Masterkurs Rechnernetze

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Advanced computer networking

Internet Protocols

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Outline

- Routing hierarchy
- Internet structure
- External BGP (E-BGP)
- Internal BGP (I-BGP)

Acknowledgements

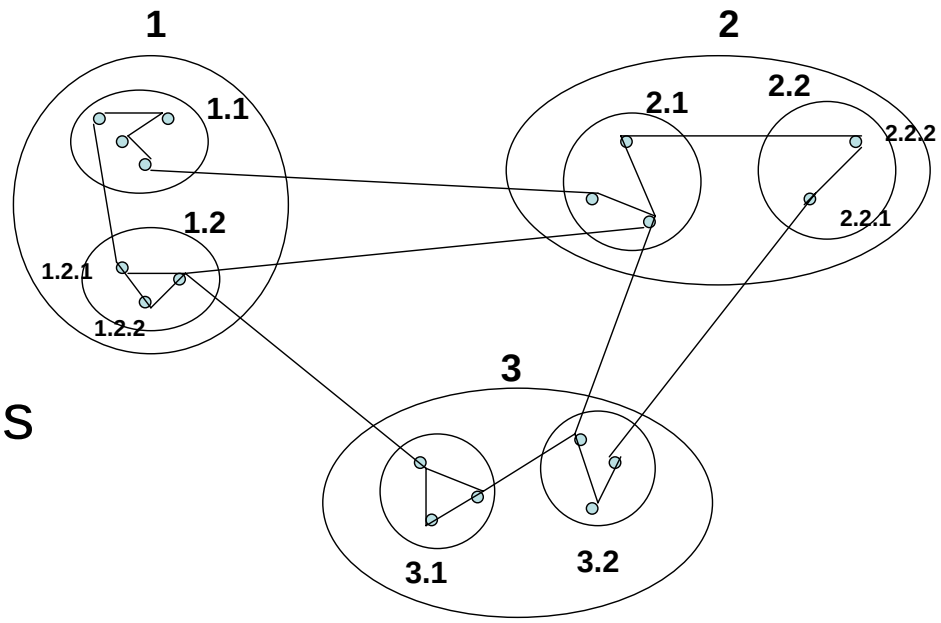
- Randy H. Katz
- Distinguished professor at UCB
- thirteeen best paper awards
- *Textbook: Contemporary Logic Design*, has sold over 100,000 copies in two editions, and has been used at over 200 colleges and universities
- the late 1980s, with colleagues at Berkeley, he developed Redundant Arrays of Inexpensive Disks (RAID)
- Prior research interests have included: database management, VLSI CAD, high performance multiprocessor (Snoop cache coherency protocols) and storage (RAID) architectures, transport (Snoop TCP) and mobility protocols spanning heterogeneous wireless networks, and converged data and telephony network and service architectures.

Routing Hierarchies

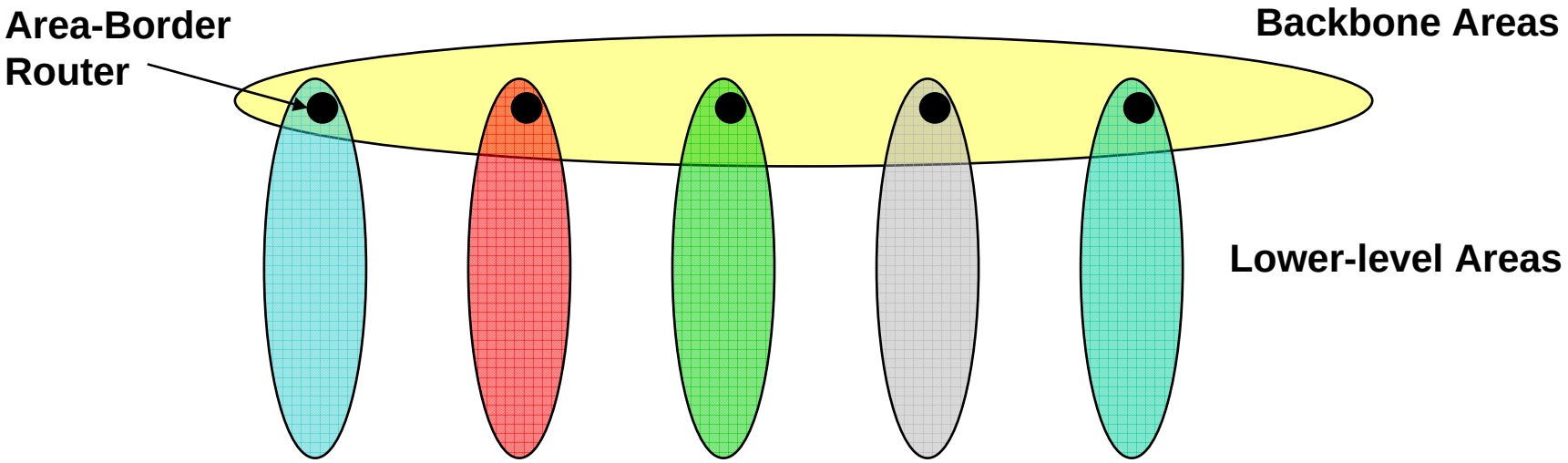
- Flat routing doesn't scale
  - Storage → Each node cannot be expected to store routes to every destination (or destination network)
  - Convergence times increase
  - Communication → Total message count increases
- Key observation
  - Need less information with increasing distance to destination
  - Need lower diameters networks
- Solution: area hierarchy

Areas

- Divide network into areas
  - Areas can have nested sub-areas
  - Constraint: no path between two sub-areas of an area can exit that area
- Hierarchically address nodes in a network
  - Sequentially number top-level areas
  - Sub-areas of area are labeled relative to that area
  - Nodes are numbered relative to the smallest containing area



Routing Hierarchy

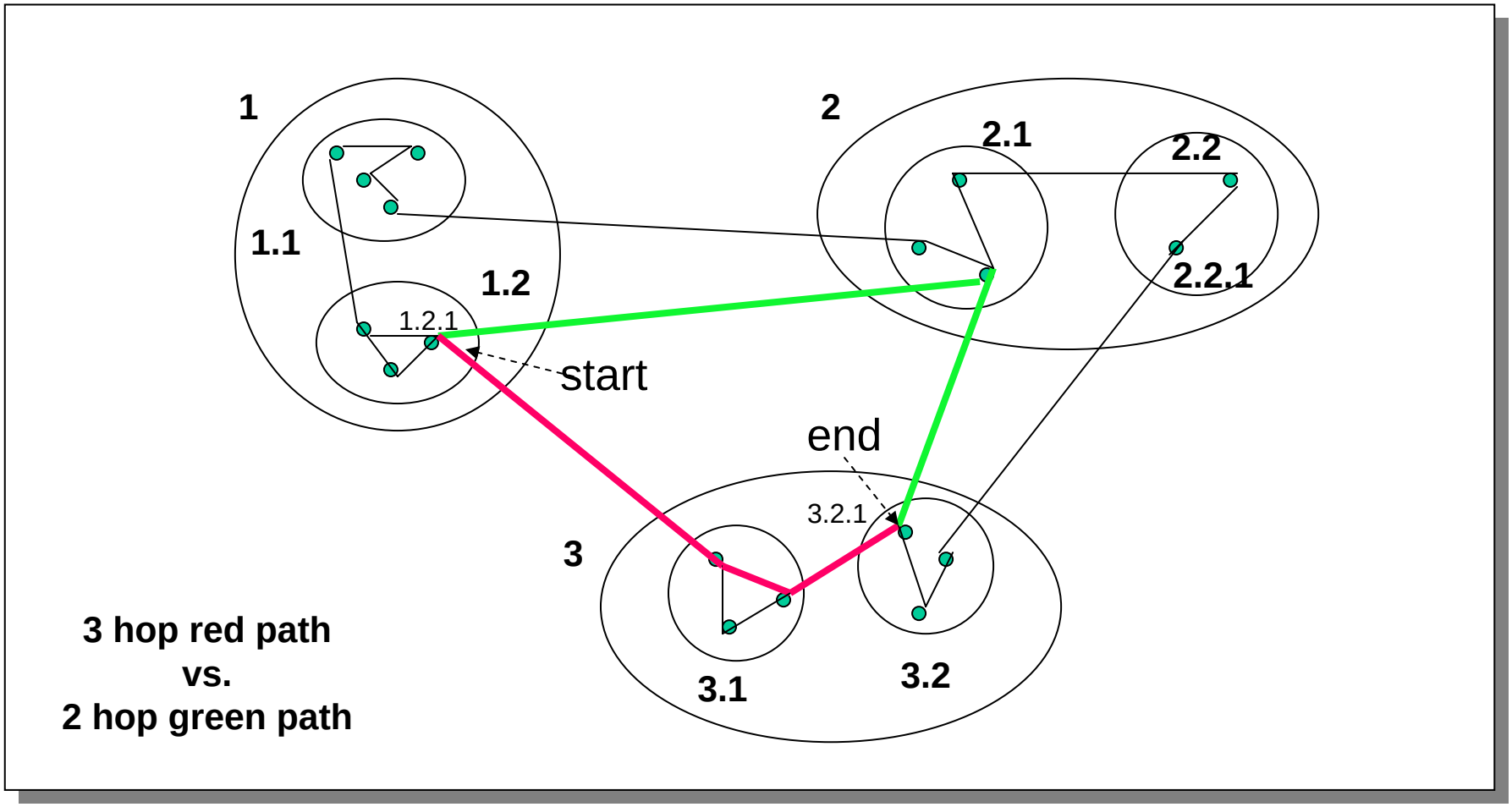


- Partition Network into “Areas”
  - Within area
    - Each node has routes to every other node
  - Outside area
    - Each node has routes for other top-level areas only
    - Inter-area packets are routed to nearest appropriate border router
- Constraint: no path between two sub-areas of an area can exit that area

Routing

- Within area
  - Each node has routes to every other node
- Outside area
  - Each node has routes for other top-level areas only
  - Inter-area packets are routed to nearest appropriate border router
- Can result in sub-optimal paths

Path Sub-optimality



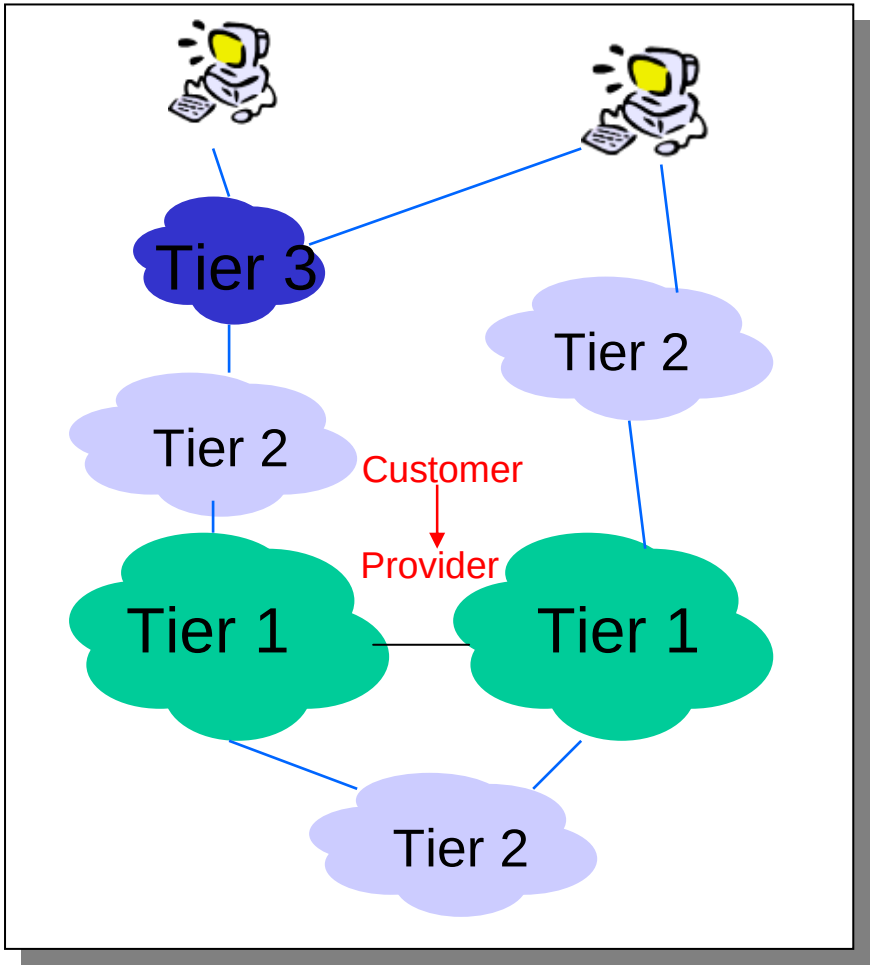
A Logical View of the Internet

- National (Tier 1 ISP)
  - “Settlement-free” and “Default-free” with global reachability info

  Eg: AT & T, UUNET, Sprint
- Regional (Tier 2 ISP)
  - Regional or country-wide

  Eg: Pacific Bell
- Local (Tier 3 ISP)

  Eg: Telerama DSL



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Internet's Area Hierarchy

- Autonomous System (AS)?
  - A set of routers under a single technical administration, using an *interior gateway protocol (IGP)* and common metrics to route packets within the AS and using an *exterior gateway protocol (EGP)* to route packets to other AS's
- Each AS assigned unique ID
- AS's peer at network exchanges

History: IGP

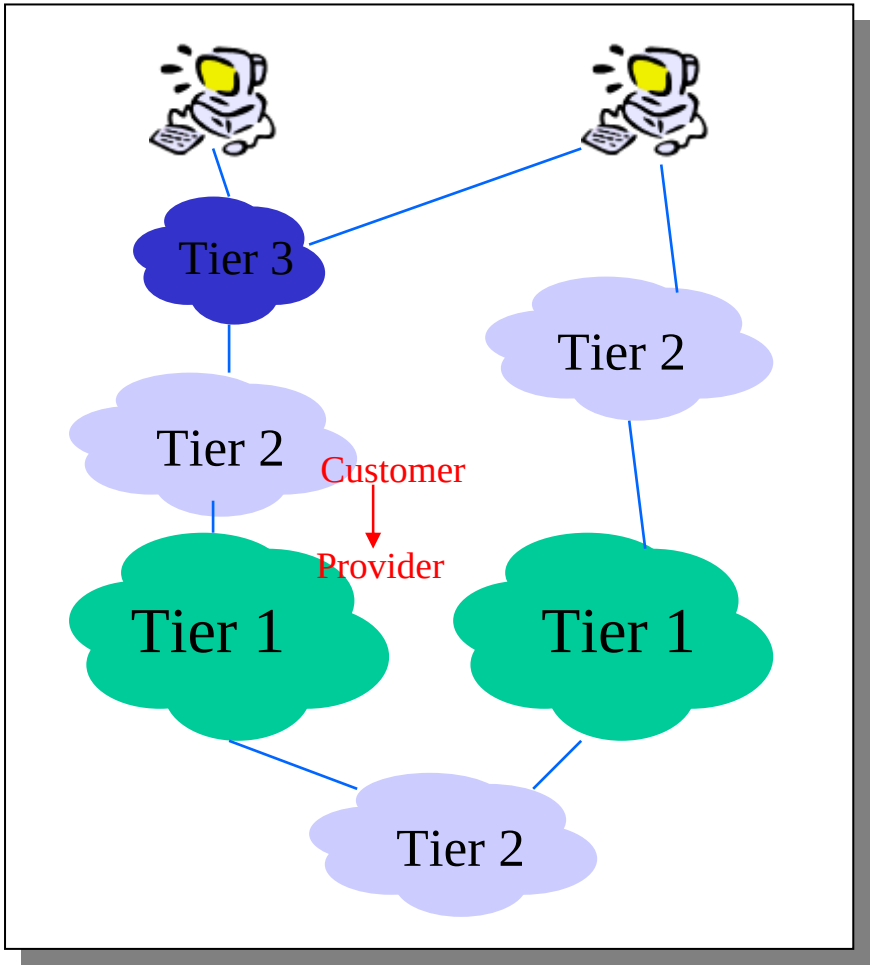
- Most common IGPs:
  - RIP: Routing Information Protocol (v1: 1988, v2: 1994)
  - OSPF: Open Shortest Path First (1988 - 1998)
  - IS-IS: Intermediate system to intermediate system (mid to end 90s)
  - EIGRP: Enhanced Interior Gateway Routing Protocol (Cisco proprietary, mid-80s)

History: EGP

- Mid-80s: EGP
  - Reachability protocol (no shortest path)
  - Did not accommodate cycles (tree topology)
  - Evolved when all networks connected to NSF backbone
- Result: BGP introduced as routing protocol
  - Latest version = BGP 4
  - BGP-4 supports CIDR
  - Primary objective: connectivity not performance

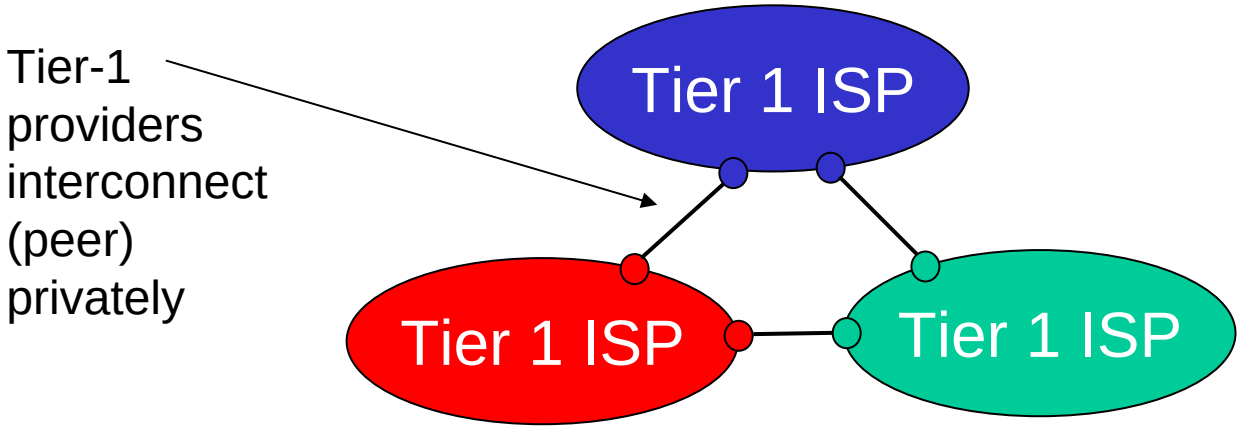
A Logical View of the Internet

- Tier 1 ISP
  - "Default-free" with global reachability info
- Tier 2 ISP
  - Regional or country-wide
- Tier 3 ISP
  - Local

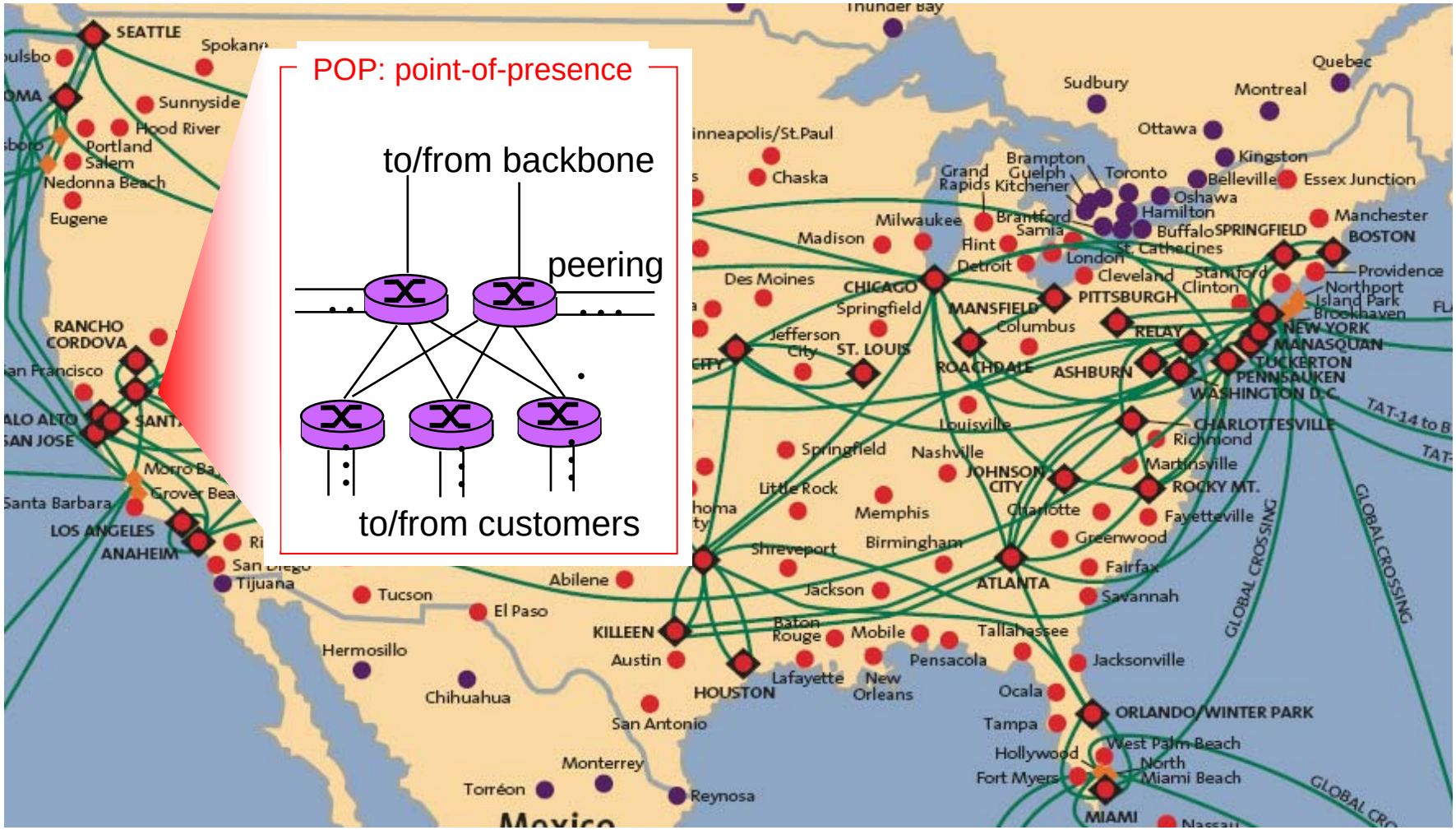


Internet structure: network of networks

- roughly hierarchical
- at center: “tier-1” ISPs (e.g., Verizon, Sprint, AT&T, Cable and Wireless), national/international coverage
  - treat each other as equals

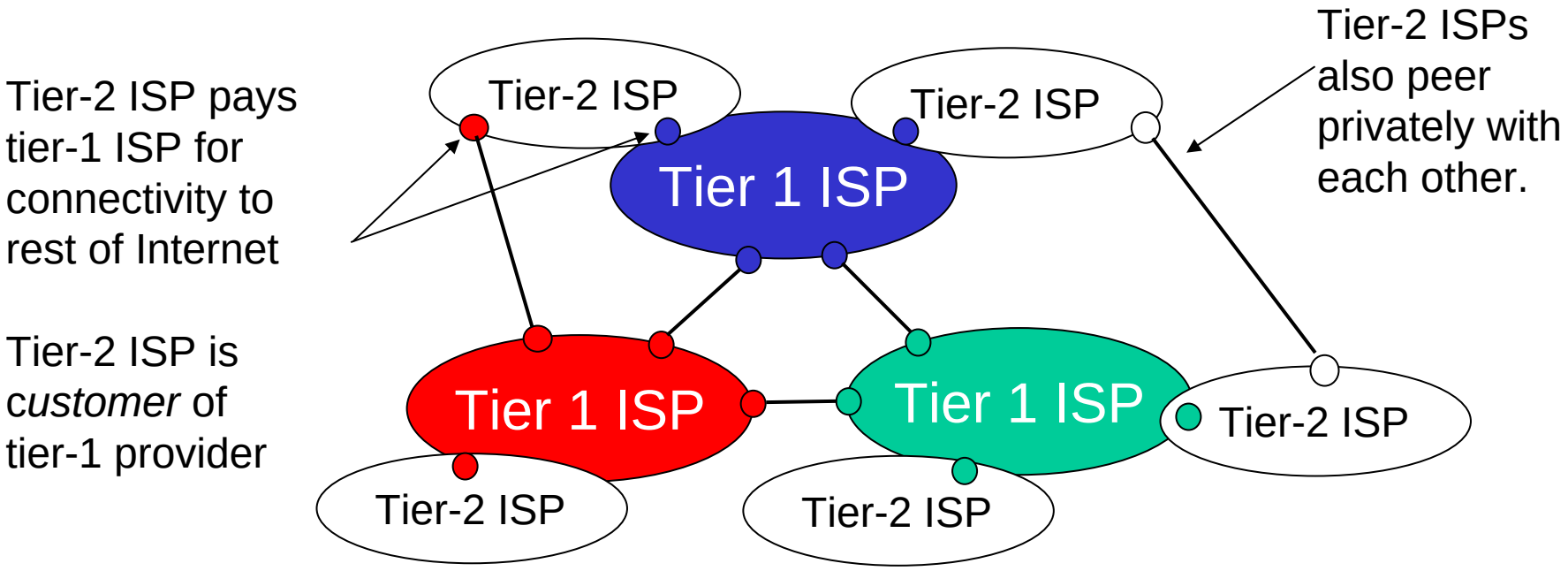


Tier-1 ISP: e.g., Sprint



Internet structure: network of networks

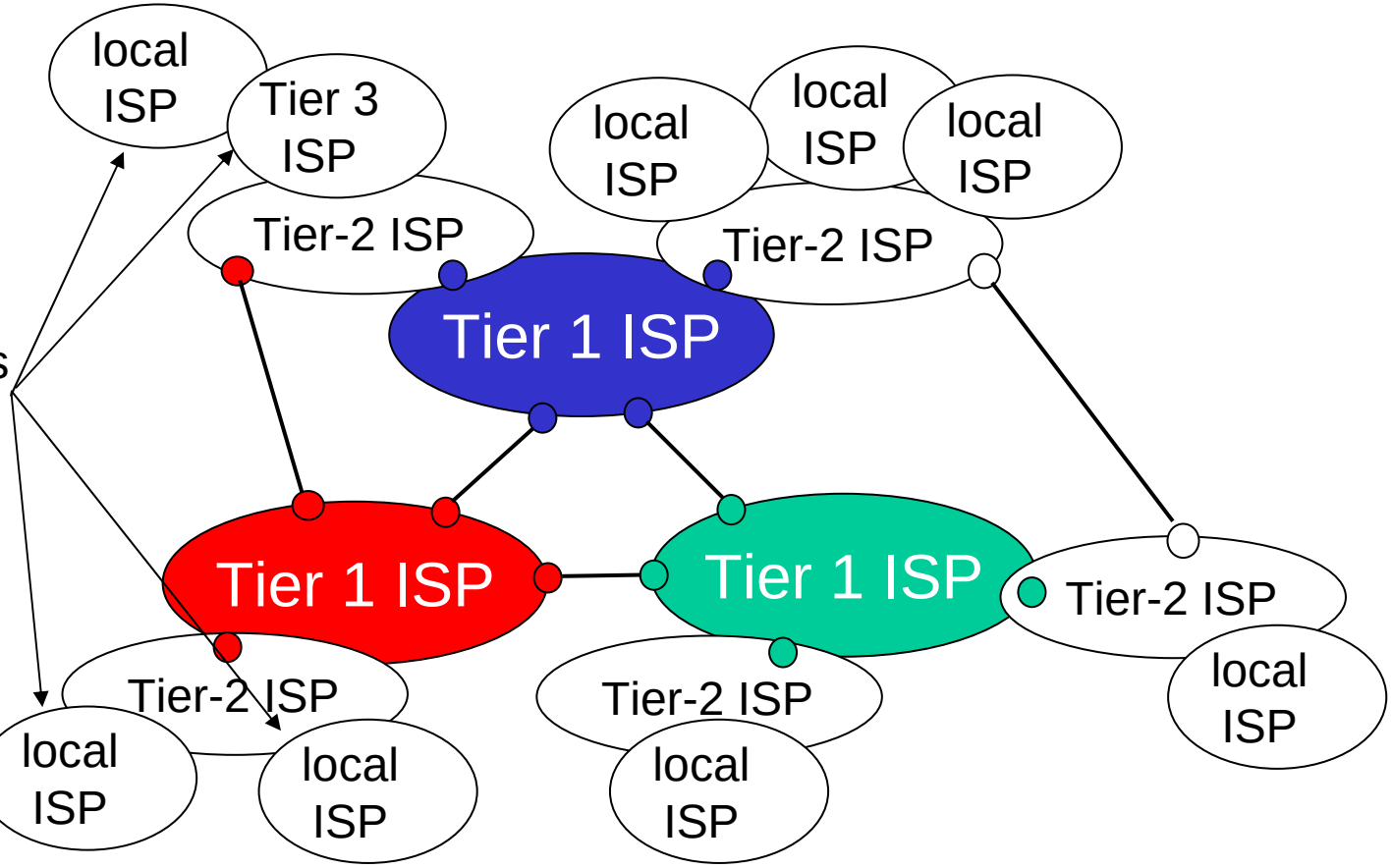
- "Tier-2" ISPs: smaller (often regional) ISPs
  - Connect to one or more tier-1 ISPs, possibly other tier-2 ISPs



Internet structure: network of networks

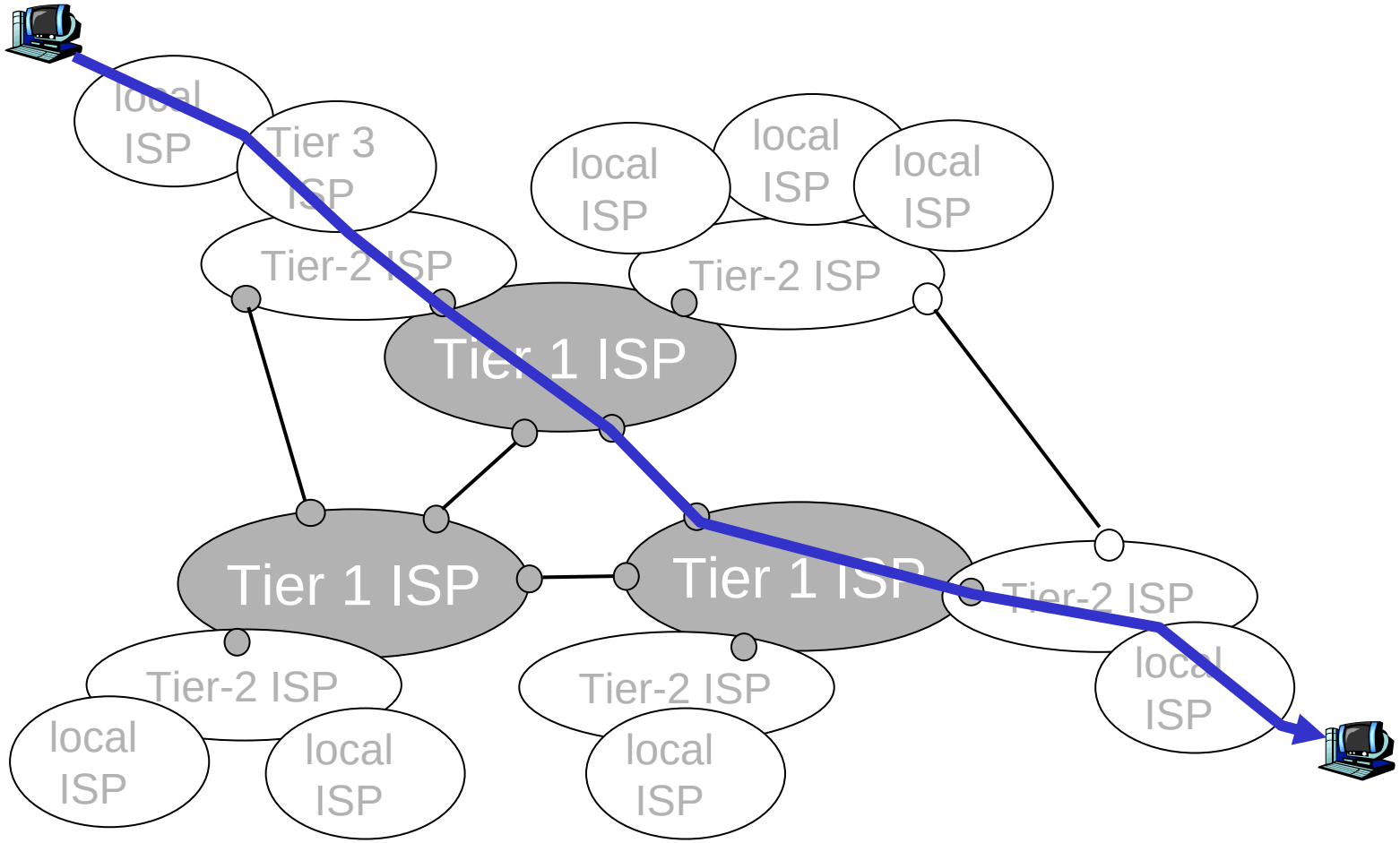
- "Tier-3" ISPs and local ISPs
  - last hop ("access") network (closest to end systems)

Local and tier-3 ISPs are *customers* of higher tier ISPs connecting them to rest of Internet



Internet structure: network of networks

- a packet passes through many networks!



Transit vs. Peering