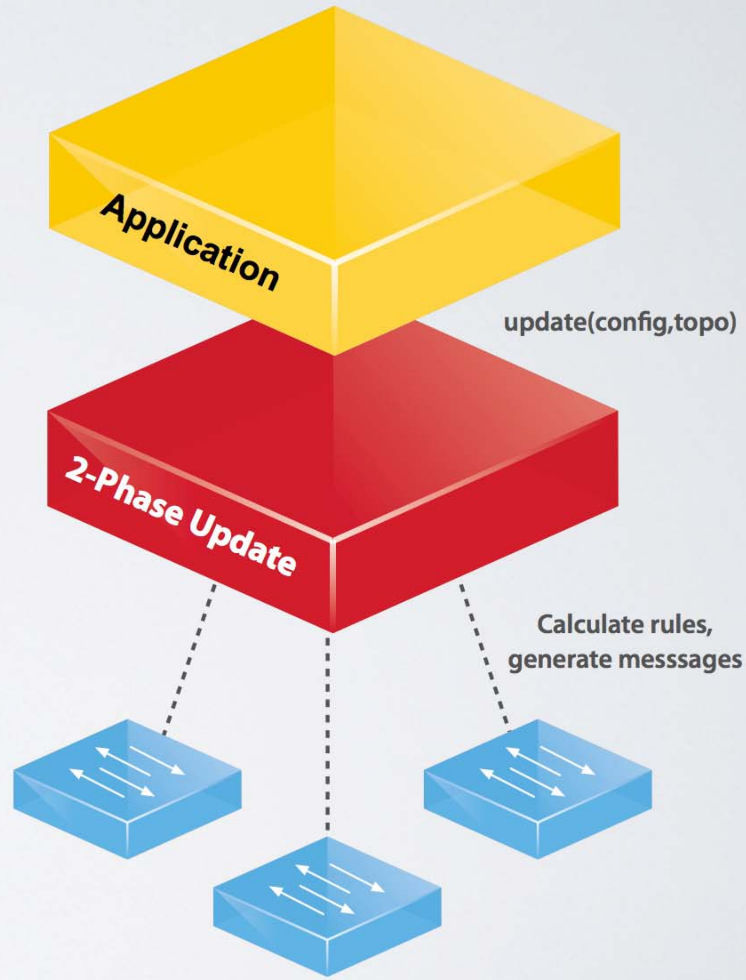
2-Phase Update

Overview

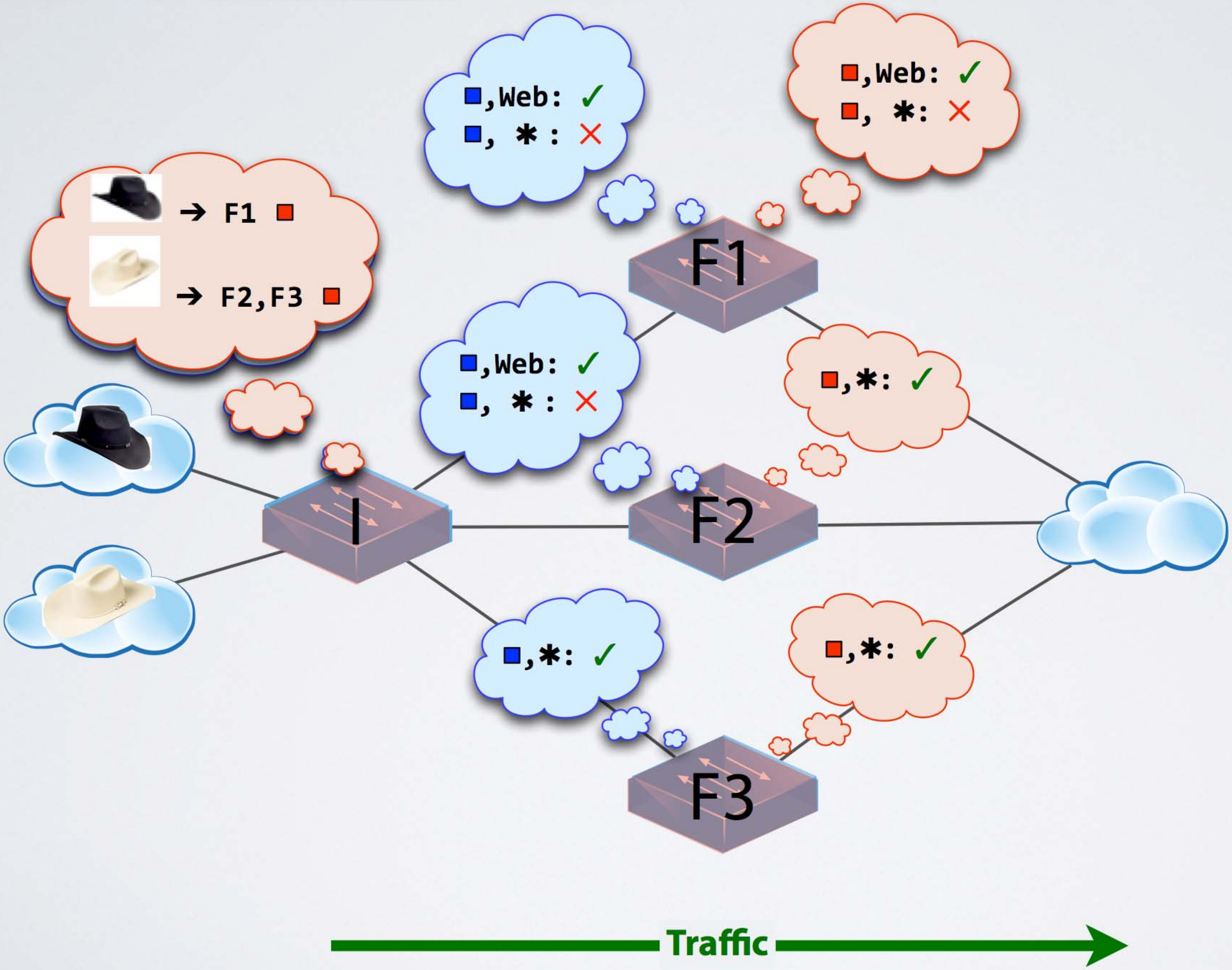
- Runtime instruments configurations
- Edge rules stamp packets with version
- Forwarding rules match on version

Algorithm (2-Phase Update)

1. Install new rules on internal switches, leave old configuration in place
2. Install edge rules that stamp with the new version number



2-Phase Update in Action



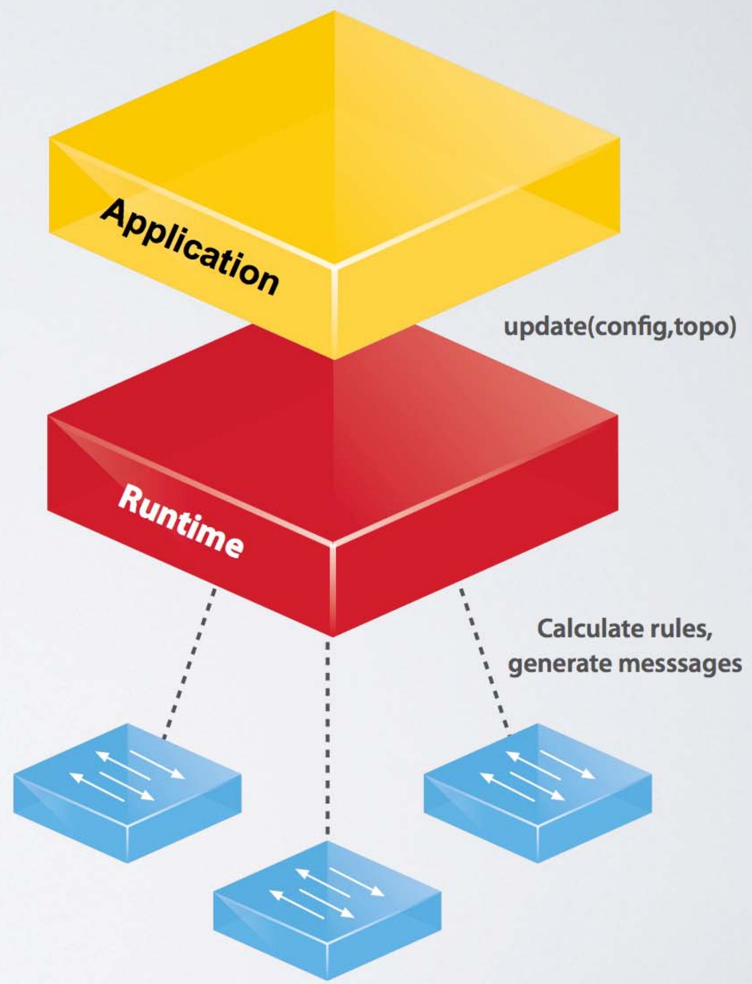
Optimized Mechanisms

Optimizations

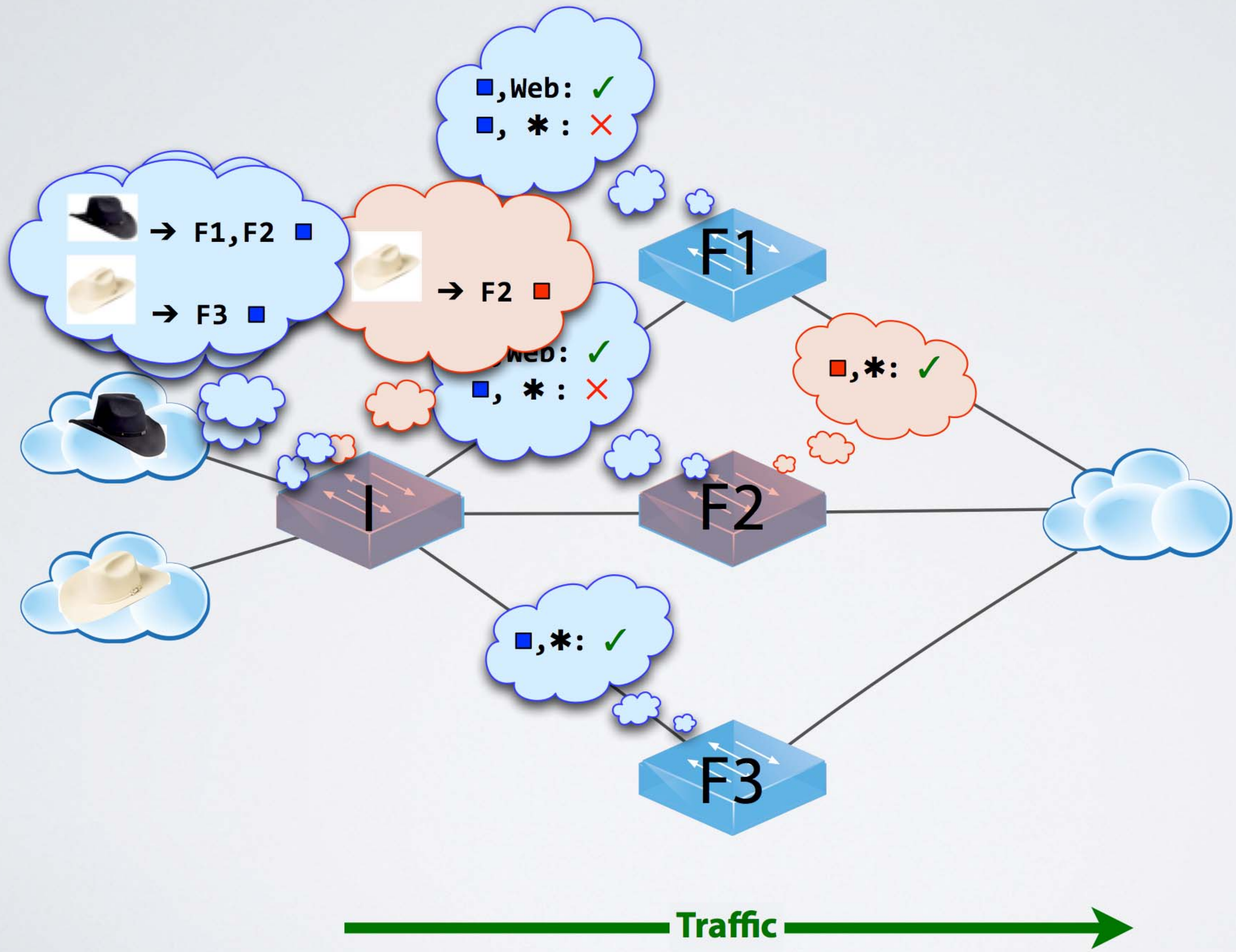
- Extension: strictly adds paths
- Retraction: strictly removes paths
- Subset: affects small # of paths
- Topological: affects small # of switches

Runtime

- Automatically optimizes
- Power of using abstraction



Subset Optimization



Correctness

Question: How do we convince ourselves these mechanisms are correct?

Solution: We built an operational semantics, formalized our mechanisms and proved them correct

Example: 2-Phase Update

1. Install new rules on internal switches, leave old configuration in place } Unobservable
2. Install edge rules that stamp with the new version number } One-touch

Theorem: Unobservable + one-touch = per-packet.

IMPLEMENTATION
&
EVALUATION

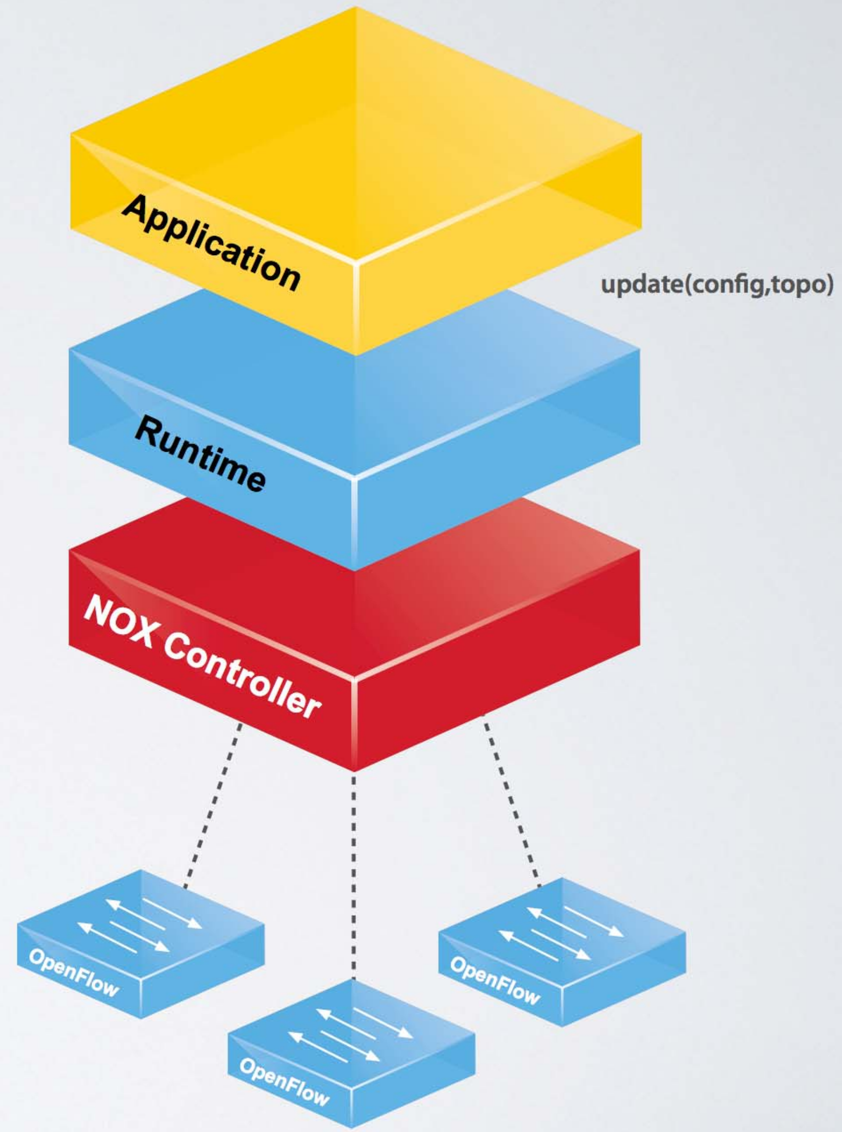
Implementation

Runtime

- NOX Library
- OpenFlow 1.0
- 2.5k lines of Python
- `update(config, topology)`
- Uses VLAN tags for versions
- Automatically applies optimizations

Verification Tool

- Checks OpenFlow configurations
- CTL specification language
- Uses NuSMV model checker



Evaluation

Question: How much extra rule space is required?

Setup

- Mininet VM

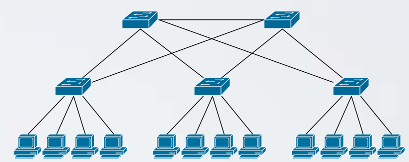
Applications

- Routing and Multicast

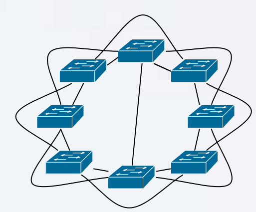
Scenarios

- Adding/removing hosts
- Adding/removing links
- Both at the same time

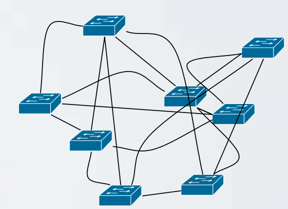
Topologies



Fattree

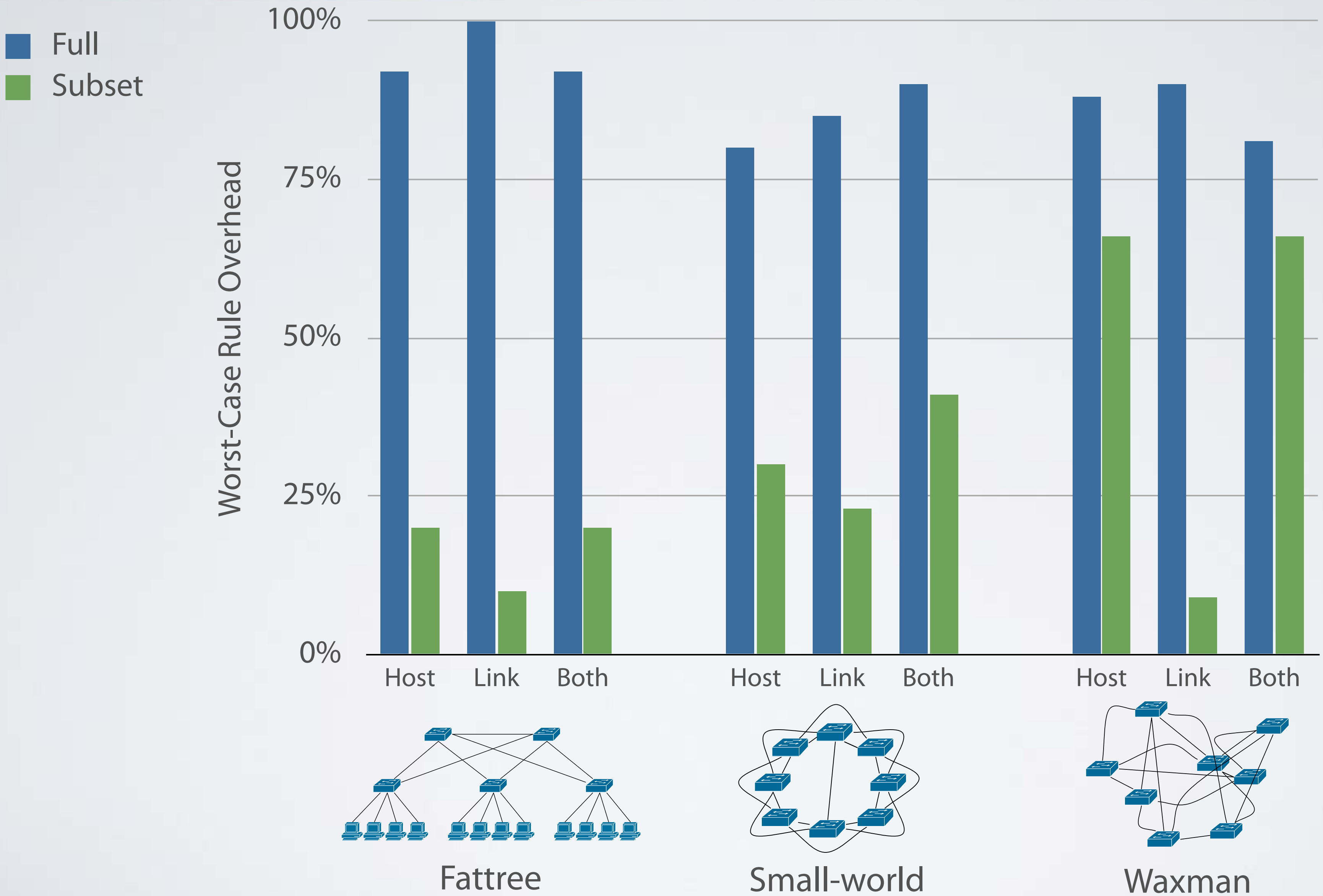


Small-world



Waxman

Results: Routing Application



WRAP UP

Conclusion

Update abstractions

- Per-packet
- Per-flow

Mechanisms

- 2-Phase Update
- Optimizations

Implementation

- Runtime
- Verifier

Formal model

- Network operational semantics
- Universal property preservation

Thank You!

Collaborators

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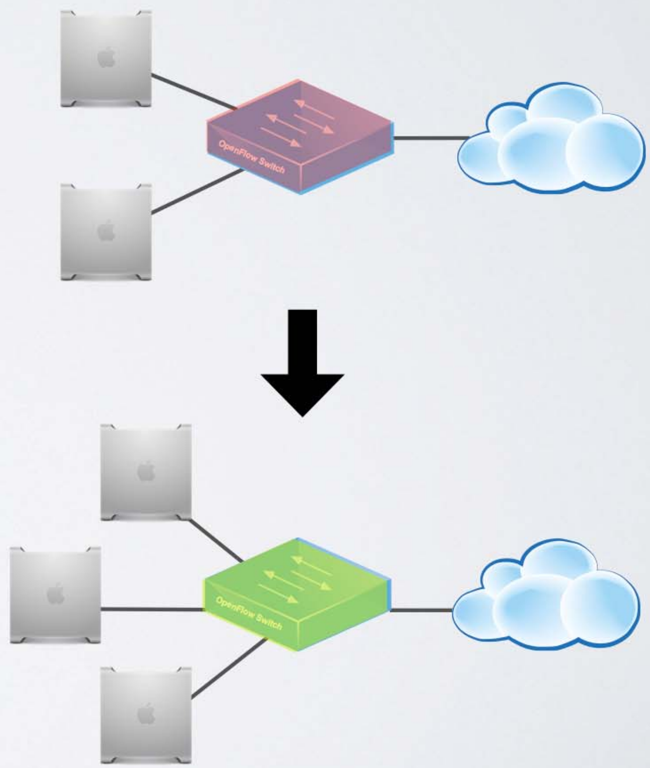
frenetic

http://frenetic-lang.org

BACKUP SLIDES

Beyond Per-Packet

Per-flow consistent update
Each *set* of related packets processed with old or new configuration, but not a mixture of the two.



Use Cases

- Load balancer
- Flow affinity
- In-order delivery

Mechanism

- 2-Phase Update + "flow tracking"