Switch classifications

We’ll consider multiple ways of classifying switches:
1. By location in hierarchical network
2. By functionality
3. By modularity of implementation
4. By form of switching fabric (details later)
Hierarchical networks

A network can be defined recursively as...

1. Multiple nodes connected by a link
2. Multiple networks connected by multiple nodes

Images from Peterson & Davie?
Benefits of hierarchical switching

- Heterogeneous access networks
- Localise problems
- Localised traffic needn’t burden core
  Spatial locality – how much usually leaves a workgroup
  switch to the next level of the hierarchy?

Align network topology with geography?
Benefits of hierarchical switching (continued)

Align network topology with geography:

- **Distribute** management/administration of network
- **Different operators** for different *levels* of the hierarchy:
  - **Local area**: private institutional network
  - **Metropolitan area**: public network providers
    - Few provide physical infrastructure: Telstra, Optus
    - Multiple provide service: +ISPs
  - **Wide area**: many provide physical infrastructure and service

But benefits of alignment with *organisational boundaries* may be stronger, as we’ll see later when covering Virtual LANs
Examples of network hierarchy

1. The Bell Telephone system

(before divestiture in 1984, after which it lost its regular structure)
Examples of network hierarchy

2. The Internet

Reach

Internet2

+ “Dot bombs”: Global Crossing, UUnet, ...

NSPs

AARnet (NSP 1)

Optus (NSP 2)

Telstra (NSP 3)

(nswrno)

ISPs

UNSW (ISP 1)

AOL (ISP 2)

OzEmail (ISP 3)

BigPond (ISP 4)

NSP = Network Service Provider

ISP = Internet Service Provider

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Hierarchical switching in the Internet

Exercise: Use `traceroute` to view which networks packets traverse to reach their destination.

Many servers available through `www.traceroute.org`

e.g.: `www.telstra.net`
  `------------------`
  `reach.com`
  `------------------`
  `bbnplanet.net`
  `------------------`
  `mit.edu`

  `------------------`
  `unsw.edu.au`
  `------------------`
  `aarnet.net.au`
  `------------------`
  `pnw-gigapop.net`
  `------------------`
  `ucaid.edu`
  `------------------`
  `nox.org`
  `------------------`
  `mit.edu`

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Path from UNSW to www.irtf.org

$ traceroute www.irtf.org
traceroute to www.irtf.org (192.150.187.18), 30 hops max, 38 byte packets
1 eebu4s1.uwn.unsw.EDU.AU. 92.171.149.in-addr.arpa (149.171.92.2) 14.624ms 0.775ms 1.040ms
2 129.94.255.181 (129.94.255.181) 0.436ms 0.409ms 0.384ms
3 gig2-2.nswrnosbb.nswrno.net.au (138.44.1.37) 0.582ms 0.563ms 0.527ms
4 vlan948.gbe3-0.sccn1.broadway.aarnet.net.au (192.231.212.49) 1.450ms 0.805ms 0.758ms
5 pos1-0.sccn1.seattle.aarnet.net.au (192.231.212.34) 157ms 156ms 157ms
6 Abilene-PWAVE-1.peer.pnw-gigapop.net (198.32.170.43) 166ms 165ms 166ms
7 snvang-sttlng.abilene.ucaid.edu (198.32.8.10) 174ms 173ms 173ms
8 losang-snvang.abilene.ucaid.edu (198.32.8.94) 180ms 180ms 180ms
9 hpr-lax-gsr1--abilene-LA-10ge.cenic.net (137.164.25.2) 190ms 190ms 190ms
10 dc-lax-dc1--lax-hpr1-ge.cenic.net (137.164.22.12) 181ms 181ms 181ms
11 dc-sac-dc1--lax-dc1-10ge.cenic.net (137.164.22.127) 190ms 190ms 189ms
12 dc-oak-dc2--csac-dc1-ge.cenic.net (137.164.22.110) 201ms 201ms 201ms
13 dc-oak-dc1--oak-dc2-ge.cenic.net (137.164.22.124) 192ms 193ms 192ms
14 dc-svl-dc1--oak-dc1-10ge.cenic.net (137.164.22.30) 192ms 193ms 193ms
15 ucb--svl-dc1-egm.cenic.net (137.164.23.66) 194ms 194ms 193ms
16 fast4-0-0.inr-667-eva.Berkeley.EDU (128.32.0.99) 203ms 203ms 204ms
17 router2-fast0-0-0.ICSI.Berkeley.EDU (169.229.0.30) 195ms 195ms 195ms
18 www.irtf.org (192.150.187.18) 195ms 195ms 194ms

common phrases:
gig, ge: Gigabit Ethernet
pos: Packet Over SONET

3 delay measurements for each hop
Delays vary with link congestion

Large increase in delay as packets pass over the Pacific Ocean
Networking terms borrowed from trees

Certain networking terms come from the structural similarities between networks and trees

**Leaves**: The perimeter of the network, e.g. end-users.

**Branches**: Join leaves & branches together.

**Trunk**: High capacity, joins everything together.

**Root (singular)**: Foundation for remainder.
Examples of hierarchical network terms

Terms borrowed from trees:

**Spanning Tree Protocol** - Bridges elect a root for the tree.

**Multicast** - “leaf-initiated join”; *pruning* and *grafting*

Other terms that describe hierarchy:

Core/backbone *vs* periphery/edge
Outline
Switch classification 1: By location in hierarchical network

Private networks moving towards network core

Desktop switch (may merely be a shared-media LAN)

Workgroup / LAN switches

Campus switch

Enterprise switches

Access networks

Public networks

Distribution / “transport” networks

Cisco Catalyst 4006

Cisco 12000 router

D-Link DES-1250G

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Switch trends as location in hierarchy changes

How do switches change as you move into the network core?

1. **Availability** becomes increasingly important
   - High-reliability components
   - Redundancy in power supplies, even redundant fabrics
   - Hot swapping of line interfaces & power supplies
   - May employ “protection switches” to bypass failed switches (low switching rate, high throughput)

2. **Throughput** becomes increasingly important
   (though load may be less variable)

3. **Reduced functionality**, e.g. NAT, DHCP servers, firewalls, QOS tend to be implemented in workgroup switches but not core switches.
Switch trends as location in hierarchy changes
(continued)

4. Fewer **interfaces** with higher capacity (& cost)
e.g. fiber (not TP), SM (not MM)
   May also offer *public*-network interfaces, e.g. ISDN – low-speed, pay-per-use

5. More heterogeneous interfaces (**although workgroup switch often has fast link for trunks**)

6. More symmetrical data flow

7. Transit switching (**anycast**), rather than line switching (**unicast**)
Outline
Switching network taxonomy

Each network at one level of a public network usually connects to multiple networks at higher levels in order to provide fault tolerance.
Unicast and anycast switching

Terms used in public networks:

**Line switches**: unicast: specific input to specific output

**Transit switches**: anycast: specific input to one of several outputs, e.g., several lines connecting this switch to another.
Switch classification 2: 
By functionality

Terms used for components in space-division networks†:

**Connection network** *(unicast)*: Any *specified* unused input may be connected to any *specified* unused output.

**Concentrator network** *(anycast)*: Any *specified* input may be connected to any *unspecified* output. (e.g. select *any* telephone operator who is available; select *any* available trunk)

**Expansion network** *(multicast)*: A specified input may be connected to several specified outputs.

† Which we’ll define next week. This basically means that spatially separated paths through the switch can concurrently carry different information through the switch.
Outline
Switch classification 3:
By modularity of implementation

**Bounded systems:** fixed, pre-determined configuration.

**Stackable switches:** intra-stack connection:
- high-speed port (e.g. Gigabit Ethernet)
- Low Voltage Differential Signaling (LVDS)

**Chassis switches:**

Increasing:
- cost
- performance
- flexibility
Dominant manufacturers

**Computing background** (common in access networks)

- D-Link
- Netgear
- Extreme
- 3Com
- Cisco
- Juniper

**Telephony background** (common in core networks)

- NEC
- Lucent
- Nortel
- Marconi
- Alcatel
Cisco

One of the pioneers
Established IOS that provides consistent interface to their systems
Preaches IOS and products through certification programs, e.g. CCNA, CCNP, CCIE
Good support networks
Expensive

Online tour of Carrier Routing System (CRS)-1
Outline
History

Switching (and hence switches) preceded routing.
⇒ separation between “switch” (e.g. phone switch) and packet networks (using gateways, routers, etc)

In the 1990s, the “need for speed” led to new “switching” techniques ⇒ association between “switch” and “fast”.

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Pronunciation of “routing”

“Roo’·ting” is what fans do at a football game, what pigs do for truffles under oak trees in the Vaucluse, and what nursery workers intent on propagation do to cuttings from plants.

“Rou’·ting” is how one creates a beveled edge on a tabletop or sends a corps of infantrymen into full-scale, disorganized retreat.

Either pronunciation is correct for routing, which refers to the process of discovering, selecting, and employing paths from one place to another (or to many others) in a network.”

– D. Piscitello and A. Chapin: *Open Systems Networking: TCP/IP and OSI*

Or more succinctly: “there are two different ways to pronounce the word router, either as “rootor” or as “rowter,” and people waste a lot of time arguing over the proper pronunciation [Perlman 1999].” [Kurose and Ross, p. 475]

+ **Australian slang!**

Truffle hunting photo from www.paristempo.com/art/06truf-pig.jpg

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Marketing classification

The most widespread, and eventually you have to use it to purchase products
Designed/evolved to earn revenue for manufacturers: It’s easy to upsell to a
bewildered customer

**Router**: A multiport device that uses network layer (e.g. IP) headers to decide
which port to forward packets on
- e.g. Cisco 7000 series *router*

**Switch**: A multiport device that uses link layer (e.g. Ethernet) headers to decide
which port to forward packets on
- e.g. Cisco Catalyst 2900 Series

This course deals with the design of both routers *and* switches, in the marketing
sense.
Concerns about marketing terms

- Classification according to layer (switch=link, router=network) doesn’t say anything about **different functionality**.

- **Doesn’t this just shift the question to one of numbering layers?**
  - e.g. is ATM a link layer or a network layer technology?
  - ATM is a link layer: You can send IP packets *over* it
  - ATM is a network layer: It concatenates links to form a path between systems connected to the ATM network.

- **What is a “layer 3 switch”?** e.g. Cisco Catalyst 4840G
  - or for that matter, a “switch router”, e.g. Cisco Catalyst 8500
  - Answer: A fast router.

- And **questions arising in other layers** (apart from link/network):
  - Layer 4: What is layer 4 switching?
    - e.g. Cisco Catalyst 6500 Series Content Switching Module
  - Layer 2: Do switches differ from bridges?
  - Layer 1: What do we call a device that operates only at the physical layer (e.g. MEMS photonic switch using mirrors)? What some such devices are called “lambda routers”?
The issue of speed

A “router” may require more processing than a “switch”, so may operate slower† (packets/sec) for a given technology

Ethernet switch:
1. Use frame addresses to index a database, indicating which outgoing port to use.
2. Start forwarding to outgoing port (needn’t wait to check CRC)

Router:
1.2: Ethernet processing (check destination address, check CRC, frame validity checks), and only once that is complete, pass the packet up to the network layer
+ 3. IP processing (check destination address, decrement TTL, packet validity checks, IPv4 segmentation&reassembly)

⇒ perception that routers are slower than (Ethernet) switches

Heaven forbid us marketing a device whose name has “slow” connotations!
→ “switch router” “layer 3 switch” = fast router (e.g. lots of hardware, start IP processing before receive Ethernet CRC).
Classification by implementation

Packet switches traditionally operated on datagrams: self-contained data units.
Routing/switching/forwarding decisions (e.g. which port, which queue, etc) can be made:

- **Each time** a datagram arrives. This causes appreciable load:
  - processing to make these decisions
  - bandwidth to convey information used for decision making
- **At the beginning** of a flow of packets. Store the state, and refer back to those decisions whenever subsequent packets arrive. Couldn’t this reduce the processing load?

⇒ “Fast Packet Switching” (e.g. ATM):
1. Set up state info in switches
2. Transfer data
3. Release state info in switches

e.g. “switches” contain more state information than “routers” & this state info is explicitly established and released for each flow/connection.
Functional classification of verbs

Functional sense of the words:

**Routing**: Determining *how* to get there: Which output port should be used to get to the destination?

**Switching**: The process of going there: Moving information from input ports to appropriate output ports.

Automotive analogy:
   Routing = Navigating, Switching (lanes) = driving the vehicle

The 2 functions can be physically separated
   e.g. ATM & MPLS: device that determines routes may be separate (e.g. it could be centralised & omniscient) from the devices that actually do the switching

**This course deals with switching** in the general sense.
   We care about achieving functionality, not with naming products.
   It does *not* deal with routing, neither algorithms (e.g. Bellman-Ford) nor protocols (e.g. BGP). (It does deal with routers.)

† Sometimes called “forwarding” to avoid confusion about switching being only part of the role of a switch.

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Nouns: Switch and router

Note that this definition supersedes that given in week 1!!

“Switch” in the functional sense: Any device with multiple ports that aims
to direct unicast traffic only on one port that leads to the destination.

Notes:
“multiple ports” – multiple input ports alone would be a multiplexer;
multiple output ports alone a demultiplexer
“aims to” – bridges may not be able when they haven’t learned the
destination’s location
“one port” rather than “the port” – there might be choices; which port is
the best is a routing decision.

A router is a type of switch that deals with network layer headers.
“a type of switch” ⇒ switch functions (fabrics, packet classification,
scheduling, buffer management etc) are used in routers.
Bridges vs switches

Bridges are a form of “switch”:
• Functional sense: They aim to forward traffic to specific output ports.
• Marketing sense: They operate in the link layer.

But for historical reasons,
1980s: bridge ports were usually connected to shared media networks because:
• bridge ports were expensive (most bridges had 2 or 4 ports)
• most hosts were connected to shared media.
However, they work the same way if single devices connect to their ports.
1990s:
• bridges became cheaper, allowing more (e.g. 20) ports (“multiport bridge”)
• hosts were connected to twisted pair
• bridges became faster, processing frames at “wire-speed” (“media-rate”)
Bridges became known as “switches”, particularly “Ethernet switches”
“Marketers chose to call their products switches primarily to differentiate them from the (more primitive) [non-wire speed] bridges of old.” [Seifert, p. 150]

Fundamentally, their internal operation hasn’t changed.
Bottom-line definitions

**Switch**: Any device with multiple ports that aims to direct input traffic only to the port(s) that leads to the destination(s).

**Router**: A switch that deals with network layer headers.

**Bridge**: A switch that deals with link layer headers.
A variety of textbook definitions

Sources:

• Keshav
• Peterson and Davie
• Kurose and Ross
• Tanenbaum
• McDysan
• Telecom Glossary 2000 [http://www.atis.org/tg2k/]
Keshav’s definitions

**Switch:** “A switch allows data arriving at any of its inputs to be transferred to any of its outputs.” p. 6 & details in Chapter 8

**Routing:** “How can we determine the shortest path from a source to a destination, or the best tree along which to distribute data from a source to a set of destinations? This is the problem of *routing*” p. 7 & details in Chapter 11
Peterson & Davie’s definitions

see pp. 234-237

“the core job of a switch is to take packets that arrive on an input and forward (or switch) them to the right output so that they will reach their appropriate destination. Knowing which output is the right one requires the switch to know something about the possible routes to the destination. The process of accumulating and sharing this knowledge, the second problem for a packet switch, is called routing.”
Kurose and Ross

Section 5.6 pp. 475-6

“routers are store-and-forward packet switches that forward packets using network-layer addresses. Although a switch is also a store-and-forward packet switch, it is fundamentally different from a router in that it forwards packets using MAC addresses. Whereas a router is a layer-3 packet switch, a switch is a layer-2 packet switch.”
Tanenbaum’s definitions

“As an aside, some people make a distinction between routing and switching. Routing is the process of looking up a destination address in a table to find where to send it. In contrast, switching uses a label taken from the packet as an index into a forwarding table. These definitions are far from universal, however.”


Notes:
“some people” but not Tanenbaum?
The distinction here is the method used for classification, with routing presumably being necessary when identifiers are large (globally unique)
"10.2.2 Routing versus switching
Routing is often contrasted with switching. ... The primary difference is that switching occurs at Layer 2, the data link layer, of the OSI model and routing occurs at Layer 3. This distinction means routing and switching use different information in the process of moving data from source to destination.

Another difference between switched and routed networks is switched networks do not block broadcasts."

“The features and functionality of Layer 3 switches and routers have numerous similarities. The only major difference between the packet switching operation of a router and a Layer 3 switch is the physical implementation. In general-purpose routers, packet switching takes place in software, using microprocessor-based engines, whereas a Layer 3 switch performs packet forwarding using application specific integrated circuit (ASIC) hardware.”

“Today, switches are also able to filter according to the network-layer protocol. This blurs the demarcation between switches and routers. A router operates on the network layer using a routing protocol to direct traffic around the network. A switch that implements advanced filtering techniques is usually called a brouter. Brouters filter by looking at network layer information but they do not use a routing protocol.”
References in Keshav

Datagrams and virtual circuits, pp. 48-53, 175-6

See also Keshav’s Infocom97 panel presentation on “Routing vs. Switching” http://www.cs.cornell.edu/skeshav/talks/infocom97panel/

Switching vs routing terminology:
  Keshav: pp. 6-7: Definitions, Ch. 8: Switches, Ch. 11: Routing