MIRED: Managing IP Routing is Extremely Difficult

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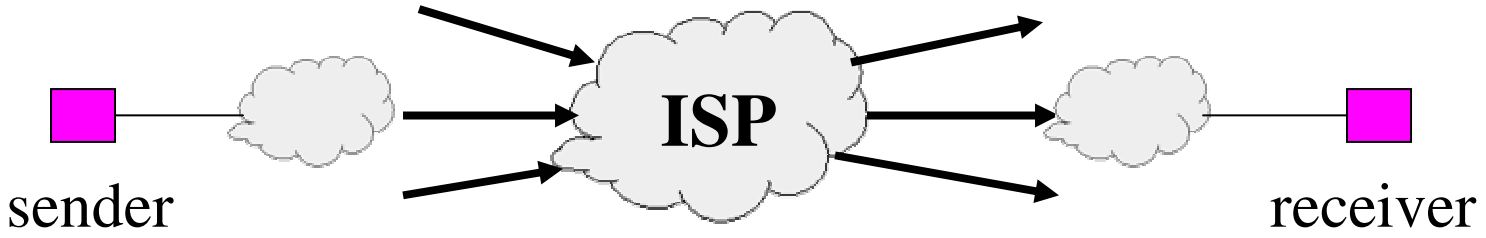
Outline

- Operational view of IP routing
  - Autonomous Systems and IP routing
  - Challenges of managing IP routing protocols
- Managing IP routing
  - Detecting/fixing problems
  - Traffic engineering
  - Router configuration
- Limitations on routing management
  - Common challenges across management tasks
  - Thoughts on how the Knowledge Plane can help

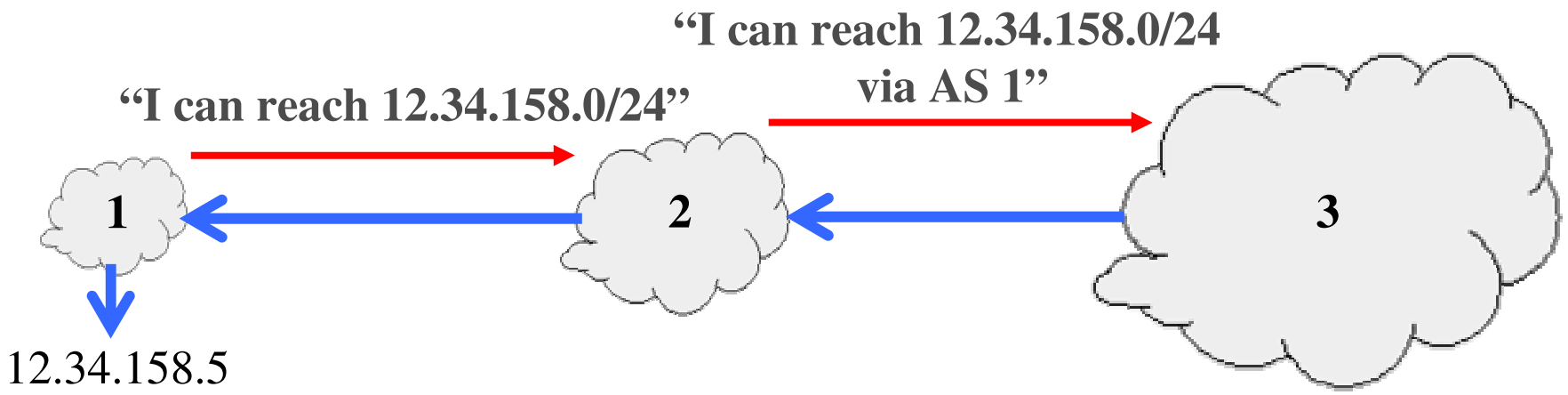
IP Networks

- IP networks are
  - Decentralized (loose confederation of Autonomous Systems)
  - Self-configuring (no global registry of topology)
  - Stateless (limited information in the routers)
  - Connectionless (no fixed connection between hosts)
- These attributes contribute
  - To the success of IP networks
  - To the rapid growth of the IP networks
  - … and the difficulty of controlling IP networks!



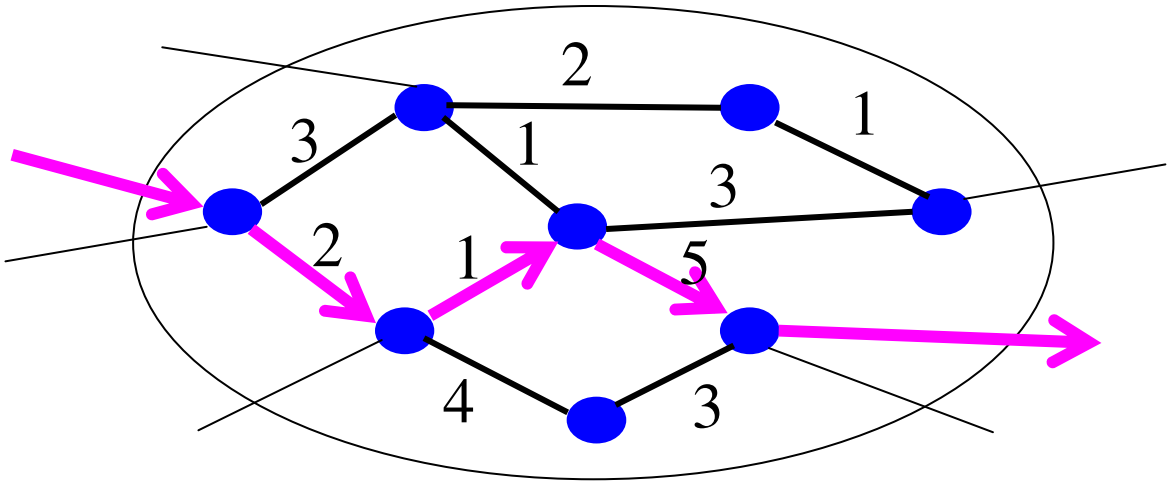
Interdomain Routing: Border Gateway Protocol

- ASes exchange info about who they can reach
  - IP prefix: block of destination IP addresses
  - AS path: sequence of ASes along the path
- Policies configured by the AS's network operator
  - Path selection: which of the paths to use?
  - Path export: which neighbors to tell?



Intradomain Routing: OSPF or IS-IS

- Shortest path routing based on link weights
  - Routers flood the link-state information to each other
  - Routers compute the "next hop" to reach other routers
- Weights configured by the AS's network operator
  - Simple heuristics: link capacity or physical distance
  - Traffic engineering: tuning the link weights to the traffic



Routing Management Problems

- Routing anomalies
  - Hijacked routes: misdirected/lost traffic
  - Blackholes: unreachable destination hosts
  - Route flapping: unstable routes, links, peers,…
  - Convergence: transient delay, loss, and reordering
- Overloaded routers
  - CPU/bandwidth: processing the routing messages
  - Memory: storing the routing and forwarding tables
- Unpredictable routing after network changes
  - Topology: failures, maintenance, new link,…
  - Configuration: BGP policies, OSPF weights,…

Routing Management Challenges

- Router configuration
  - Languages: non-standard “assembly language”
  - Granularity: individual routers not a network
  - Tools: limited tools for automated provisioning
  - Legacy: existing manually-configured networks
- Routing constraints
  - Performance: limit congestion and end-to-end latency
  - Stability: avoid/minimize route convergence delay
  - Financial: minimize total charges based on usage
  - Legal: adhere to customer SLAs and peering contracts

Operator Tasks: Prevent/Diagnose Problems

- Identifying hijacked BGP routes
  - Detect BGP routes for *your* addresses announced by other ASes
  - Monitor BGP updates from outside vantage points
- Preventative filtering of bogus routes
  - Filter BGP advertisements from customers based on AS path
  - Analyze BGP routes to infer AS provider-customer relationships
- Root-cause analysis (routing level)
  - Determine location and cause of a sequence of BGP route updates
  - Data-mine BGP update messages from multiple vantage points
- Root-cause analysis (forwarding level)
  - Determine location and cause of anomalies in the data path
  - Combine traceroute probes with BGP-derived IP-to-AS mapping

Operator Tasks: Traffic Engineering

- Predict effects of routing changes (*intra*domain)
  - Model effects of changing OSPF/IS-IS link weights
  - Capture how traffic leaves the AS to other domains
  - Measure current topology, routing, and traffic matrix
  - (Also incorporate fate-sharing of IP links at the transport level)
- Predict effects of routing changes (*inter*domain)
  - Model effects of changing BGP routing policies
  - Avoid changes that have uncontrollable side effects
  - Measure current traffic volumes destined to each IP prefix
  - (Any ways for neighboring ASes to coordinate their efforts???)
- Select good ways to tune the routing parameters
  - Codify the many operational constraints in “objective function”
  - Search for “good” changes to the routing configuration

Operator Tasks: Router Configuration

- Assess configuration of existing network
  - Check for errors and visualize the network design
  - Reverse engineer the configuration templates & rules
  - Collect, parse, & join the router configuration files
- Verify key properties of routing system
  - Ensure consistent BGP policies and route filters
  - Apply "sufficient condition" tests for convergence within an AS
  - Analyze configuration files and BGP/OSPF messages
  - (Any way to support multi-AS BGP checks?)
- Automate router provisioning
  - Codify technical questionnaire, data model, and template/rules
  - Drive router provisioning directly from the database
  - (Any way to support multi-AS routing configuration?)

Key Ingredients of Per-AS Routing Management

- Network measurements
  - Topology, configuration, routing, traffic, and performance
  - Multiple types of measurement data and many vantage points
  - Construct an AS-wide view to detect, diagnose, and fix
- Multiple domains of control
  - Protective filtering at boundaries between domains
  - Detecting and diagnosing problems via measurement
  - Limiting and predicting side effects on other domains
- Accurate predictive models
  - “What-if” models for traffic engineering, capacity planning, etc.
  - Accounting for uncertainty (randomization, non-determinism)
  - Sufficient-condition checks for routing convergence properties

Implications on the Knowledge Plane

- Sensors: IP measurement platform
  - Multiple kinds of data from multiple vantage points
  - On-demand probing to aid in troubleshooting
  - Formats, time base, APIs, views, event notification, etc.
- Analysis: multi-AS routing management
  - Data mining/inference to diagnose routing anomalies
  - Consistency checking of interdomain routing policies
  - Support for end-to-end provisioning of routing protocols
- Actuators: multi-AS control actions
  - Predicting effects of routing/topology changes
  - Inter-AS interaction to coordinate routing changes
  - Balance between coordination and independence