COSC 417 Topics in Networking

TOPIC 2: AUTONOMOUS SYSTEMS

SCHEDULE

1. *Autonomous Systems*
    1. *What is an Autonomous System*
    2. *Types of Autonomous System*
2. *Inter-AS Routing*

WHAT IS AN AUTONOMOUS SYSTEM?

- An *autonomous system* is a group of routers under common administrative control
- An autonomous system may be run by a service provider, institution, or company
- Within an AS, one or more IP prefix blocks have a common routing policy for traffic

AN EXAMPLE OF WHAT THIS MEANS

- Hurricane Electric operates an AS under the number 6939
- This AS comprises a number of CIDR IP prefix “blocks”
- Hurricane Electric is the common administrator and policy-setter for these IP ranges

As Number	As Name	CIDR Range
6939	Hurricane Electric LLC	5.152.177.0/24
6939	Hurricane Electric LLC	5.152.179.0/24
6939	Hurricane Electric LLC	5.152.181.0/24
6939	Hurricane Electric LLC	5.152.182.0/23
6939	Hurricane Electric LLC	12.177.5.0/24
6939	Hurricane Electric LLC	12.192.16.0/23
6939	Hurricane Electric LLC	23.142.192.0/24

AS NUMBERS

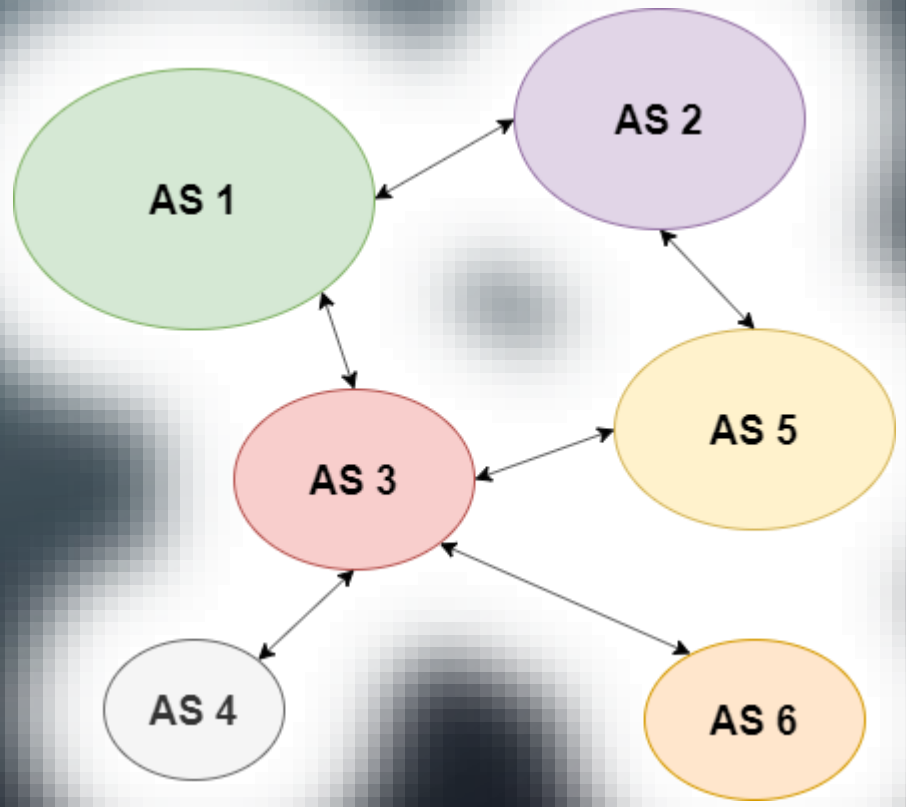
- Autonomous Systems are uniquely identified by their *Autonomous System Number* or *ASN*
- Regional registries assign ASNs as needed (fees apply)
- In the previous example, Hurricane Electric is uniquely identified as ASN 6939
- This is important, as the unique ASN is used as part of the routing protocol that connects ASNs

HOW AUTONOMOUS SYSTEMS SHAPE THE NET

- Autonomous Systems range in size from vast, *tier 1* networks to small *stub* networks that serve individual customers
- Through internal and external routing protocols, it is possible to route data from one autonomous system to another – this is what underpins the World Wide Web

ROUTING BETWEEN AUTONOMOUS SYSTEMS

- Traffic from a machine in AS 1 needs to be delivered to a machine in AS 5 – What routes are possible?

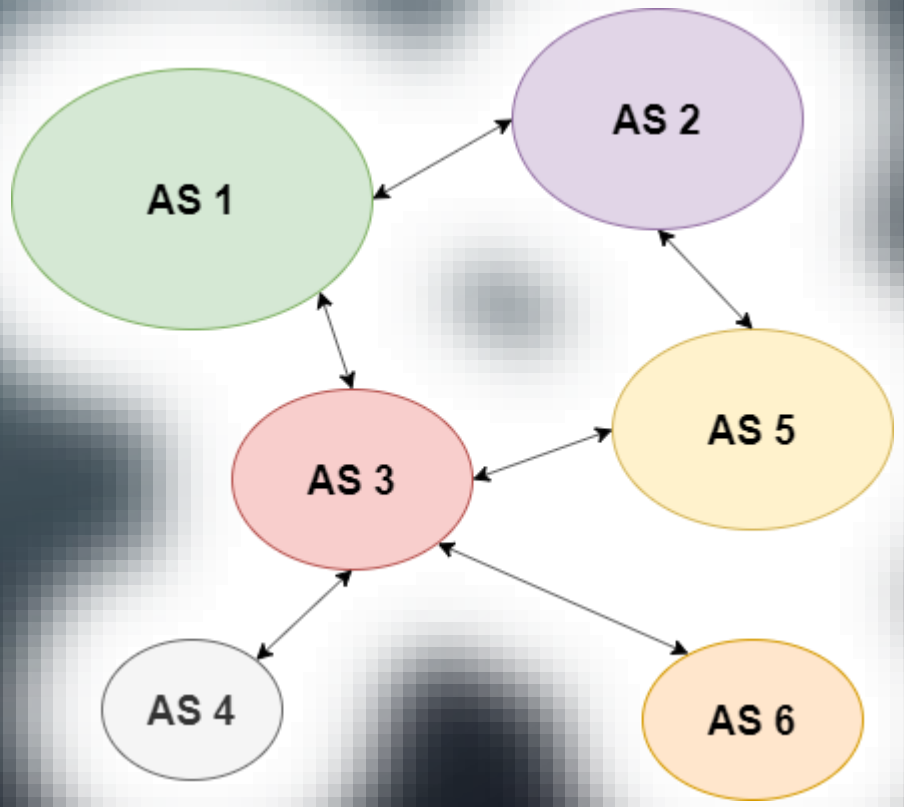


ROUTING BETWEEN AUTONOMOUS SYSTEMS

AS 1 → AS 2 → AS 5

AS 1 → AS 3 → AS 5

- The route chosen will depend on many factors, including routing policy and network conditions



CONNECTIONS BETWEEN AUTONOMOUS SYSTEMS

- Autonomous systems can be connected in several ways
- *Peer* relationships and *Transit* relationships between Autonomous Systems
- *Stub* versus *Transit* systems
- *Multi-home* vs *Single-home* stubs

PEER AND TRANSIT RELATIONSHIPS

- A peered relationship between Autonomous Systems means that traffic can be exchanged without cost
- A transit relationship between Autonomous Systems is used to describe when one system sells access to another system at a price (an ISP)

HOW COST AFFECTS ROUTING

AS 1 → AS 2 → AS 5

AS 1 → AS 3 → AS 5

- Consider the routes from before: if AS 1 has a peering relationship with AS 3 and a transit relationship with AS 2, which route do you think it would prefer?

HOW COST AFFECTS ROUTING

AS 1 → AS 2 → AS 5

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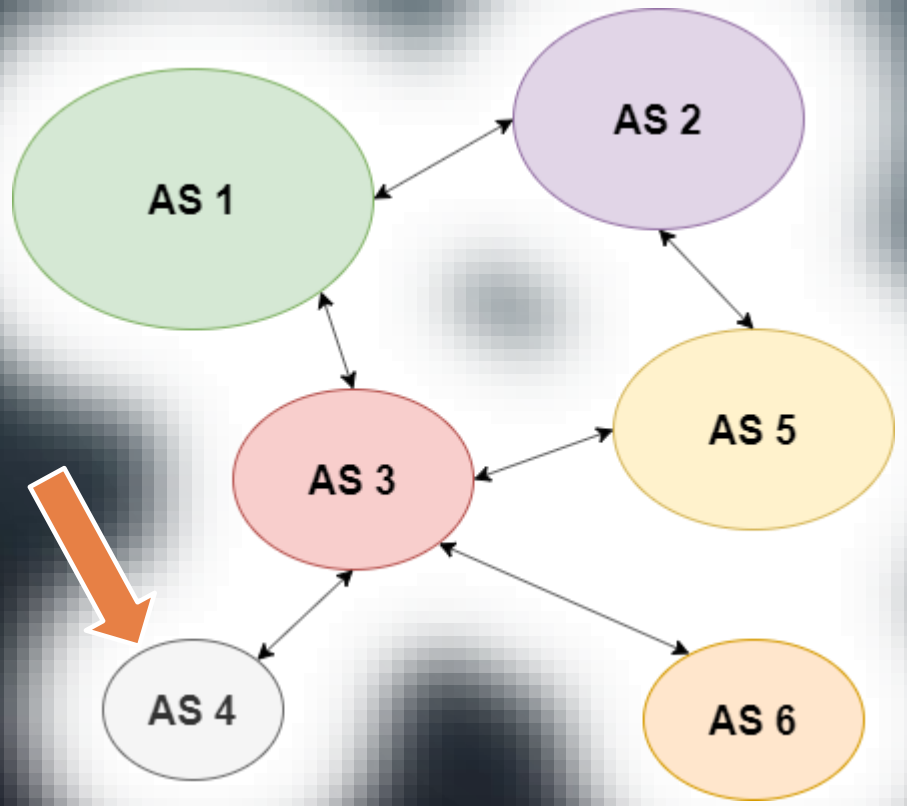
- Consider the routes from before: if AS 1 has a peering relationship with AS 3 and a transit relationship with AS 2, which route do you think it would prefer?

HOW COST AFFECTS ROUTING

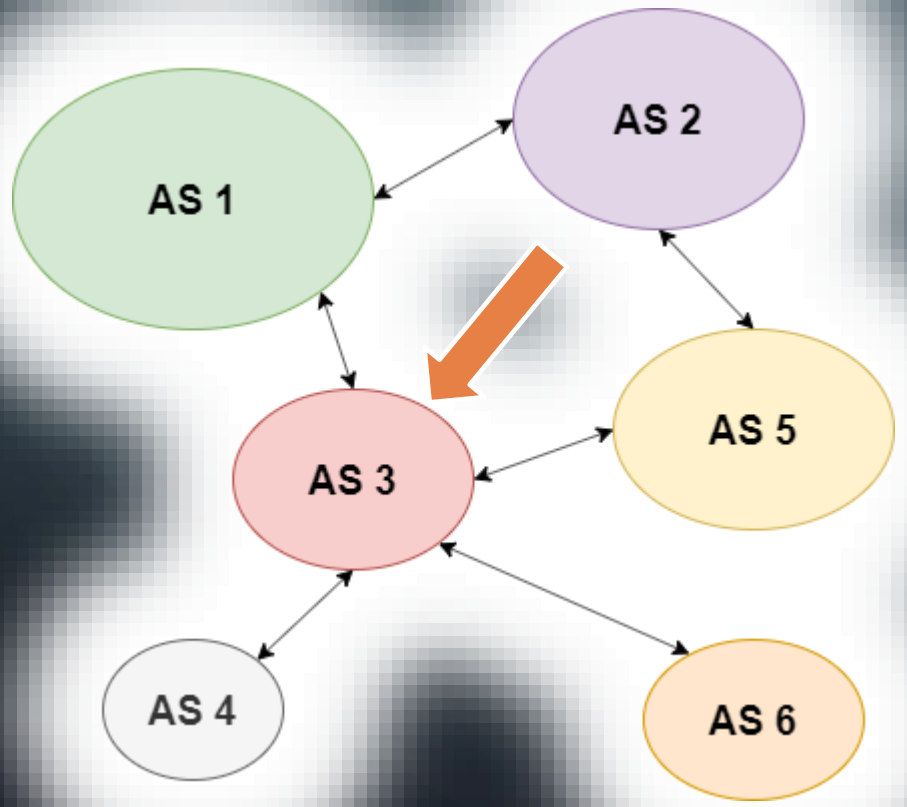
- Cost plays a part in determining the routing policy of an Autonomous System
- Get as many peer relationships to large Autonomous Systems as possible
- Use routing policy to discourage routing on more expensive transit links → use peering links instead

STUB AND TRANSIT AUTONOMOUS SYSTEMS



- A stub is an autonomous system connected to only one other autonomous system
- For example – a small ISP that buys access from another ISP

STUB AND TRANSIT AUTONOMOUS SYSTEMS



- A transit AS is an AS that offers a connection from one system to another
- For example, AS 3 could offer linkages to AS 1, 5, 4, and 6

NETWORK TIERS

- We can use these properties to roughly group networks into tiers
- Tier 1 networks are all peered to each other, and offer transit services to smaller Tier 2 networks
- Tier 2 networks in turn may offer transit and peering between each other, as well as to Tier 3 networks
- Tier 3 networks are usually stubs such as end users or small ISPs

THE TIER 1 NETWORKS

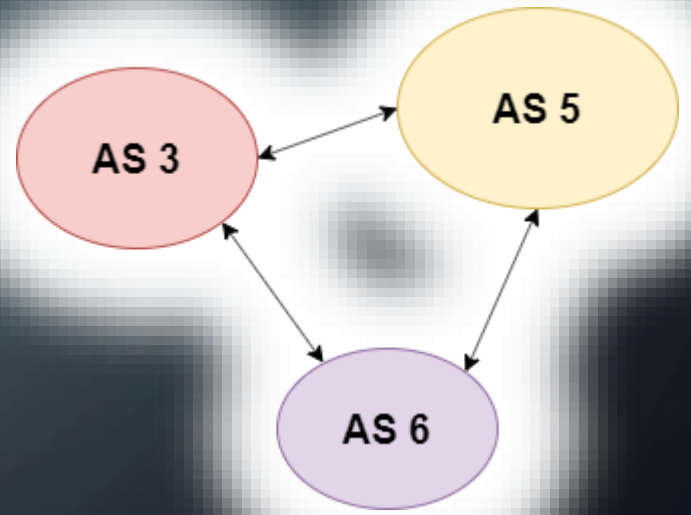
- A tier one network, by virtue of peering relationships and vast size, can reach ~100% of the network without paying anything
- Tier 1 networks include AT&T, Sprint, Verizon, CenturyLink, Tata Communications
- Hurricane Electric – not quite, but close (missing some routes to major T1 providers)

SINGLE HOME AND MULTI HOME ROUTING

- Stubs (Tier 3 networks) may be multi-homed or single-homed
- A single-homed stub connects to only one AS
- A multi-homed stub connects to more than one AS
- However, since it's a stub, it doesn't allow traffic to transit through between the connected AS's

SINGLE HOME AND MULTI HOME ROUTING

- If AS 6 was a multi-homed stub, this means that it can send/receive traffic through AS 3 and AS 5
- However, AS 3 could not route traffic to AS 5 *via AS 6*



WHAT IS MULTI-HOME FOR?

- The major purpose of multi-home routing is to increase reliability
- If one AS becomes unavailable for some reason (interruption in linkage, router failure, etc), the other can be used to route traffic instead
- Helps avoid singular failure points (as long as the linked AS's aren't in turn linked to a singular parent)

WHAT DOES THIS ALL MEAN?

- We should think of our network traffic as hopping from autonomous system to autonomous system
- Stubs, transit networks, and transit/peering links all shape how traffic actually moves through our network

INTER-AS ROUTING (BGP)

INTER-AS ROUTING

- When routing between two Autonomous Systems, a *Border Gateway Protocol (BGP)* is used
- BGP allows the exchange of routing information between autonomous systems and is used to decide what routes will be used

BGP CORE CONCEPTS

- BGP is used to route *between* Autonomous Systems
- BGP is used to define *paths* from one AS to another
- BGP allows policy to be applied that changes how routes may be chosen

THE BGP PROTOCOL

- Current version is BGP4, original BGP specifications published in 1989
- BGP information is sent via TCP (Transmission control protocol) via port 179
- Each router sends out updates of currently available routes

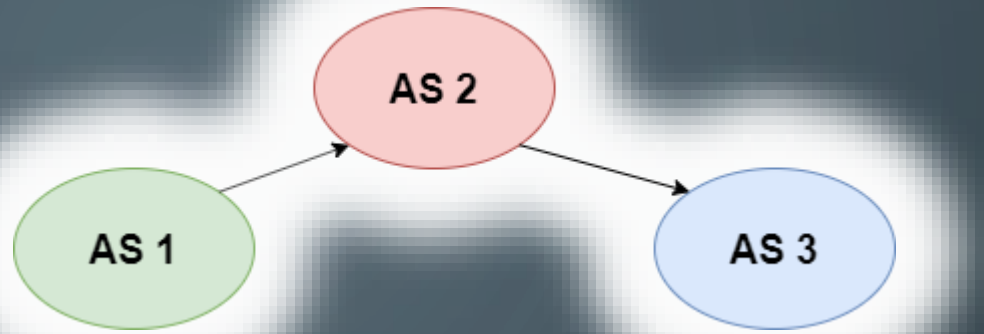
ADVERTISING ROUTES

- In BGP, a gateway router (a router at the edge of the autonomous system) will advertise which autonomous systems can be reached
- For example, they may advertise themselves (their own AS), as well as another AS that they are connected to and can be reached by transit

THE AS-PATH

- The AS-PATH is used to described a given path from one AS to another
- As an AS re-advertises routes it has received, it adds it's own AS to the AS-PATH variable
- The AS-PATH variable then identifies each AS that will be transited through for the route

AN EXAMPLE



- AS 1 advertises itself to AS 2 → ASPATH: 1
- AS 2 advertises itself to AS 3, and re-advertises AS 1 with an appended ASPATH → ASPATH: 1 2
- AS 3 now has two routes: one to AS 1, and one to AS 2

IN REAL LIFE

Network	Next Hop	Metric	LocPrf	Weight	Path
128.138.0.0/16	206.51.46.23	285	100	0	14041, 104

- This is a route from a Hurricane Electric router to an NIST time server at the University of Colorado
- The Next Hop is the next IP address in transit – which is outside the Hurricane Electric AS
- The Path contains two more Autonomous systems: 14041, and 104

IN REAL LIFE

Network	Next Hop	Metric	LocPrf	Weight	Path
128.138.0.0/16	206.51.46.23	285	100	0	14041, 104

- 206.51.46.23 is an IP in the 14041 AS, registered to the University Corporation for Atmospheric Research → Provider of ISP services to universities
- After transiting 14041, it would enter AS 104 – registered to the University of Boulder, Colorado.

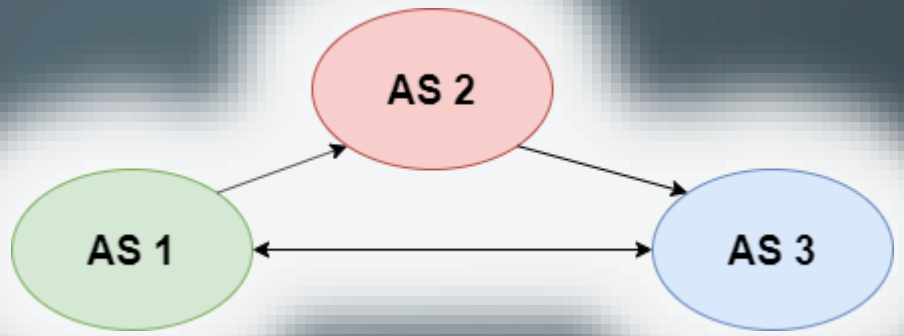
WHY IS THIS INTERESTING?

- Using routing table data, we can actually see how traffic will be routed and the organizational units it flows through (from big providers to smaller stub providers)
- We can also use this information to determine what underlying routing policies exist

THE REAL PURPOSE OF THE AS-PATH

- The AS-Path isn't really meant for navigation – that's what the next-hop is for
- The AS-Path is actually to prevent loops in the routing algorithm
- Consider: if you have three conjoined systems, and they keep re-advertising each other, how do we avoid having looping routes?

ROUTE LOOPING



- What if we end up with a route like this?

  AS 1 → AS 2 → AS 3 → AS 1 → AS 2 → AS 3…

- Routes won't be re-advertised if they already contain the current AS in the AS-Path (no duplicate ASNs allowed in the AS-Path)

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SO LONG, FOLKS!