CS 181AG
Lecture 5

Routing Protocols: Distance Vector

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Assignment Reading

- Should the internet be treated and regulated as a public utility?

Recap

- Last time: Intro to Routing Layer
  - IP Addresses
  - Role of Routers
    - Choose which next hop to send packets to and store in FIB
    - Look up FIB and send packets
  - Routing Game

Routing Protocol Categories

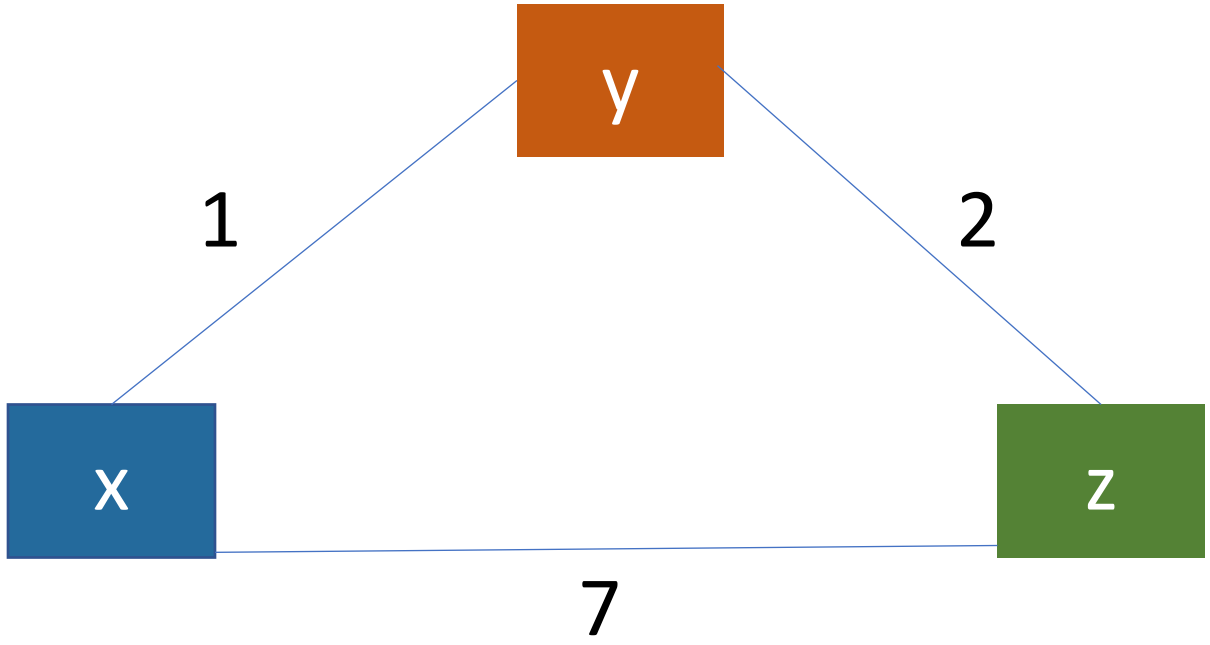
- Link State: everyone keeps full topology
- Distance Vector: today’s topic!

Today’s Goals

- Distance-Vector Routing Protocol
- Interdomain Routing
- Intro to Border Gateway Protocol

Bellman-Ford Algorithm

- Define distances at each node
  - $d_x(y)$ = least cost path from x to y
  - $c_x(y)$ = cost of direct link from x to y
- $d_x(y) = \min(c_x(v) + d_v(y))$ for all x's neighbors v



Distance Vector Routing Protocol

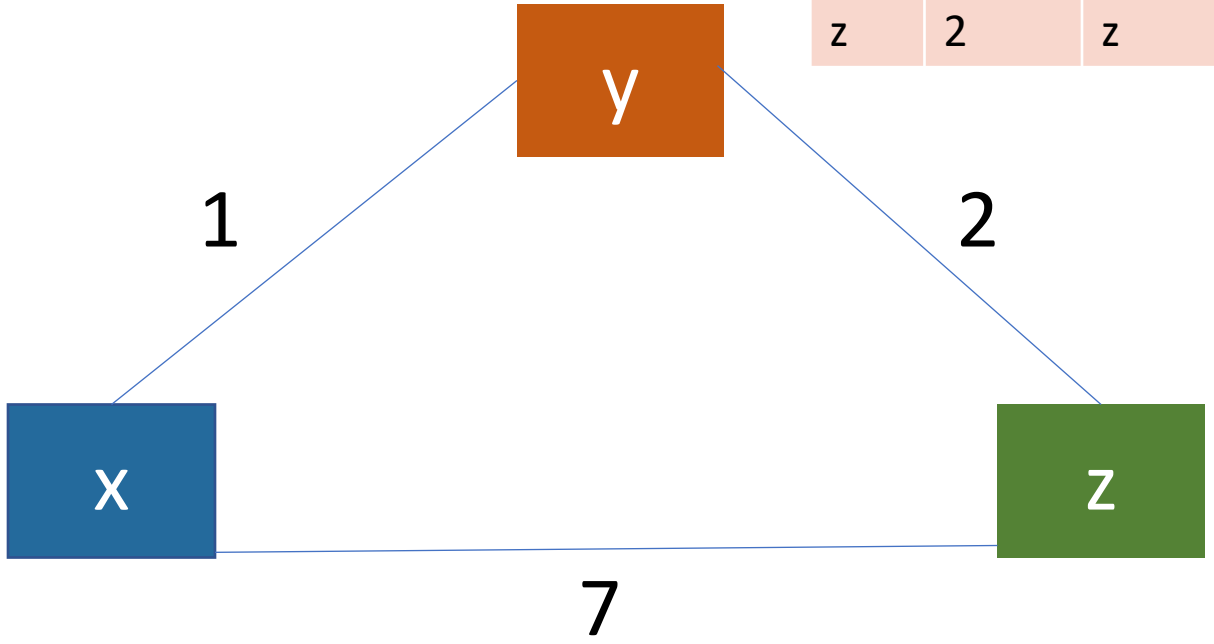
- Each node maintains the cost and next hop for each node
- Each node periodically sends dst and cost to neighbors
- Neighbors update their own DV tables
- Over time, distance vectors converge

Dst	Cost	Next hop
x	0	-
y		
z		

Round 1

- When protocol starts, each node only knows about its neighbors

Dst	Cost	Next hop
x	1	x
y	0	-
z	2	z



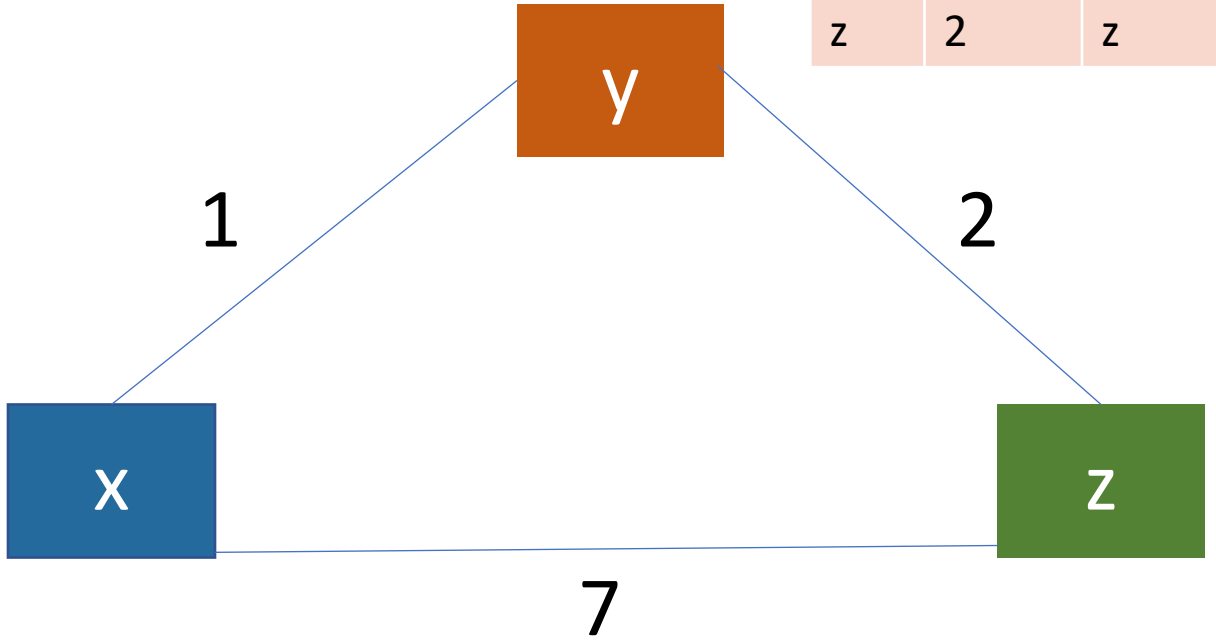
Dst	Cost	Next hop
x	0	-
y	1	y
z	7	z

Dst	Cost	Next hop
x	7	x
y	2	y
z	0	-

Round 2

- Each subsequent round would be the same without any links changing

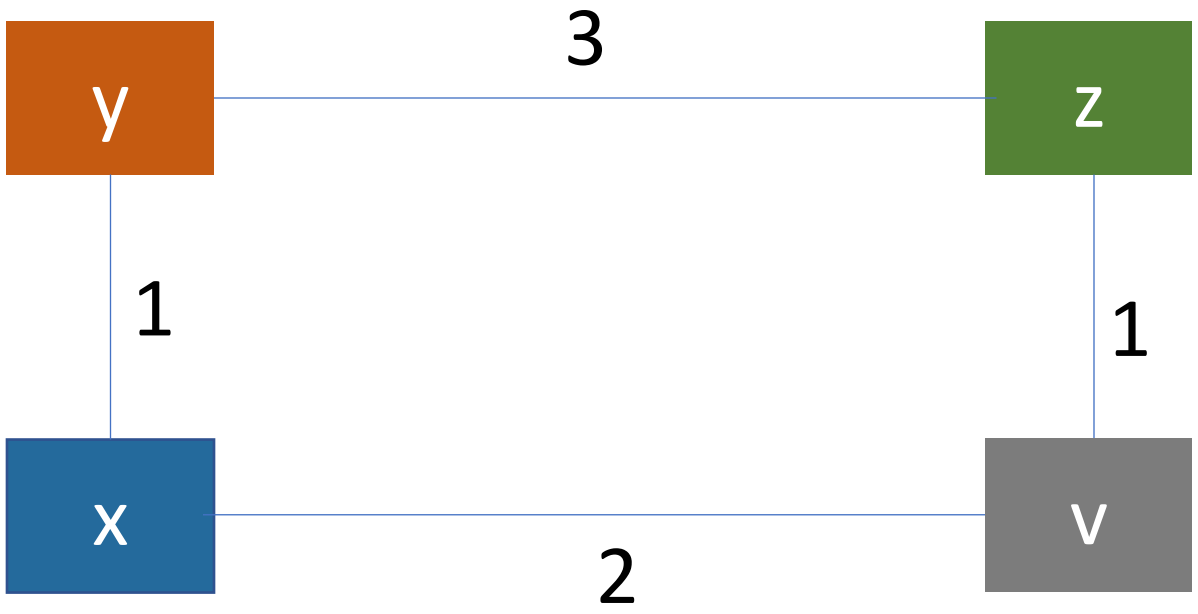
Dst	Cost	Next hop
x	1	x
y	0	-
z	2	z



Dst	Cost	Next hop
x	0	-
y	1	y
z	3	y

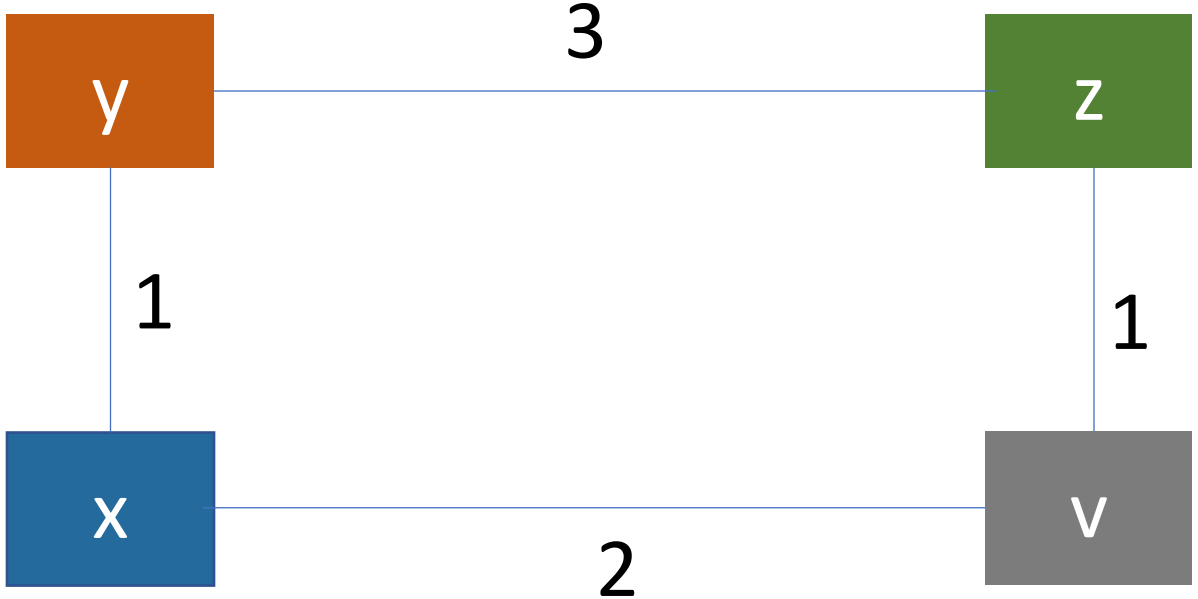
Dst	Cost	Next hop
x	3	y
y	2	y
z	0	-

A 4-node Example



Round 1

Dst	Cost	Next hop
x	1	x
y	0	-
z	3	z
v	∞	-



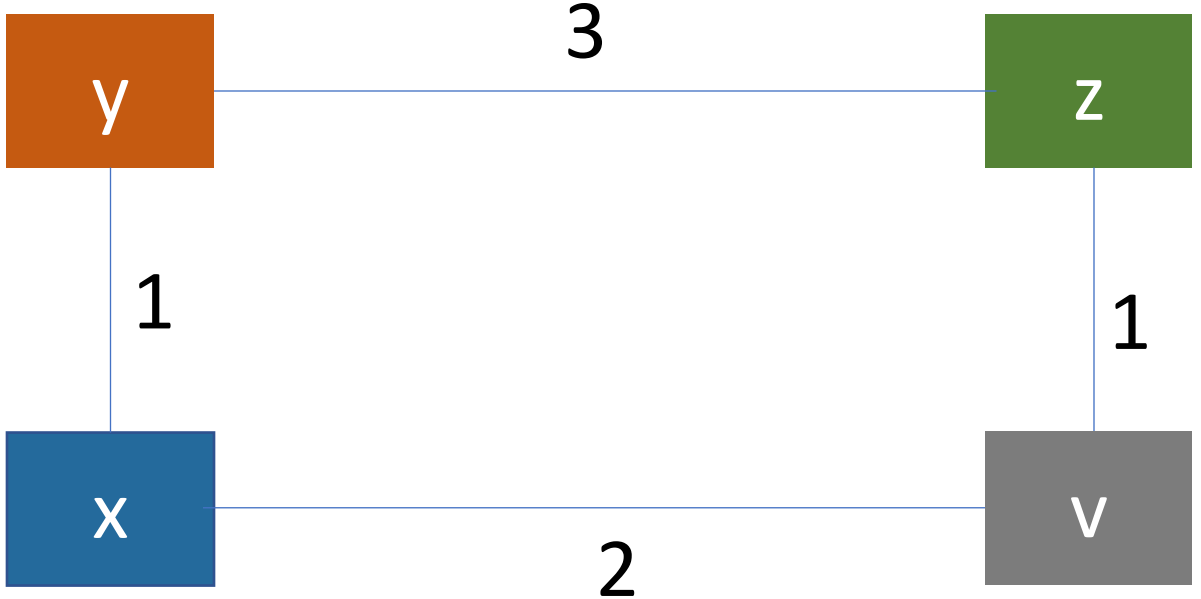
Dst	Cost	Next hop
x	∞	-
y	3	y
z	0	-
v	1	v

Dst	Cost	Next hop
x	0	-
y	1	y
z	∞	-
v	2	v

Dst	Cost	Next hop
x	2	x
y	∞	-
z	1	z
v	0	-

Round 2

Dst	Cost	Next hop
x		
y		
z		
v		



Dst	Cost	Next hop
x		
y		
z		
v		

Dst	Cost	Next hop
x		
y		
z		
v		

Dst	Cost	Next hop
x		
y		
z		
v		

Link Cost Changes

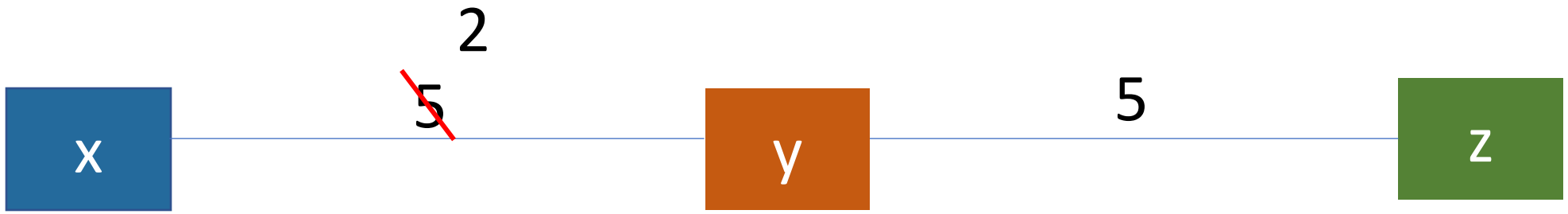
Dst	Cost	Next hop
x	0	-
y	5	y
z	10	y

Dst	Cost	Next hop
x	5	x
y	0	-
z	5	z

Dst	Cost	Next hop
x	10	y
y	5	y
z	0	-

Link Cost Changes

- It's hard to reason about exactly how messages will converge because timing of messages matters
- Good news travels fast!



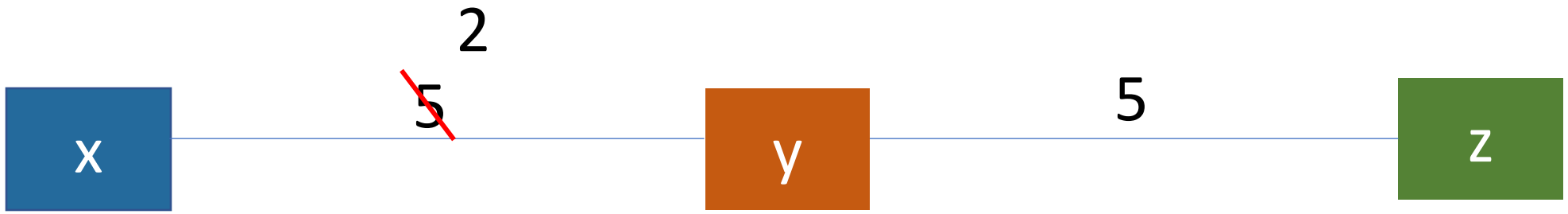
Dst	Cost	Next hop
x	0	-
y	2	y
z	10	y

Dst	Cost	Next hop
x	2	x
y	0	-
z	5	z

Dst	Cost	Next hop
x	10	y
y	5	y
z	0	-

Link Cost Changes

- It's hard to reason about exactly how messages will converge because timing of messages matters
- Good news travels fast!



Dst	Cost	Next hop
x	0	-
y	2	y
z	7	y

Dst	Cost	Next hop
x	2	x
y	0	-
z	5	z

Dst	Cost	Next hop
x	7	y
y	5	y
z	0	-

Link Cost Changes

Dst	Cost	Next hop
x	0	-
y	5	y
z	10	y

Dst	Cost	Next hop
x	5	x
y	0	-
z	5	z

Dst	Cost	Next hop
x	10	y
y	5	y
z	0	-

Link Cost Changes

Dst	Cost	Next hop
x	0	-
y	5	y
z	10	y

Dst	Cost	Next hop
x	5	x
y	0	-
z	5	z

Dst	Cost	Next hop
x	10	y
y	5	y
z	0	-

Link Cost Changes

- If y receives a message from z before sending, it updates based on z's message

Dst	Cost	Next hop
x	0	-
y	5	y
z	10	y

Dst	Cost	Next hop
x	15	z
y	0	-
z	5	z

Dst	Cost	Next hop
x	10	y
y	5	y
z	0	-

Link Cost Changes

- Then z updates based on y's message

Dst	Cost	Next hop
x	0	-
y	5	y
z	10	y

Dst	Cost	Next hop
x	15	z
y	0	-
z	5	z

Dst	Cost	Next hop
x	20	y
y	5	y
z	0	-

Link Cost Changes

- y updates again based on z's message…
- Count-to-Infinity Problem

Dst	Cost	Next hop
x	0	-
y	5	y
z	10	y

Dst	Cost	Next hop
x	20	z
y	0	-
z	5	z

Dst	Cost	Next hop
x	20	y
y	5	y
z	0	-

Solutions

- Poison Reverse: Advertise infinity to anyone whose path you will take

Dst	Cost	Next hop
x	0	-
y	5	y
z	10	y

Dst	Cost	Next hop
x	5	x
y	0	-
z	5	z

Dst	Cost	Next hop
x	10	y
y	5	y
z	0	-

Solutions

- Advertise infinity to anyone whose path you will take

Dst	Cost	Next hop
x	0	-
y	∞	-
z	∞	-

Dst	Cost	Next hop
x	0	-
y	5	y
z	10	y

Dst	Cost	Next hop
x	5	x
y	0	-
z	5	z

Dst	Cost	Next hop
x	10	y
y	5	y
z	0	-

Solutions

- Advertise infinity to anyone whose path you will take

Dst	Cost	Next hop
x	∞	-
y	0	-
z	5	z

Dst	Cost	Next hop
x	0	-
y	5	y
z	10	y

Dst	Cost	Next hop
x	5	x
y	0	-
z	5	z

Dst	Cost	Next hop
x	10	y
y	5	y
z	0	-

Solutions

- Advertise infinity to anyone whose path you will take

Dst	Cost	Next hop
x	5	x
y	0	-
z	∞	-

Dst	Cost	Next hop
x	0	-
y	5	y
z	10	y

Dst	Cost	Next hop
x	5	x
y	0	-
z	5	z

Dst	Cost	Next hop
x	10	y
y	5	y
z	0	-

Solutions

- Advertise infinity to anyone whose path you will take

Dst	Cost	Next hop
x	∞	-
y	∞	-
z	0	-

Dst	Cost	Next hop
x	0	-
y	5	y
z	10	y

Dst	Cost	Next hop
x	5	x
y	0	-
z	5	z

Dst	Cost	Next hop
x	10	y
y	5	y
z	0	-

Solutions

- Does poison reverse solve the problem?

Dst	Cost	Next hop
x	0	-
y	5	y
z	10	y

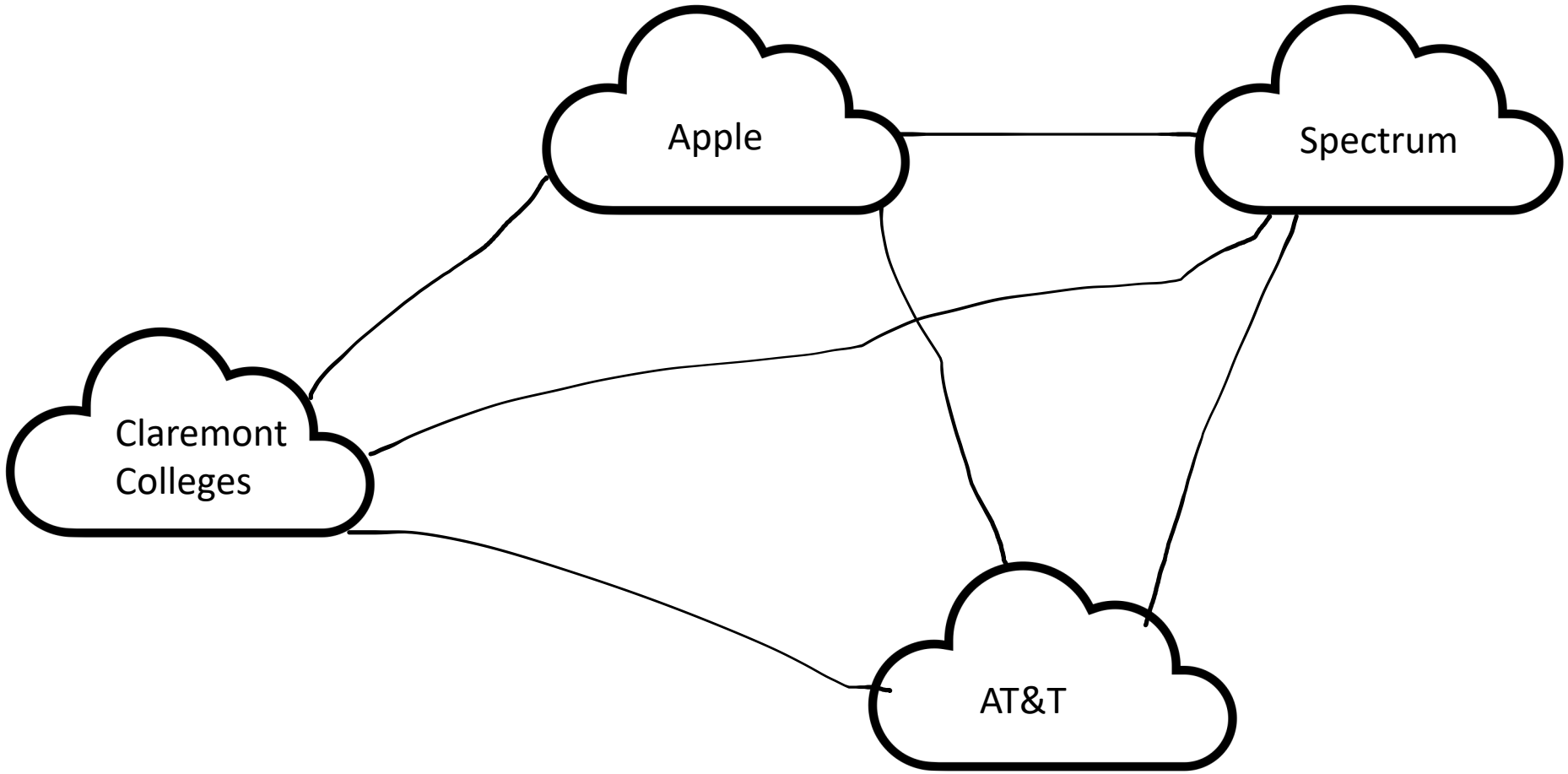
Dst	Cost	Next hop
x	5	x
y	0	-
z	5	z

Dst	Cost	Next hop
x	10	y
y	5	y
z	0	-

Solutions

- Keep whole path instead of next hop
- If you see yourself in path, don’t consider it
- Path vector protocol -> BGP

Autonomous Systems



Autonomous System

whois -h whois.arin.net as3659

ASNumber: 3659

ASName: CLAREMONT

ASHandle: AS3659

RegDate: 1994-06-08

Updated: 2012-04-02

Ref: https://rdap.arin.net/registry/autnum/3659

OrgName: Claremont University Consortium

OrgId: CLAREM-Z

Address: 101 S Mills Ave

City: Claremont

StateProv: CA

PostalCode: 91711

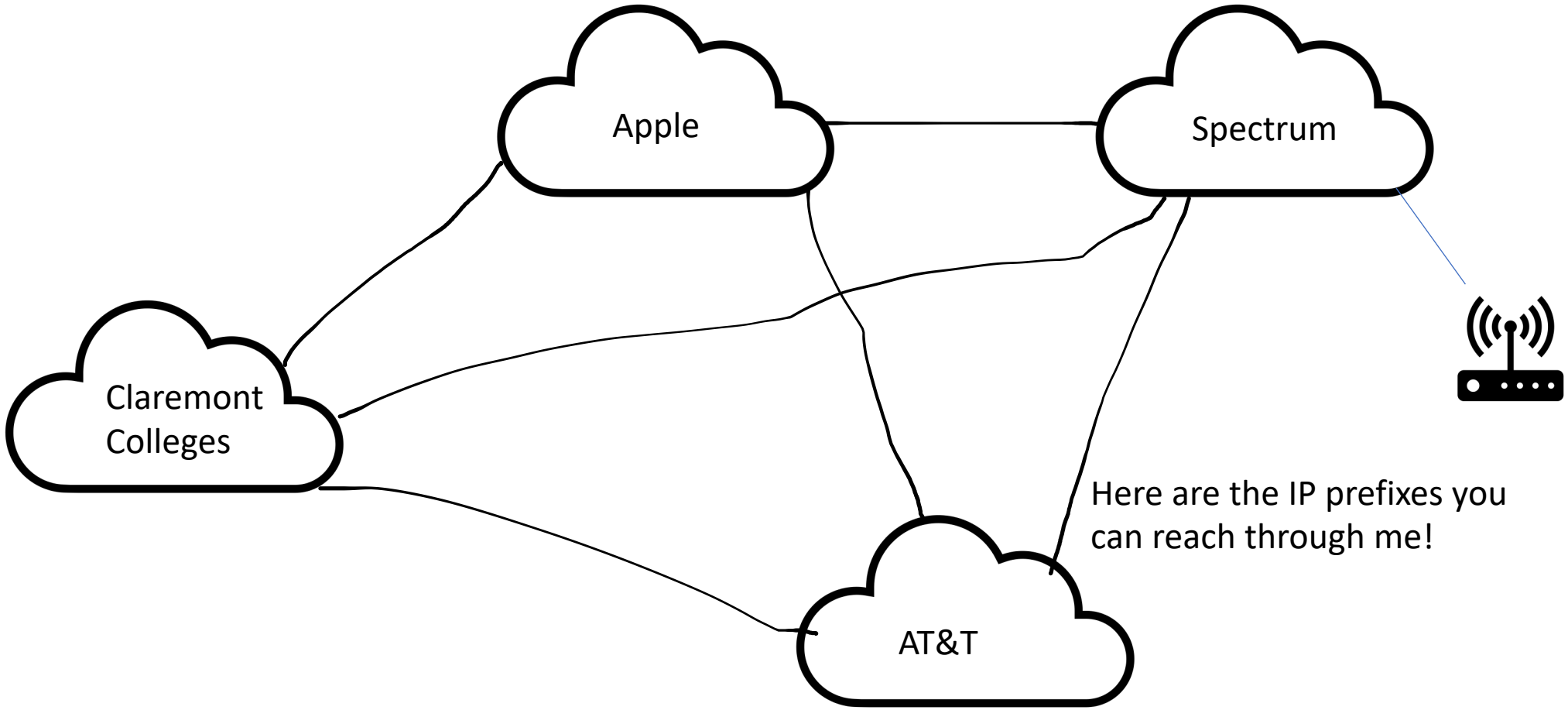
Country: US

RegDate: 2010-06-04

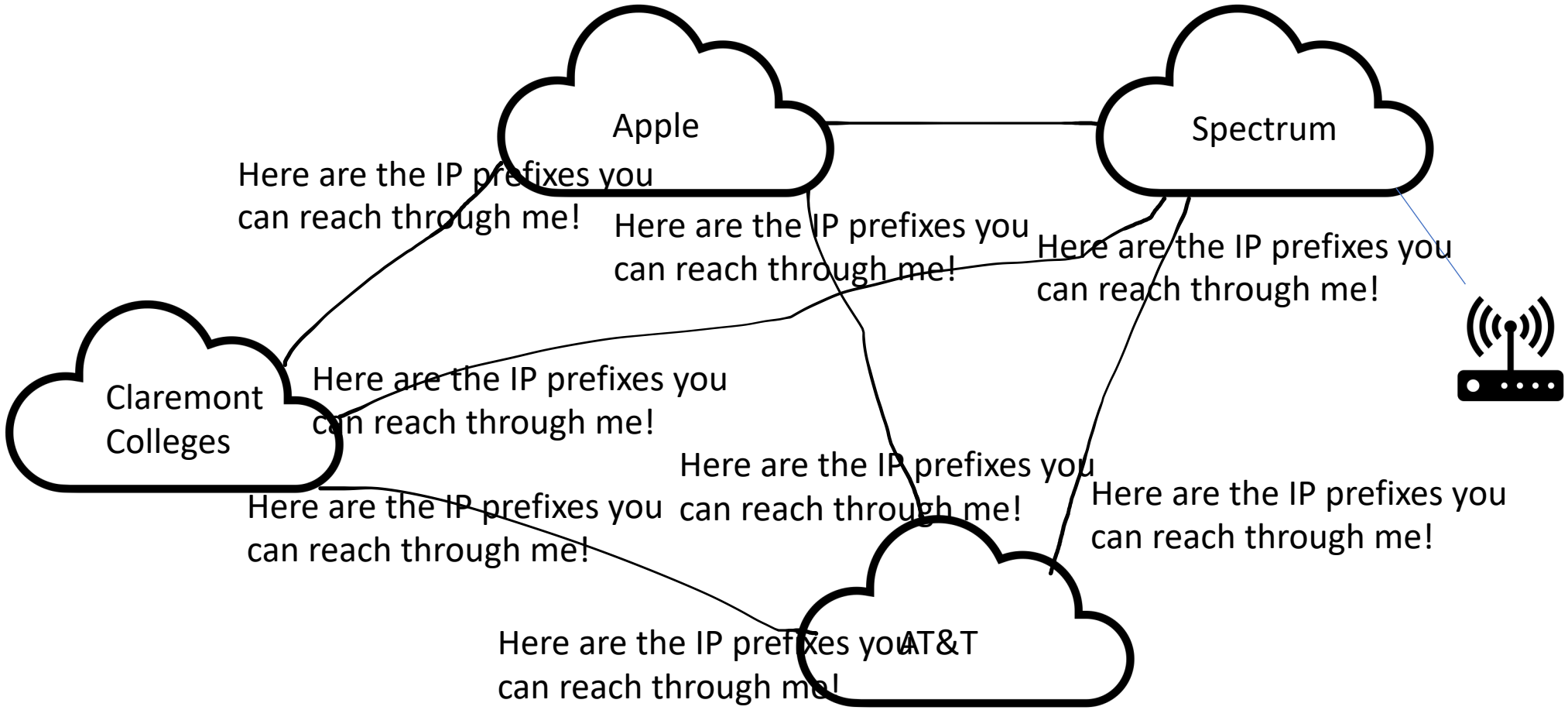
Updated: 2017-03-28

Ref: https://rdap.arin.net/registry/entity/CLAREM-Z

BGP


Apple
Spectrum
Claremont Colleges
AT&T
Here are the IP prefixes you can reach through me!

BGP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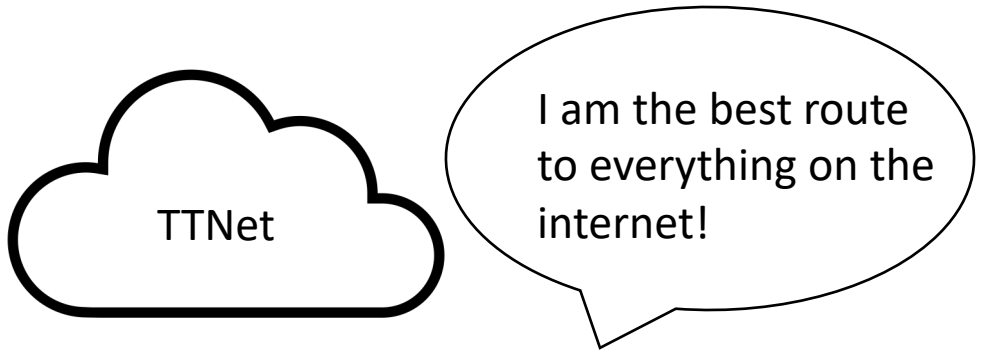
BGP and Trust

- By default, when someone tells us they can reach an IP prefix, we trust them
- Do we want to?
  - We have to!
- In practice, there are many policies around which routes to take from particular neighbors
  - Sophisticated list of metrics

When Trust Goes Wrong

- Advertising prefixes you don’t have can cause major problems
- Can be used for censorship but must be careful! (Feb 24, 2008)



Solutions

- Make sure your routes are correct
- BGPsec -> add cryptographic signature, but to deal with that, routers have to be upgraded which makes it slow to adopt