Software Defined Networking

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In this course, you will learn about software defined networking and how it is changing the way communications networks are managed, maintained, and secured.

This Module: Verification

- **Motivation:** How do you know the network is doing the right thing?
- Verification techniques
  - Configuration Verification: rcc (pre-SDN)
  - Control Plane Verification: Kinetic
  - Data Plane Verification
    - Header Space Analysis
    - Veriflow

Simple Questions are Hard

- What are all the packet headers from A that can reach B?
- What will happen if I remove an entry from a firewall?
- Is Group X provably isolated from Group Y?
- Are there any loops in the network?
- Why is my network slow?

Configuration Defines Behavior

Provides flexibility for realizing operational goals

- How traffic enters and leaves the network
  - Load balance
  - Traffic engineering
  - Primary/backup paths
- Which neighboring networks can send traffic
  - Defines business relationships and contracts
- How routers within the network learn routes
  - Scaling and performance

Flexibility ⟶ **Complexity**

Most Important Goal: Correctness

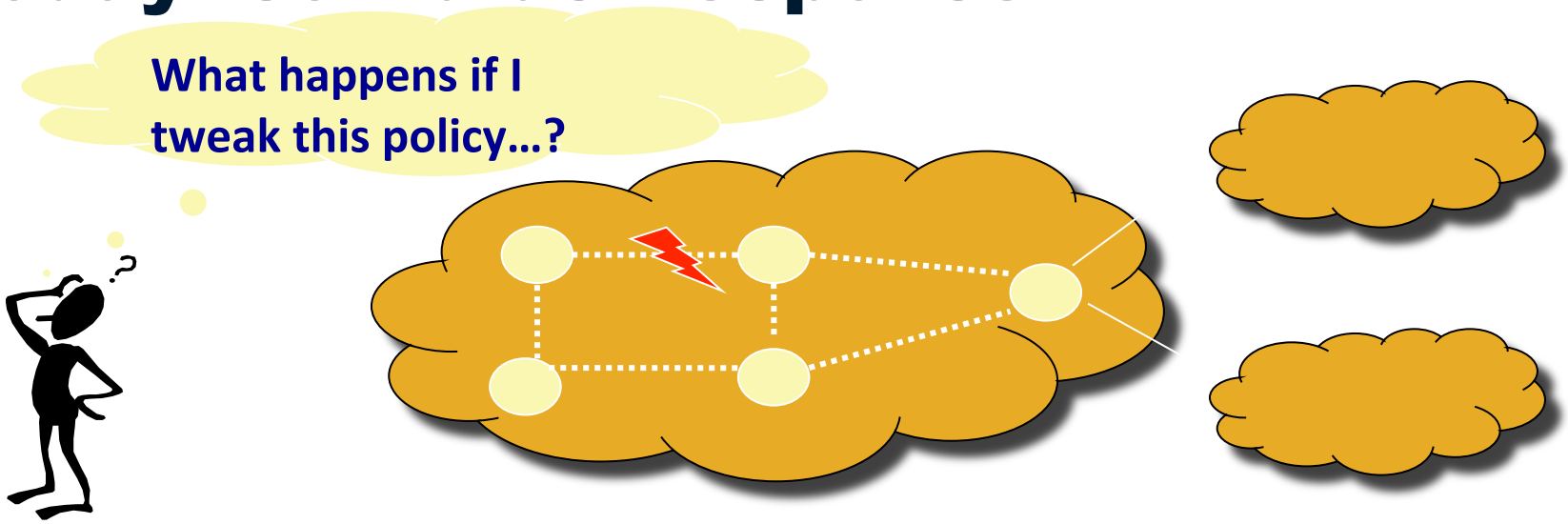
Unfortunately…

Mistakes happen!

Why?

- Configuration is difficult. Operators make mistakes.
  - Complex policies
  - Configuration is distributed across routers
- Each network independently configured
  - Unintended policy interactions

Today: Stimulus-Response

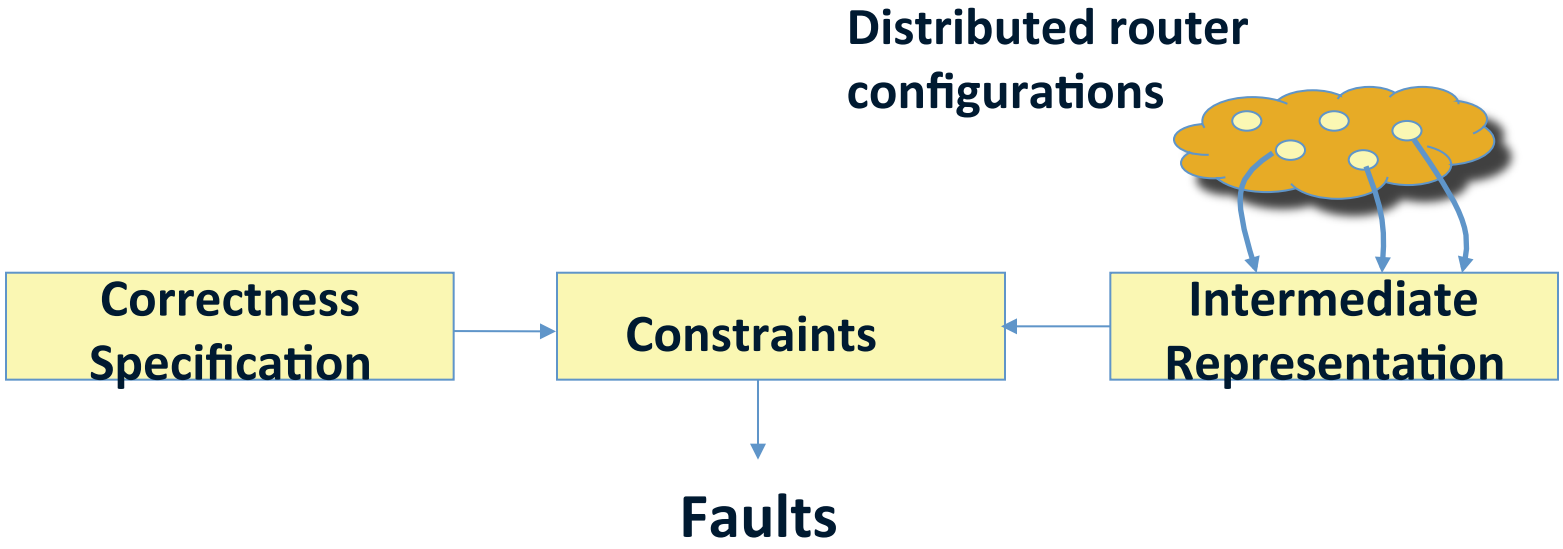


- Unacceptable programming environment
- Mistakes cause downtime
- Mistakes often not immediately apparent

Checking Configuration

- Correctness specification and constraints for global Internet routing
- rcc ("router configuration checker")
  - Static configuration analysis tool for fault detection
  - Used by network operators (including large backbone networks)
- Analysis of real-world network configurations from 17 autonomous systems

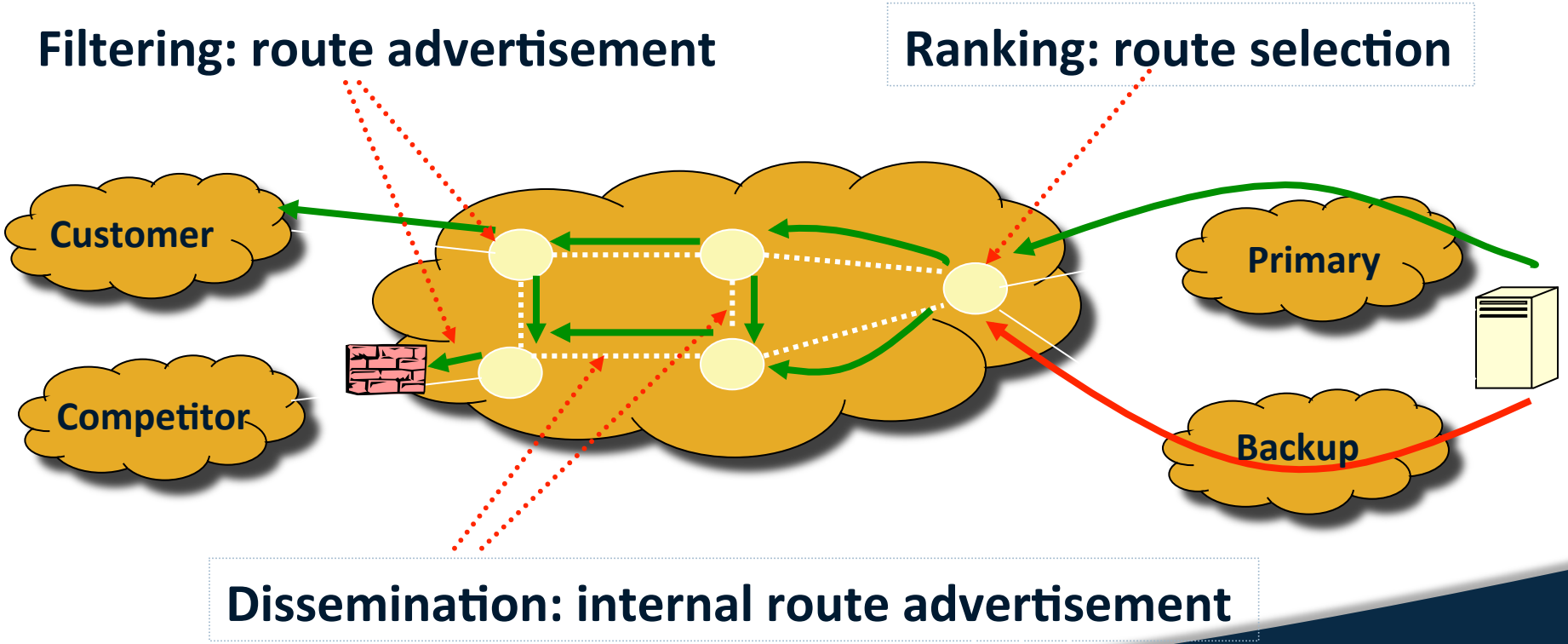
rcc Design


Distributed router configurations
Correctness Specification
Constraints
Intermediate Representation
Faults

Challenges

- Defining a correctness specification
- Deriving verifiable constraints from specification
- Analyzing complex, distributed configuration

Factoring Routing Configuration



Path Visibility

If every router learns a route for every usable path, then path visibility is satisfied.

A *usable path*:

- Reaches the destination
- Corresponds to the path that packets take when using that route
- Conforms to the policies of the routers on that path

Possible path visibility faults

Dissemination

- **Partition in session-level graph that disseminates routes**

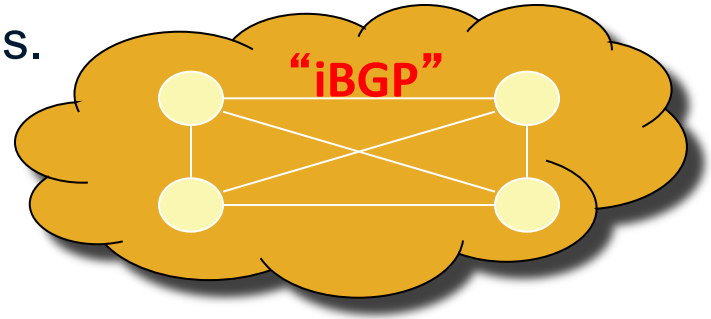
Filtering

- **Filtering routes for prefixes for usable paths**

Path Visibility: Internal BGP (iBGP)

- **Default:** dont re-advertise iBGP-learned routes.

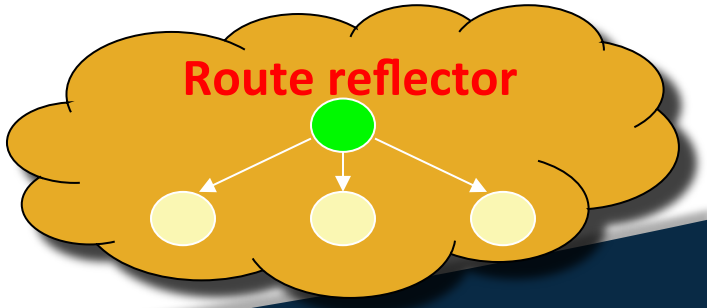
  Complete propagation requires “full mesh” iBGP. *Doesn’t scale.*



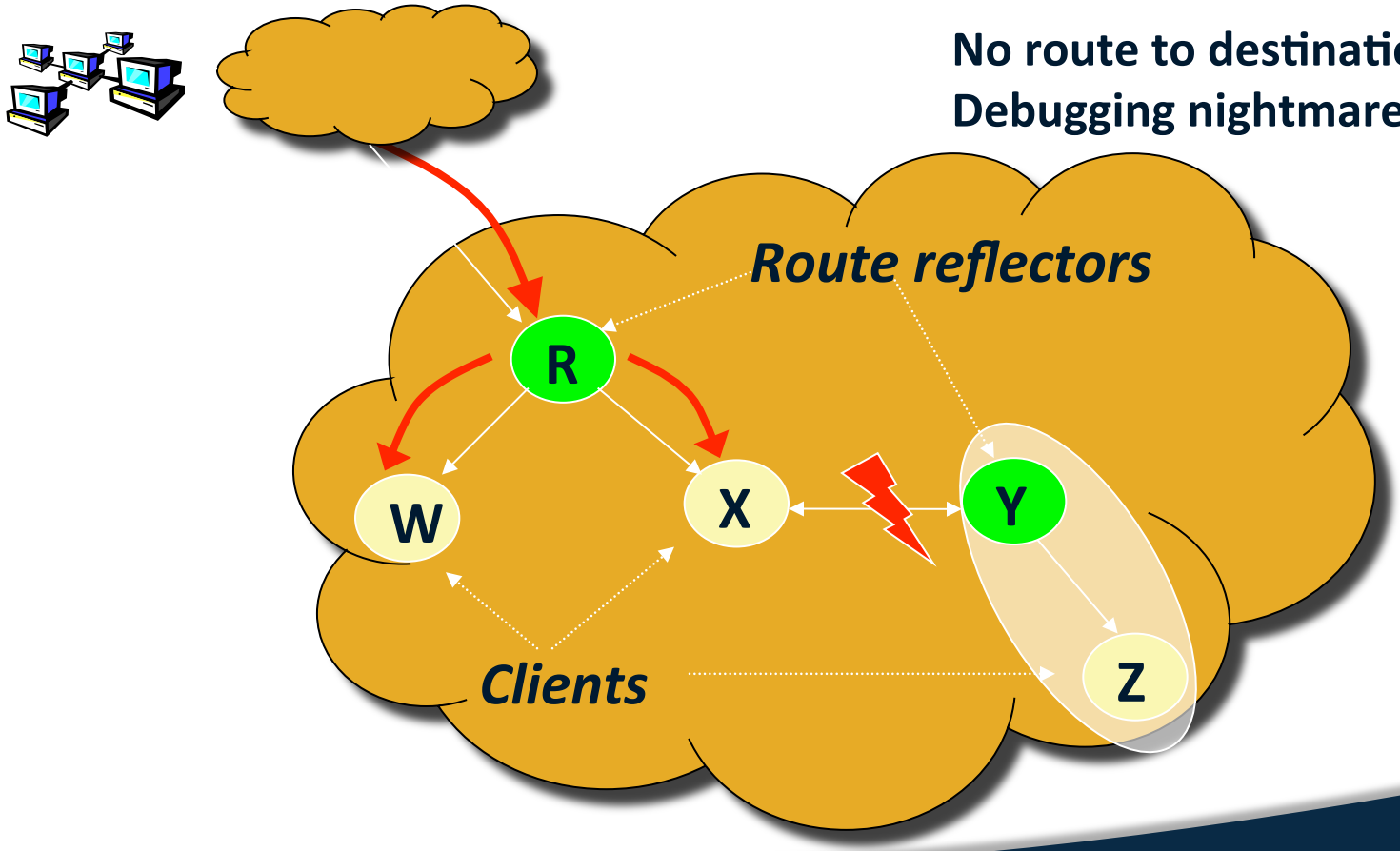
- “Route reflection” improves scaling.

  Client: re-advertise as usual.

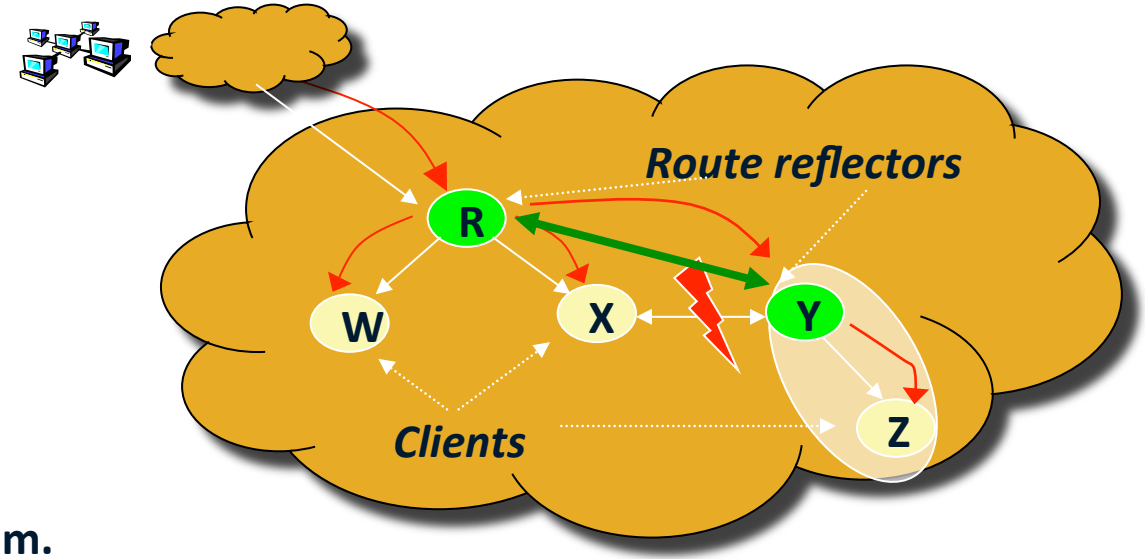
  Route reflector: reflect non-client routes to all clients, client routes to non-clients and other clients.



Path Visibility: iBGP Signaling



Path Visibility: iBGP Signaling



Theorem.
Suppose the iBGP reflector-client relationship graph contains no cycles. Then, path visibility is safisfied if, and only if, *the set of routers that are not route reflector clients forms a full mesh*.

Condition is easy to check with static analysis.

Route Validity

If every route that a router learns corresponds to a usable path, then route validity is satisfied.

A *usable path*:

- Reaches the destination
- Corresponds to the path that packets take when using that route
- Conforms to the policies of the routers on that

Possible route validity faults

Filtering

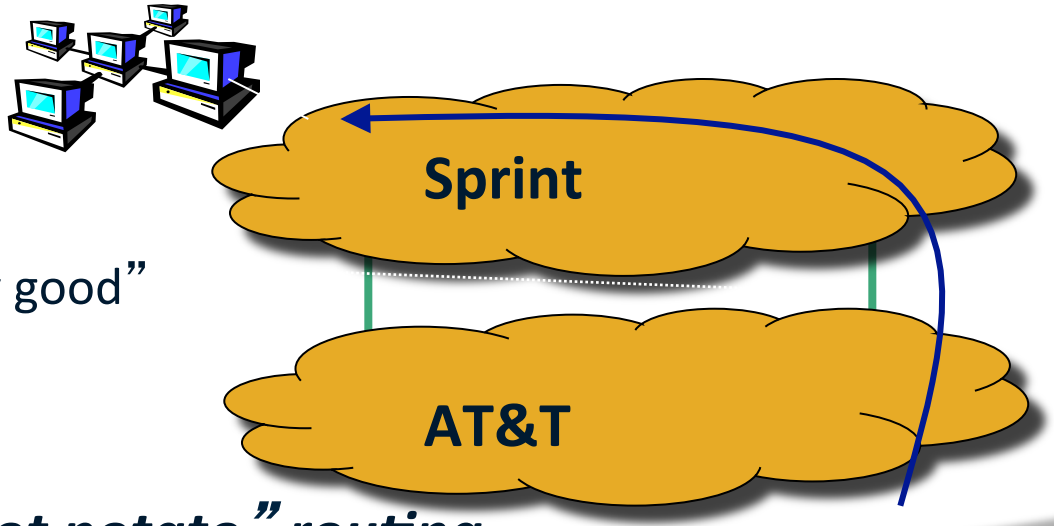
- Unintentionally providing transit service
- Advertising routes that violate higher-level policy
- Originating routes for private (or unowned) address space

Dissemination

- Loops and “deflections

Route Validity: Consistent Export

- Rules of *settlement-free peering*:
  - Advertise routes at all peering points
  - Advertised routes must have equal "AS path length"



Enables "hot potato" routing.

Summary: Verifying Config is Hard

- Distributed configuration is a bad idea.
- SDN can allow us to treat verification as a distributed program, applying concepts from software engineering, testing, formal verification…

SDN to the rescue…