BGP

CS168, Fall 2014

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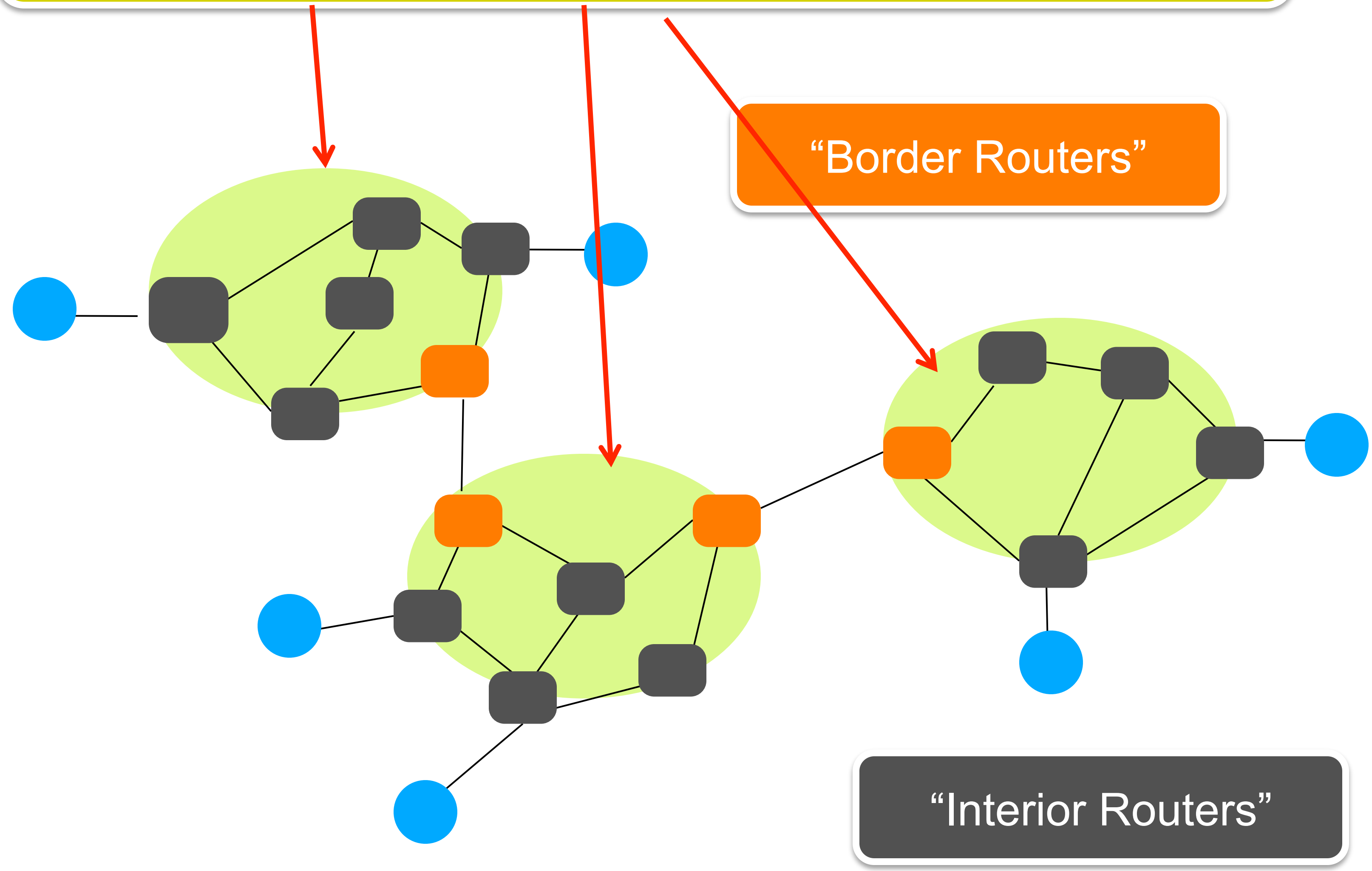
http://inst.eecs.berkeley.edu/~cs168/fa14/

Announcement

- Canceling my office hours this week (09/25)
- Instead, additional office hours
  - Monday (09/29): 1-2pm
  - Tuesday (09/30): 1-2pm

“Autonomous System (AS)” or “Domain”
Region of a network under a single administrative entity



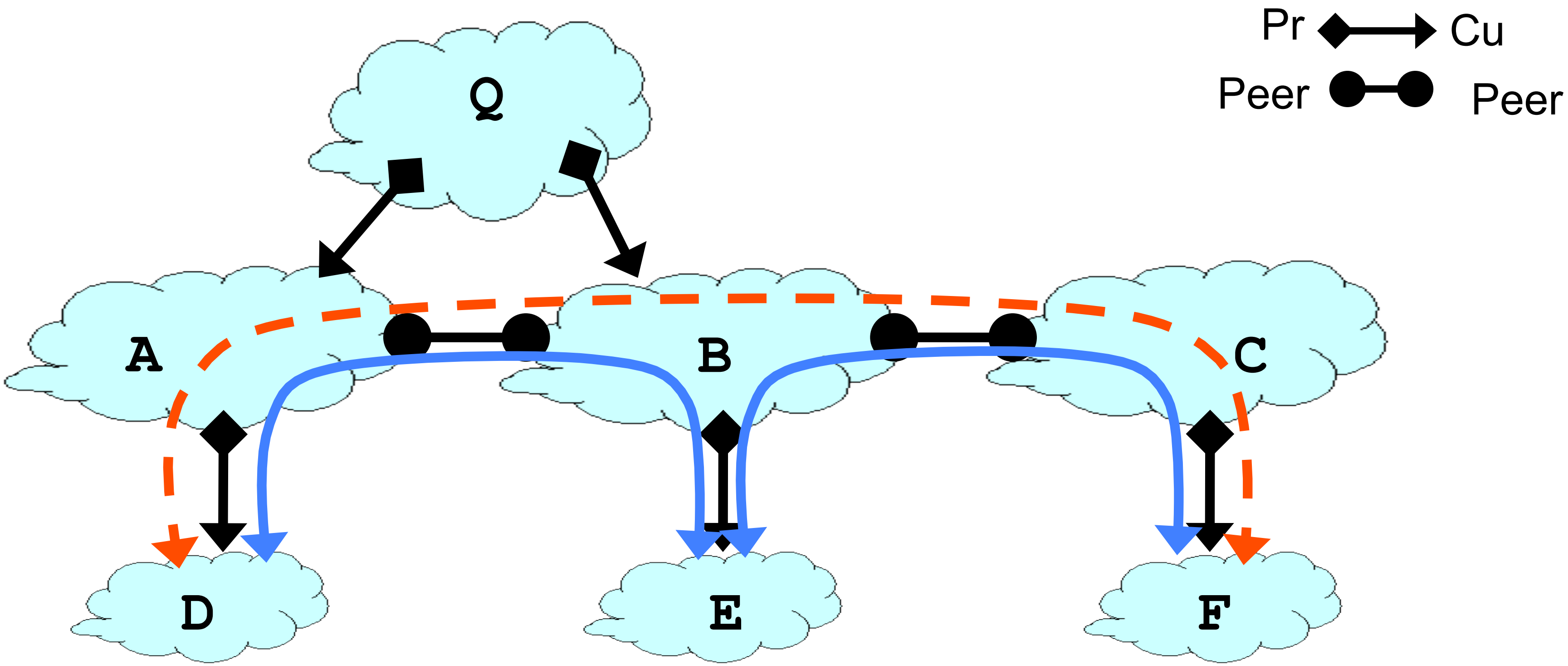
“Border Routers”

“Interior Routers”

Topology and routes shaped by the business relationships between ASes

- Three basic relationships between two ASes
  - A is a customer of B
  - A is a provider of B
  - A and B are peers
- Business implications
  - customer pays provider
  - peers don’t pay each other

Routing Follows the Money!



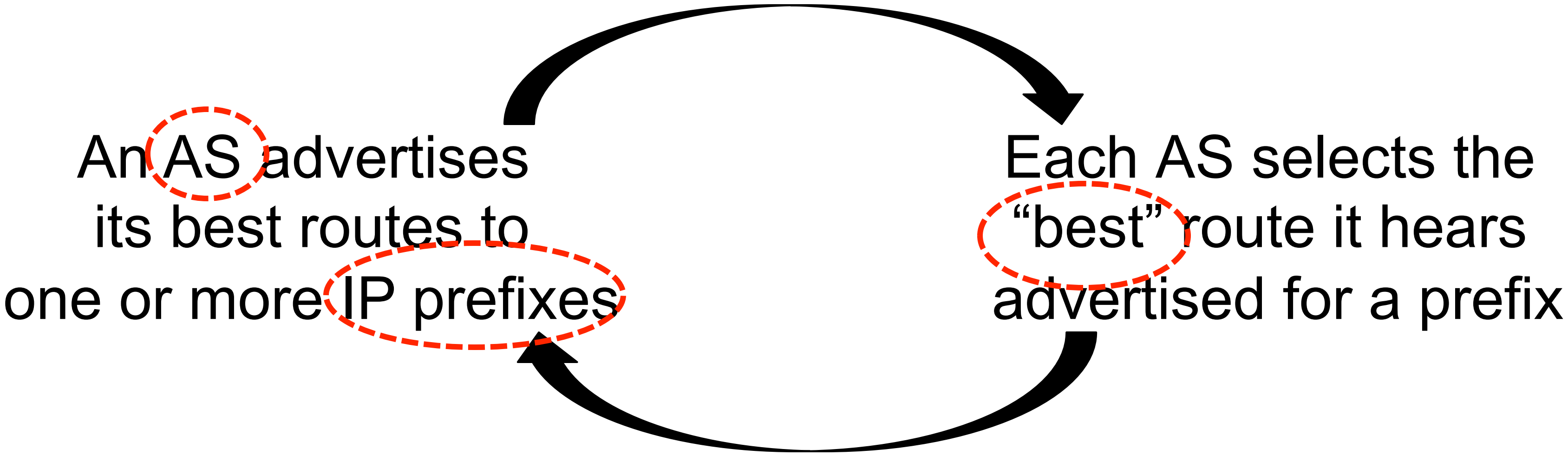
traffic allowed

traffic not allowed

Interdomain Routing: Setup

- Destinations are IP prefixes (12.0.0.0/8)
- Nodes are Autonomous Systems (ASes)
  - Internals of each AS are hidden
- Links represent both physical links and business relationships
- BGP (Border Gateway Protocol) is the Interdomain routing protocol
  - Implemented by AS border routers

BGP: Basic Idea



An AS advertises
its best routes to
one or more IP prefixes

Each AS selects the
“best” route it hears
advertised for a prefix

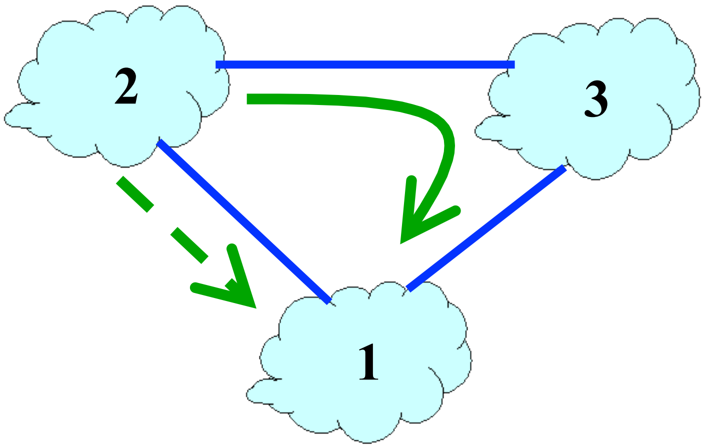
You’ve heard this story before!

BGP inspired by Distance Vector

- Per-destination route advertisements
- No global sharing of network topology information
- Iterative and distributed convergence on paths
- With four crucial differences!

Differences between BGP and DV (1) not picking shortest path routes

- BGP selects the best route based on policy, not shortest distance (least cost)



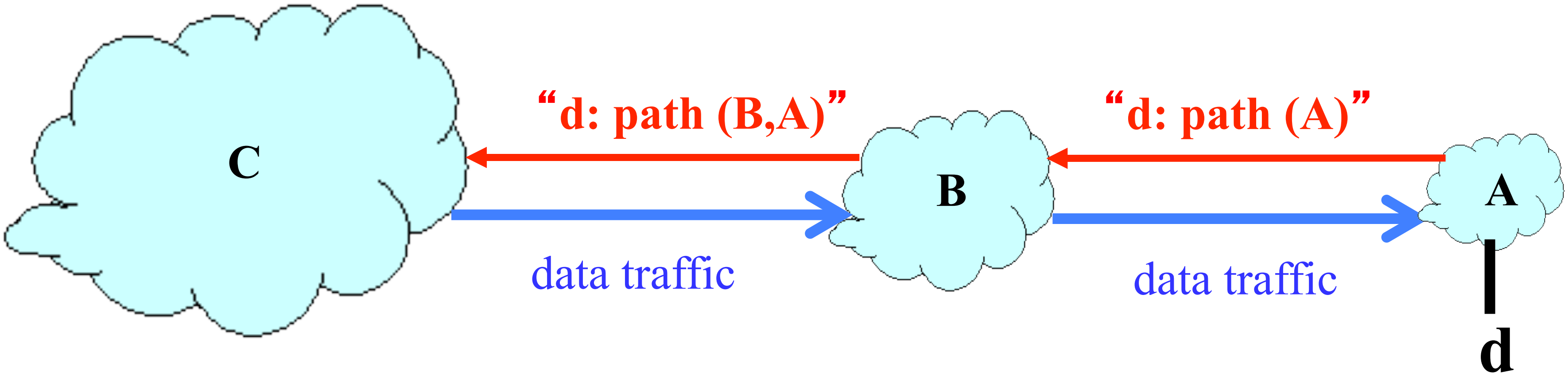
Node 2 may prefer "2, 3, 1" over "2, 1"

- How do we avoid loops?

Differences between BGP and DV

(2) path-vector routing

- Key idea: advertise the entire path
  - Distance vector: send *distance metric* per destination
  - Path vector: send the *entire path* for each destination



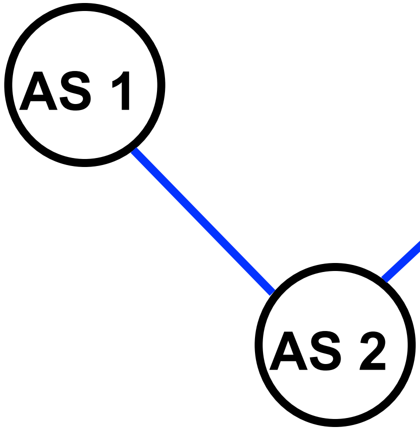
Differences between BGP and DV
(2) path-vector routing

- Key idea: advertise the entire path
  - Distance vector: send *distance metric* per destination
  - Path vector: send the *entire path* for each destination

- Benefits
  - loop avoidance is easy

Differences between BGP and DV (3) Selective route advertisement

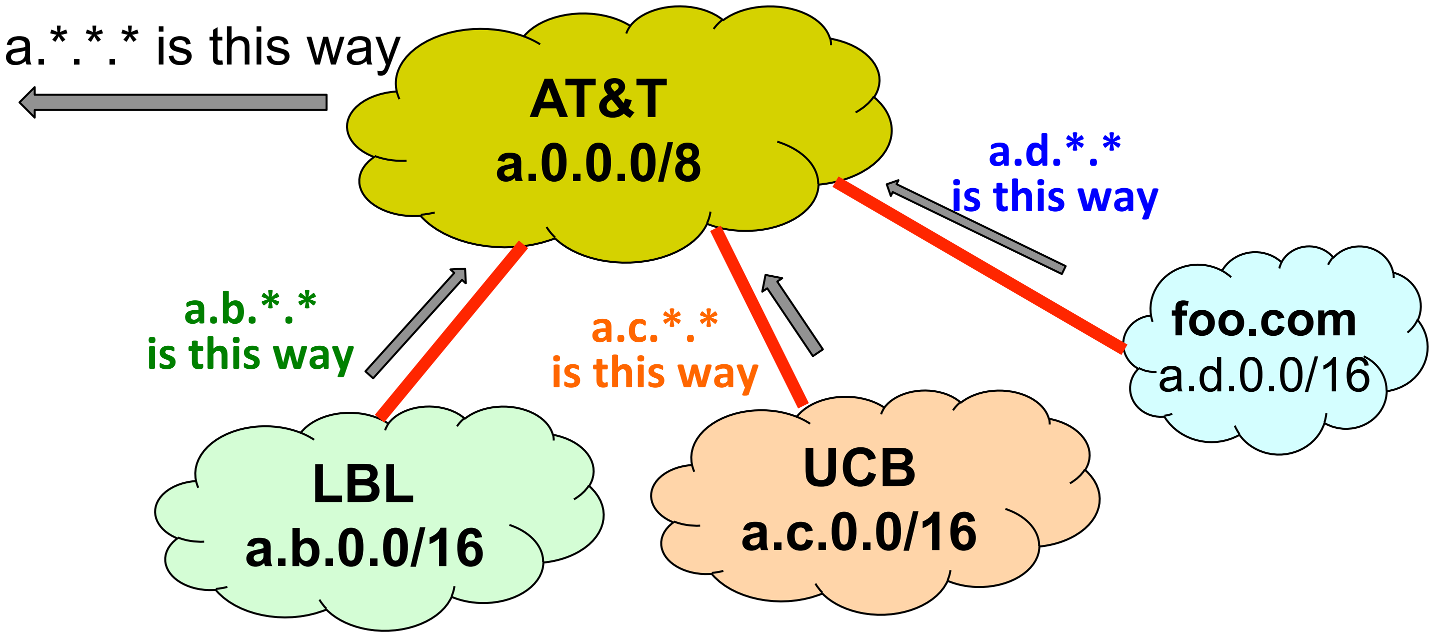
- For policy reasons, an AS may choose not to advertise a route to a destination
- Hence, reachability is not guaranteed even if graph is connected



Example: AS#2 does not want to carry traffic between AS#1 and AS#3

Differences between BGP and DV
(4) BGP may *aggregate* routes

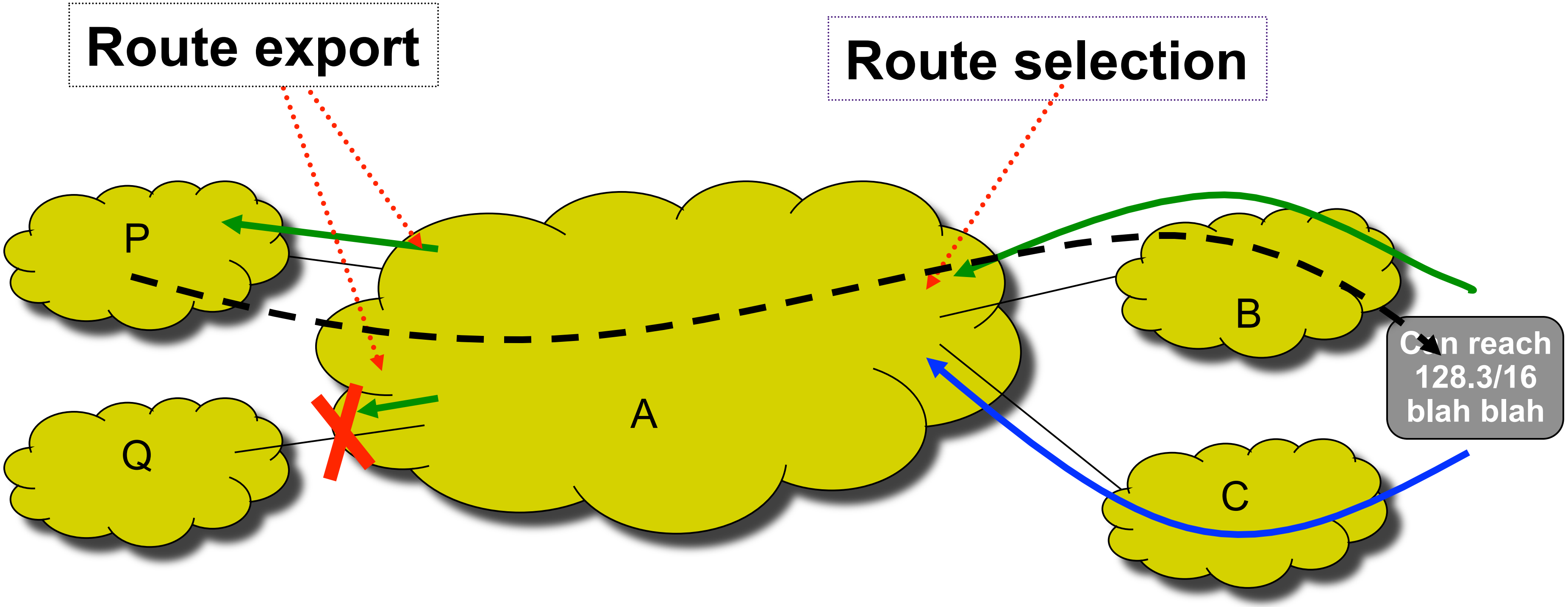
- For scalability, BGP may aggregate routes for different prefixes



BGP: Outline

- BGP policy
    - typical policies, how they’re implemented
- BGP protocol details
- Issues with BGP

Policy imposed in how routes are selected and exported



- **Selection**: Which path to use?
  - controls whether/how traffic leaves the network
- **Export**: Which path to advertise?
  - controls whether/how traffic enters the network

Typical Selection Policy

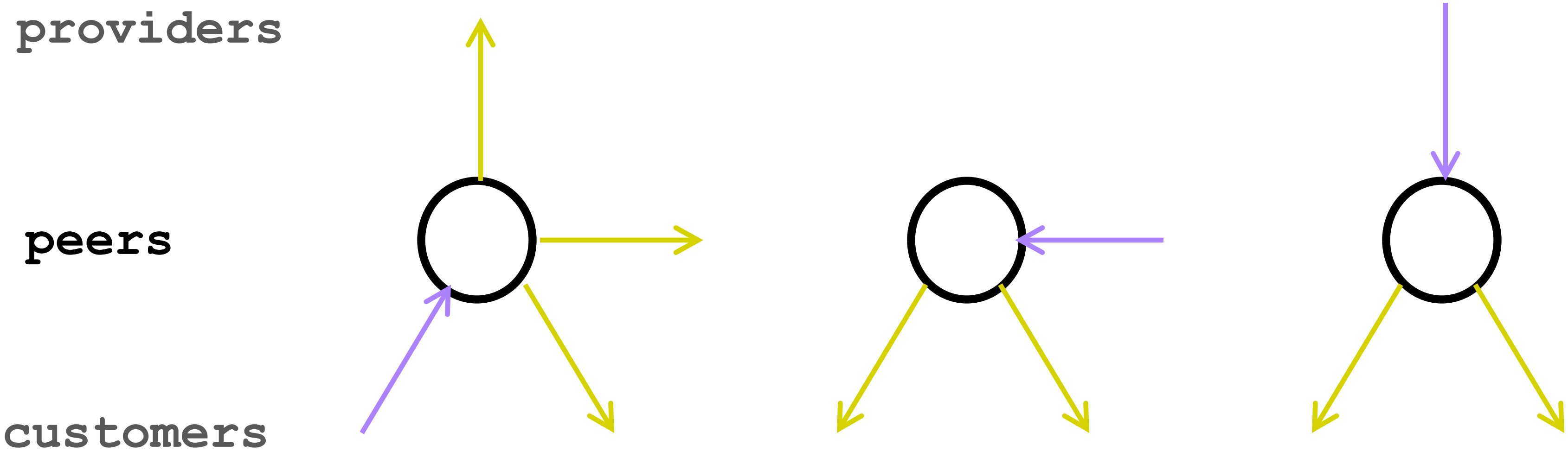
- In decreasing order of priority
  - make/save money (send to customer > peer > provider)
  - maximize performance (smallest AS path length)
  - minimize use of my network bandwidth (“hot potato”)
  - …
  - …

Typical Export Policy

Destination prefix advertised by…	Export route to…
Customer	Everyone (providers, peers, other customers)
Peer	Customers
Provider	Customers

We’ll refer to these as the “Gao-Rexford” rules
(capture common -- but not required! -- practice!)

Gao-Rexford



providers

peers

customers

With Gao-Rexford, the AS policy graph is a
DAG (directed acyclic graph) and routes are “valley free”

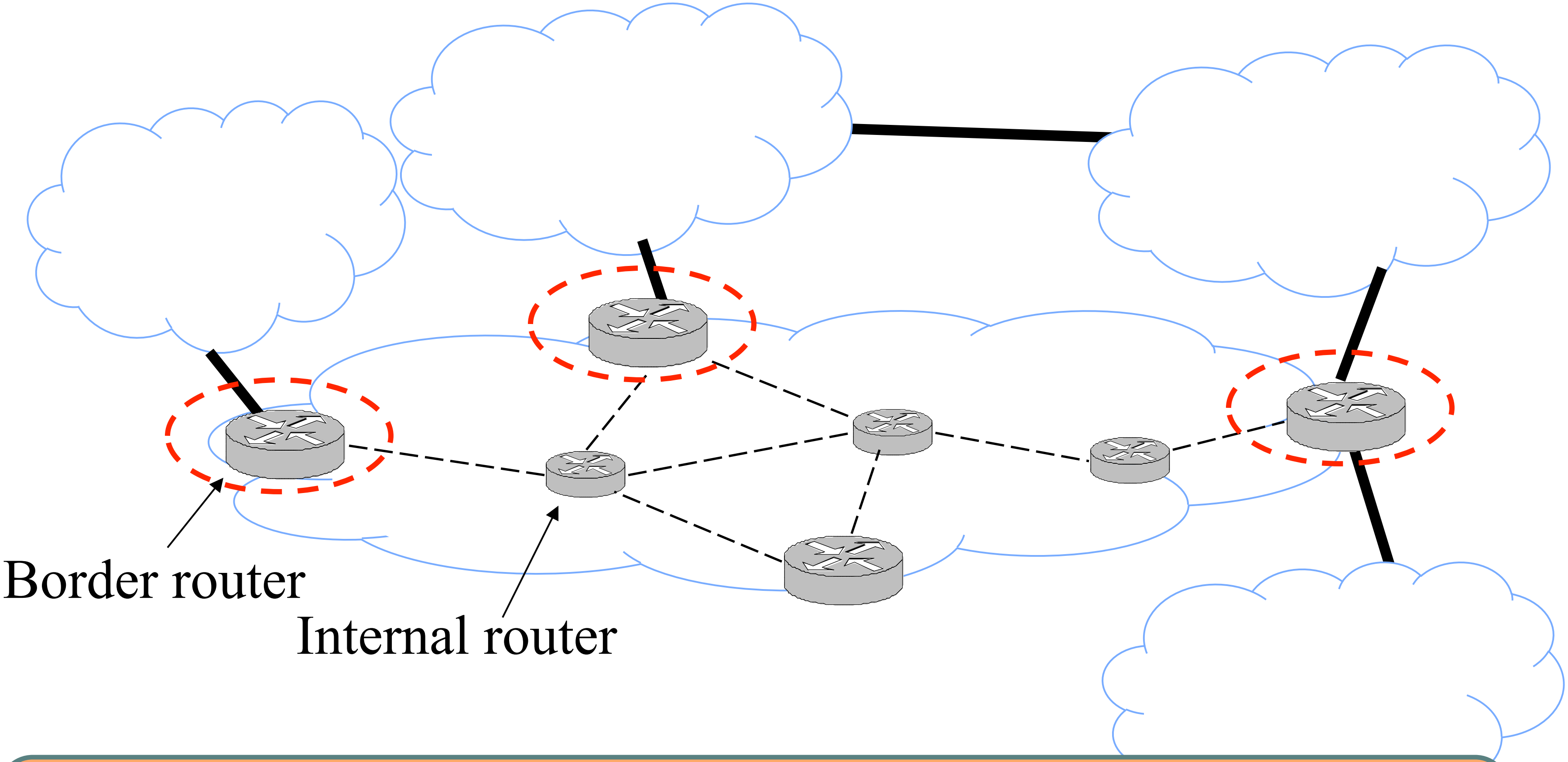
BGP: Today

- BGP policy
  - typical policies, how they're implemented

- BGP protocol details
  - stay awake as long as you can…

- BGP issues

Who speaks BGP?



Border routers at an Autonomous System

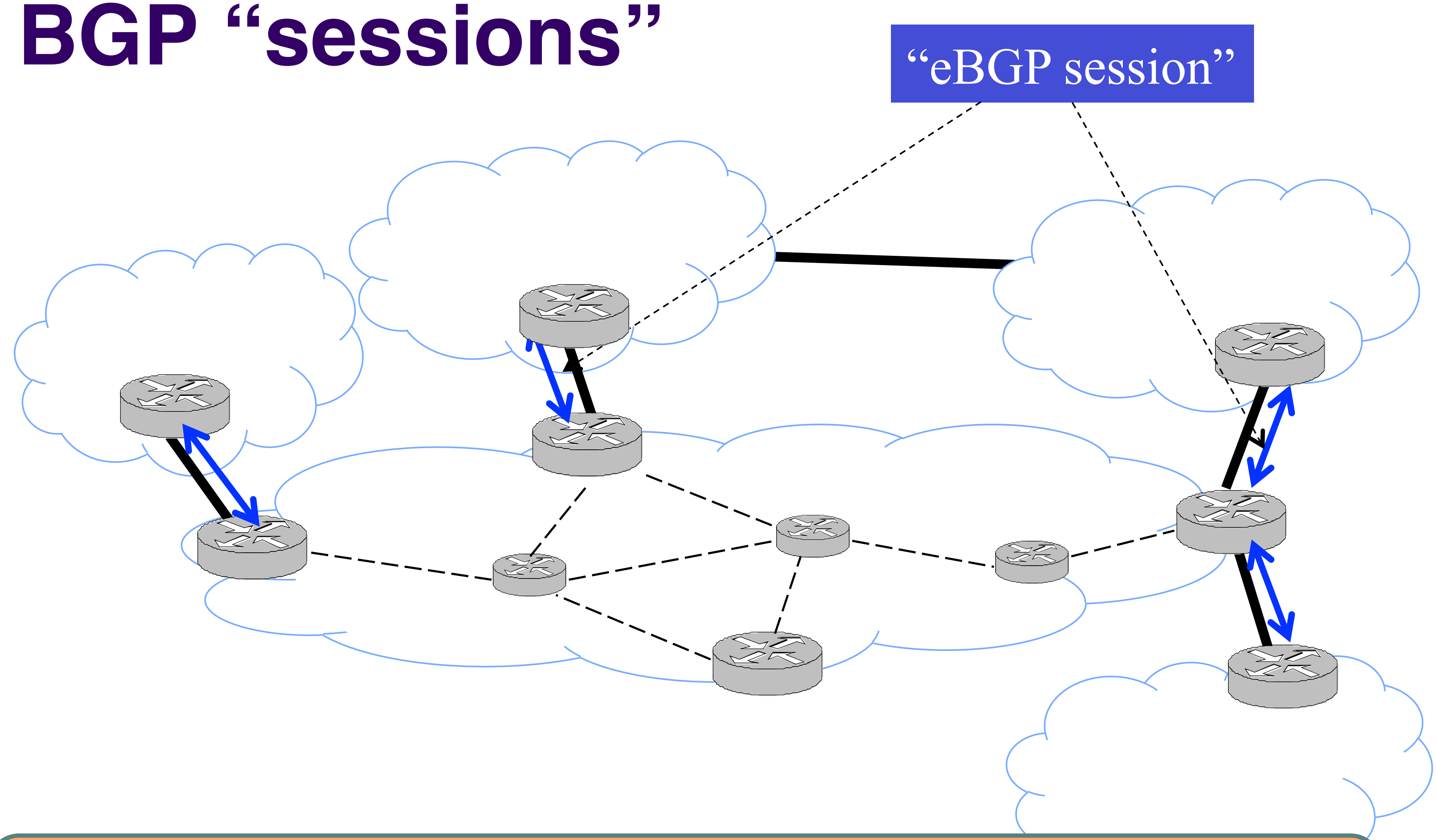
What does “speak BGP” mean?

- Implement the BGP protocol standard
  - read more here: http://tools.ietf.org/html/rfc4271

- Specifies what messages to exchange with other BGP “speakers”
  - message types (e.g., route advertisements, updates)
  - message syntax

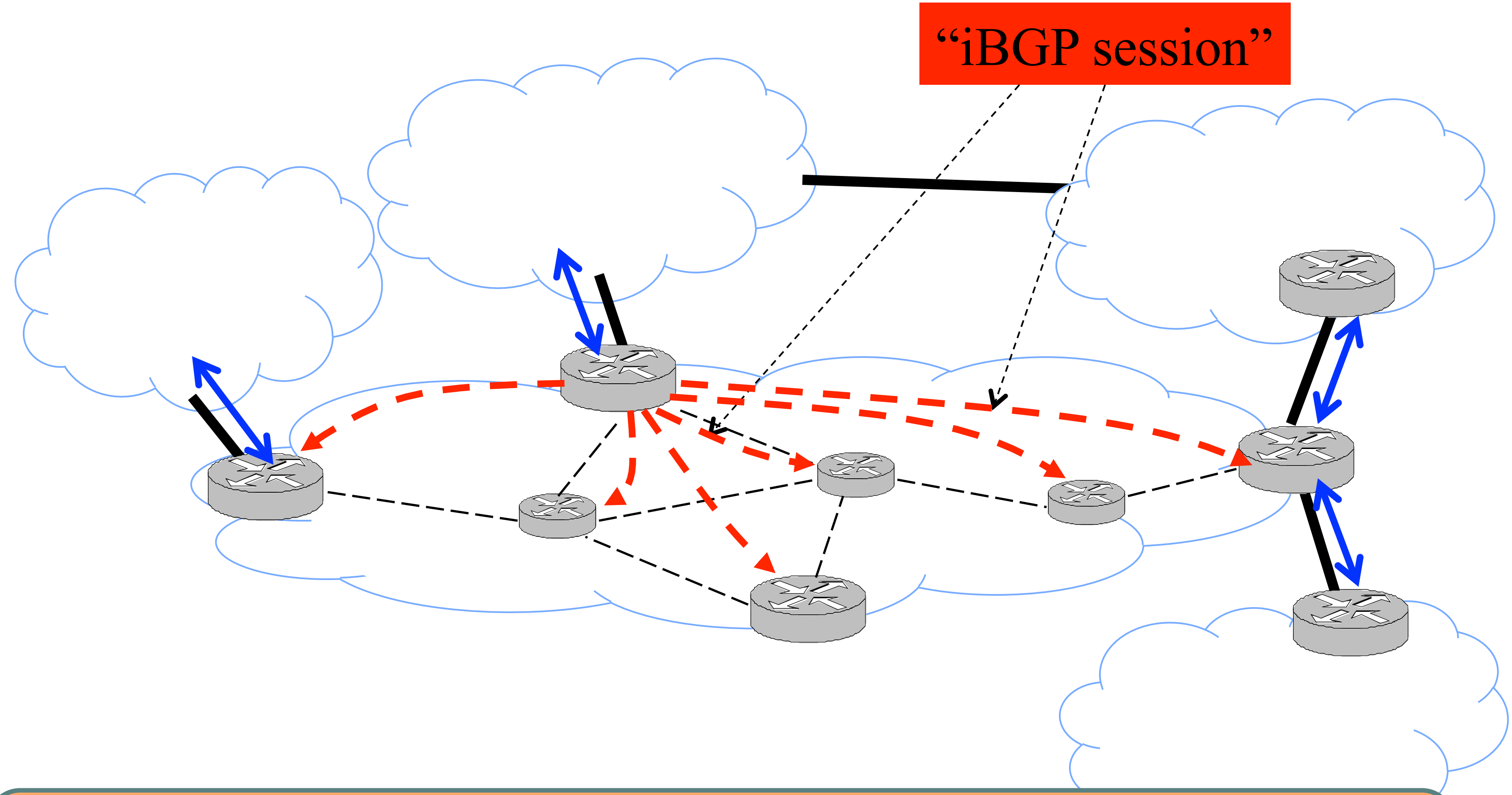
- And how to process these messages
  - e.g., *“when you receive a BGP update, do…. “*
  - follows BGP state machine in the protocol spec + policy decisions, etc.

BGP “sessions”



A border router speaks BGP with border routers in other ASes

BGP "sessions"



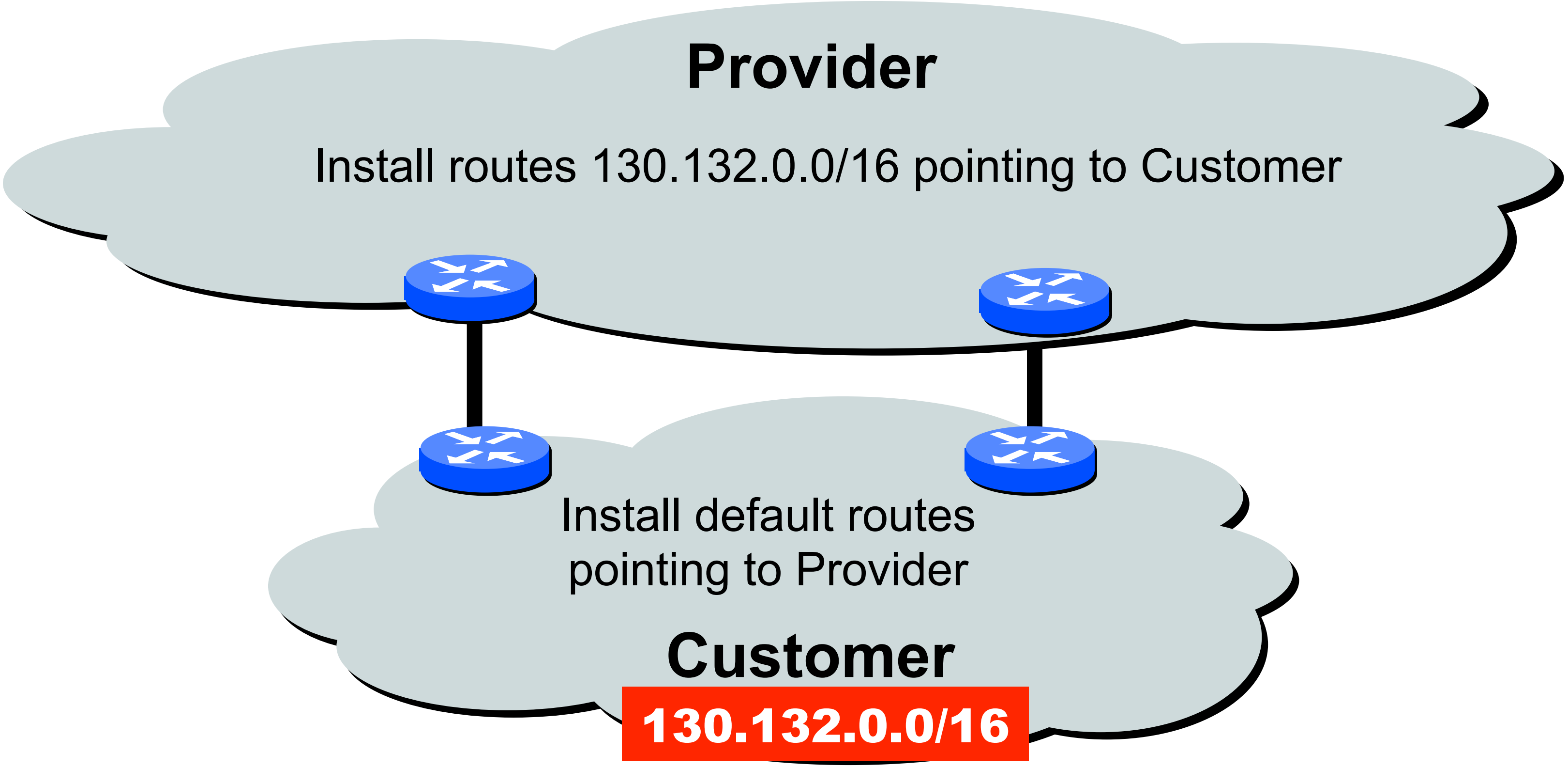
A border router speaks BGP with other (interior and border) routers in its own AS

eBGP, iBGP, IGP

- eBGP: BGP sessions between border routers in different ASes
  - Learn routes to external destinations
- iBGP: BGP sessions between border routers and other routers within the same AS
  - distribute externally learned routes internally
- IGP: “Interior Gateway Protocol” = Intradomain routing protocol
  - provide internal reachability
  - e.g., OSPF, RIP

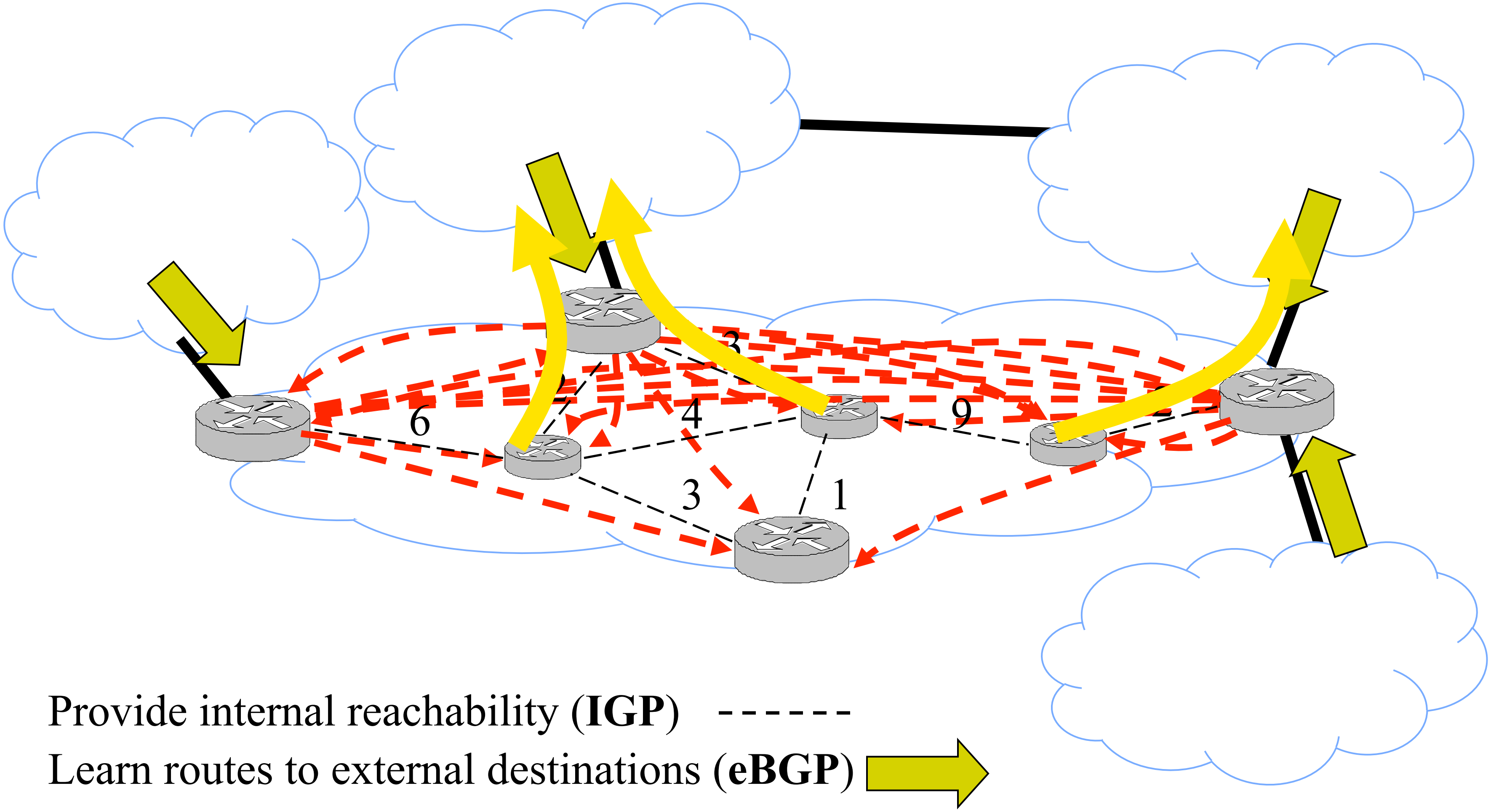
Some Border Routers Don't Need BGP

- Customer that connects to a single upstream ISP
  - The ISP can advertise prefixes into BGP on behalf of customer
  - … and the customer can simply default-route to the ISP



Provider
Install routes 130.132.0.0/16 pointing to Customer
Install default routes pointing to Provider
Customer
130.132.0.0/16

Putting the pieces together



1. Provide internal reachability (**IGP**) ------
2. Learn routes to external destinations (**eBGP**) ⇨
3. Distribute externally learned routes internally (**iBGP**) – – ▸
4. Travel shortest path to egress (IGP)

Basic Messages in BGP

- **Open**
  - Establishes BGP session
  - BGP uses TCP *[will make sense in 1-2weeks]*
- **Notification**
  - Report unusual conditions
- **Update**
  - Inform neighbor of new routes
  - Inform neighbor of old routes that become inactive
- **Keepalive**
  - Inform neighbor that connection is still viable

Route Updates

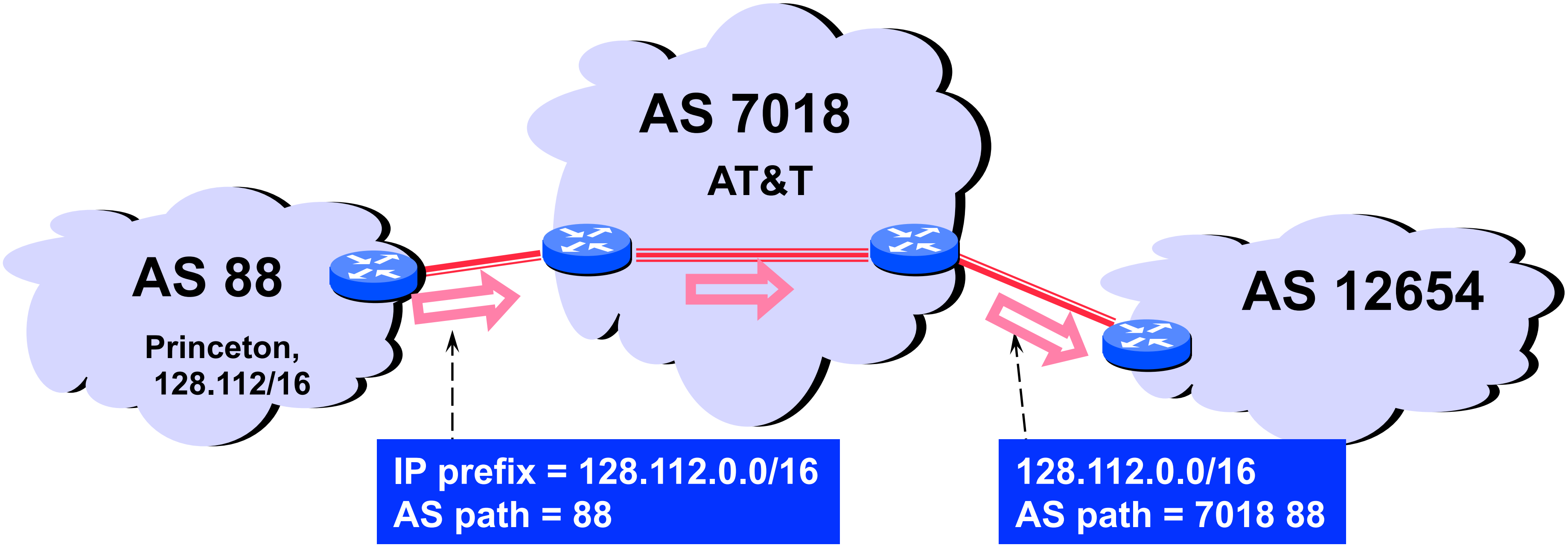
- Format *<IP prefix: route attributes>*
  - attributes describe properties of the route
- Two kinds of updates
  - announcements: new routes or changes to existing routes
  - withdrawal: remove routes that no longer exist

Route Attributes

- Routes are described using attributes
  - Used in route selection/export decisions
- Some attributes are local
  - i.e., private within an AS, not included in announcements
- Some attributes are propagated with eBGP route announcements
- There are many standardized attributes in BGP
  - We will discuss a few

Attributes (1): ASPATH

- Carried in route announcements
- Vector that lists all the ASes a route advertisement has traversed (in reverse order)



AS 88

Princeton,
128.112/16

AS 7018

AT&T

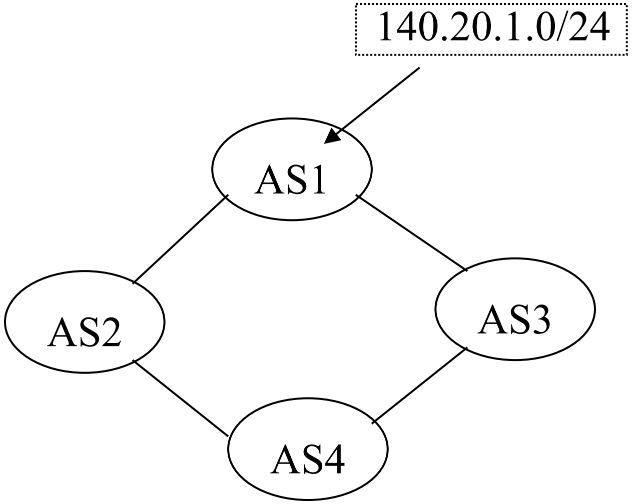
AS 12654

IP prefix = 128.112.0.0/16
AS path = 88

128.112.0.0/16
AS path = 7018 88

Attributes (2): **LOCAL PREF**

- "Local Preference"
- Used to choose between different AS paths
- The higher the value the more preferred
- Local to an AS; carried only in iBGP messages

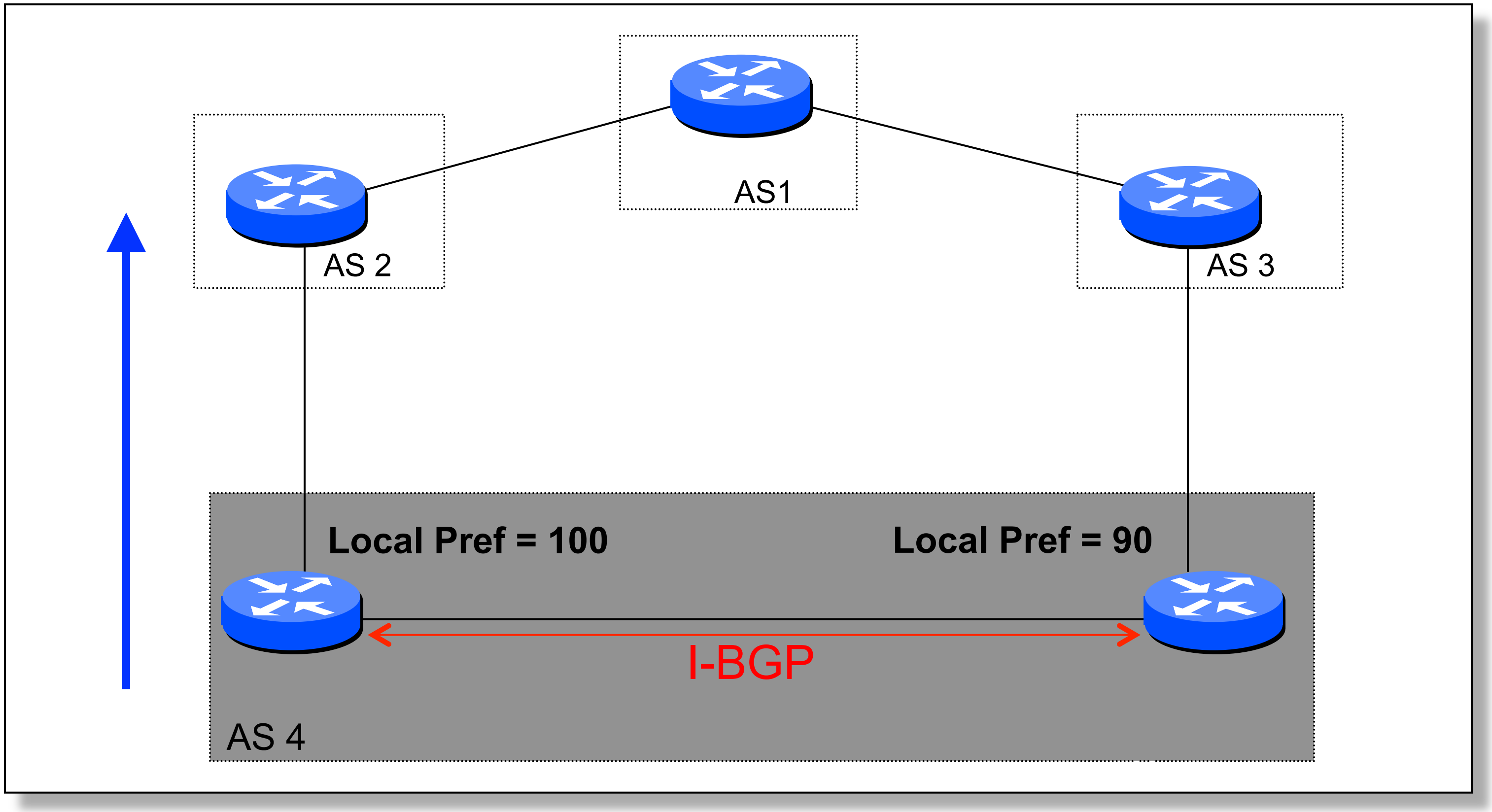


BGP table at AS4:

Destination	AS Path	Local Pref
140.20.1.0/24	**AS3 AS1**	**300**
140.20.1.0/24	**AS2 AS1**	**100**

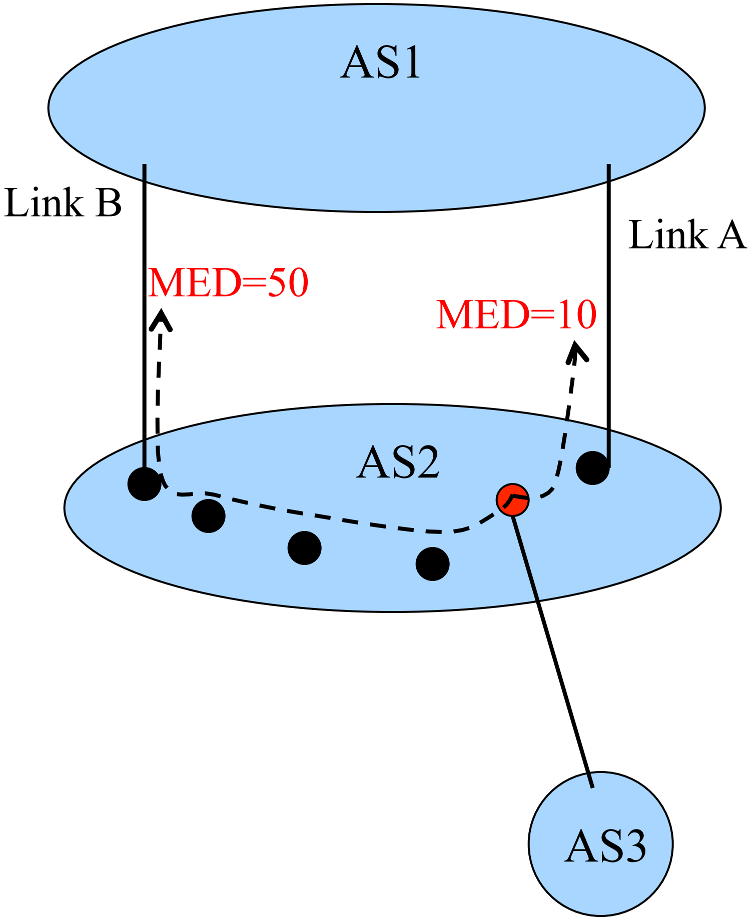
Example: iBGP and LOCAL PREF

- Both routers prefer the path through AS 2 on the left



Attributes (3) : MED

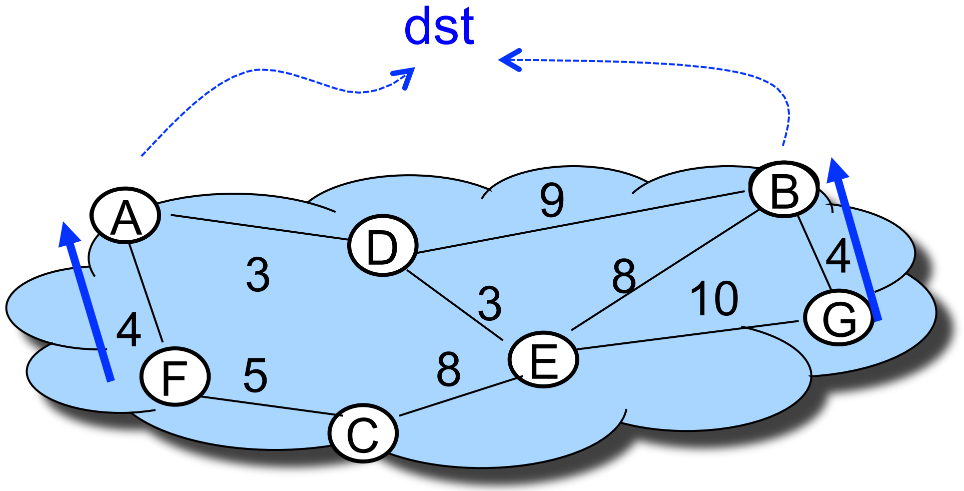
- “Multi-Exit Discriminator”
- Used when ASes are interconnected via 2 or more links to specify how close a prefix is to the link it is announced on
- Lower is better
- AS announcing prefix sets MED
- AS receiving prefix (optionally!) uses MED to select link



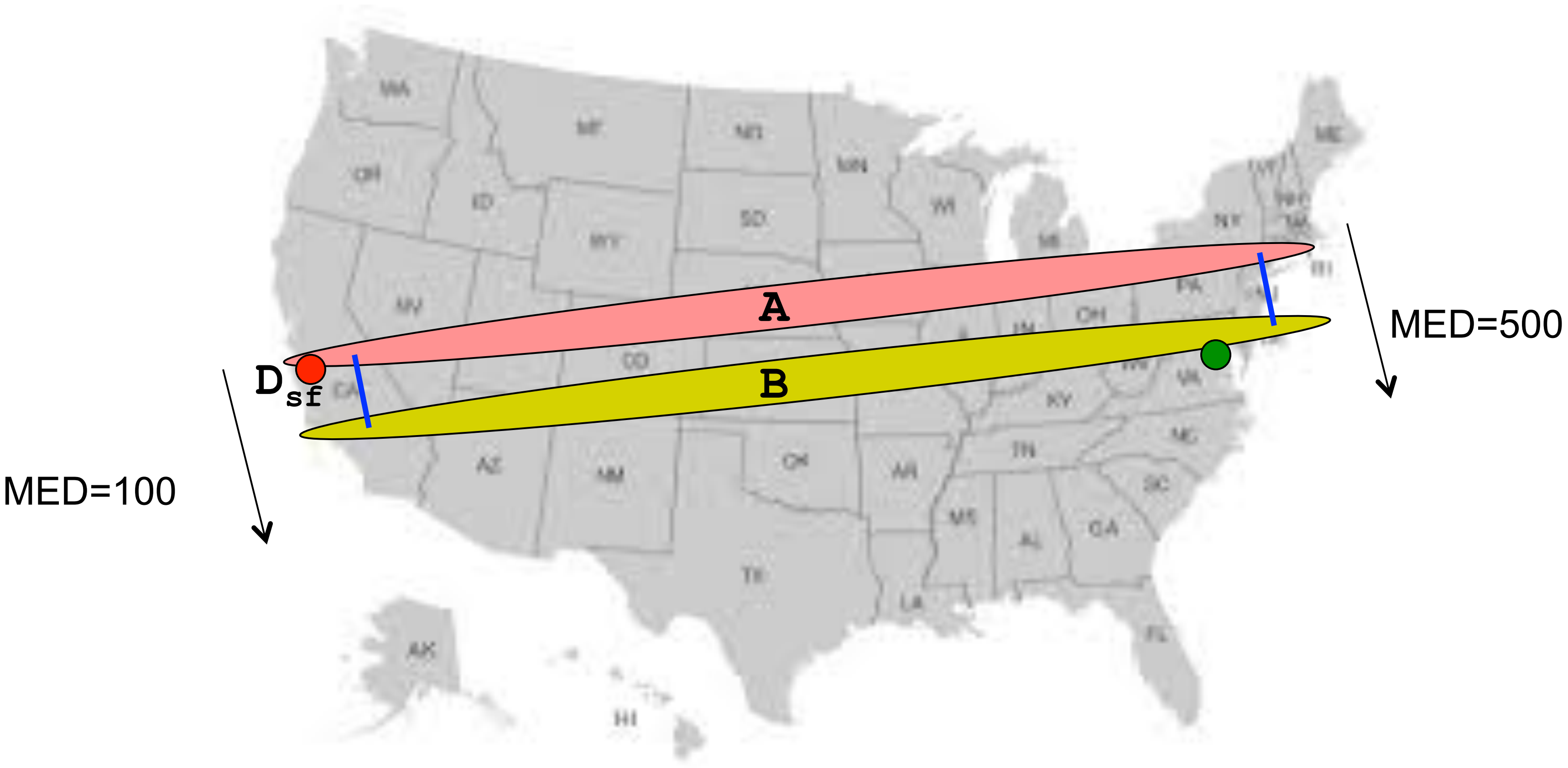
destination prefix

Attributes (4): IGP cost

- Used for hot-potato routing
  - Each router selects the closest egress point based on the path cost in intra-domain protocol



IGP may conflict with MED



Typical Selection Policy

- In decreasing order of priority
  - make/save money (send to customer > peer > provider)
  - maximize performance (smallest AS path length)
  - minimize use of my network bandwidth (“hot potato”)
  - …
  - …

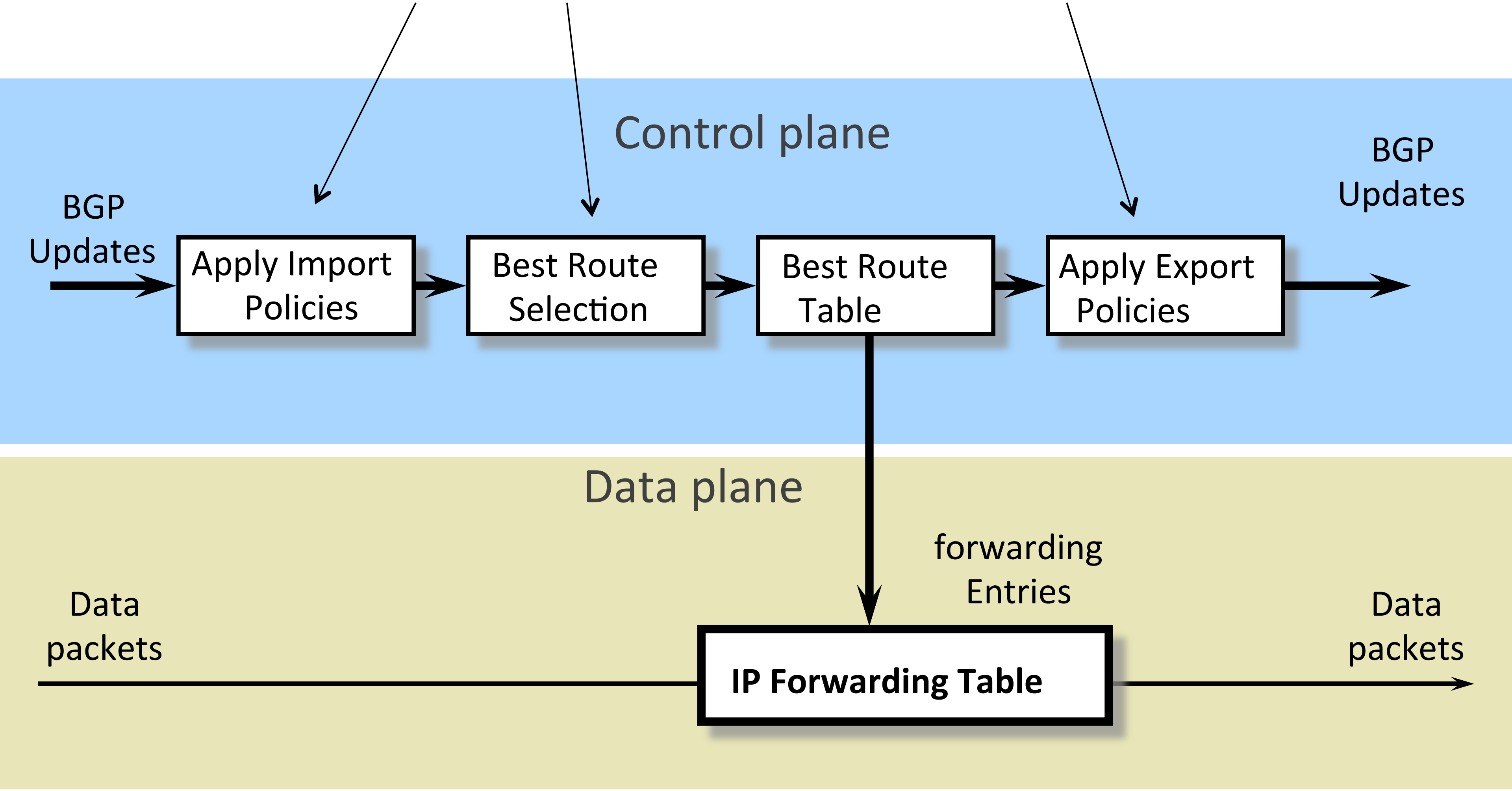
Using Attributes

- Rules for route selection in priority order

Priority	Rule	Remarks
1	LOCAL PREF	Pick highest LOCAL PREF
2	ASPATH	Pick shortest ASPATH length
3	MED	Lowest MED preferred
4	eBGP > iBGP	Did AS learn route via eBGP (preferred) or iBGP?
5	iBGP path	Lowest IGP cost to next hop (egress router)
6	Router ID	Smallest next-hop router's IP address as tie-breaker

BGP UPDATE Processing

Open ended programming.
Constrained only by vendor configuration language



BGP: Today

- BGP policy
  - typical policies, how they're implemented

- BGP protocol details

- BGP issues

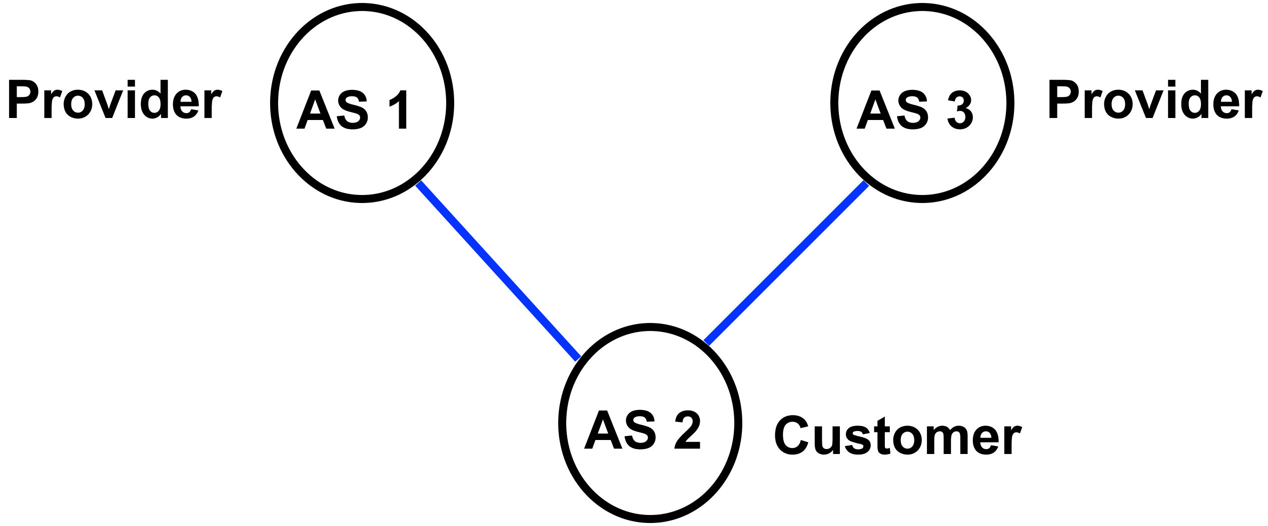
Issues with BGP

- Reachability
- Security
- Convergence
- Performance
- Anomalies

Reachability

- In normal routing, if graph is connected then reachability is assured

- With policy routing, this does not always hold



Security

- An AS can claim to serve a prefix that they actually don’t have a route to (blackholing traffic)
  - Problem not specific to policy or path vector
  - Important because of AS autonomy
  - *Fixable: make ASes “prove” they have a path*

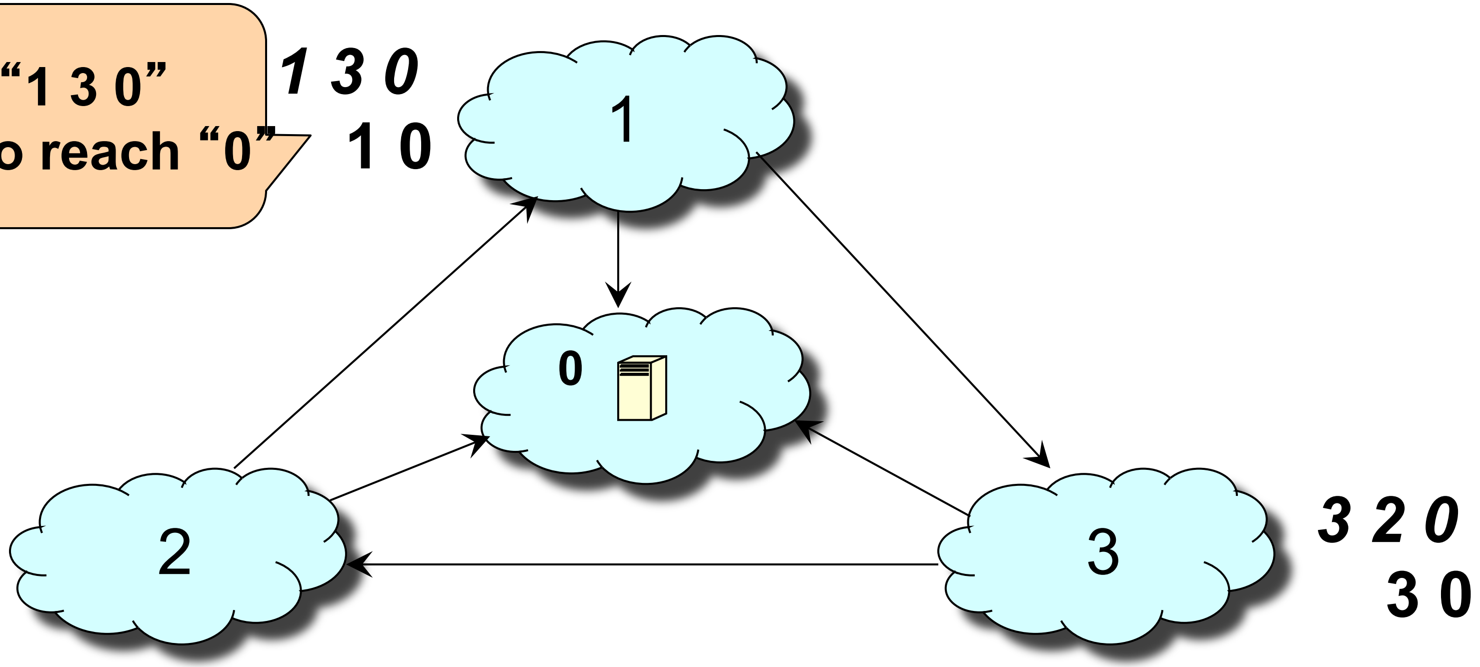
- Note: AS may forward packets along a route different from what is advertised
  - Tell customers about fictitious short path…
  - Much harder to fix!

Convergence

- Result: If all AS policies follow “Gao-Rexford” rules, BGP is guaranteed to converge (safety)

- For arbitrary policies, BGP may fail to converge!

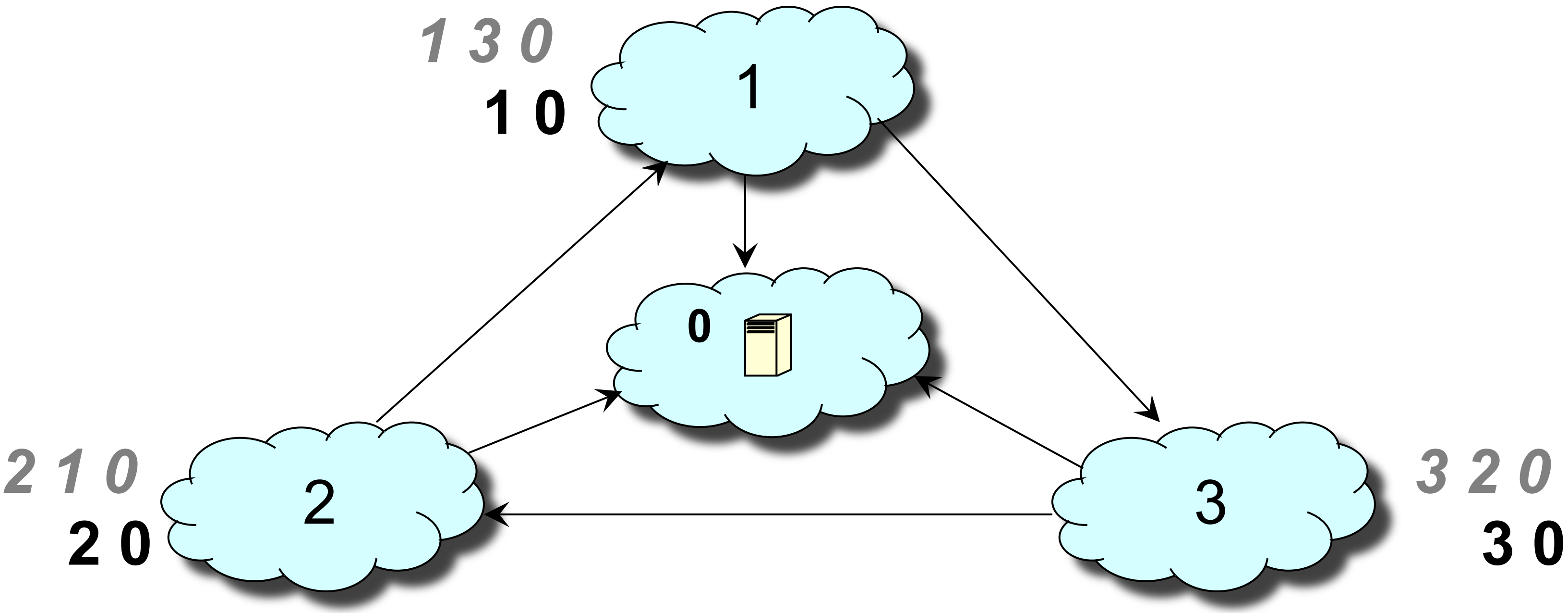
Example of Policy Oscillation



"1" prefers "1 3 0" over "1 0" to reach "0"

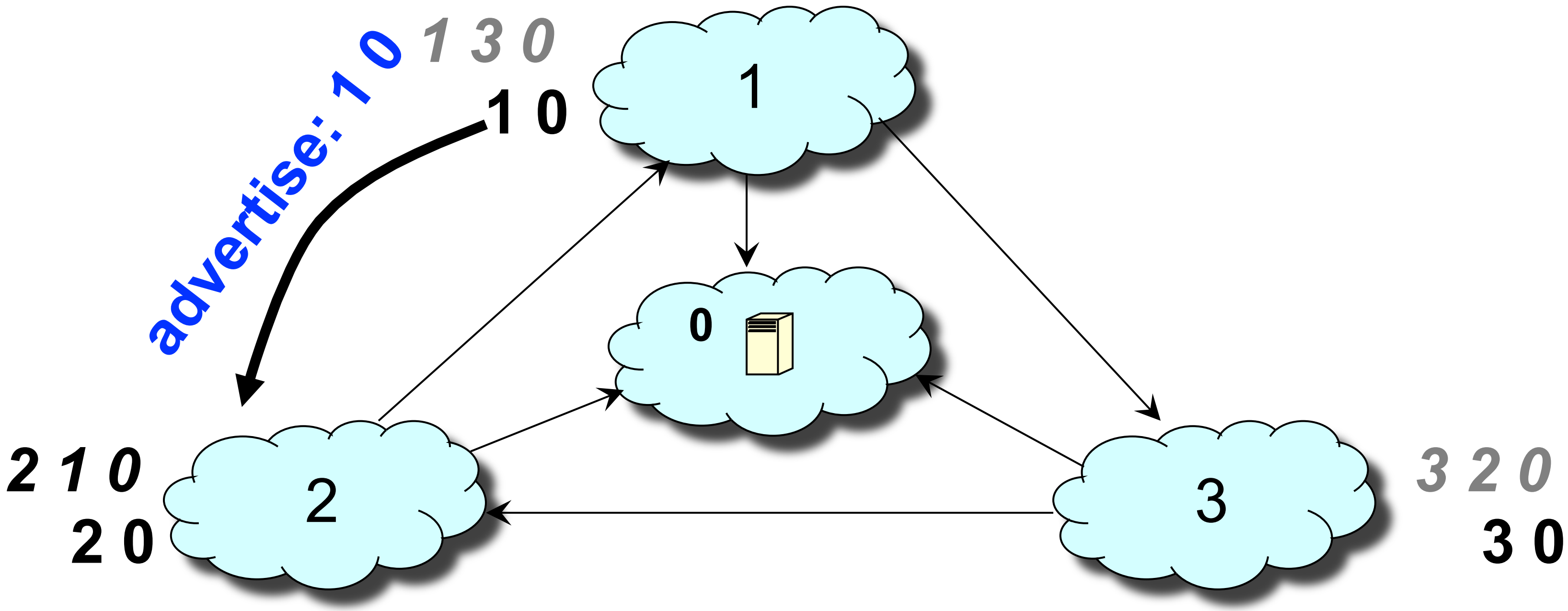
Step-by-Step of Policy Oscillation

Initially: nodes 1, 2, 3 know only shortest path to 0



Step-by-Step of Policy Oscillation

1 **advertises** its path 1 0 to 2



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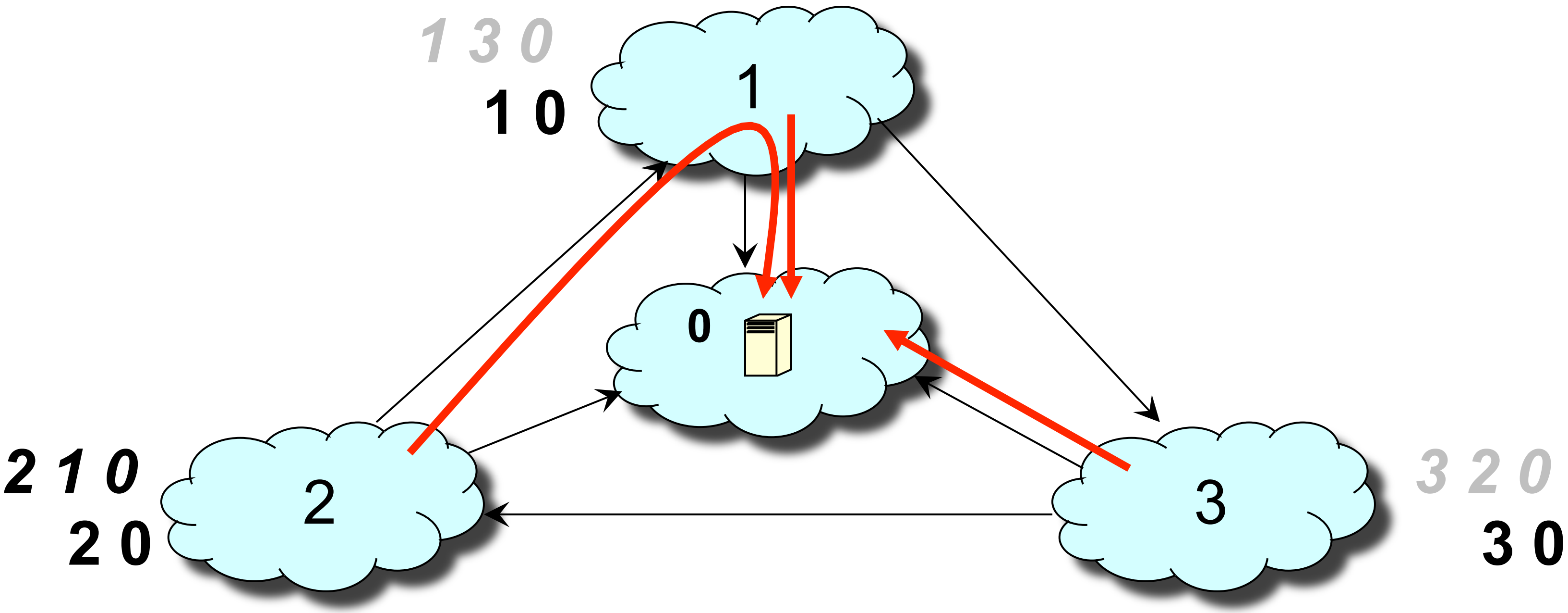
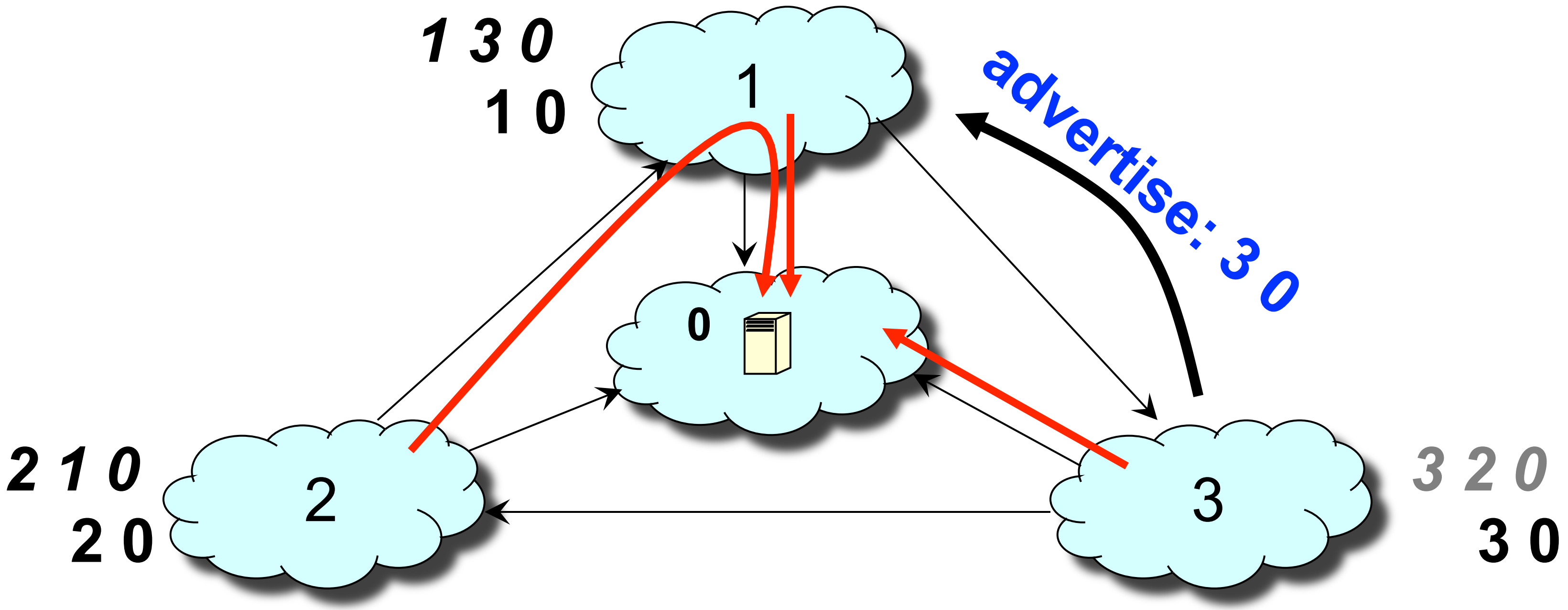
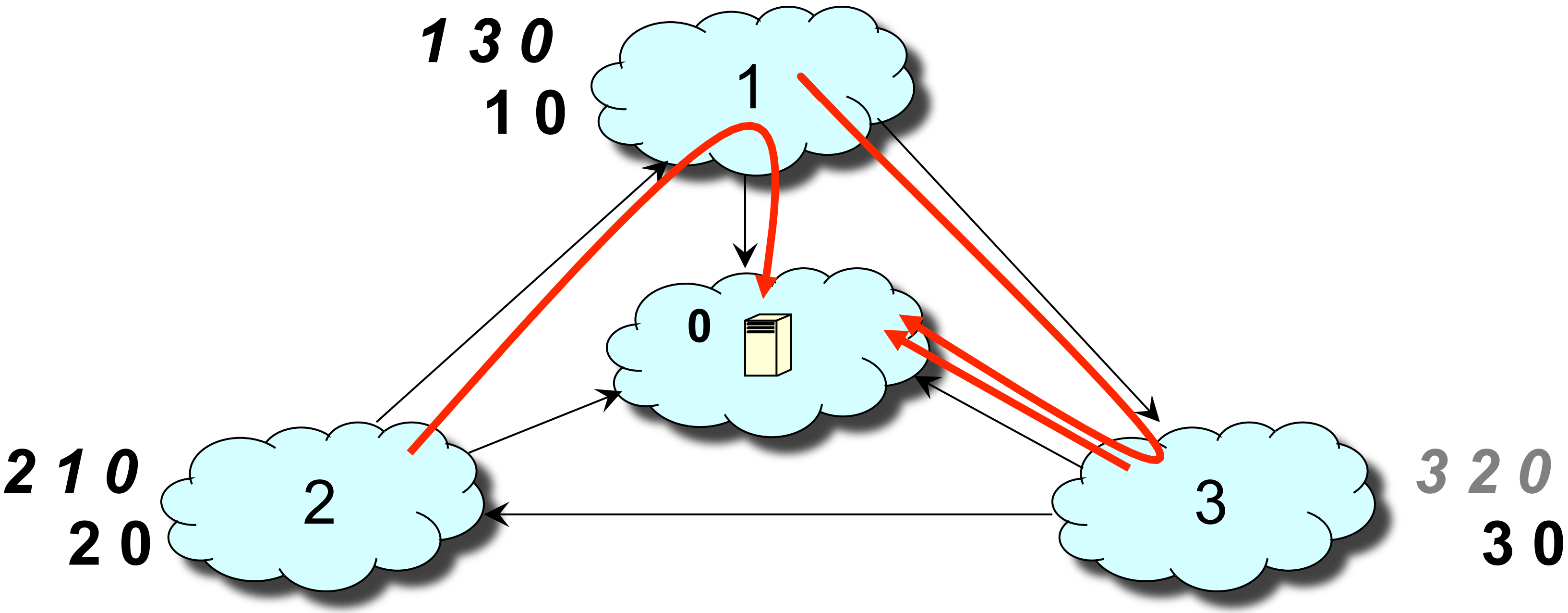


Step-by-Step of Policy Oscillation

3 **advertises** its path 3 0 to 1

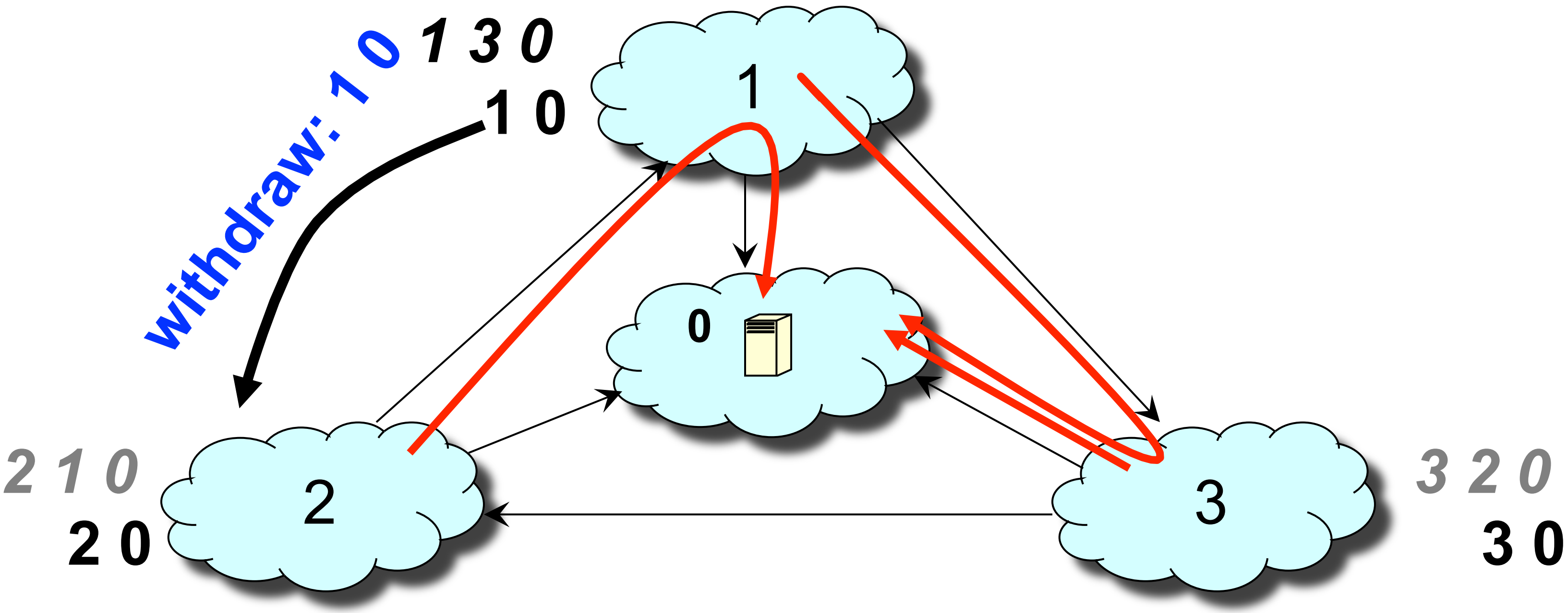


Step-by-Step of Policy Oscillation



Step-by-Step of Policy Oscillation

1 **withdraws** its path 1 0 from 2



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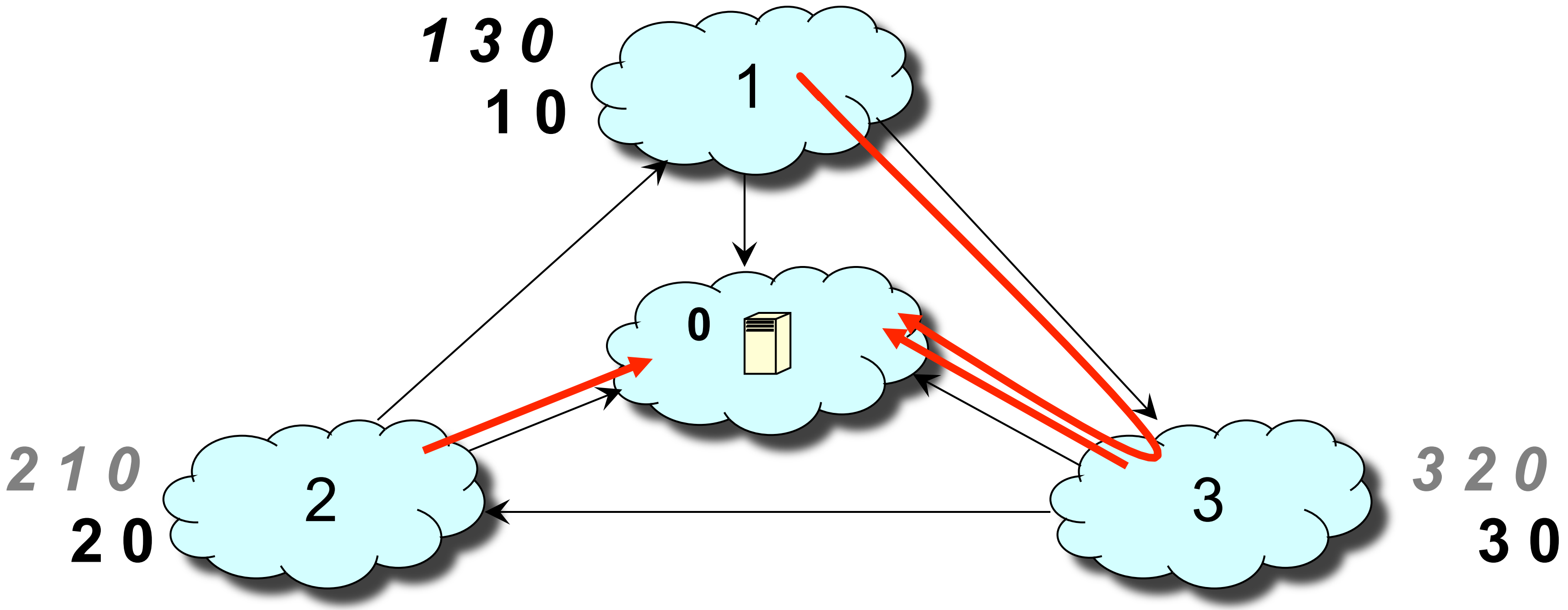
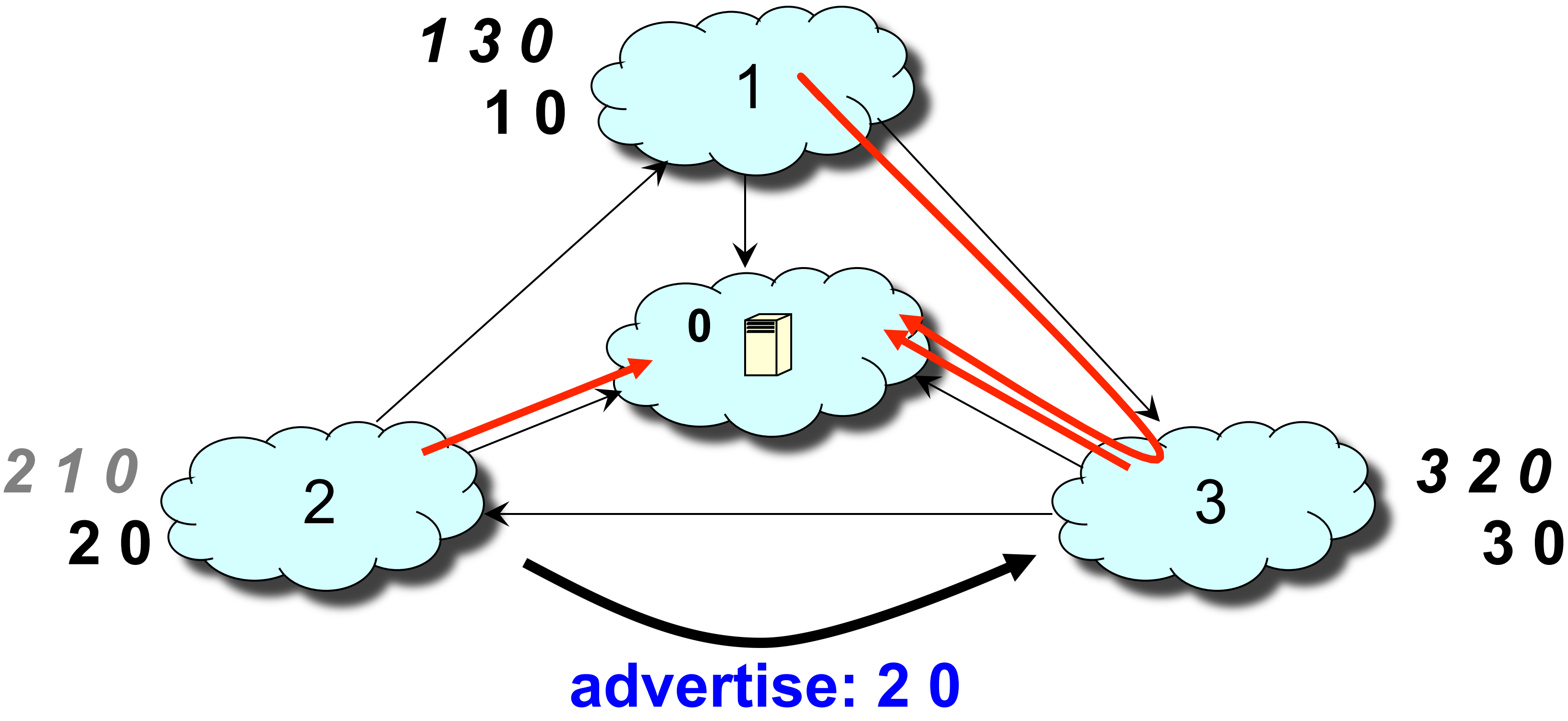
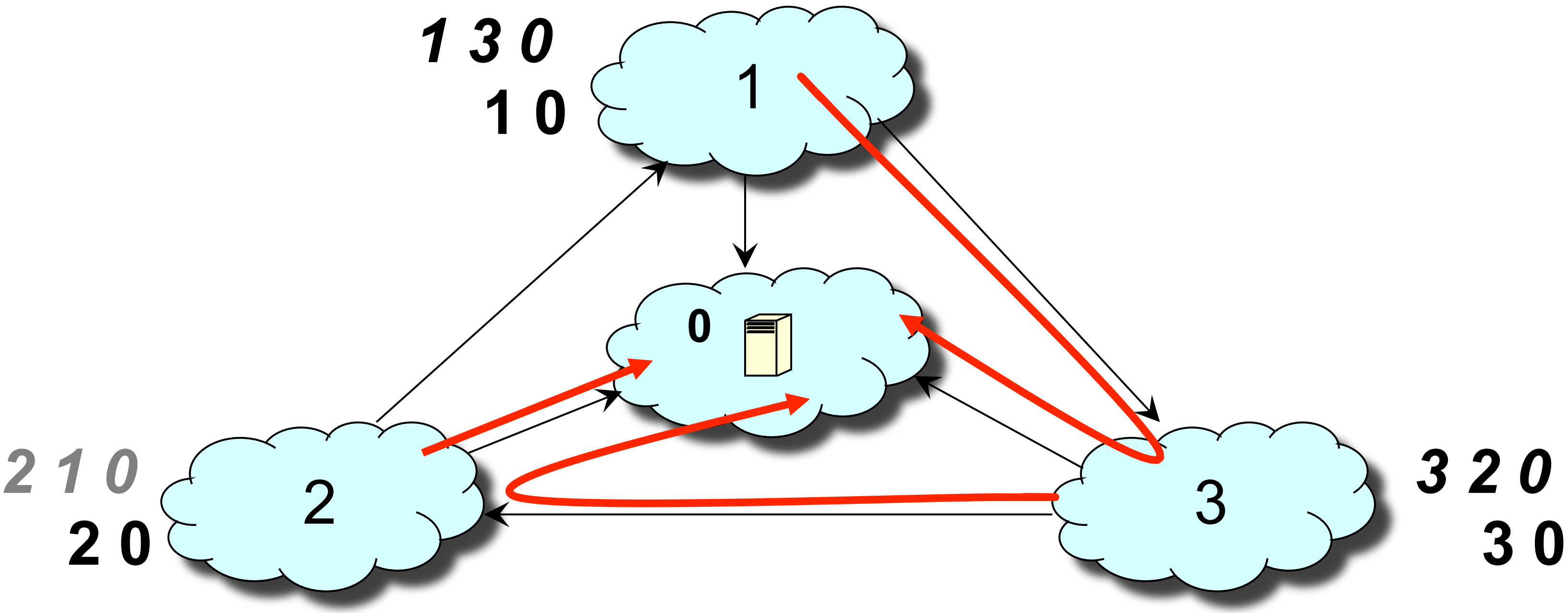


Step-by-Step of Policy Oscillation

2 **advertises** its path 2 0 to 3

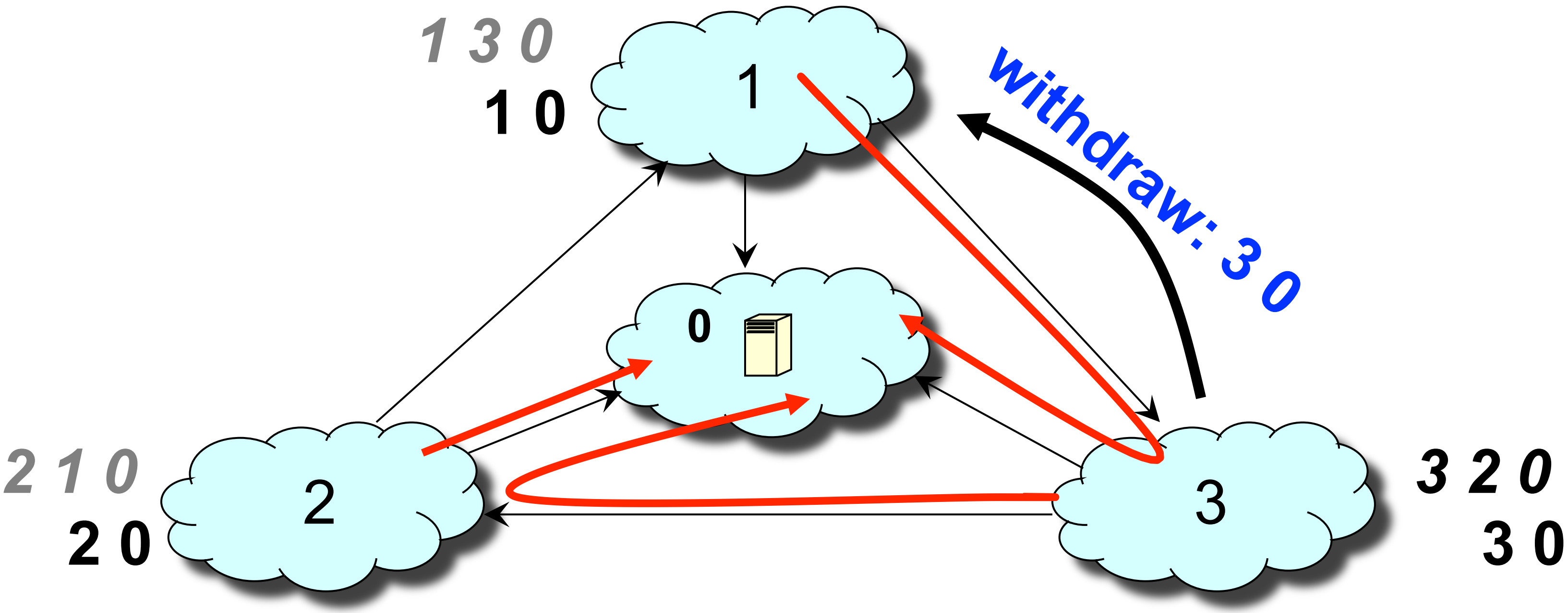


Step-by-Step of Policy Oscillation



Step-by-Step of Policy Oscillation

3 **withdraws** its path 3 0 from 1



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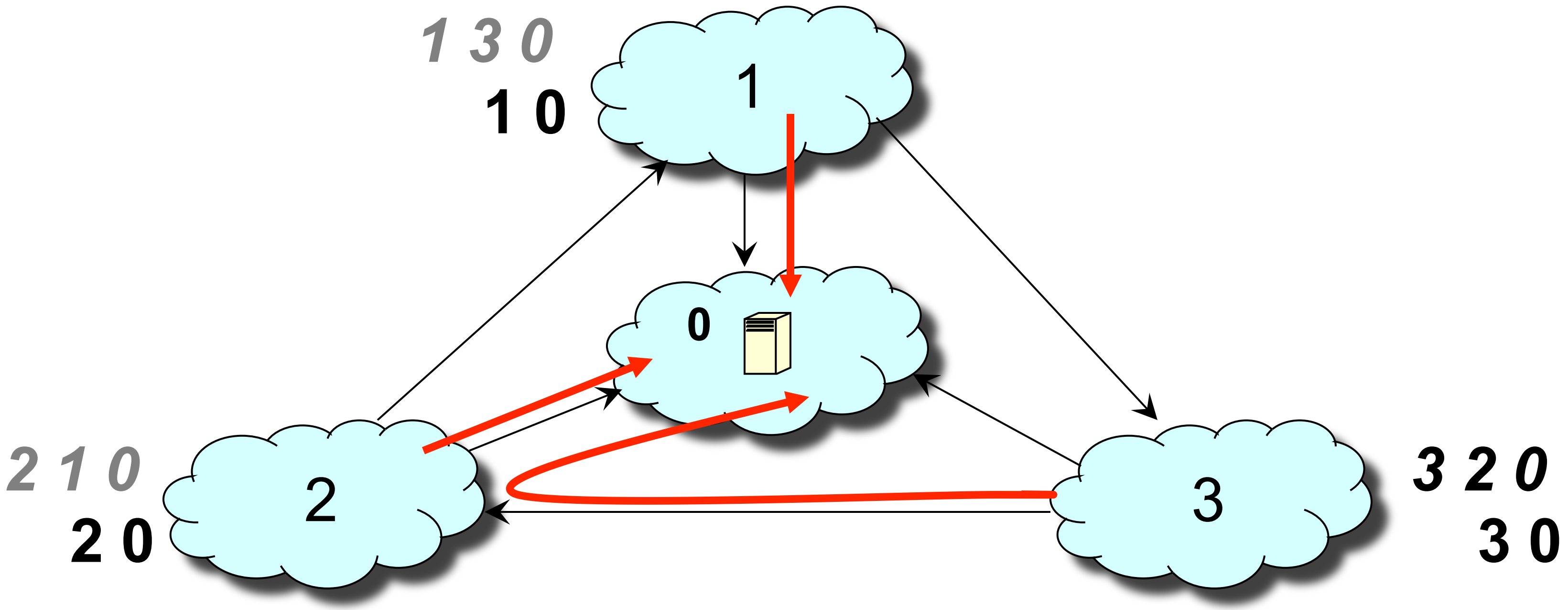
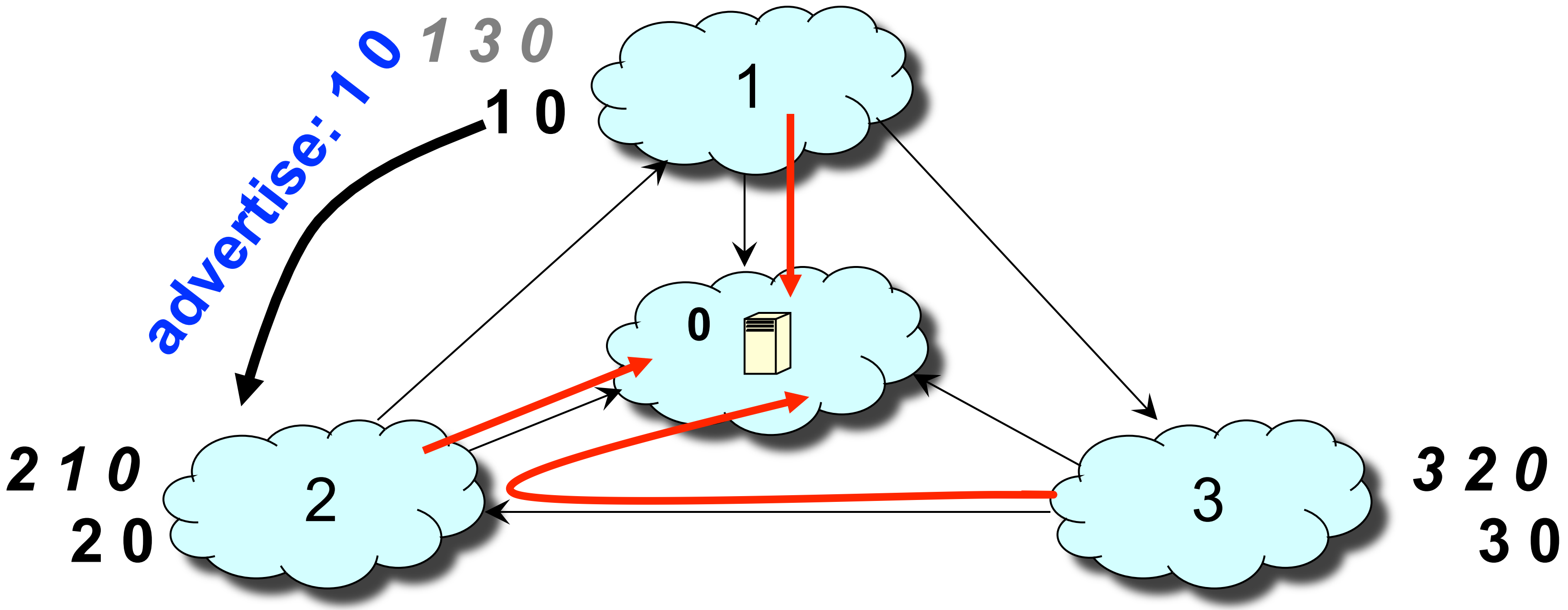


Step-by-Step of Policy Oscillation

1 **advertises** its path 1 0 to 2



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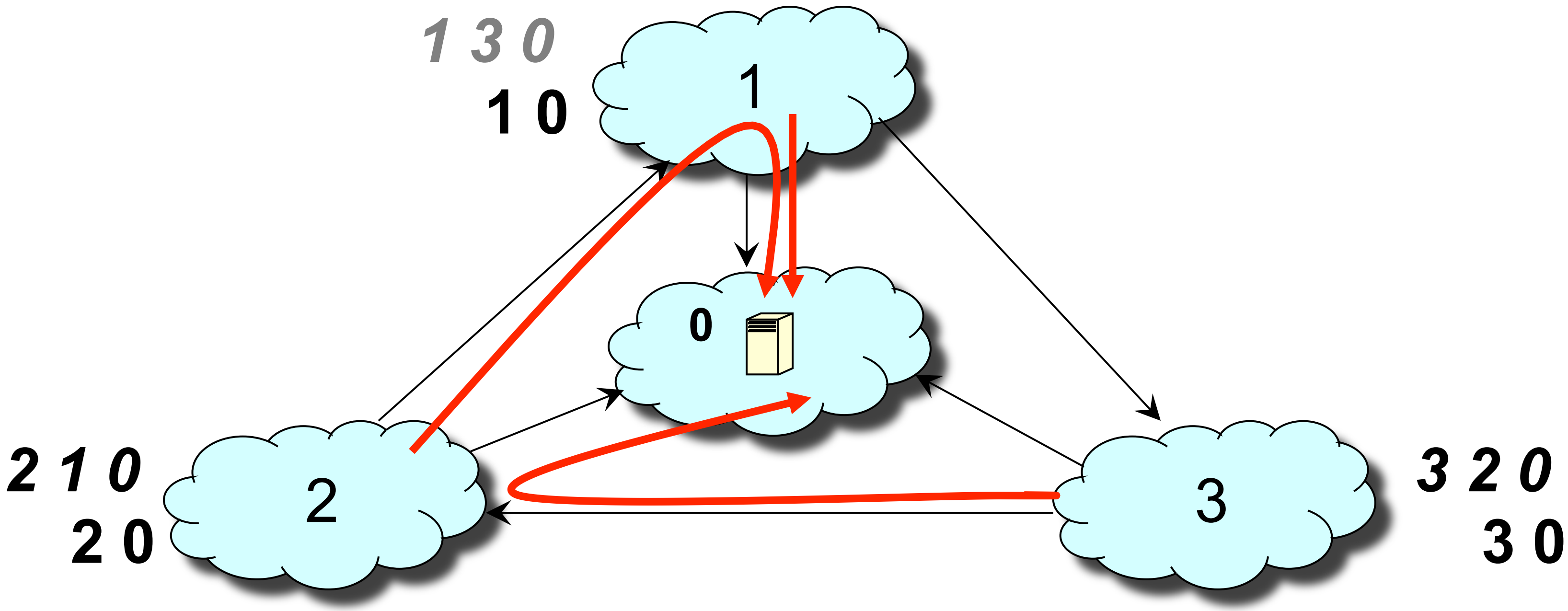
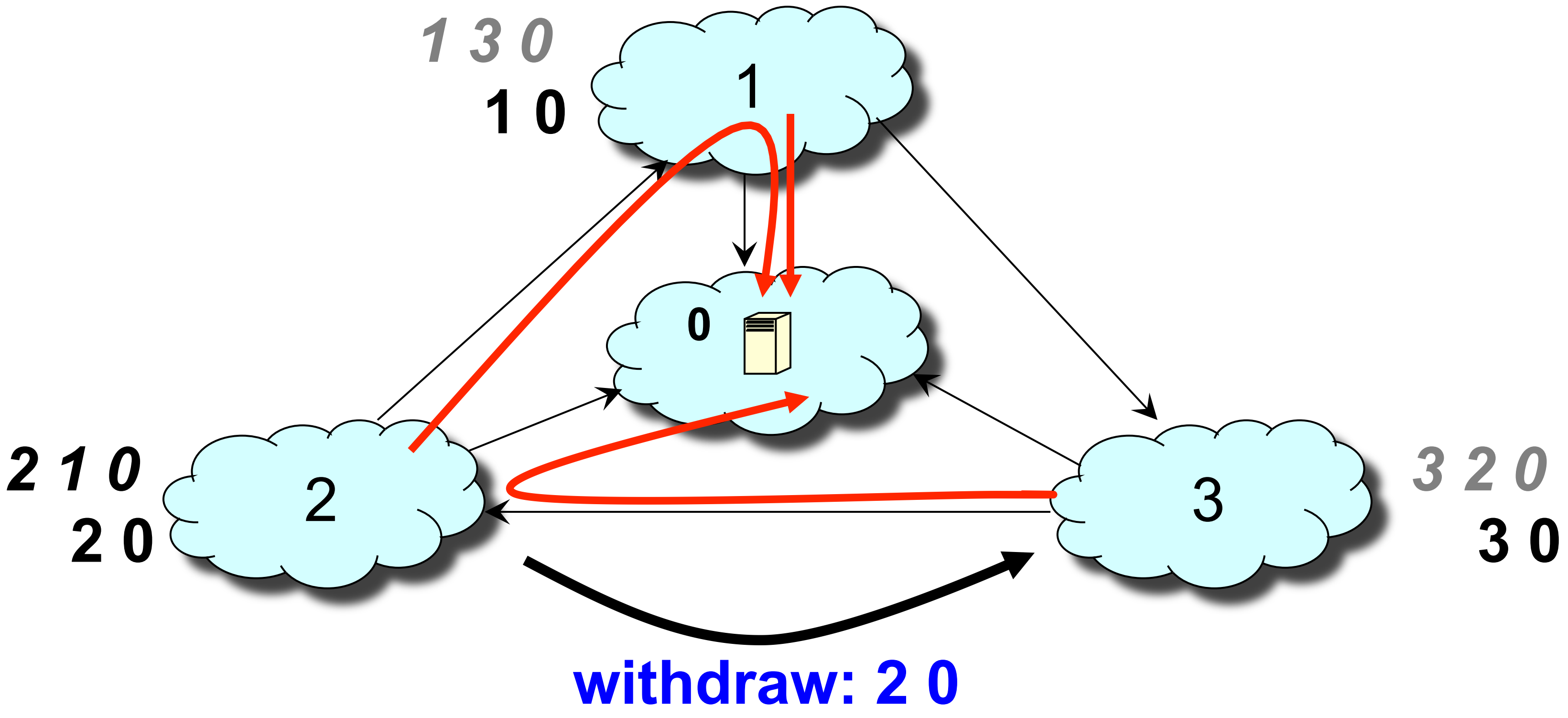
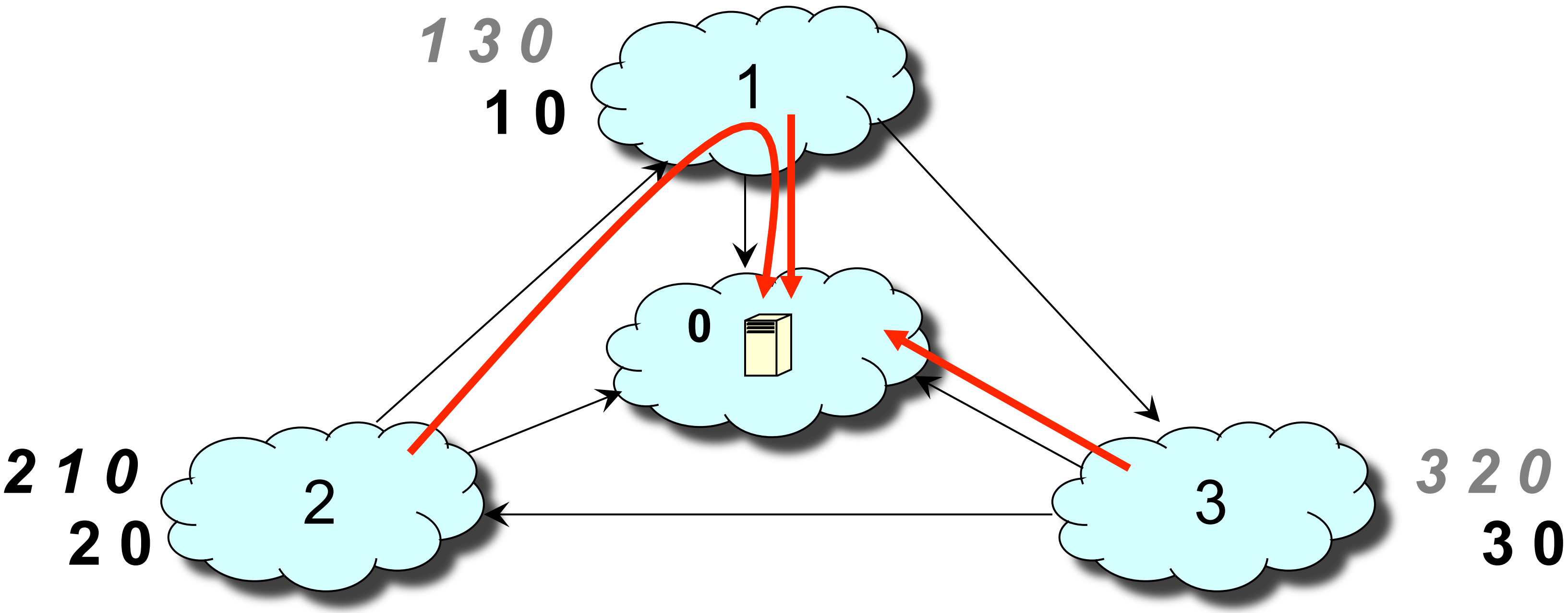


Step-by-Step of Policy Oscillation

2 **withdraws** its path 2 0 from 3



Step-by-Step of Policy Oscillation



We are back to where we started!

Convergence

- Result: If all AS policies follow "Gao-Rexford" rules, BGP is guaranteed to converge (safety)

- For arbitrary policies, BGP may fail to converge!

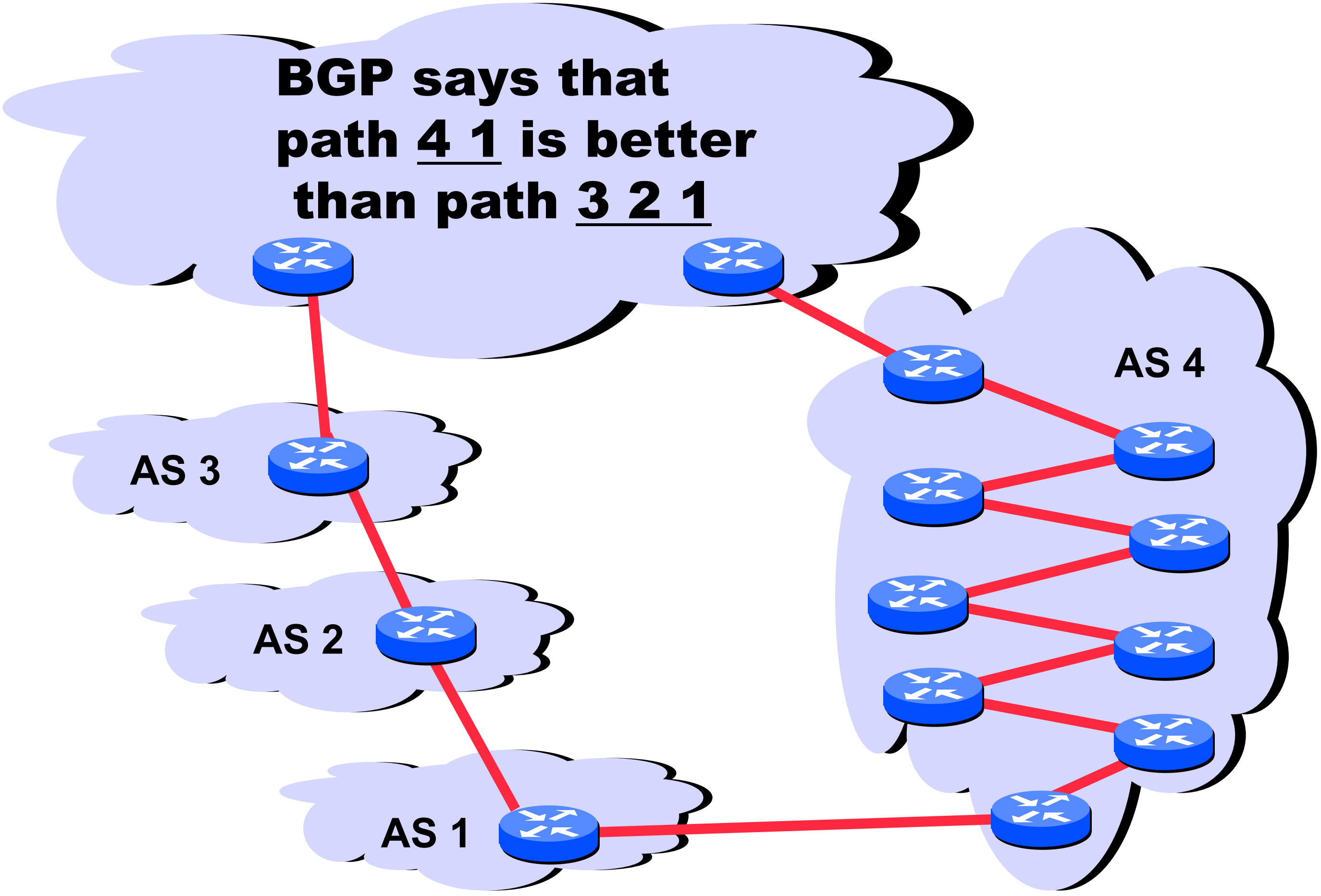
- Why should this trouble us?

Performance Nonissues

- Internal routing (non)
  - Domains typically use “hot potato” routing
  - Not always optimal, but economically expedient
- Policy not about performance (non)
  - So policy-chosen paths aren’t shortest
- AS path length can be misleading (non)
  - 20% of paths inflated by at least 5 router hops

Performance (example)

- AS path length can be misleading
  - An AS may have many router-level hops



BGP says that path 4 1 is better than path 3 2 1

Real Performance Issue: Slow convergence

- BGP outages are biggest source of Internet problems

- Labovitz *et al. SIGCOMM'97*
  - 10% of routes available less than 95% of time
  - Less than 35% of routes available 99.99% of the time

- Labovitz *et al. SIGCOMM 2000*
  - 40% of path outages take 30+ minutes to repair

- But most popular paths are very stable

BGP Misconfigurations

- BGP protocol is both bloated and underspecified
  - lots of attributes
  - lots of leeway in how to set and interpret attributes
  - necessary to allow autonomy, diverse policies
  - but also gives operators plenty of rope

- Much of this configuration is manual and *ad hoc*

- And the core abstraction is fundamentally flawed
  - disjoint per-router configuration to effect AS-wide policy
  - now strong industry interest in changing this! [later: SDN]

BGP: How did we get here?

- BGP was designed for a different time
  - before commercial ISPs and their needs
  - before address aggregation
  - before multi-homing

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- **1989 : BGP-1 [RFC 1105]**
  - **Replacement for EGP (1984, RFC 904)**
- **1990 : BGP-2 [RFC 1163]**
- **1991 : BGP-3 [RFC 1267]**
- **1995 : BGP-4 [RFC 1771]**
  - **Support for Classless Interdomain Routing (CIDR)**

Next Time.

- Wrap up the network layer!
  - the IPv4 header
  - IP routers