Institut für Kommunikations-Technik

Introduction to Internet Architecture – Limitations of Current Internet

Future Internet Communication Technologies

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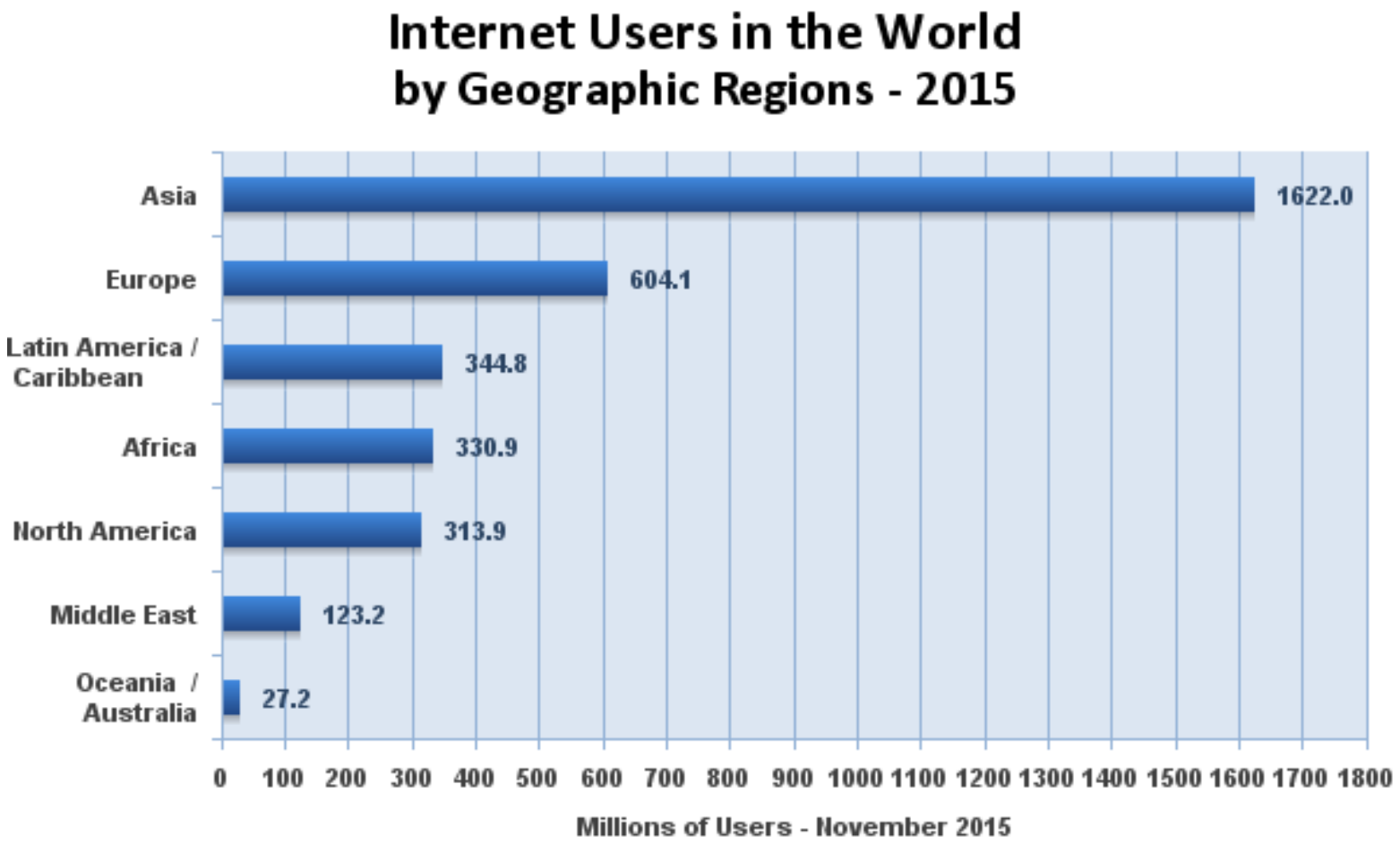
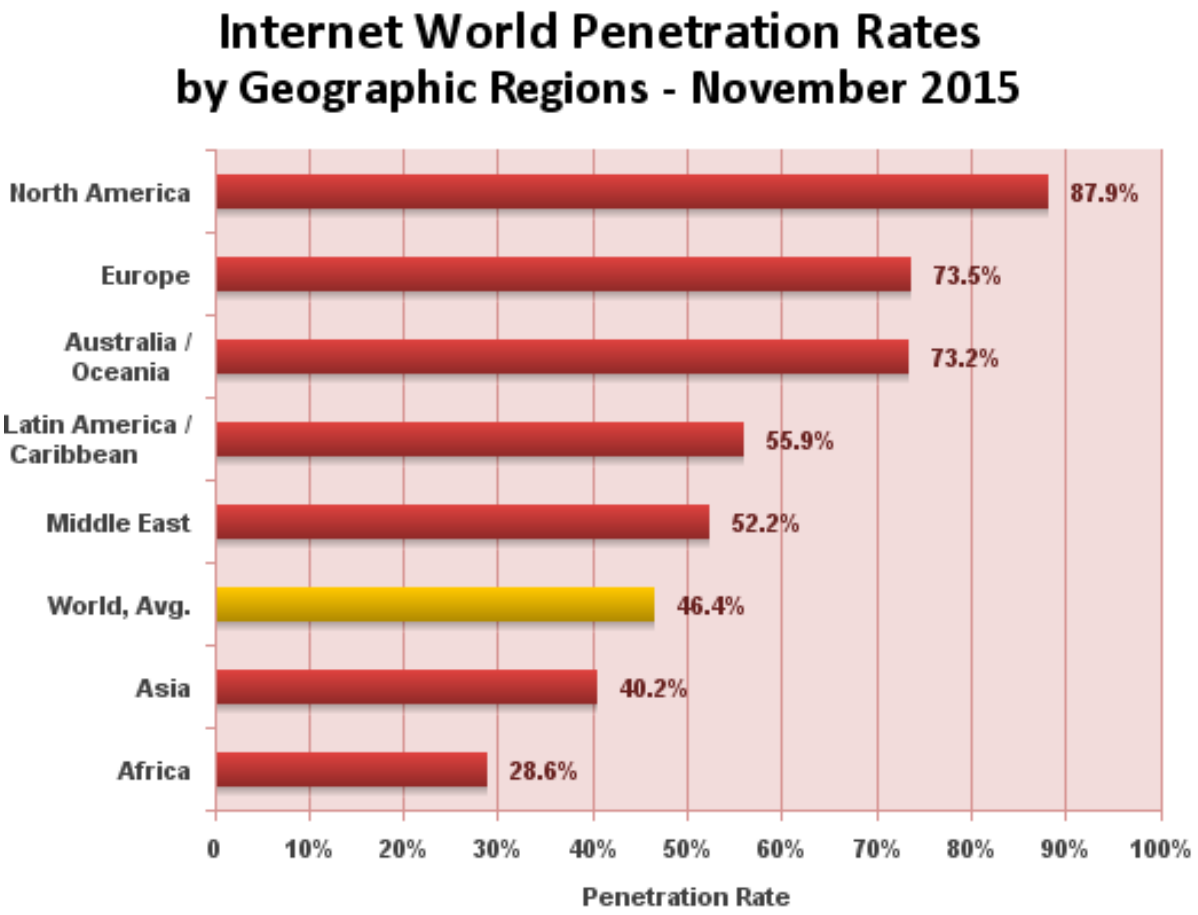
Internet Users



Source: Internet World Stats - www.internetworldstats.com/stats.htm
3,366,261,156 Internet users estimated for November 30, 2015

Internet Penetration



Source: Internet World Stats - www.internetworldststs.com/stats.htm
Penetration Rates are based on a world population of 7,259,902,243 and 3,366,261,156 estimated Internet users on November 30, 2015.

Internet Applications

- Proliferation of internet applications:
  - Web, e-mail, FTP
  - Multimedia streaming, IPTV
  - Internet telephony (Skype, FaceTime, etc.)
  - Video conferencing
  - Online gaming
  - Remote terminal access
  - File distribution (peer-to-peer)

- It is very hard to predict the applications of tomorrow:
  - The evolution of the applications has been quite surprising so far

Diverse Application Requirements

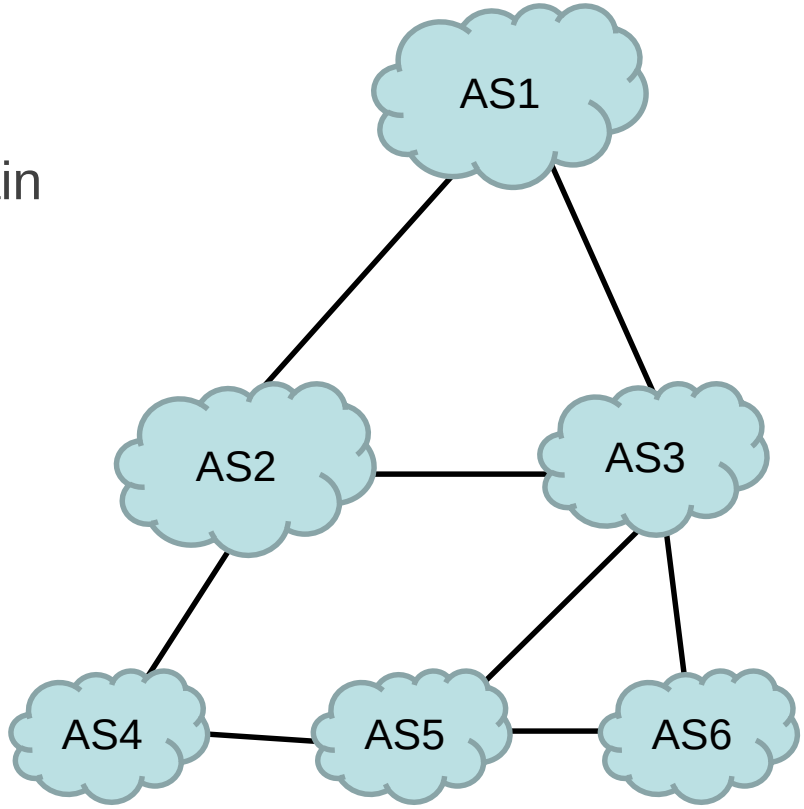
Application	Throughput	Packet Loss	Delay
Web	Elastic	No loss	Tolerant
File transfer	Elastic	No loss	Tolerant
E-mail	Elastic	No loss	Tolerant
Real-time video	100Kbps – 5Mbps	Tolerant	150 ms
Video on-demand	100Kbps – 5Mbps	Tolerant	some secs
Internet telephony	8Kbps – 128Kbps	Tolerant	100 ms

Internet Infrastructure

Autonomous Systems

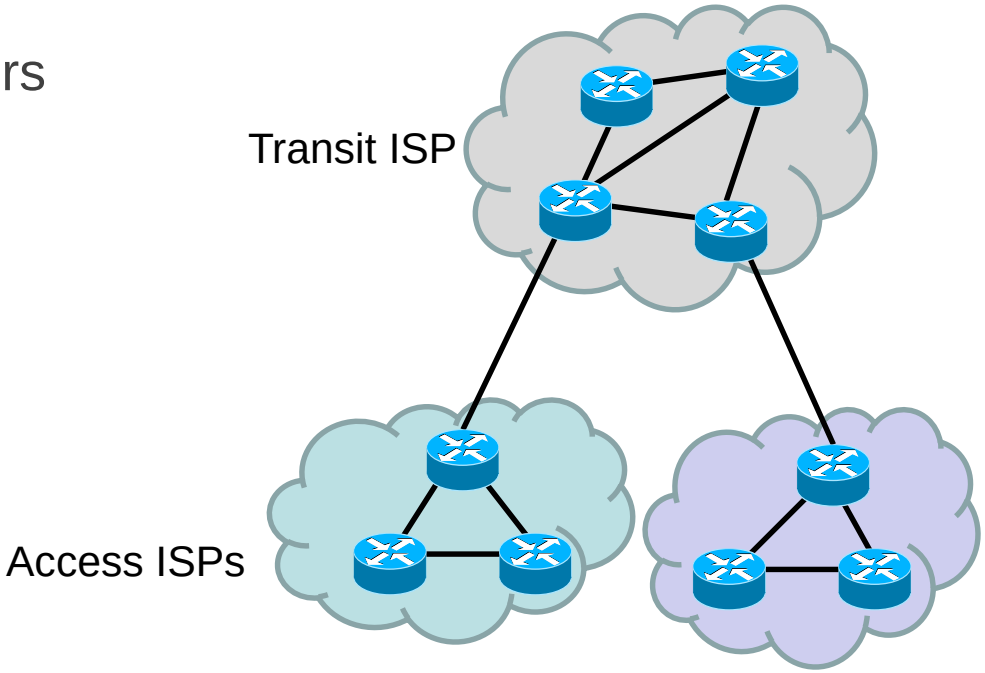
- Internet is composed of Autonomous Systems (ASes)
  - “Network of networks”

- Autonomous System (AS):
  - Independently administrative domain
  - More than 47.000 ASes
    - Internet Service Providers (ISPs)
    - Content Distribution Networks
    - Enterprise Networks
    - University Campus Networks



Internet Infrastructure Overview

- Internet Core:
  - Mesh of interconnected routers
  - Infrastructure offered by multiple ISPs



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- Access Networks:
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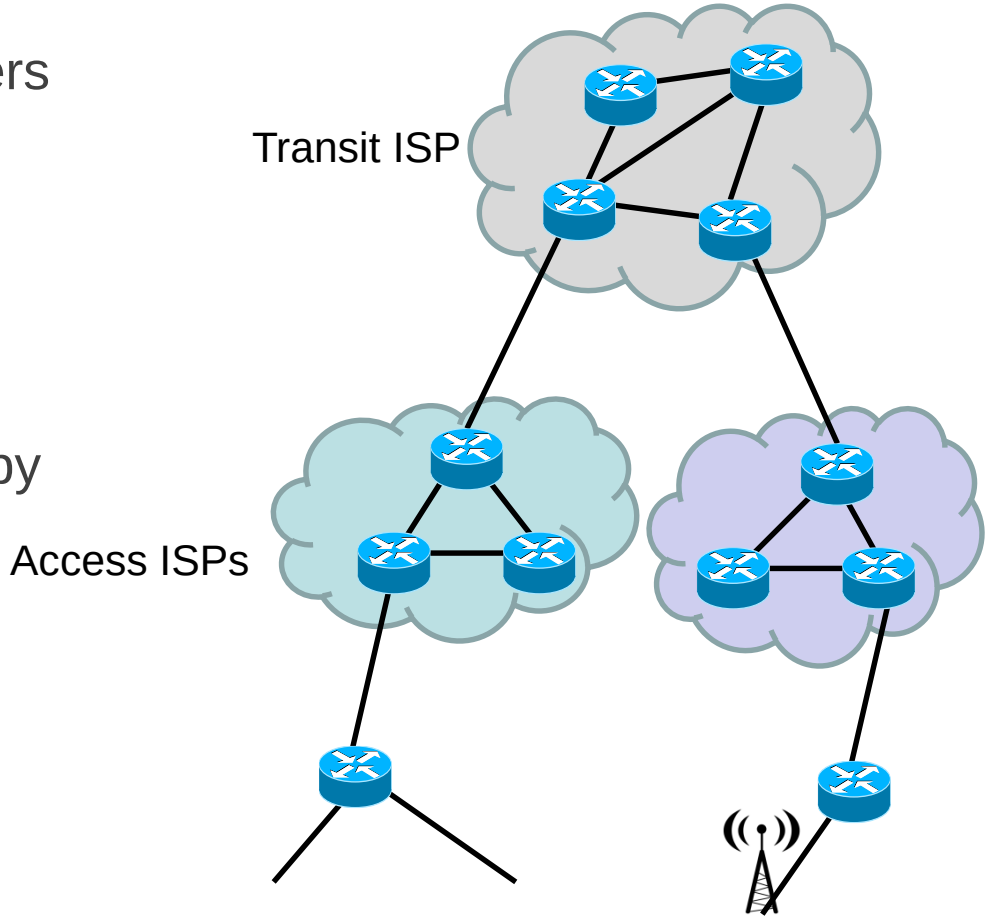

Internet Infrastructure Overview

- Internet Core:
  - Mesh of interconnected routers
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- Access Networks:
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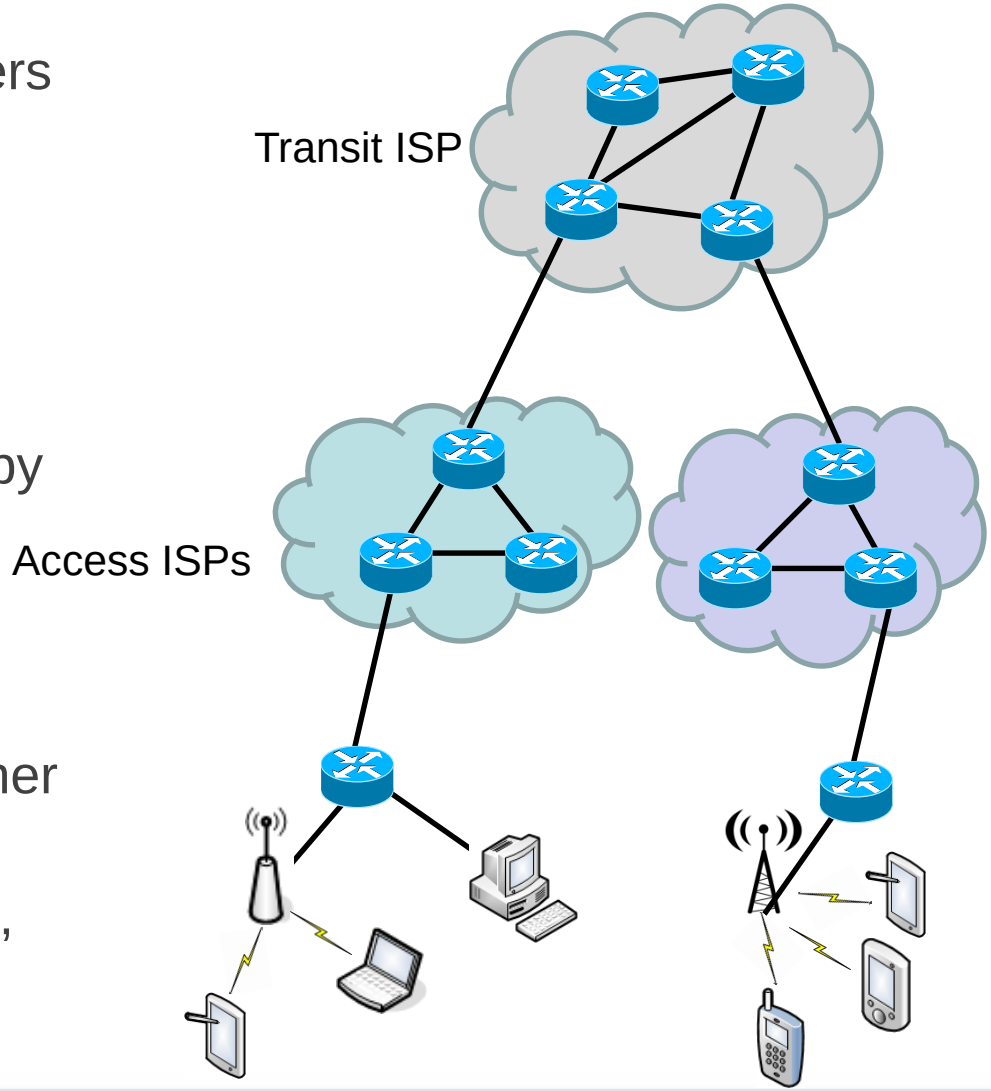
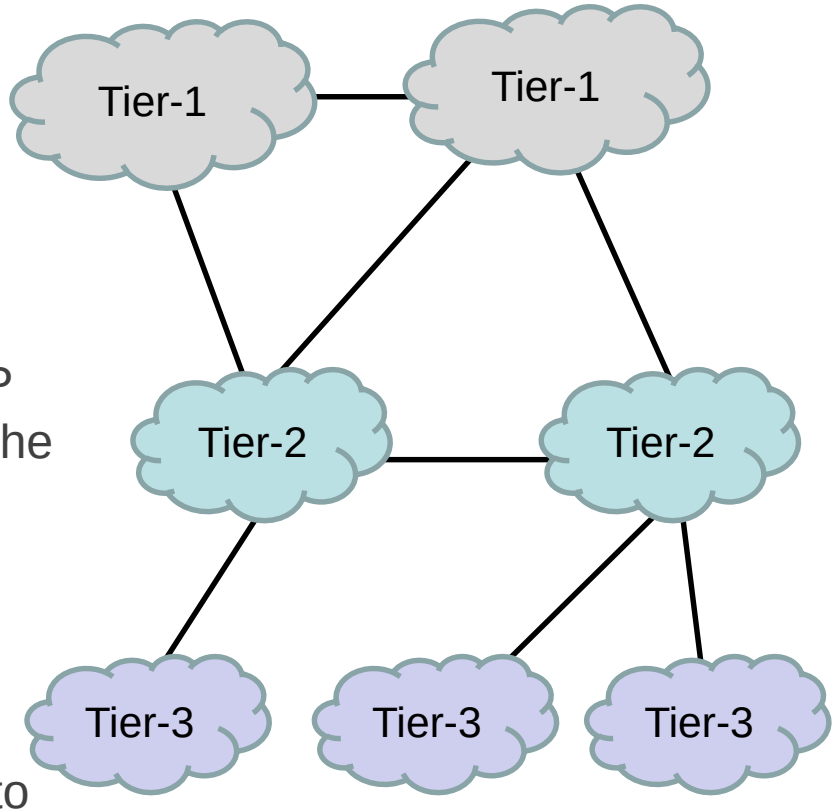
- End-systems:
  - Desktops, laptops, PDAs, other mobile terminals
  - Run applications (web, email, voice, video, etc.)

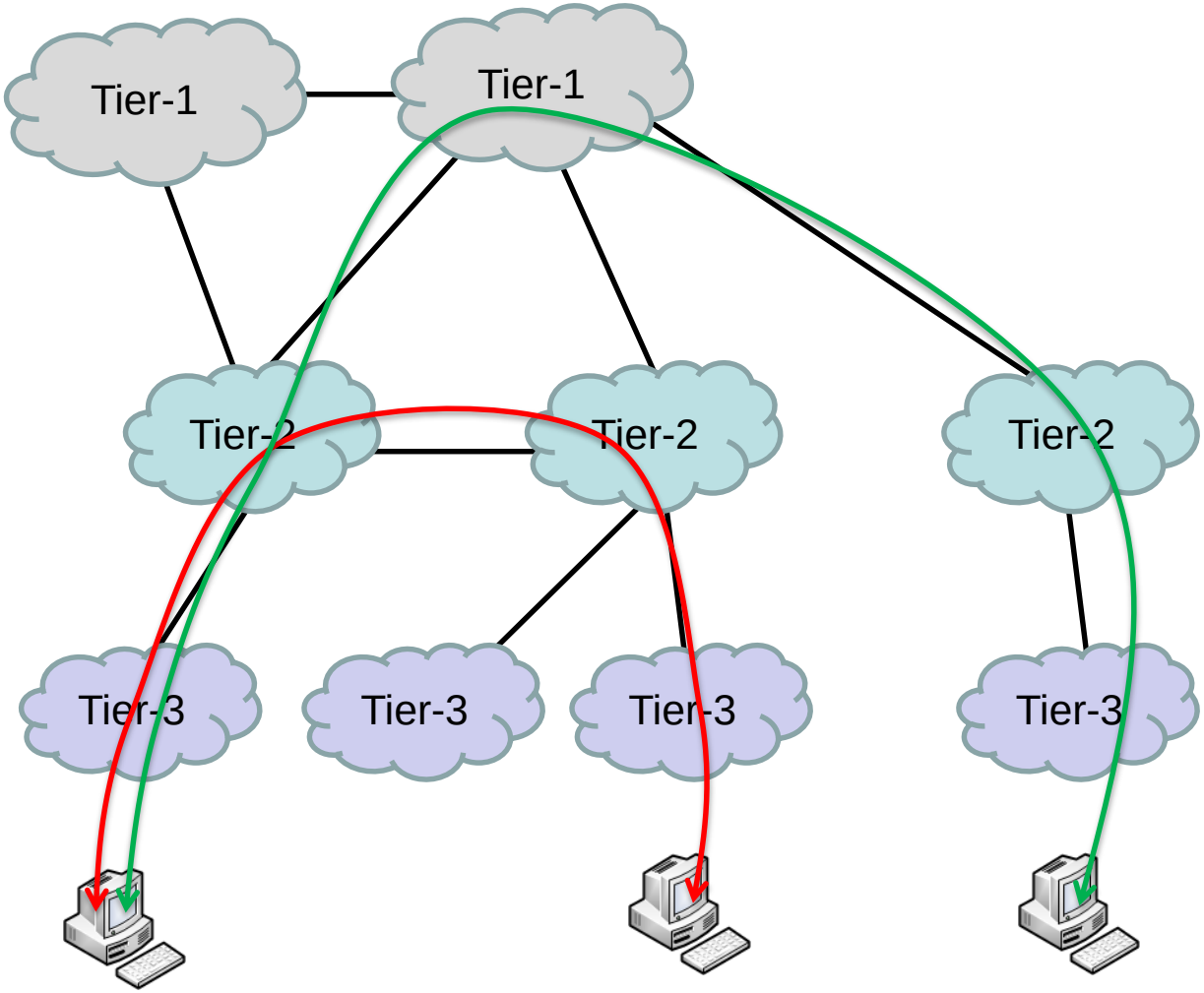


ISPs Taxonomy

- Tier-1 ISPs
  - Transit-free networks that peer with other Tier-1 ISPs
  - e.g., Sprint, Verizon, AT&T, Deutsche Telekom
- Tier-2 ISPs
  - Peer with other ISPs but still purchase IP transit to reach at least some portion of the Internet
  - Peer with at least one Tier-1 ISP
- Tier-3 ISPs
  - Solely purchase transit from other ISPs to reach the Internet
  - Peer with at least one Tier-2 ISP



Internet Paths Across Transit Providers



A Tier-1 ISP (Sprint)

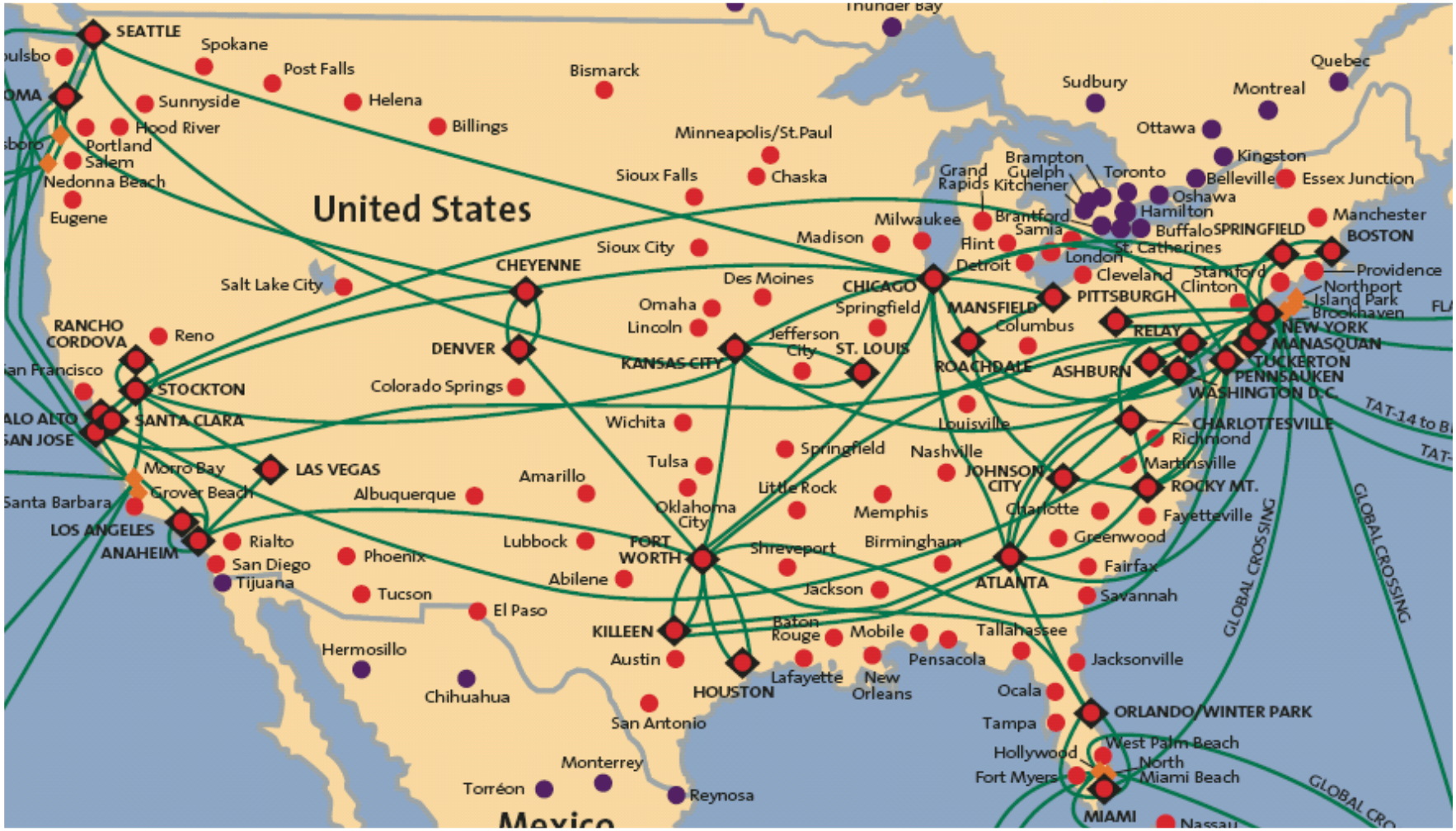
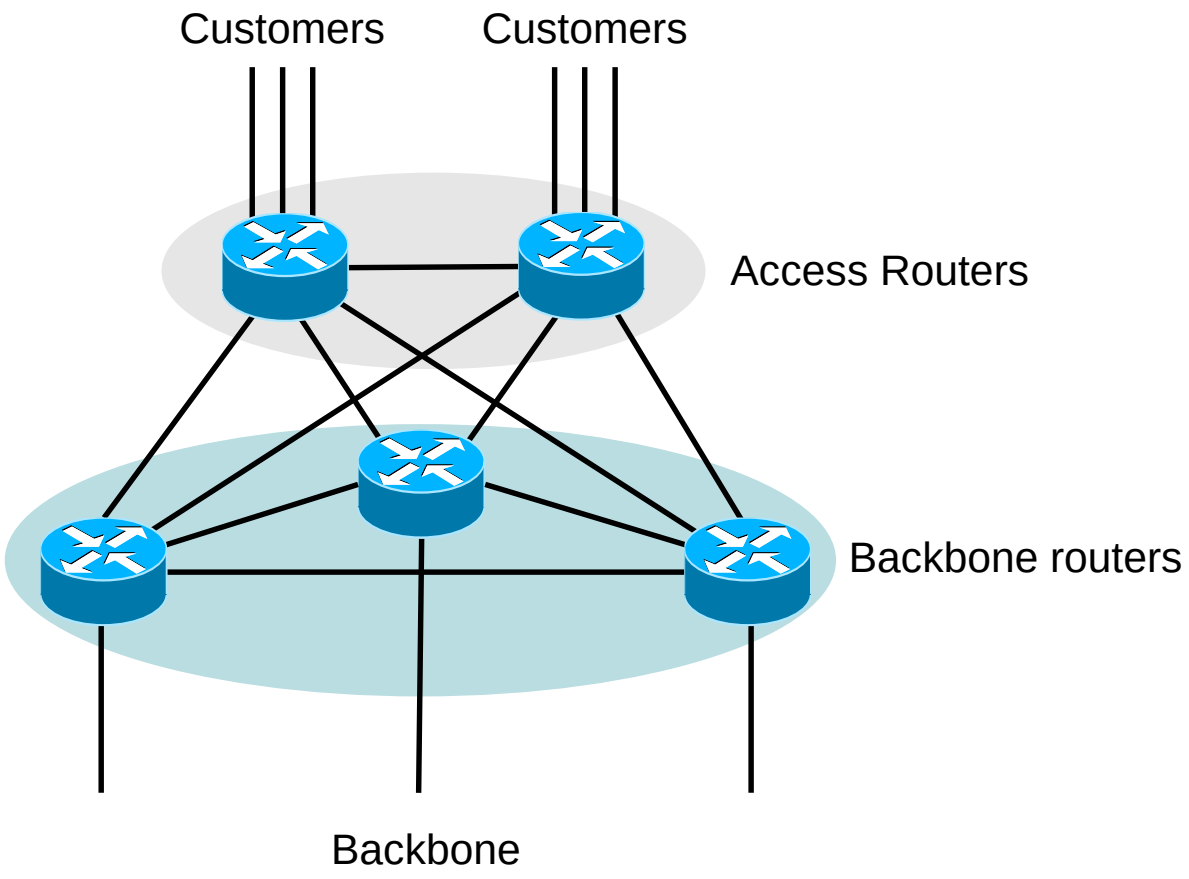


Figure from Computer Networking, A Top-Down Approach

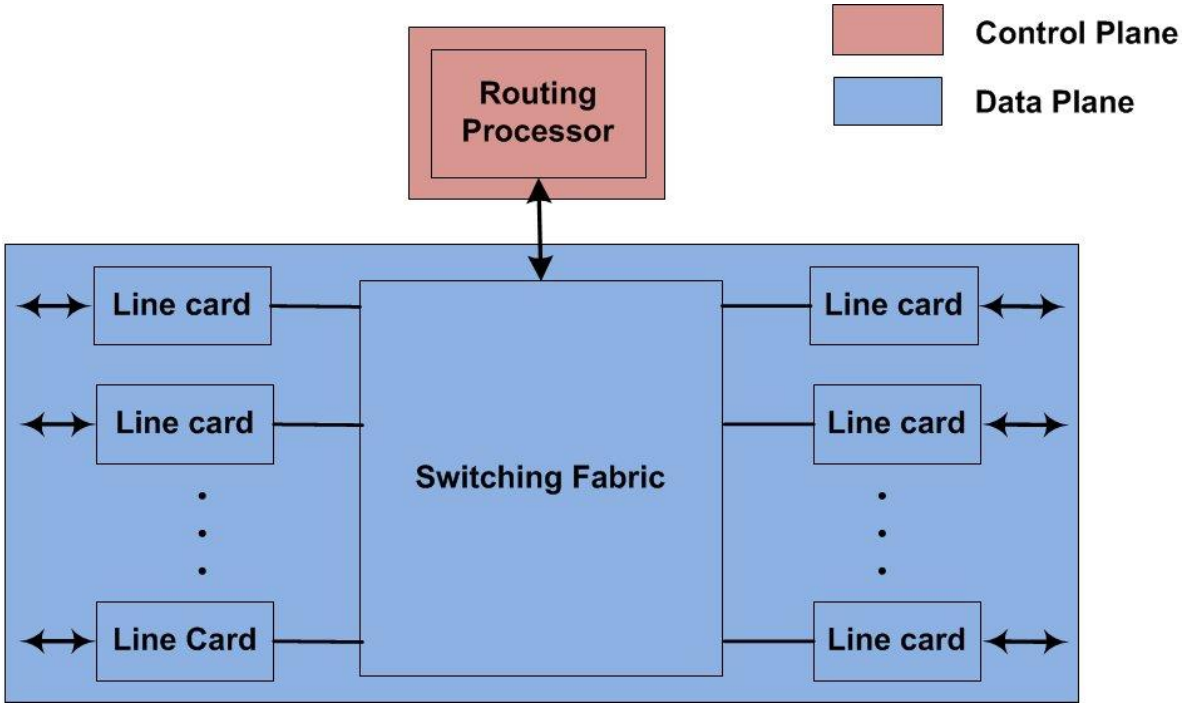
Point Of Presence (PoP)

- A Point of Presence (PoP) consists of access and backbone routers in a specific physical location (i.e., a city or large metropolitan area)



Routers

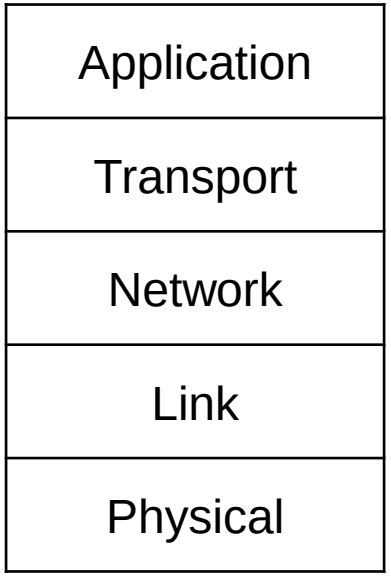
- Data plane:
  - Forwards packets from input to output (speed)
- Control plane:
  - Runs routing protocols to compute the paths that packets will follow



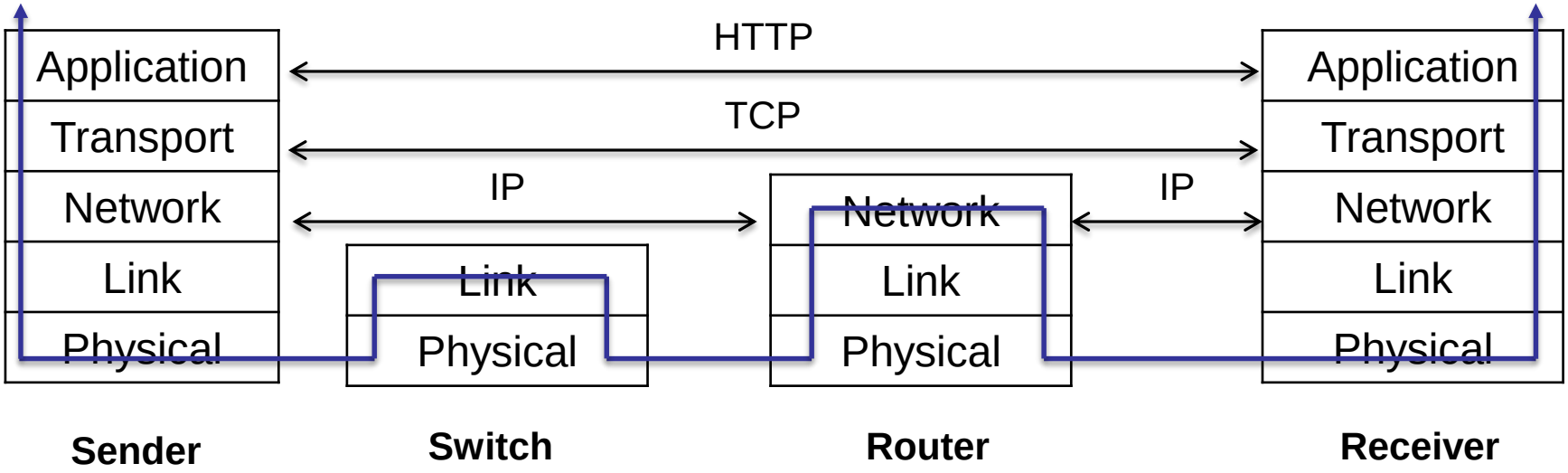
Internet Layering

Internet Layering

- Application:
  - Network application protocols
    - HTTP, FTP, SMTP, DNS, etc.
- Transport:
  - End-to-end data transfer
    - TCP, UDP
- Network:
  - Routing and packet forwarding between end-hosts
    - IP, OSPF, RIP, BGP, etc.
- Link:
  - Data transfer between a pair of neighboring nodes
    - Ethernet, PPP
- Physical:
  - Bits coding into signals for transmission over medium



Layered Representation of Network Nodes



Limitations of Current Internet

Problems with Current Internet (1)

- Address space depletion:
  - IANA's primary address pool was exhausted on February 3, 2011 when the last 5 blocks were allocated to the 5 Regional Internet Registries
  - IPv6 is only partially deployed
  - Network address translation (NAT) is currently the solution

- Lack of Quality-of-Service (QoS) support:
  - Hard to deploy QoS mechanisms (e.g., RSVP, DiffServ) across ISPs
  - Best-effort data delivery (i.e., no guarantees in terms of throughput or latency)

- Security:
  - Viruses, worms, spyware, ….
  - Denial of Service (DoS) attacks
    - Very hard to combat distributed DoS (DDoS) attacks which are launched by botnets

Problems with Current Internet (2)

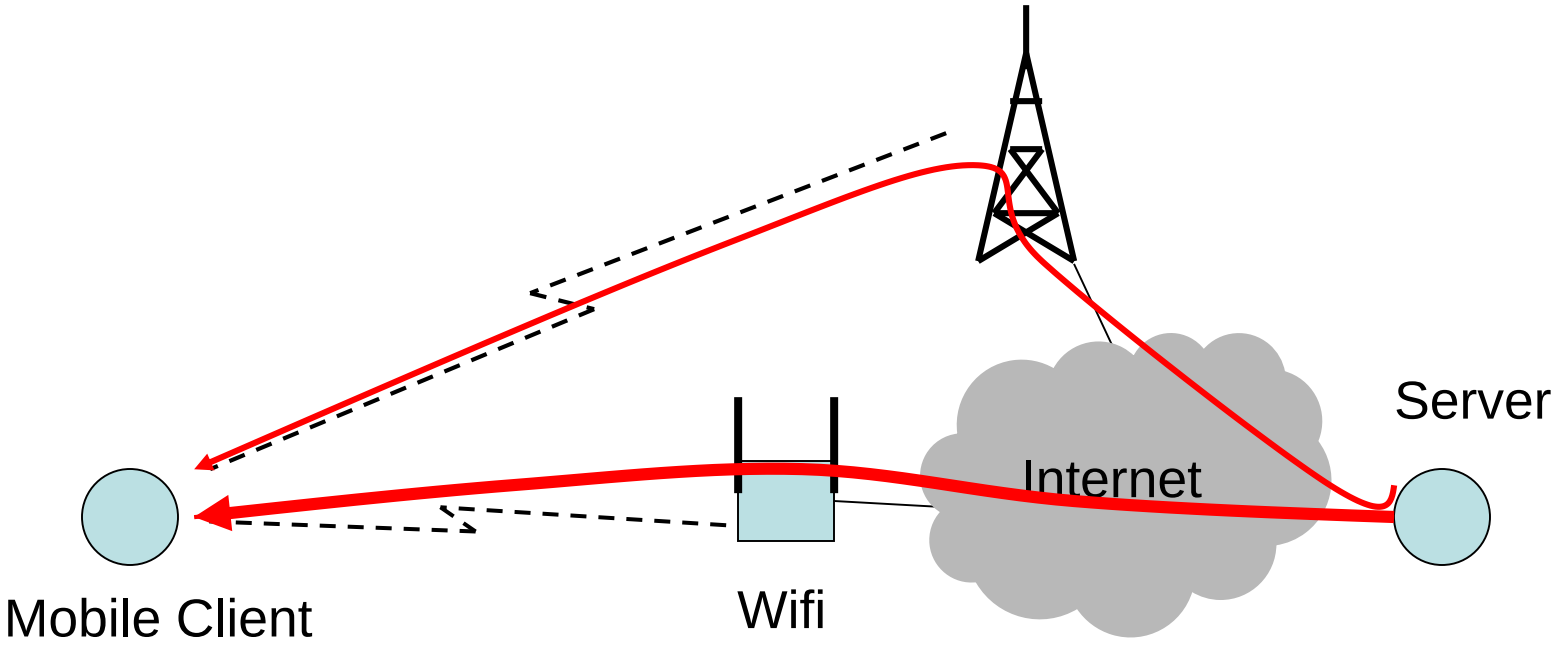
- Spam:
  - Content-based spam filters yield many false-positives
- Application deployment issues:
  - Middleboxes (e.g., NAT, firewall, IDS) violate Internet layering
    - They process packets above layer 3 (e.g., inspect or rewrite port numbers) without being the end-points of a connection
  - Applications tunneled over HTTP to pass firewalls
  - Hard to deploy TCP-incompatible transport protocols
- Lack of persistent data names:
  - When data is moved, the name is no longer valid
  - Currently addressed with DNS and HTTP redirections

New Device Features

- Mobility
  - Proliferation of mobile devices and applications
  - Users want to access Internet without service disruption on-the-go
  - Limited support for mobility (e.g., Mobile IP)

- Multi-homing
  - User devices (e.g., laptops, mobile phones) may have multiple interfaces (e.g., Wifi and 3G)
  - Splitting traffic between interfaces can significantly increase throughput and provide resilience
  - Multi-path routing and congestion control have not been yet deployed in the Internet

Multi-Path Data Transport



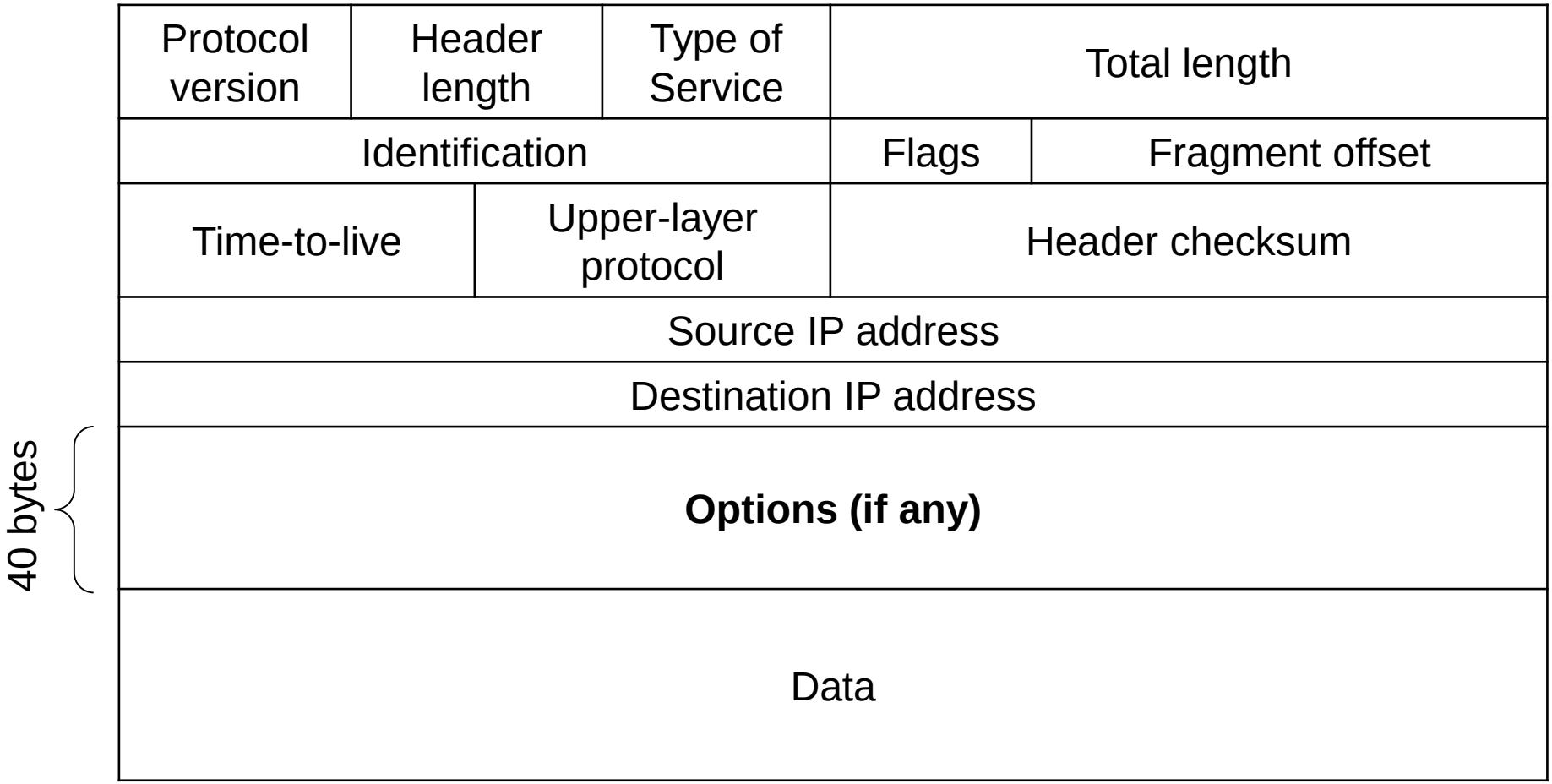
Architectural Ossification

- New technologies have been deployed only at the edge:
  - Congestion control protocols
  - Content distribution
  - Overlay routing
  - Peer-to-peer protocols

- The Internet core has remained almost unchanged:
  - Same protocols: IP(v4), BGP, DNS

Why the Internet has not evolved?

- IPv4 was designed to be extensible (via the “Options” field)



“IP Options is not an Option”

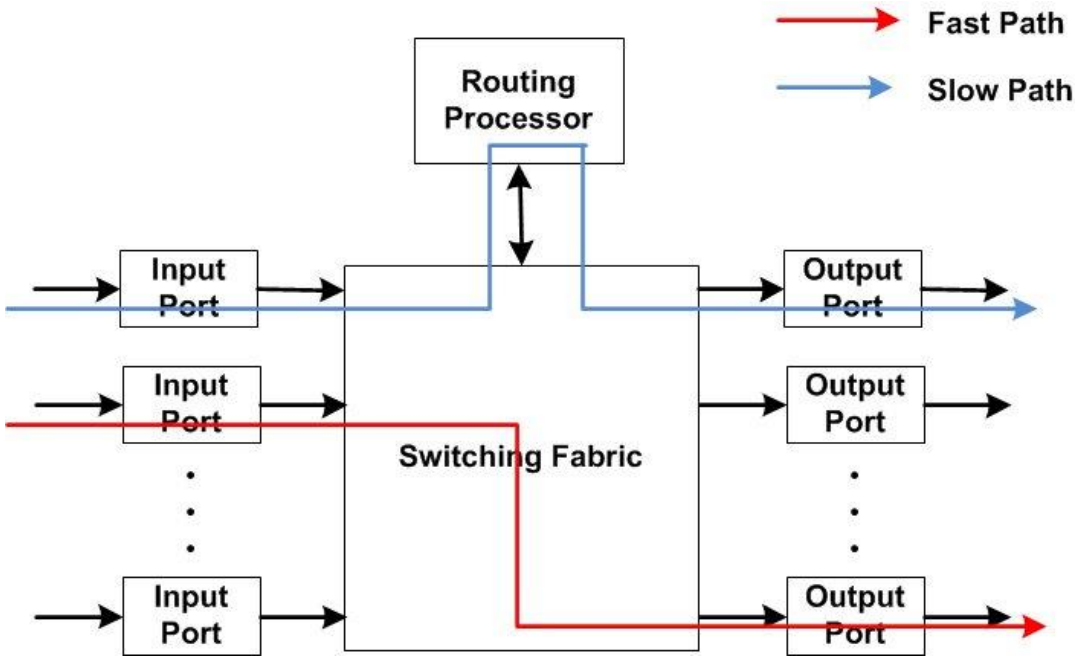
- Packets with IP options are likely to be dropped:

Option	# Paths	Success Rate
No option	17.457	100.00
Timestamp	6.049	34.65
Record Route	9.430	54.02

R. Fonseca, et al., “IP Options are not an option”, 2005

Why packets with IP options are dropped?

- Packets with IP options have to be processed on the slow path:
  - Packet processing on the slow path is resource intensive
  - Network operators may prefer to configure the routers to drop packets with options to prevent the router's CPU overload
  - Cisco routers include a "drop-options" command



What about IPv6?

- IPv6 separates the use of options:
  - hop-by hop option header
  - end-to-end option header

- Hop-by-hop headers are intended for intermediate routers, and thus are the only ones that affect the Internet core

- Unfortunately, IPv6 deployment is very slow

References

- M. Handley, **Why the Internet only just works,** BT Journal 2006
- A. Feldmann, **Internet Clean-Slate Design: What and Why?,** ACM CCR 2007
- R. Fonseca, et al., **IP Options are not an option**, 2005