# Lecture 16:
# Border Gateway Protocol

CSE 123: Computer Networks

Alex C. Snoeren

Some figures courtesy Mike Freedman

# Lecture 16 Overview

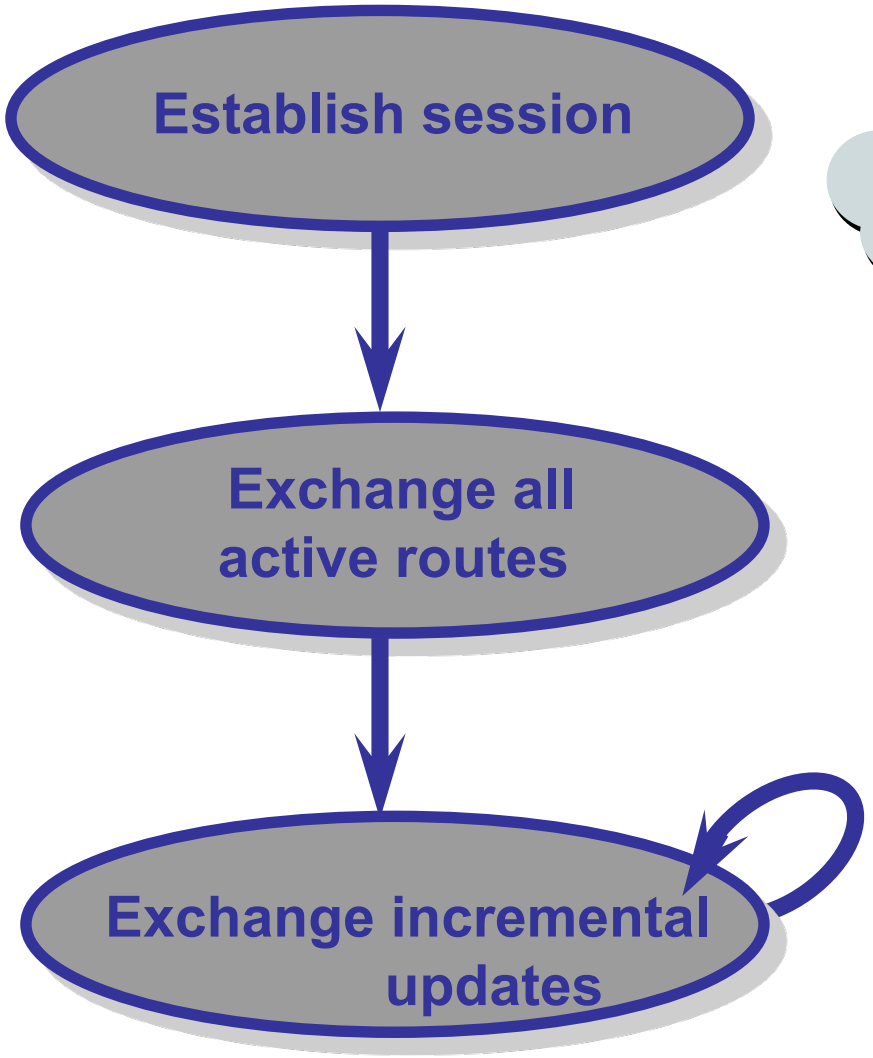
- Border Gateway Protocol (BGP)
  - The canonical path vector protocol
  - How routing gets done on the Internet today
- AS relationships
  - Customer/Provider
  - Multihoming
  - Peer-to-peer
- Internet AS hierarchy

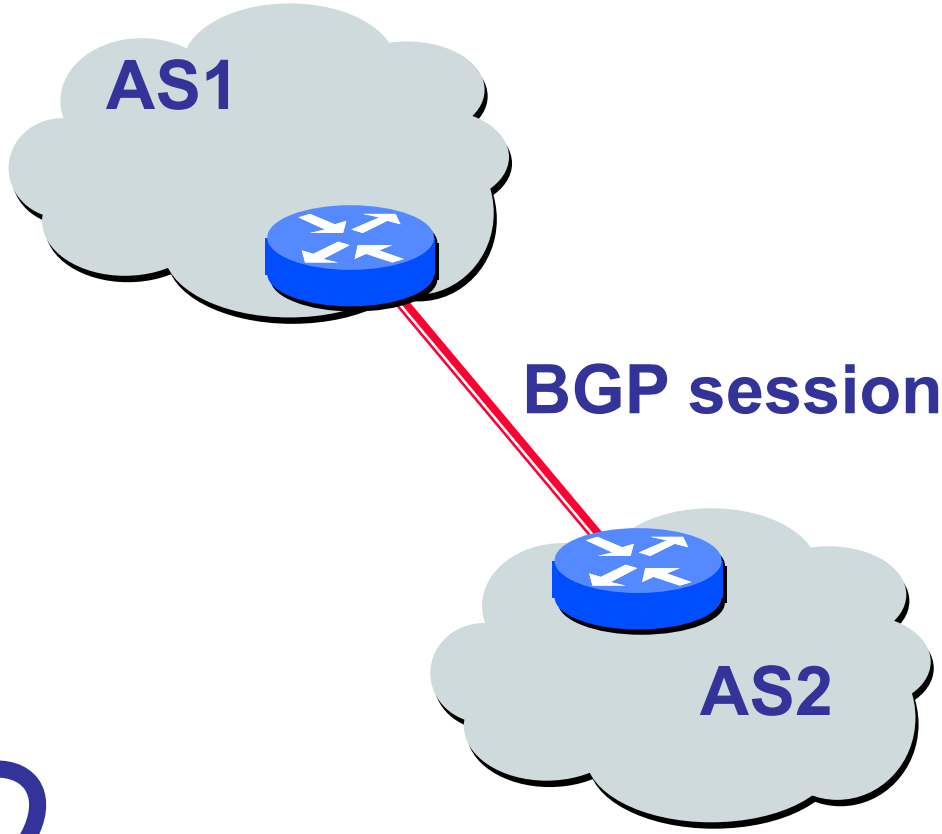
# Border Gateway Protocol

- Interdomain routing protocol for the Internet
  - Prefix-based path-vector protocol
  - Policy-based routing based on AS Paths
  - Evolved during the past 28 years

- **1989 : BGP-1 [RFC 1105], replacement for EGP**
- **1990 : BGP-2 [RFC 1163]**
- **1991 : BGP-3 [RFC 1267]**
- **1995 : BGP-4 [RFC 1771], support for CIDR**
- **2006 : BGP-4 [RFC 4271], update**

# Basic BGP Operation



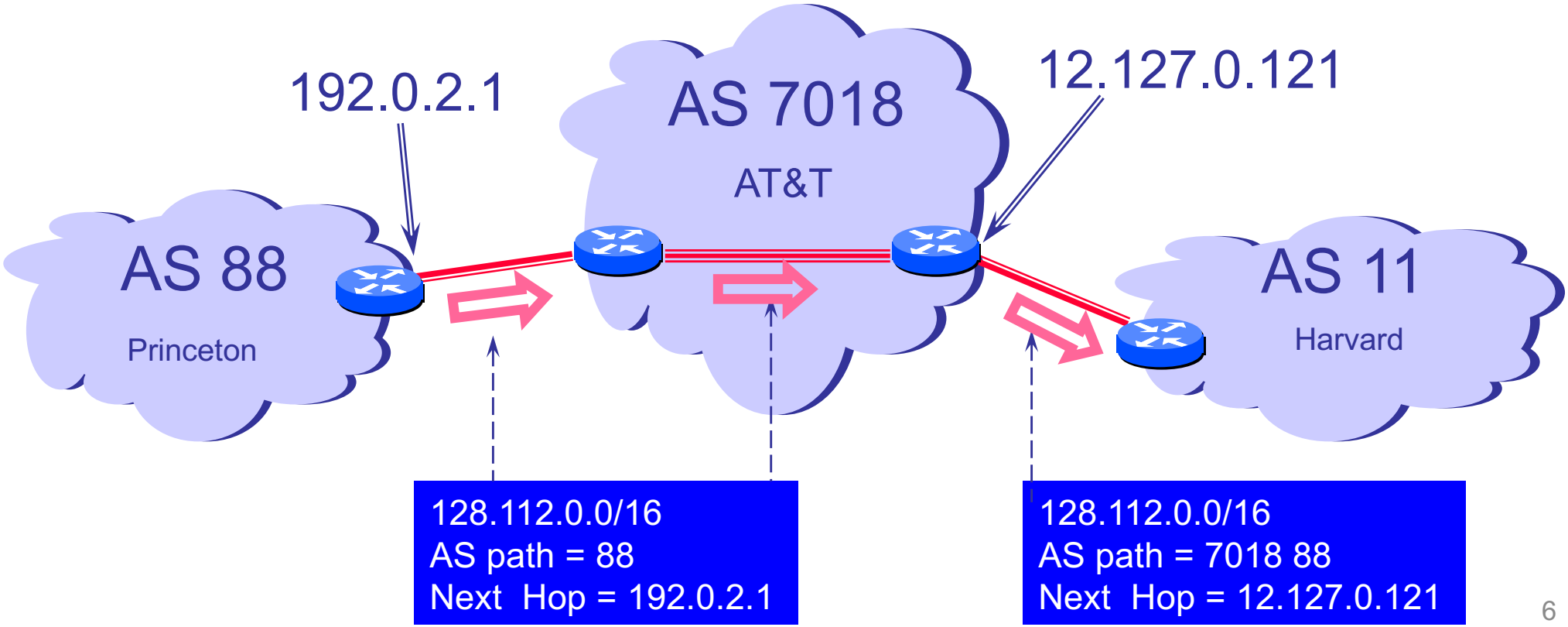

While connection is ALIVE exchange route UPDATE messages

# Step-by-Step

- A node learns multiple paths to destination
  - Stores all of the routes in a routing table
  - Applies policy to select a single active route
  - … and may advertise the route to its neighbors
- Incremental updates
  - Announcement
    - » Upon selecting a new active route, add own node id to path
    - » … and (optionally) advertise to each neighbor
  - Withdrawal
    - » If the active route is no longer available
    - » … send a withdrawal message to the neighbors

# A Simple BGP Route

- Destination prefix (e.g., 128.112.0.0/16)
- Route attributes, including
  - AS path (e.g., "7018 88")
  - Next-hop IP address (e.g., 12.127.0.121)

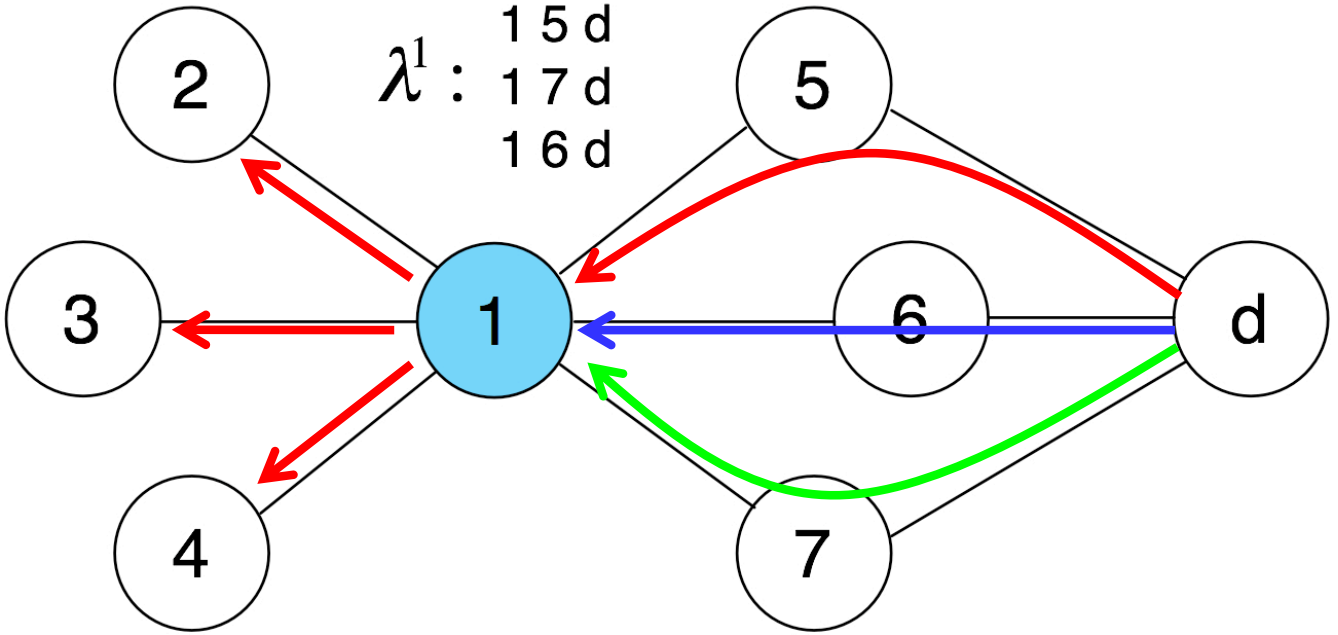


# (some) BGP Attributes

- **AS path:** ASs the announcement traversed
- **Next-hop**: where the route was heard from
- **Origin:** Route came from IGP or EGP
- **Local pref:** Statically configured ranking of routes within AS
- **Multi Exit Discriminator:** preference for where to *exit* network
- **Community:** opaque data used for inter-ISP policy

# Export Active Routes

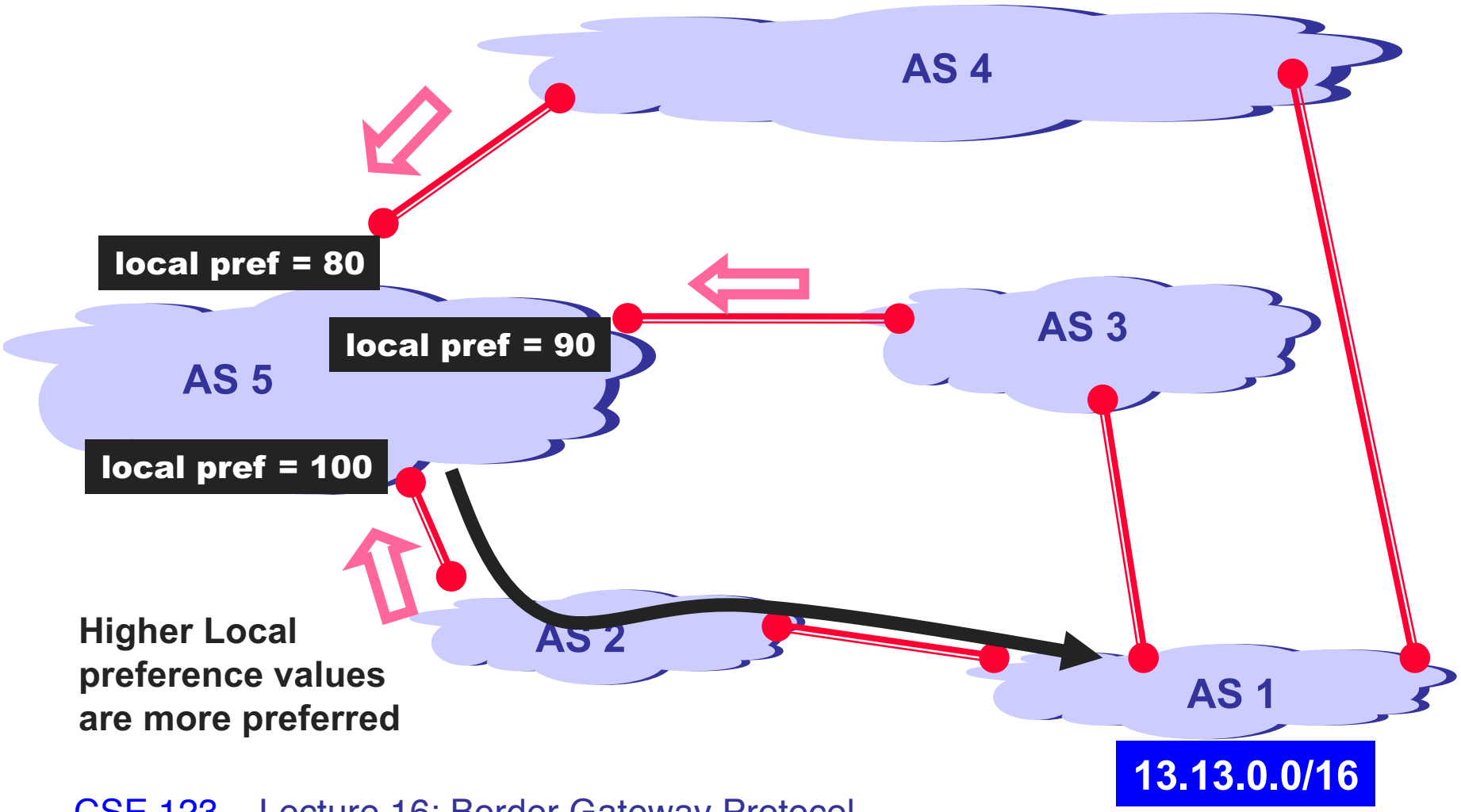
- In conventional path vector routing, a node has one ranking function, which reflects its routing policy



# BGP Decision Process

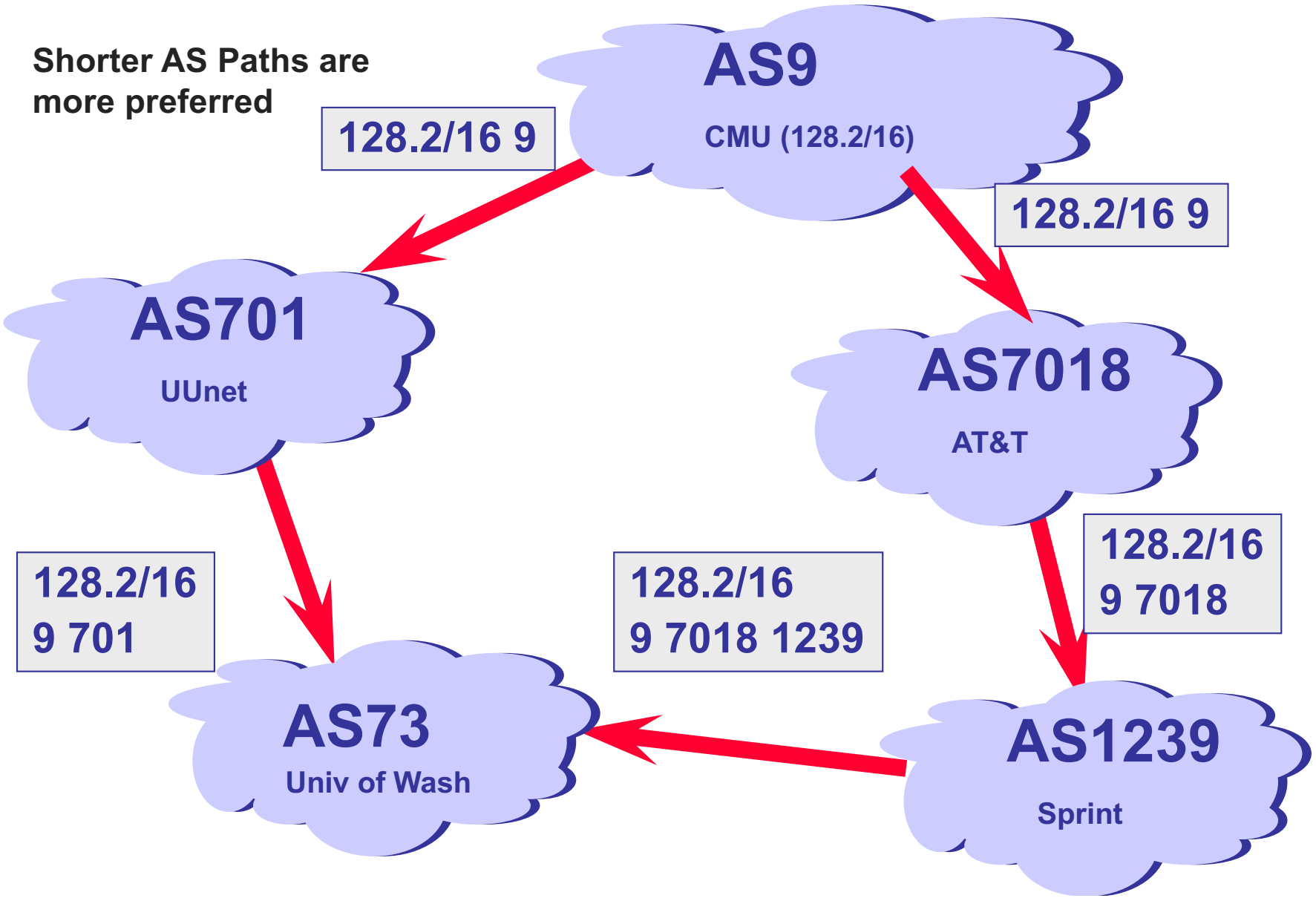
- Default decision for route selection
  - Highest local pref, shortest AS path, lowest MED, prefer eBGP over iBGP, lowest IGP cost, router id
- Many policies built on default decision process, but…
  - Possible to create arbitrary policies in principal
    - » Any criteria: BGP attributes, source address, prime number of bytes in message, …
    - » Can have separate policy for inbound routes, installed routes and outbound routes
  - Limited only by power of vendor-specific routing language

# Example: Local Pref

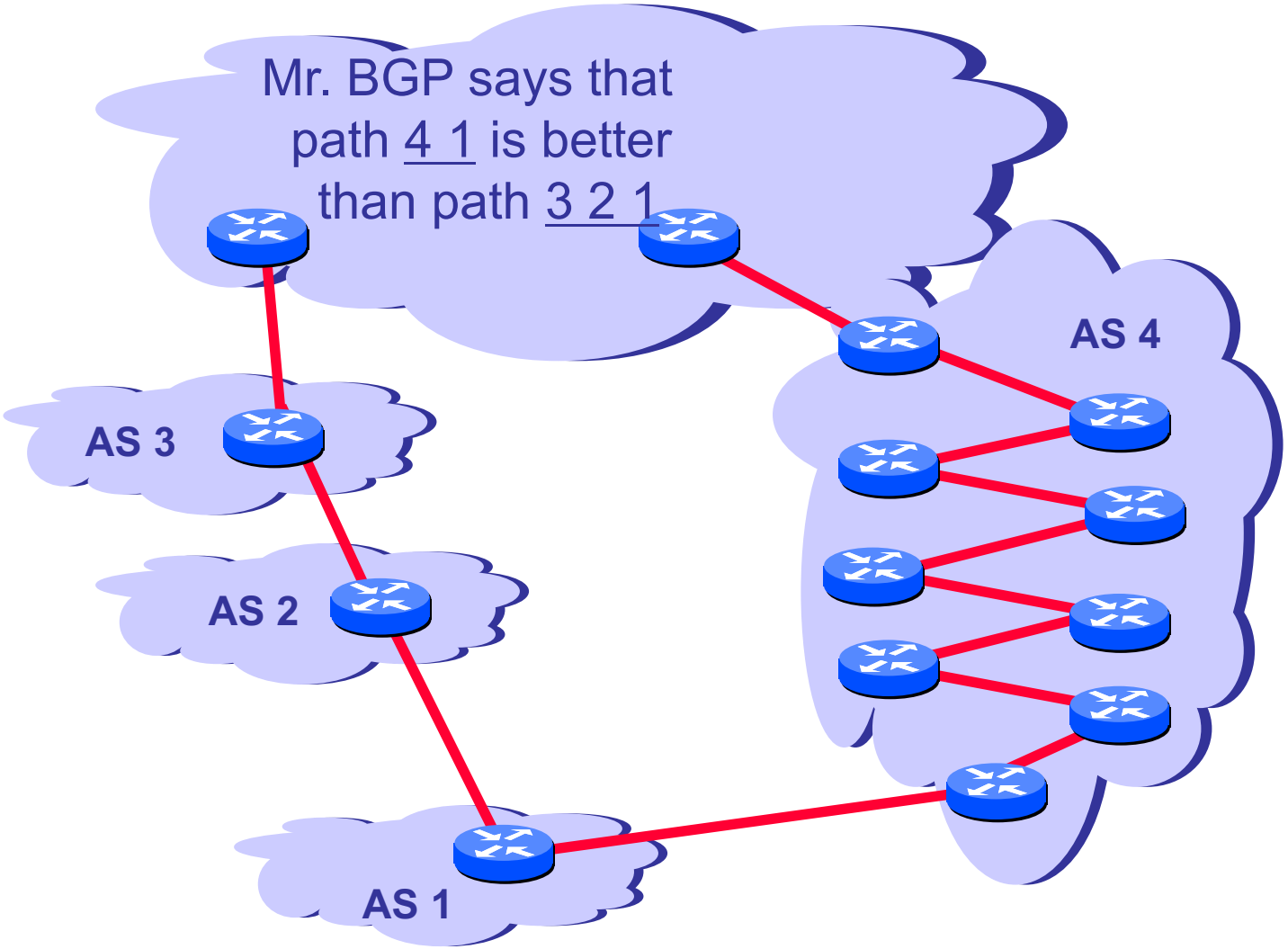



**Higher Local preference values are more preferred**

# Example: Short AS Path



# AS Paths *vs.* Router Paths



# BGP Has Lots of Problems

- Instability
  - Route flapping (network x.y/z goes down… tell everyone)
  - Long AS-path decision criteria defaults to DV-like behavior (bouncing)
  - Not guaranteed to converge, NP-hard to tell if it does
- Scalability still a problem
  - >500,000 network prefixes in default-free table today
  - Tension: Want to manage traffic to very specific networks (eg. multihomed content providers) but also want to aggregate information.
- Performance
  - Non-optimal, doesn't balance load across paths

# A History of Settlement

- The telephone world
  - LECs (local exchange carriers) (e.g., PacBell, NYNEx)
  - IXCs (inter-exchange carriers) (e.g., Sprint, AT&T)
- LECs MUST provide IXCs access to customers
  - This is enforced by laws and regulation
- When a call goes from one phone company to another:
  - Call billed to the caller
  - The money is split up among the phone systems – this is called "settlement"

# Business Relationships

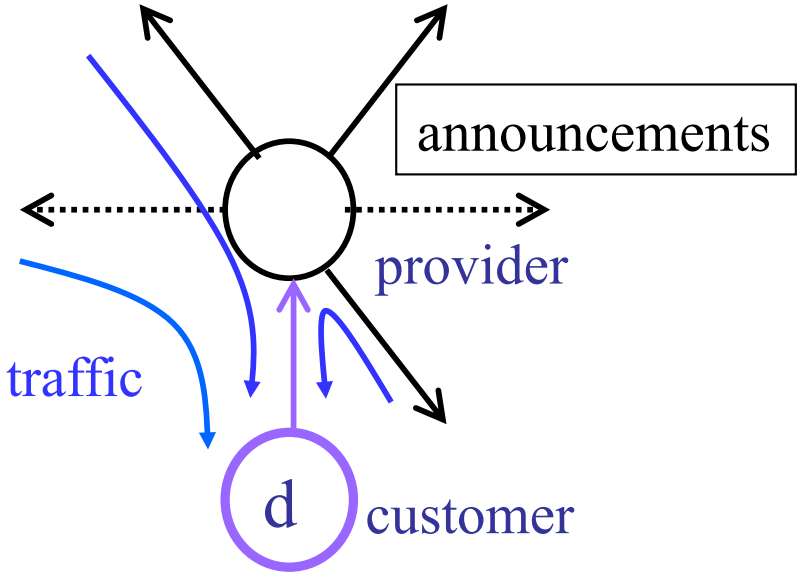
- Neighboring ASes have business contracts
  - How much traffic to carry
  - Which destinations to reach
  - How much money to pay

- Common business relationships
  - Customer-provider
    - » E.g., Princeton is a customer of USLEC
    - » E.g., MIT is a customer of Level3
  - Peer-peer
    - » E.g., UUNET is a peer of Sprint
    - » E.g., Harvard is a peer of Harvard Business School

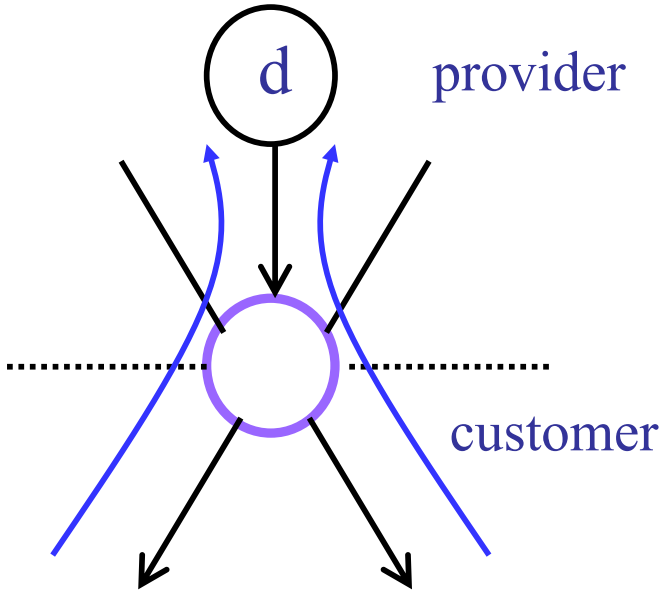
# Customer/Provider

- Customer needs to be reachable from everyone
  - Provider tells all neighbors how to reach the customer
- Customer does not want to provide transit service
  - Customer does not let its providers route through it

Traffic **to** the customer

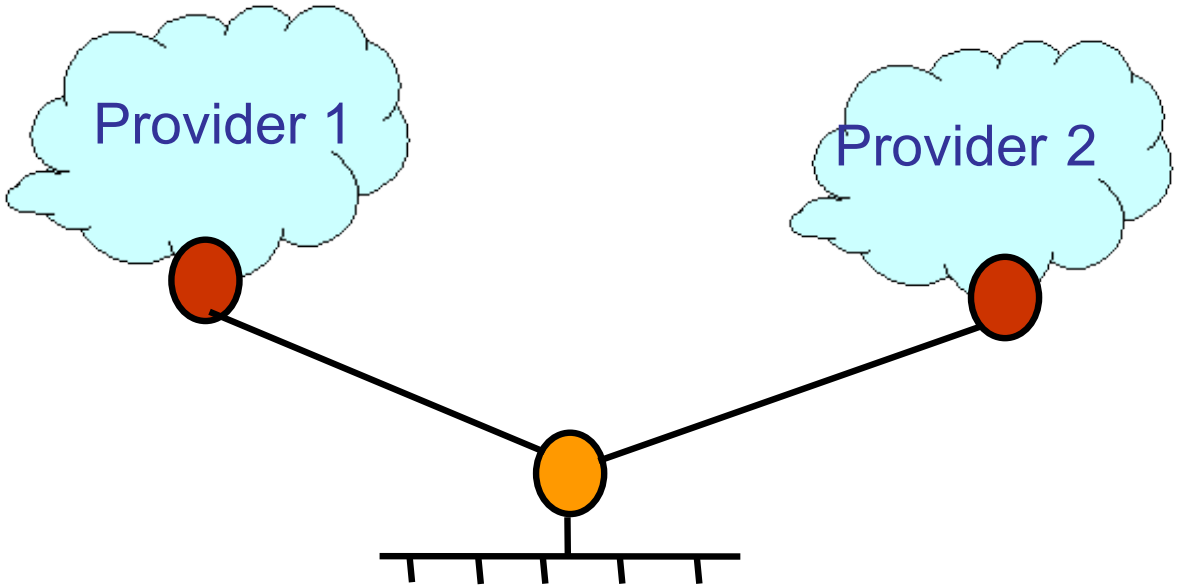



Traffic **from** the customer



# Multi-Homing

- Customers may have more than one provider
  - Extra reliability, survive single ISP failure
  - Financial leverage through competition
  - Better performance by selecting better path
  - Gaming the 95$^{th}$-percentile billing model



# For Next Time

- Read P&D 3.4
- NO CLASS MONDAY!
- Homework 3 due WEDNESAY