



# Internet Interconnection

CYBR 4400 / 5400: Principles of Internet Policy, Lecture 3-6

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# Today's Lecture

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- ❖ Midterm on Friday!
- ❖ Network Interconnection Lecture

# Midterm on Friday, March 6

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- ✿ All short answer, multiple choice, true / false type of questions on Canvas on Units 1-3
- ✿ Bring laptop to class
- ✿ 50 minutes for ~40 - 50 questions
- ✿ Study suggestions
  - ✿ Class notes, Lectures, Roadmaps, Readings (in support of lecture topics)

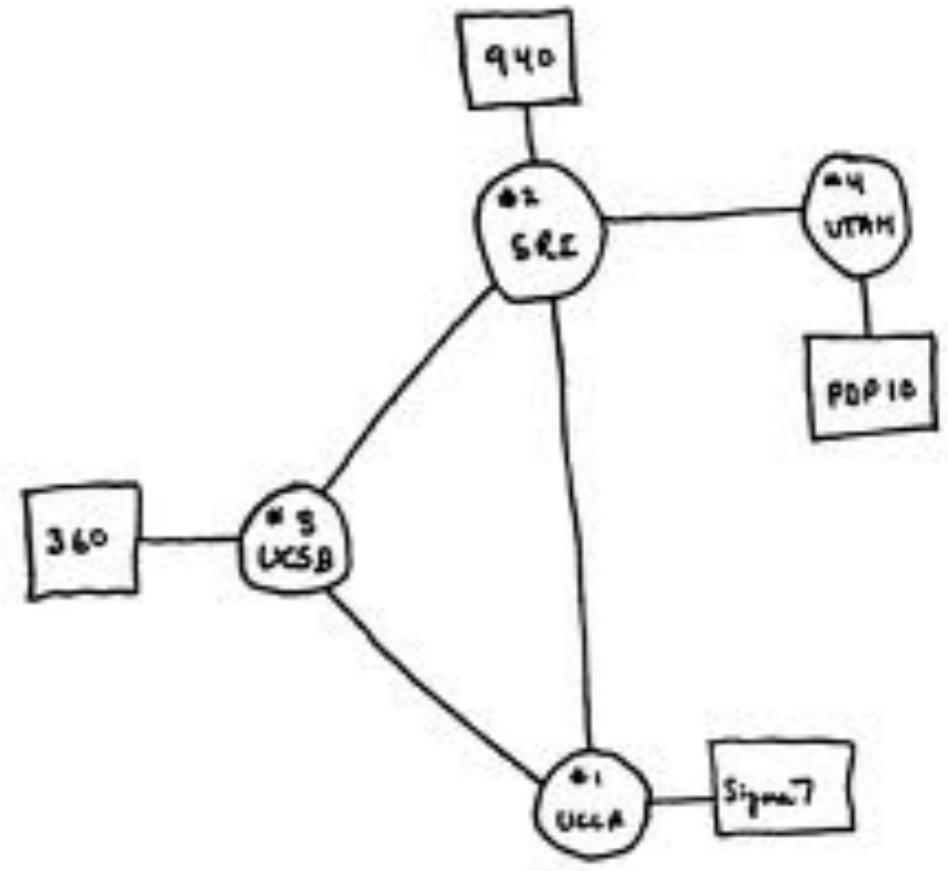
# Network Interconnection

*Physical linking of two networks for the mutual exchange of traffic*

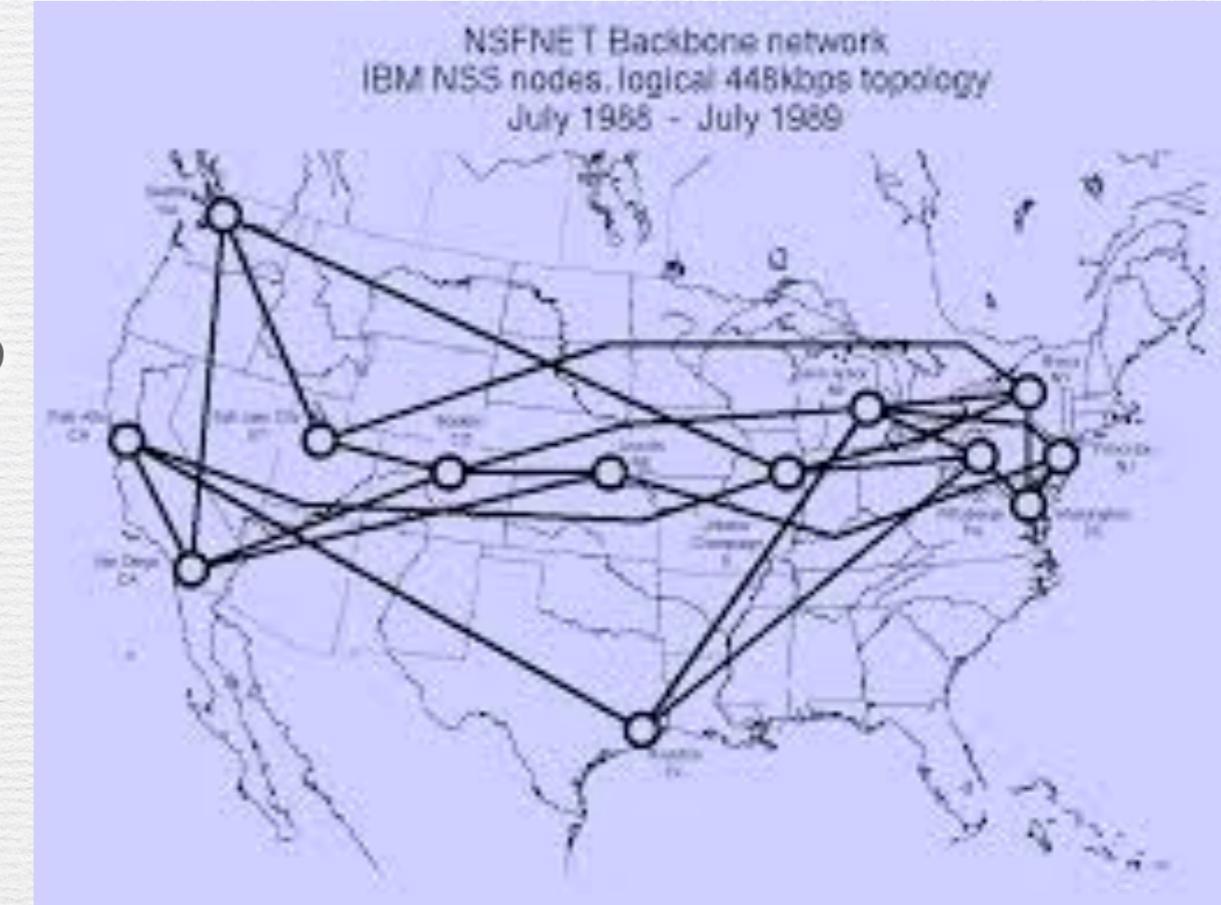


# Internet Origins

- Idea of Paul Baran, RAND
  - Network of interconnected nodes
- Network developed by Advanced Research Projects Agency (ARPANet)
  - Digital, packet-switched
  - Initially linked together government laboratories
  - Applications through early 1990s were file exchanges, remote login to mainframe computers, newsgroups, and emails



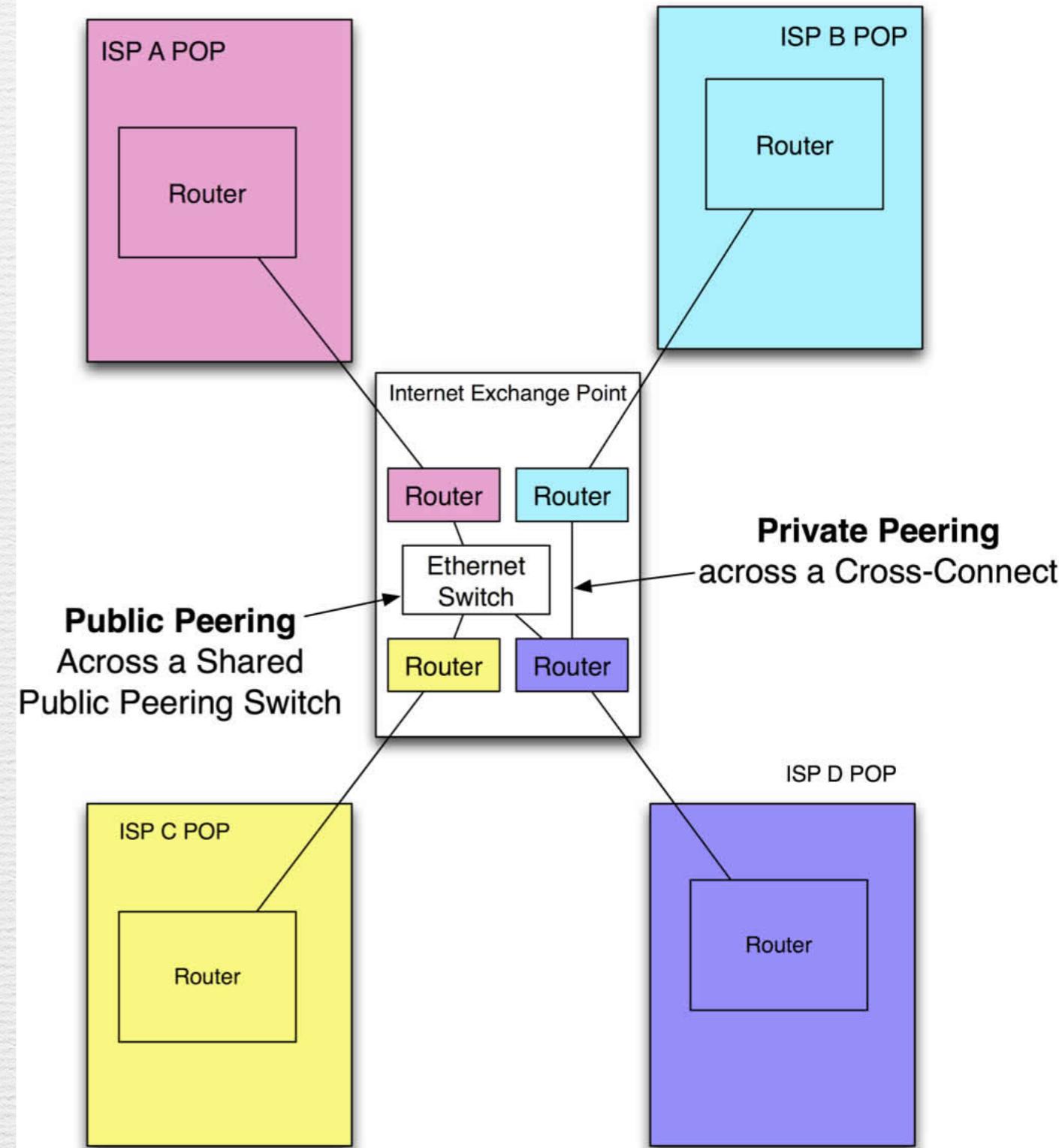
# Internet Origins



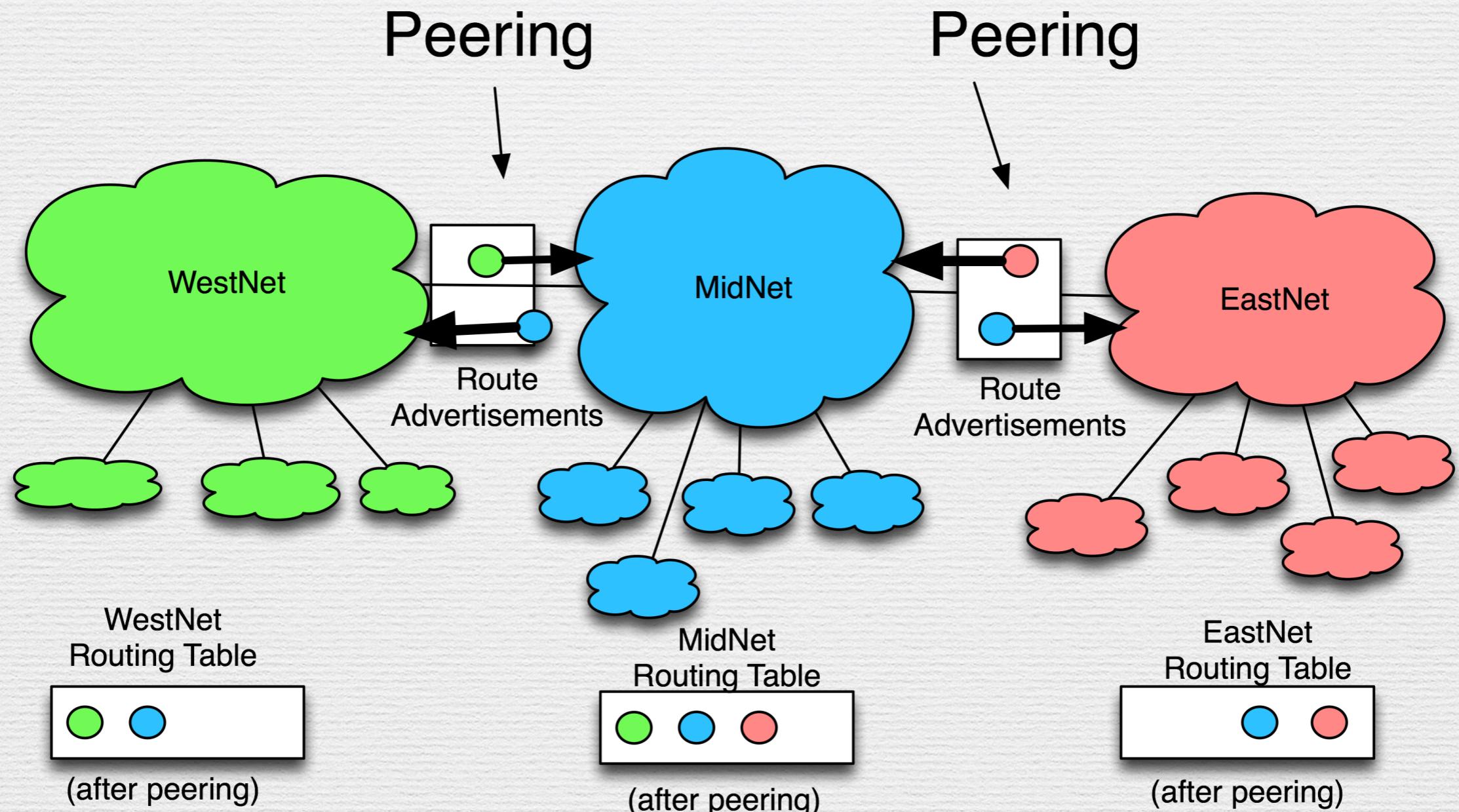
- Federal government sponsorship critical
  - National Science Foundation spent \$200M to support “NSFNet” – TCP/IP network connecting universities
  - Privatized NSFNet in early 1990s

# Evolution of the Internet

- Network Access Points (mid 1990s)
  - Public network exchange facilities where ISPs connected to each other through “settlement free” peering
- Internet Exchange Points (IXPs)
  - Carrier-neutral data centers
  - Where ISPs interconnect across shared public peering switch or private peering



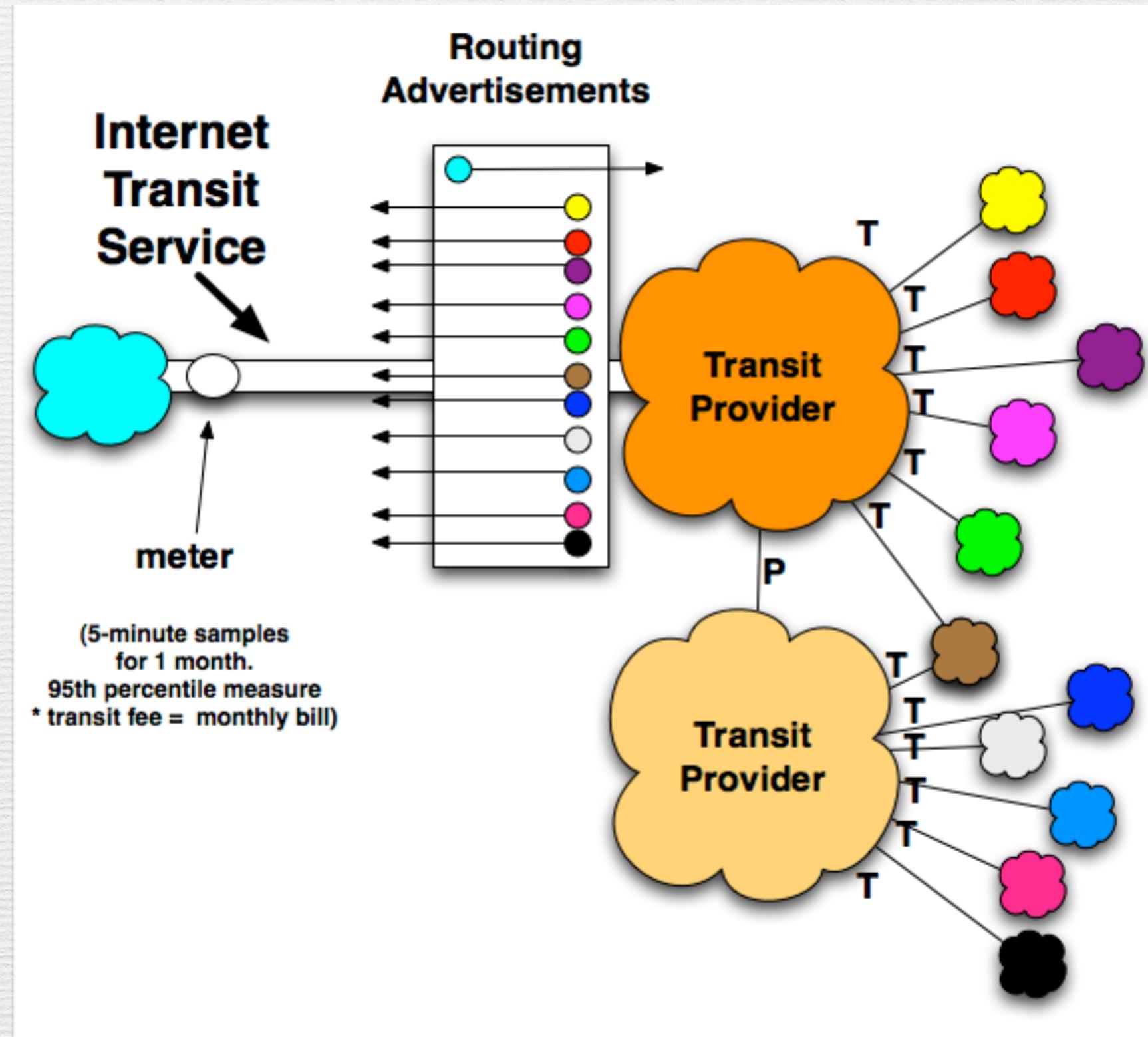
# Peering Interconnection Agreements



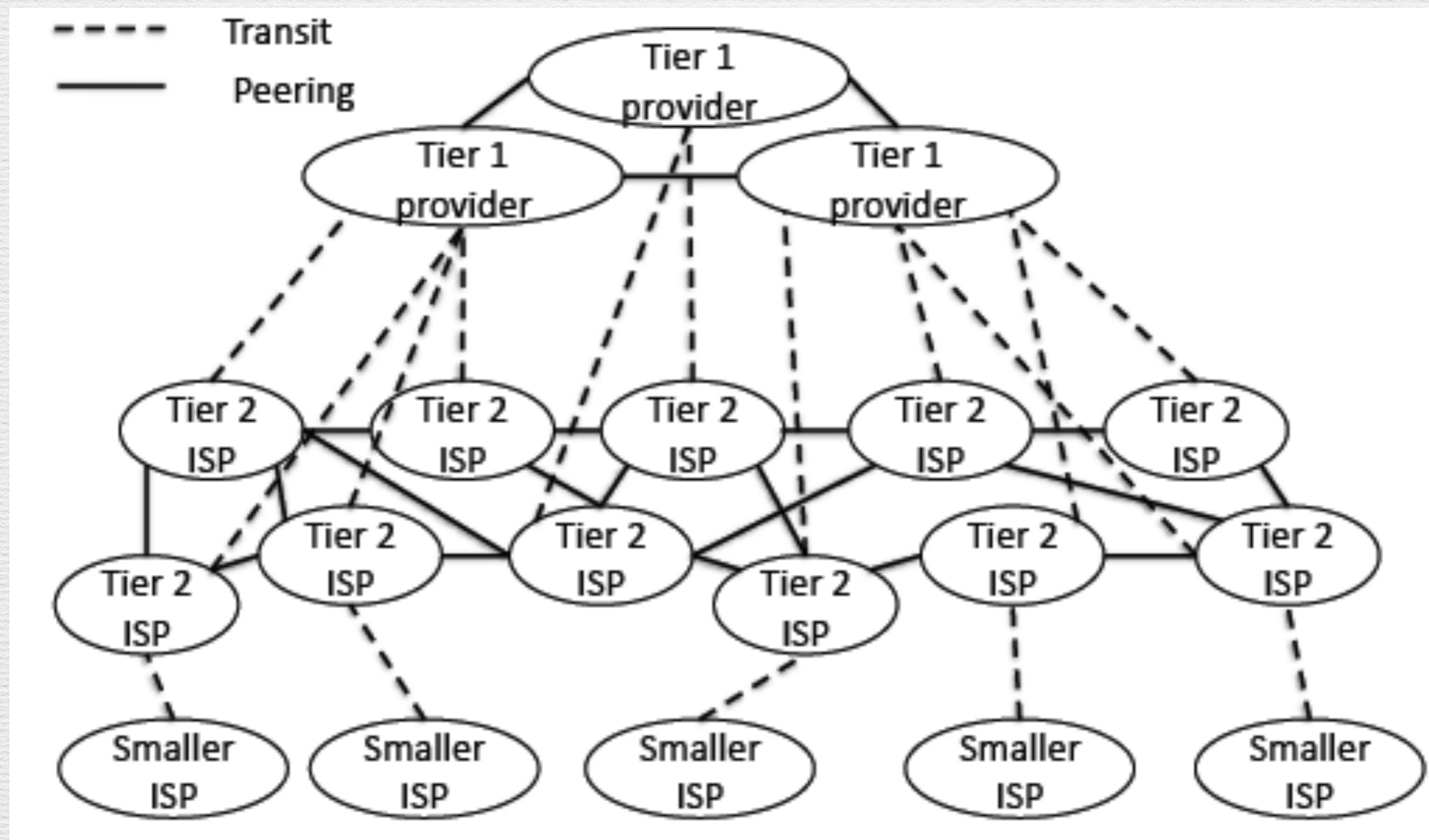
- Business relationship, whereby companies reciprocally provide access to each others' customers
- Non-transitive relationship
- Often “settlement free” but can be paid

# Transit Interconnection Agreements

- Business relationship whereby one ISP provides (usually sells) access to all destinations in its routing table
- Typically metered service
- Growth in Interconnection

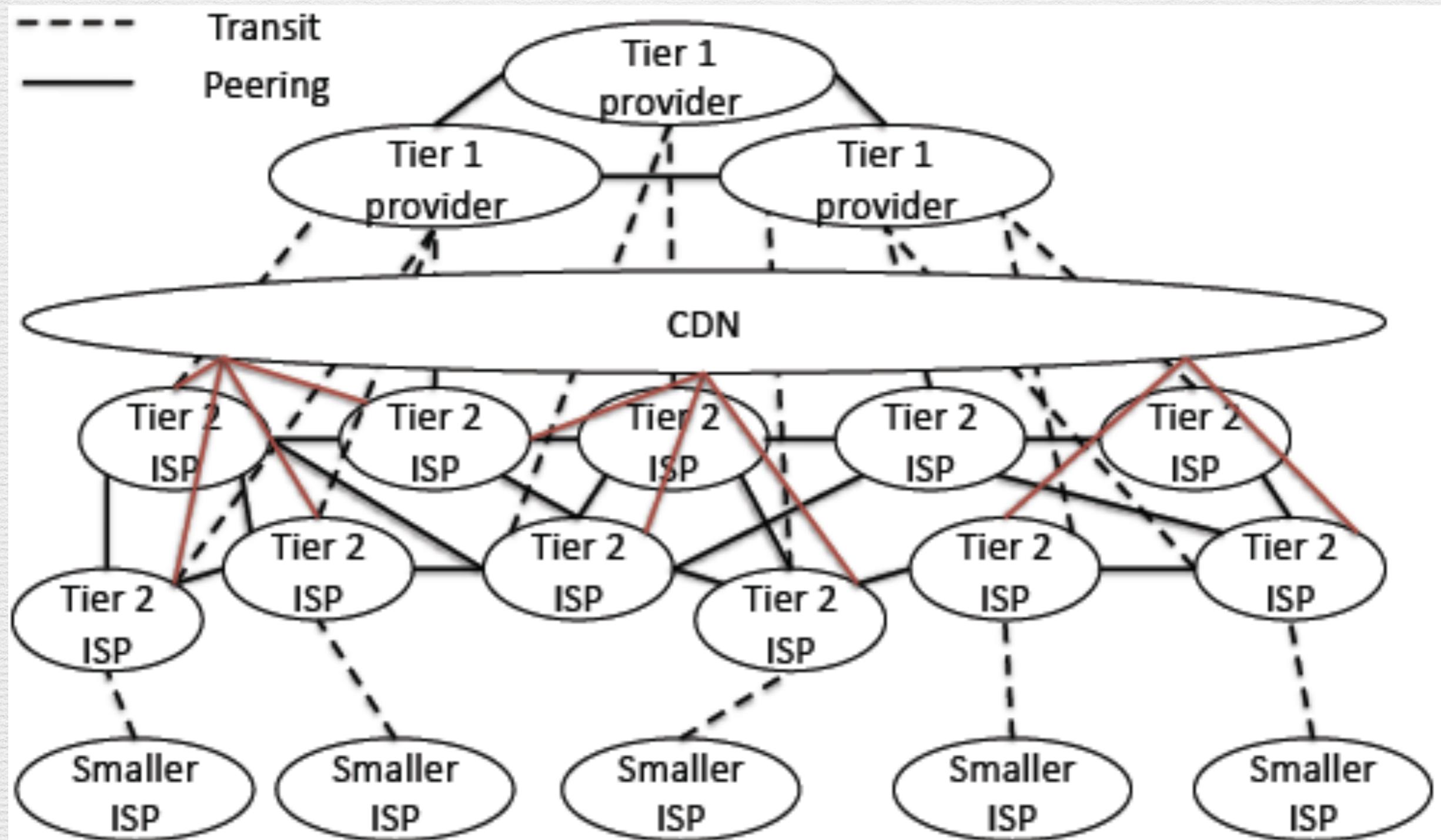


# Internet Interconnection



Source: Claffy, KC and Clark, David D., Platform Models for Sustainable Internet Regulation (August 15, 2013). TPRC 41: The 41st Research Conference on Communication, Information and Internet Policy. Available at SSRN: <http://ssrn.com/abstract=2242600> or <http://dx.doi.org/10.2139/ssrn.2242600>

# Internet Interconnection with CDNs



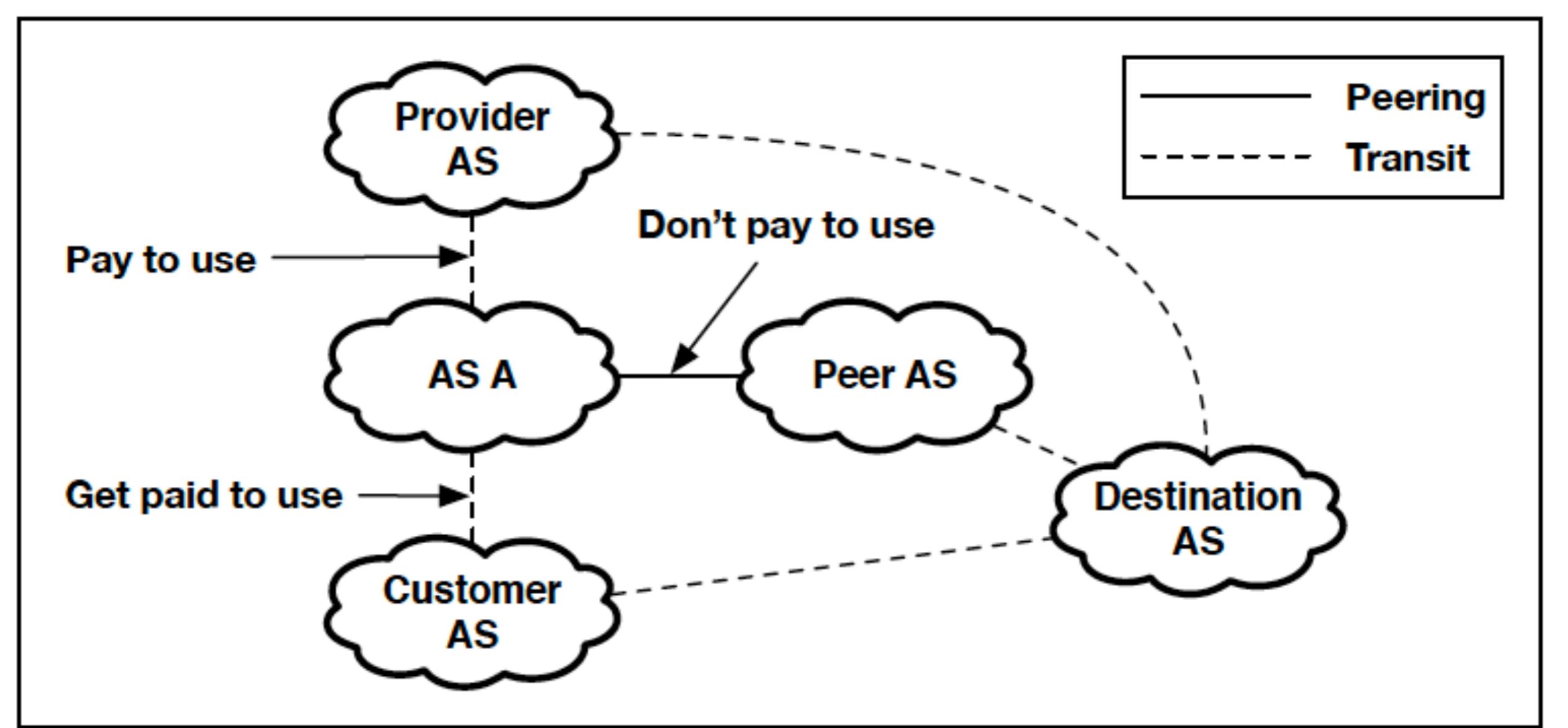
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# Discussion Questions

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# Describe the route preference of AS A in the figure below.



# Describe 3 Motivations for Peering

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# Define the Following Peering Policies of a Network Operator

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- ❖ Open
- ❖ Selective
- ❖ Restrictive

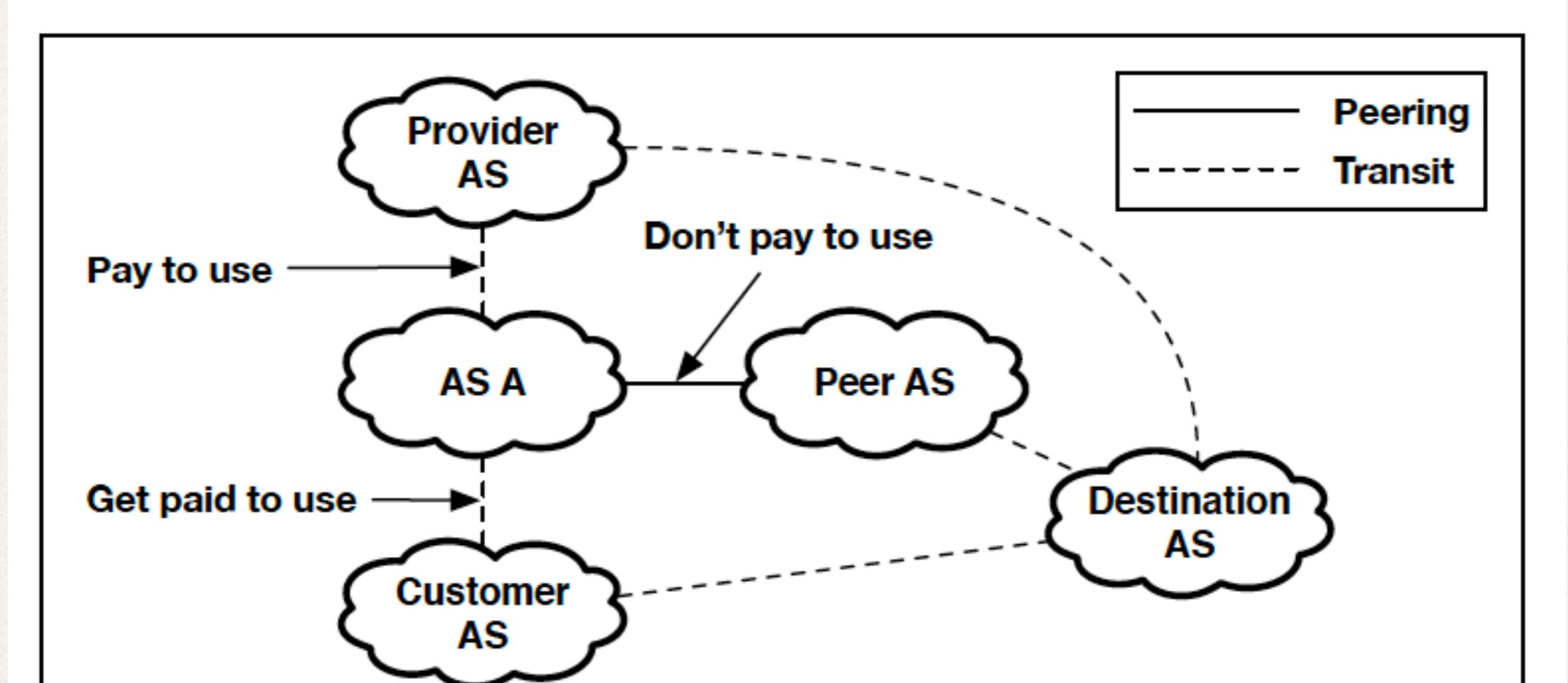
# What is “De-Peering”?

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# What is Hot Potato and Cold Potato Routing?

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# Describe the route preferences of AS A in the figure below (1 points)



AS A will generally prefer the route to the destination via its customer (which it gets paid to use) over the route to the destination through either its peer (which it does not pay to use) or its provider (which it pays to use).

# Describe 3 Motivations for Peering (3 points)

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- ✿ Network effects
- ✿ Increased redundancy
- ✿ Increased routing control
- ✿ Reduced latency
- ✿ Reduced congestion
- ✿ Improved traffic management
- ✿ Reduced cost

# Define the Following Peering Policies of a Network Operator (3 points)

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- ✿ Open
  - ✿ Will peer with any other party
- ✿ Selective
  - ✿ Will peer with any other party that meets criteria described in the peering policy (i.e., minimum traffic exchanged, number of peering points, staffed NOCs)
- ✿ Restrictive
  - ✿ Will generally not peer with other parties

# What is “De-Peering”? (1 point)

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- ✿ Networks are disconnected
- ✿ Results in partial loss of Internet reachability
- ✿ Results in no loss of Internet reachability

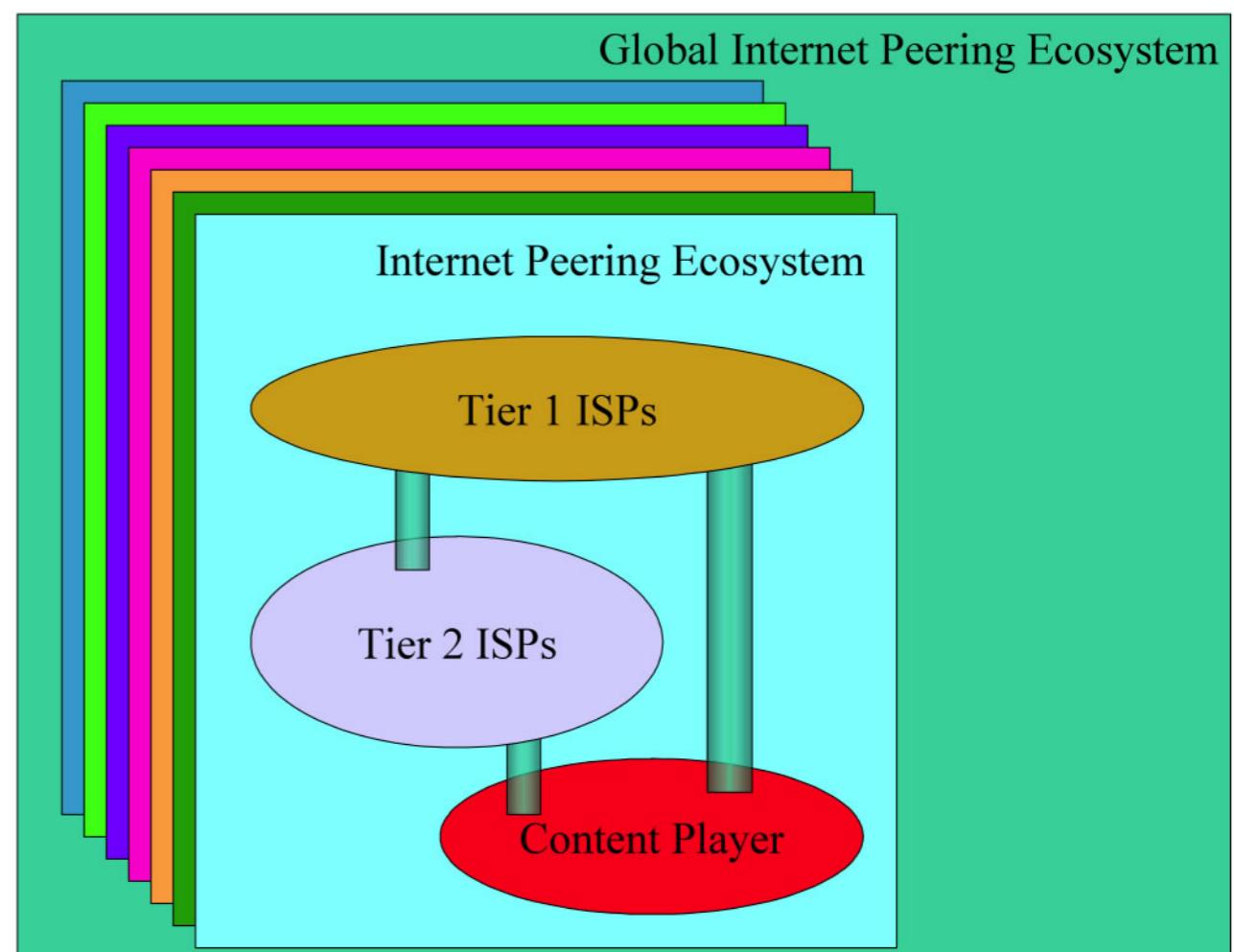
# What is Hot Potato and Cold Potato Routing? (2 points)

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- ✿ Hot Potato: “nearest exit” routing
  - ✿ Resulting economics of traffic sender having less burden than those receiving often cited in peering disputes (primary reason for balanced traffic ratio requirements in some peering contracts)
- ✿ Cold Potato: routing to keep traffic on network as long as possible; exchange of traffic as close to destination as possible
  - ✿ Used frequently by content providers to optimize user experience

# Interconnection Arrangement Not Regulated Until 2015

- Tier 1 backbones do not need transit services
- Tier 1 providers competition for transit business of smaller backbones has kept transit prices in check
- Antitrust oversight monitors market power
  - 1998: Justice Department required divestiture of MCI backbone in merger with WorldCom
  - 2000: Justice Department blocked Worldcom/MCI/Sprint merger



Source: <http://peering.drpeering.net/>

# 2015 FCC Net Neutrality Rules on Internet Traffic Exchange

- Definition for broadband Internet access service includes exchange of Internet traffic by an edge provider or an intermediary with the broadband ISP
- Premature to adopt prescriptive rules to address any problems for Internet traffic exchange that have arisen or may arise
- Adopts case-by-case approach to monitor traffic exchange and developments in this market

# A Difference of Opinion

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Restoring Internet Freedom rules (2018) decided that Internet traffic exchange, premised on privately negotiated agreements or case-by-case basis, not a telecommunications service

# Changing Characteristics of Internet Traffic

Traffic Attribute	Comment
Destination	Access ISPs increasingly important destination and source of Internet traffic
Volume	New broadband apps driving Internet traffic growth, particularly online video services
Symmetry	Asymmetry over access ISPs will grow with streaming video — reason for more paid peering
Peak Usage	Internet peak usage period now occurs over most of the day —increasing impact of congested links
Adaptive Impact	Adaptive streaming and routing complicates capacity planning

Source: Reed, David and Warbritton, Donny and Sicker, Douglas, Current Trends and Controversies in Internet Peering and Transit: Implications for the Future Evolution of the Internet (August 20, 2014). 2014 TPRC Conference Paper.

# New Developments Changing the Economics of Peering

New Development	Comment
Interconnection Cost	IXPs connecting among themselves in a grid using “open” standards—more Tier 2 and Tier 3 ISPs can peer with each other
Network Investment	More transparent or recognized framework for network investment may help reconcile large gaps in value driving controversies
Emergence of Online Video	Increasing number of private CDNs for video-based content providers
Strategic Business Considerations	Peering arrangements reflect business relationships; rapid changes quickly shift leverage positions and tactics

Source: Reed, David and Warbritton, Donny and Sicker, Douglas, Current Trends and Controversies in Internet Peering and Transit: Implications for the Future Evolution of the Internet (August 20, 2014). 2014 TPRC Conference Paper.

# Strategic Implications

Strategic Implication	Comment
Defining Network Cost	Value of interconnection agreements increasingly reflect underlying network costs in lieu of symmetry, etc...
Allowing Dynamic Nature of Content	Peering agreements need flexibility to adjust to content innovation and evolving roles of different network segments
Separate Content Networks in the Core	More large content providers will build network cores
Less Reliance on Tier 1 ISPs	Transit prices decrease with technology and less demand—small ISPs peer more using remote peering and Open-IX IXPs

Source: Reed, David and Warbritton, Donny and Sicker, Douglas, Current Trends and Controversies in Internet Peering and Transit: Implications for the Future Evolution of the Internet (August 20, 2014). 2014 TPRC Conference Paper.