Session 6A

Internet Domains and Autonomous Systems

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Session 6A: Focus

- Internet Domains
  - Internet Domain Structure
  - Stub and Transit Domains
  - Internet Exchange Points (IXP)
- Peering Relationships
  - Customer → Provider
  - Provider → Customer
- Routing Domains and Areas
  - Routing between Areas
- Autonomous Systems
  - Inter-domain Routing

Course page where the course materials will be posted as the course progresses:

Internet Domains

What is a Domain?

- A domain is the web address that you type in or search for when you browse the internet.
  - **Example**: Google.com, Yahoo.com, Netflix.com, Amazon.com, Wikipedia.com, and so on.
- There are managed by **ICANN** (Internet Corporation for Assigned Names and Numbers)
- Way back in 1985 when the internet domain name system was implemented, there were 7 top level domains:
  - **com, edu, net, org, arpa, gov, and mil**
- The most popular domain extension is **.com** followed by **.net** and **.org**.
- As of the end of the **second quarter of 2024**, there were an estimated **362.4 million** domain name registrations across all top-level domains (**TLDs**).
- A domain in networking refers to an Autonomous System (**AS**) that operates under a single administrative control.

Internet Domain Name Structure

Component	Value	Description
Scheme	**http**	Protocol used to access the resource (HTTP).
Subdomain	**www**	Indicates the World Wide Web subdomain, typically used for web services.
SLD	**google**	The main domain name representing the entity (Google Inc.).
TLD	**.com**	Top-level domain indicating a commercial entity.

SLD: Second Level Domain

Top Level Domains (TLDs) - Info

Top-Level Domains (examples)

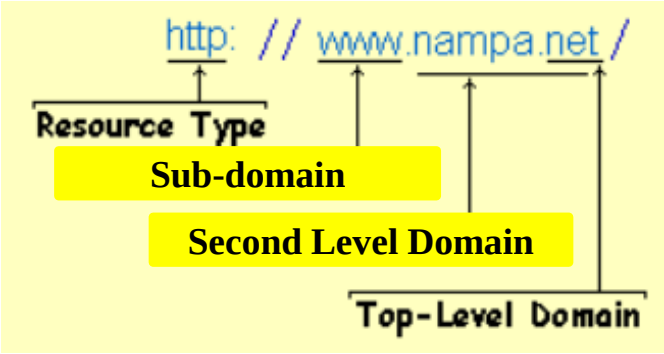
.com	Commercial
.net	Network etc
.org	Non-profit
.edu	Education
.mil	US Military
.int	International
.gov	US Government
.biz	Business
.info	Information

Note: The most popular TLD is:

.com (37%)

More about domains.

Internet Domain Structure: Explained



Top-Level Domain **Generic TLD (gTLD)**

The top level domain is a huge group of similar types of domain names. Some are restricted to only certain people, like .gov **Other Examples: .org, .net, .edu, .mil**

Second Level Domain Name

Registered domain name such as google

Sub-domain

The **www** subdomain is commonly used for the main website, but many other subdomains can be used for different purposes

Other alternative sub-domains:

Common: blog, mail, support, help, etc.
Location-based: us, uk, in, etc.
Business: admin, portal, hr, test, etc.

Resource Type

The type of page. Typical web pages are HTTP, an acronym for 'Hyper Text Transfer Protocol'. HTTPS is secure HTTP. Other resources include, FTP, GOPHER, TELNET etc.

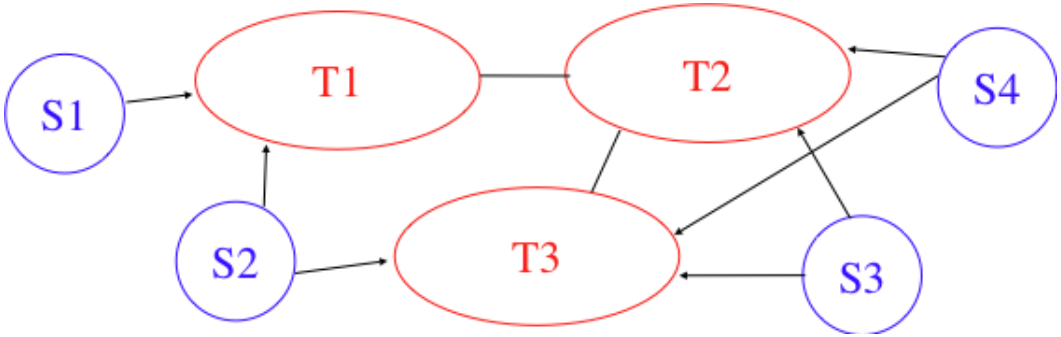
Most visited Websites (as on Nov 24) - Info

Ranking	Website	Monthly Traffic
1	google.com	132,300,000,000
2	youtube.com	72,000,000,000
3	facebook.com	12,900,000,000
4	wikipedia.org	6,700,000,000
5	instagram.com	6,500,000,000
6	reddit.com	5,700,000,000
7	bing.com	4,800,000,000
8	taboola.com	4,200,000,000
9	x.com	4,100,000,000
10	whatsapp.com	3,900,000,000

Source

Domain Types: Stub and Transit

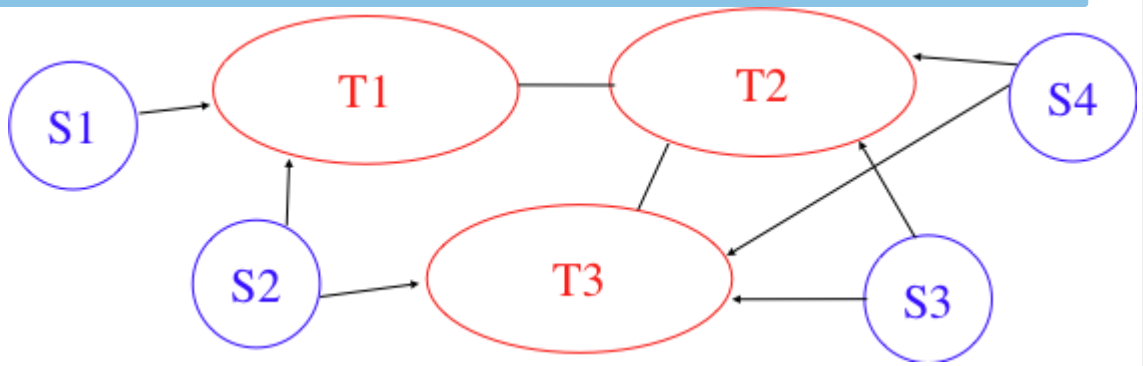
Stub: The short part of something that is left after the main part has been used



- Each domain contains a set of routers.
- Based on how **traffic flows** through them, domains can be classified into **Stub** Domains and **Transit** Domains
- A **stub** domain sends and receives packets whose source or destination are one of its own hosts.
  - Stub domain routers have default routes pointing to their only upstream provider.
- A **transit** domain is a domain that provides a transit service for other domains.
- That is, routers in the transit domain forward packets whose source and destination do not belong to the transit domain.
  - About **85%** of the **domains** in the **Internet** are **stub domains**

Domain Types: Stub and Transit

- S1 to S4 are **Stub domains**
- **T1 to T3** are **Transit domains**



- A **stub** domain that is **connected** to a **single transit domain** is called a **single-homed stub**.
- A **multi-homed stub** is a **stub** domain **connected** to **two or more transit providers**.
- List the following:
  - **Single-homed stub domains**: **S1**
  - **Multi-homed stub domains**: **S2, S3 and S4**

Ref: Domain Names

Stub Vs Transit Domains

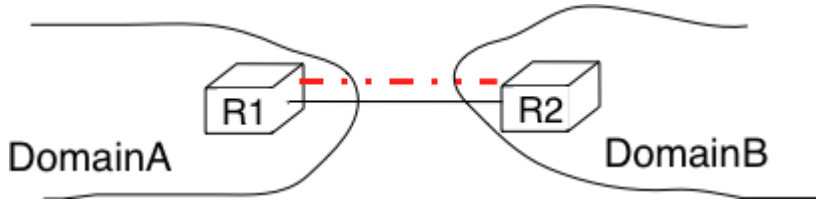
Feature	Stub Domain	Transit Domain
Connectivity	Single connection to another AS	Connected to multiple ASes
Purpose	Only sends/receives its own traffic	Forwards traffic between ASes
Routing Protocols	Uses static routes, OSPF, EIGRP	Uses BGP for external routing
Traffic Handling	Does not carry transit traffic	Routes traffic for other ASes
Examples	Small office, enterprise network	ISP, cloud provider, backbone networks

AS: Autonomous System

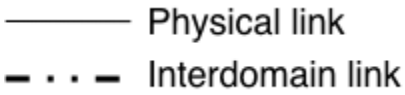
BGP: Border Gateway Protocol

EIGRP: Enhanced Interior Gateway Routing Protocol

Interconnection of Domains



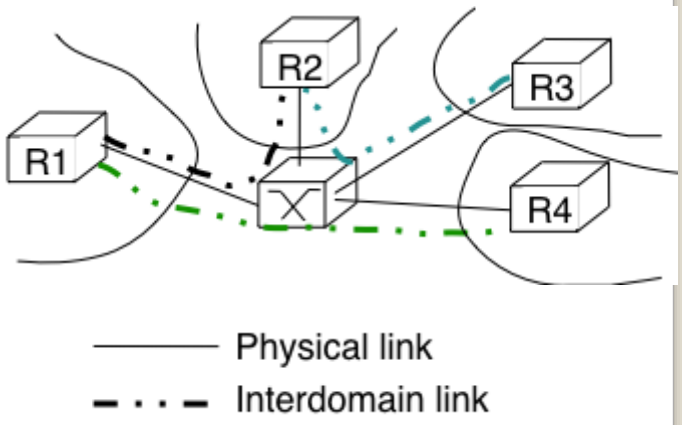
Note: Private peering links are useful when, an enterprise or university network needs to be connected to its ISP.



- Domains need to be interconnected to allow a host inside a domain to exchange IP packets with hosts located in other domains.
- From a physical perspective, domains can be interconnected in two different ways.
- The first solution is to directly connect a router belonging to the first domain with a router inside the second domain.
  - Such links between domains are called **private inter-domain** links or **private peering links**.
- In practice, for redundancy or performance reasons, **distinct physical links** are usually established **between different routers in the two domains** that are **interconnected**.

IXP: Internet Exchange Point

- However, some domains are required to be connected to hundreds of other domains.
- For some of these domains, using only private peering links would be too costly.
- A better solution to allow many domains to interconnect cheaply are the Internet eXchange Points (**IXP**)



- An IXP is usually some space in a data center that hosts routers belonging to different domains.
- A domain willing to exchange packets with other domains present at the IXP, installs one of its routers on the IXP and connects it to other routers inside its own network.
- The IXP contains a Local Area Network to which all the participating routers are connected.

IXPs in India: Mumbai, Chennai, Delhi, Kolkata, Mumbai, Bardhaman: National Internet Exchange of India (**NIXI**)

As of Dec 2023, 40 IXPs are in India

ISPs (Tier-1, 2 and 3) - Info

- **Tier-1 ISPs (Backbone Providers)**
  - Earn revenue from lower-tier ISPs, large enterprises, and CDNs.
  - **Examples**: **AT&T, Tata Communications, CenturyLink, NTT, etc**.
- **Tier-2 ISPs (Regional ISPs)**
  - Pay Tier-1 ISPs for Internet access.
  - Earn revenue from Tier-3 ISPs and businesses.
  - **Examples**: **Vodafone, Airtel, Reliance Jio, Comcast.**
- **Tier-3 ISPs (Local ISPs)**
  - Pay Tier-2 ISPs for Internet access.
  - Earn revenue from end-users (home users, businesses).
  - **Examples: BSNL, ACT Fibernet, Local cable ISPs.**

CDN: Content Delivery Network

CDN providers: Cloudflare, Akamai, Amazon CloudFront, Google Cloud CDN, Fastly

Inter-domain Routing
Peering Relationships

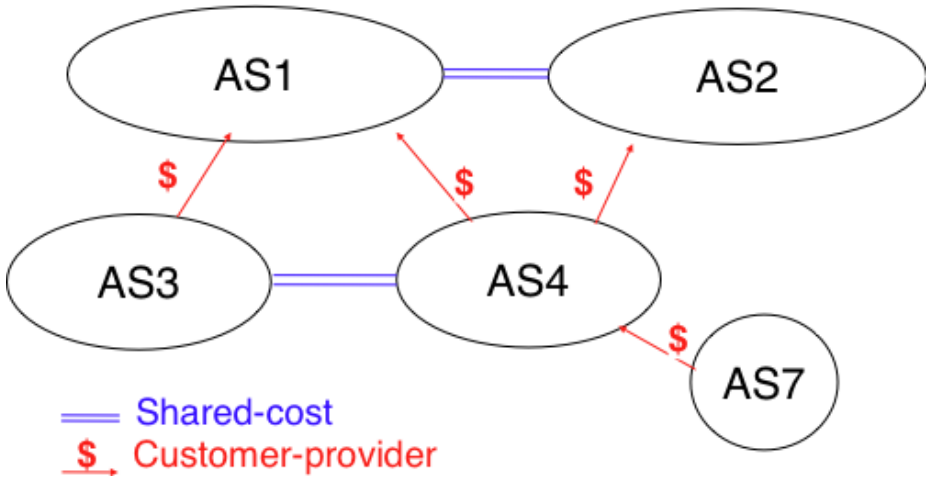
Inter-domain Vs Intra-domain Routing

- In today's highly commercial Internet, **inter-domain** routing mainly takes into account the **economical relationships** between the domains.
  - For inter-domain routing, the cost of using a route is often more important than the quality of the route measured by its delay or bandwidth
- I**ntra-domain** routing usually prefers some routes over others based on their technical merits
  - For example, minimum number of hops, minimum delay, high bandwidth routes over low bandwidth ones, etc

Inter-domain Routing: Peering Relationships

AS: **Autonomous Systems**

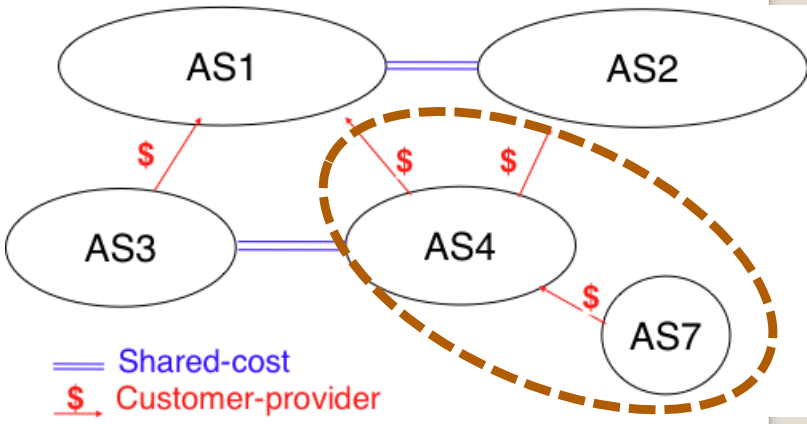
A unit of router policy, either a single network or a group of networks that is controlled by a common network administrator



- The peering relationship in Inter-domain is the **customer → provider** relationship.
- Such a relationship is used when a customer domain pays an Internet Service Provider to be able to exchange packets with the global Internet over an inter-domain link.
- A similar relationship is used when a small ISP pays a larger ISP to exchange packets with the global Internet.

Customer → Provider Relationship

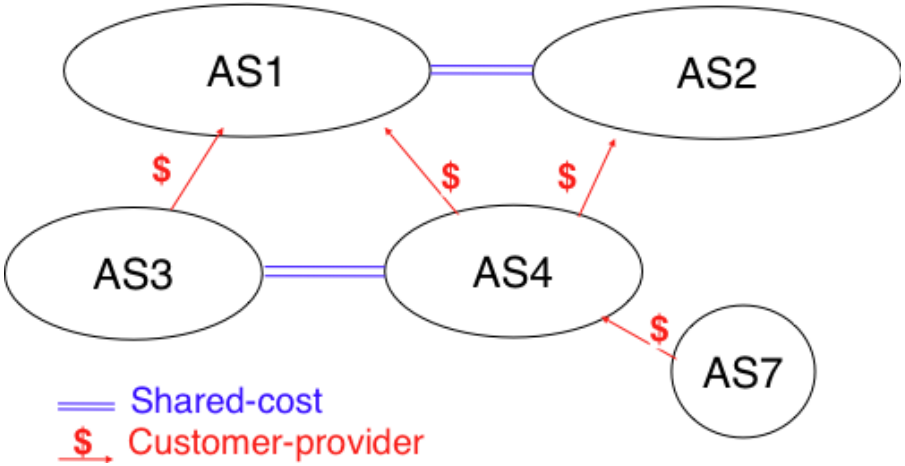
- AS7 is a stub domain that is connected to one provider, AS4.
- The contract between AS4 and AS7 allows a host inside AS7 to exchange packets with any host in the internetwork



- To enable this exchange of packets, AS7 must know a route towards any domain and all the domains of the Internet must know a route via AS4 that allows them to reach hosts inside AS7.
- From a routing perspective, the commercial contract between AS7 and AS4 leads to the following routes being exchanged:
  1. Over a **customer->provider** relationship, the customer domain advertises to its provider all its routes and all the routes that it has learned from its own customers.
  2. Over a **provider->customer** relationship, the provider advertises all the routes that it knows to its customer.

Customer → Provider Relationship

- The first rule allows the routes of the customer domain to be distributed throughout the Internet.

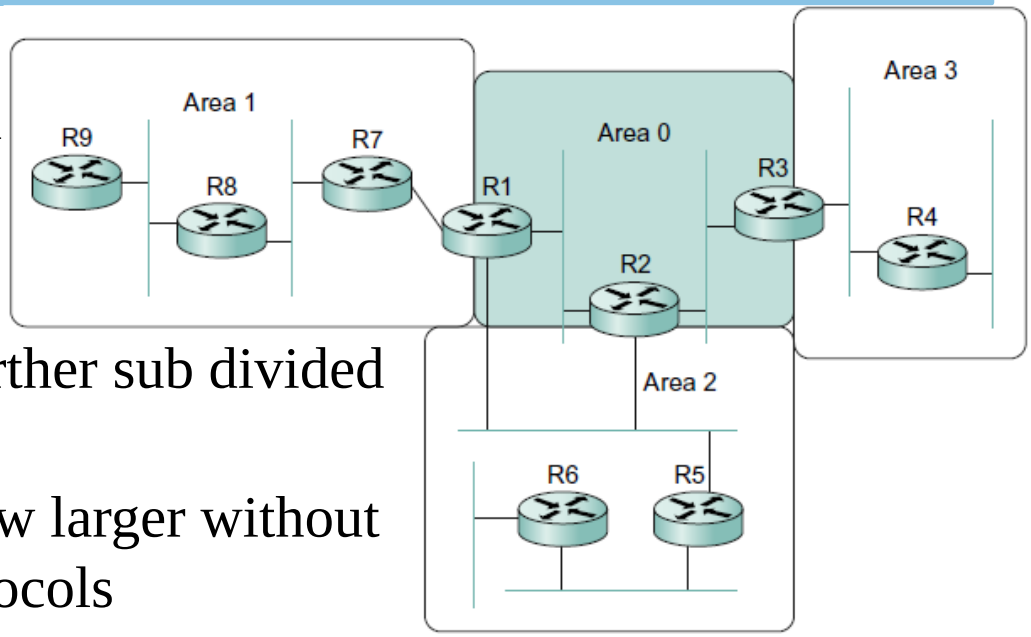


- The second rule ensures that the customer domain receives a route towards all destinations that are reachable via its provider.
- Coming back to the figure above, AS4 advertises to its two providers AS1 and AS2 its own routes and the routes learned from its customer, AS7.
- On the other hand, AS4 advertises to AS7 all the routes that it knows.
- A **shared-cost peering** relationship is usually established between domains having a similar size and geographic coverage.
  - Usually, it does not involve a payment from one domain to the other.

Routing Areas

Routing Domains and Areas

- An area is a set of routers that are administratively configured to exchange link-state information with each other.

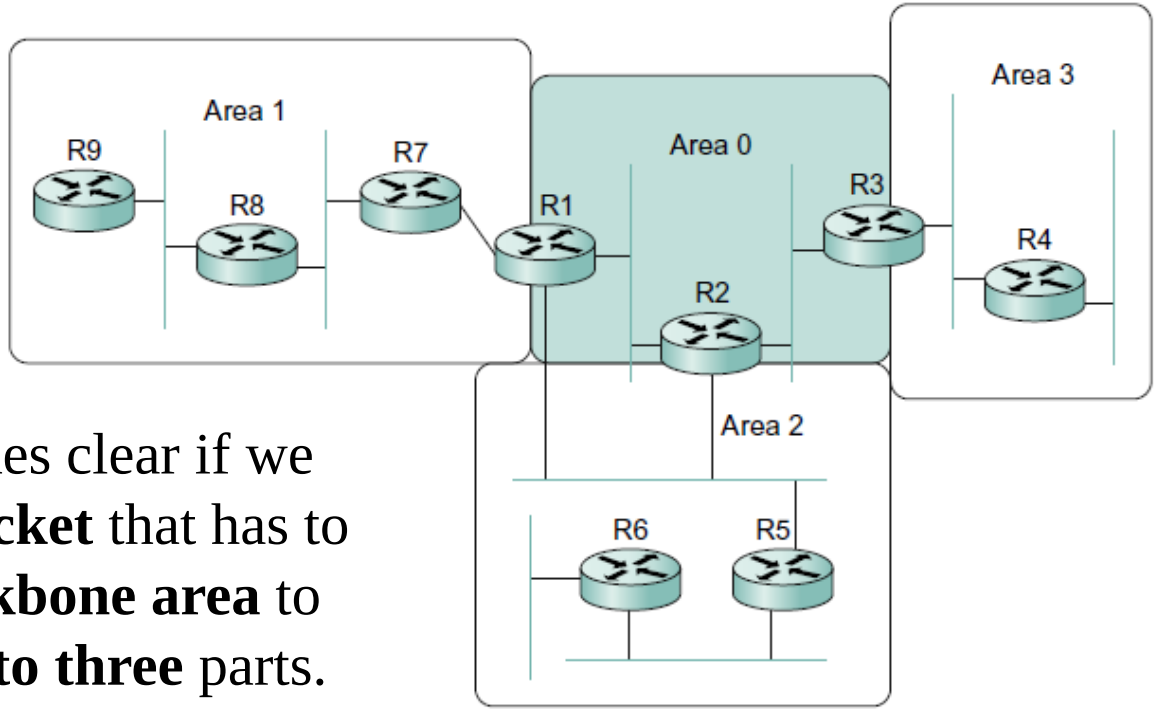


- An OSPF routing domain is further sub divided into subdomains called **areas.**
- It enables single domain to grow larger without overburdening the routing protocols

- There is one special area—the backbone area, also known as area 0.
- Routers R1, R2, and R3 are members of the backbone area.
- They are also members of at least one non-backbone area; R1 is actually a member of both area 1 and area 2.
- A router that is a member of both the backbone area and a non-backbone area is an Area Border Router (**ABR**)

Routing Between Areas

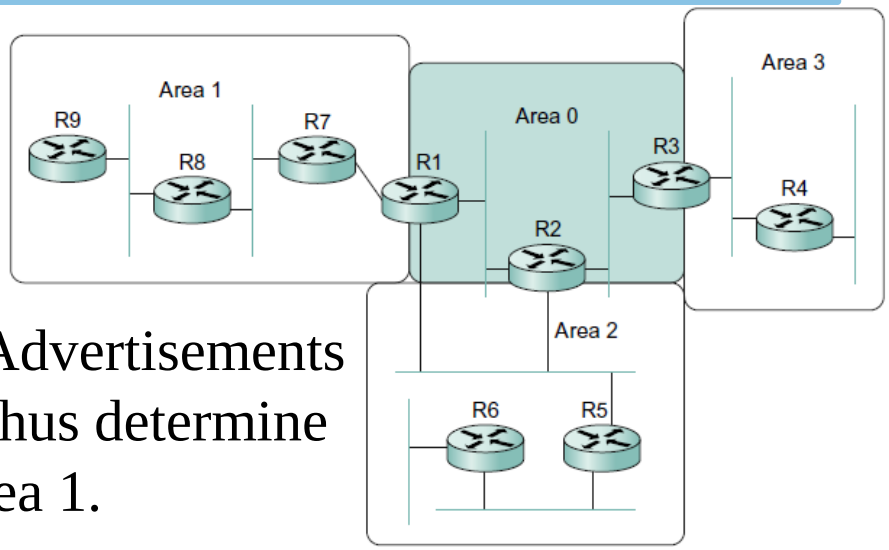
- How does a router in one area determine the right next hop for a packet destined to a network in another area?
- The answer to this becomes clear if we imagine the **path of a packet** that has to travel from **one non-backbone area** to **another** as being **split into three** parts.



1. It travels from its source network to the backbone area.
2. It crosses the source network and enters into backbone area
3. Then, finally the packet travels from the backbone area to the destination network.

Routing Between Areas: Explained

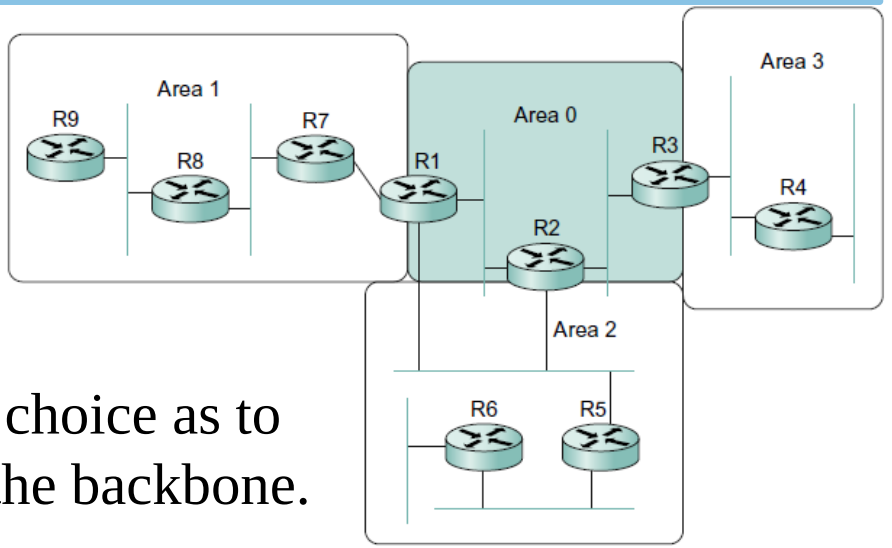
- The ABRs summarize routing information that they have learned from one area and make it available in their advertisements to other areas.



- For example, R1 receives Link-State Advertisements from all the routers in area 1 and can thus determine the cost of reaching any network in area 1.
- When R1 sends LSP into area 0, it advertises the costs of reaching the networks in area 1 much as if all those networks were directly connected to R1.
- This enables all the area 0 routers to learn the cost to reach all networks in area 1.
- The area border routers then summarize this information and advertise it into the non-backbone areas.
- Thus, all routers learn how to reach all the networks in the domain.

Areas with more than one ABRs (Area 2)

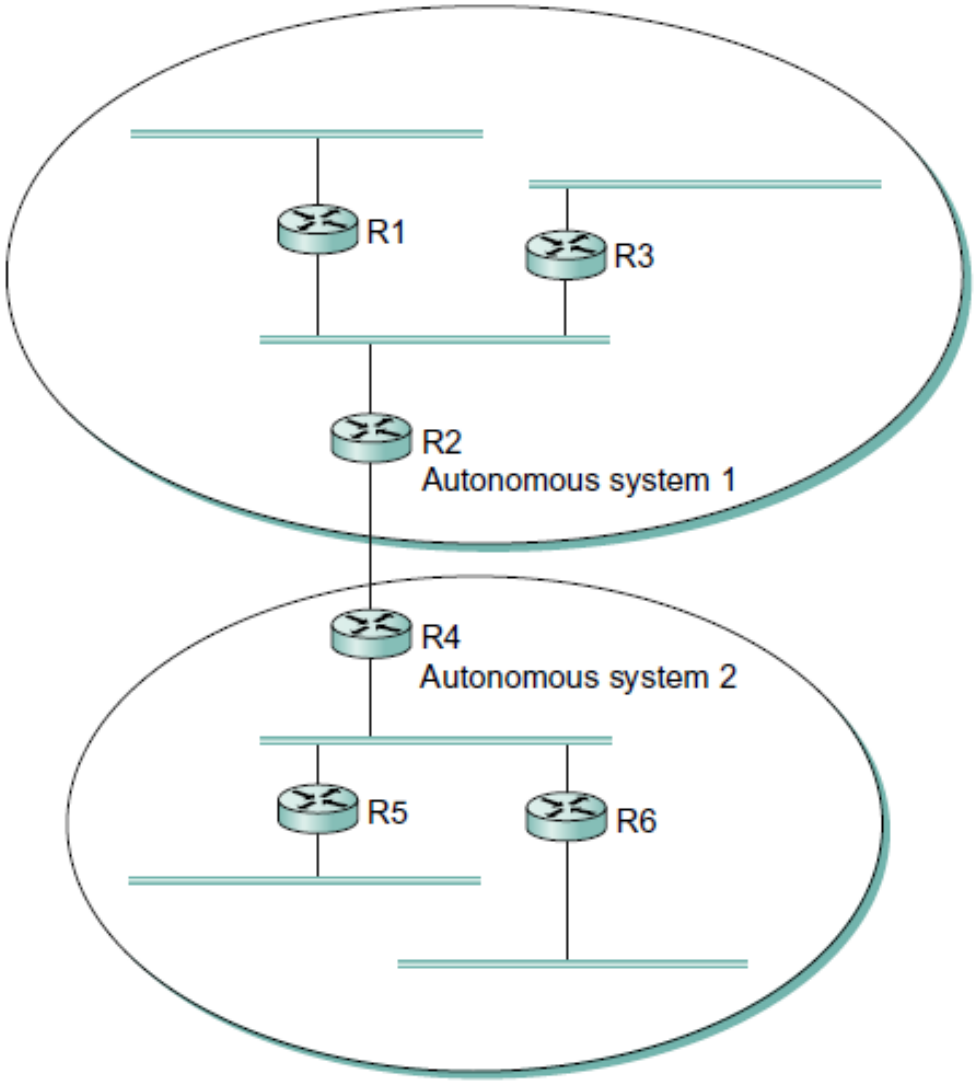
- Note that, in the case of area 2, there are two ABRs, which are R1 and R2.



- Thus area 2 routers have to make a choice as to which one they would use to reach the backbone.
- This is easy enough, since both R1 and R2 will be advertising costs to various networks, so it will become clear which is the better choice as the routers in area 2 run their shortest-path algorithm.
- For example, it is pretty clear that R1 is going to be a better choice than R2 for destinations in area 1.
- The use of areas forces all packets traveling from one area to another to go via the backbone area, even if a shorter path might have been available.

Autonomous Systems

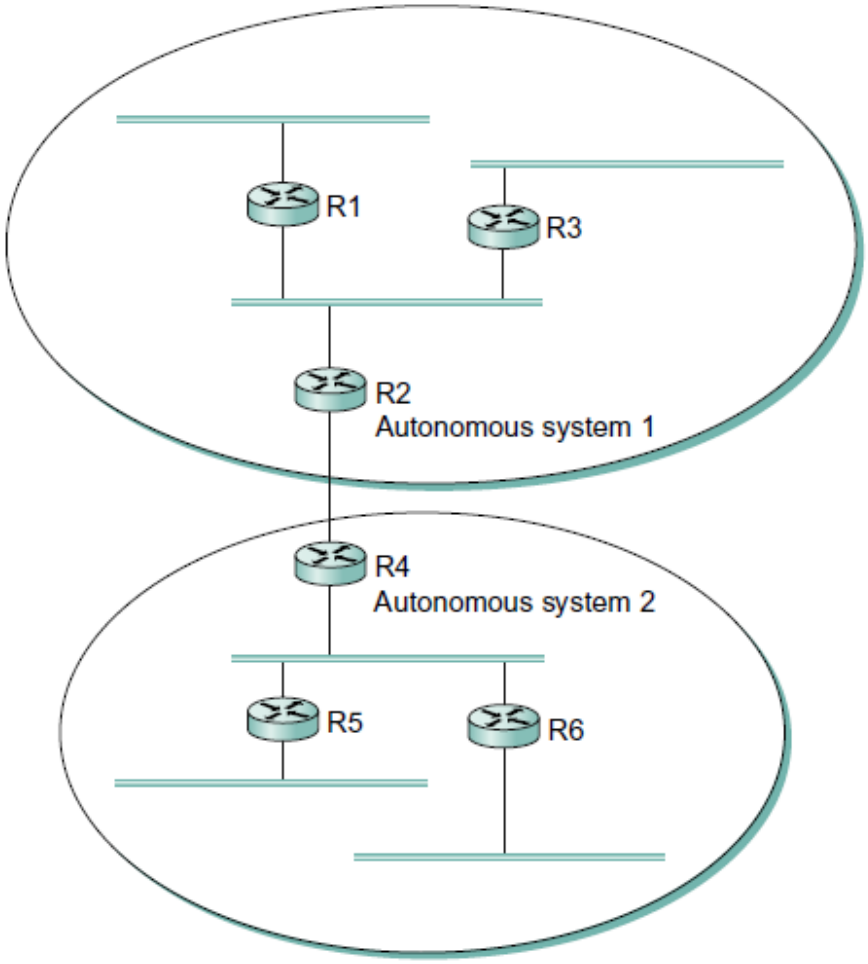
Interconnection of Autonomous Systems



- The basic idea behind autonomous systems is to provide an additional way to hierarchically aggregate routing information in a large internet, thus improving scalability.
- We now divide the routing problem into two parts:

1. Routing within a single autonomous system and
2. Routing between autonomous systems.

Autonomous Systems: Inter-domain Routing



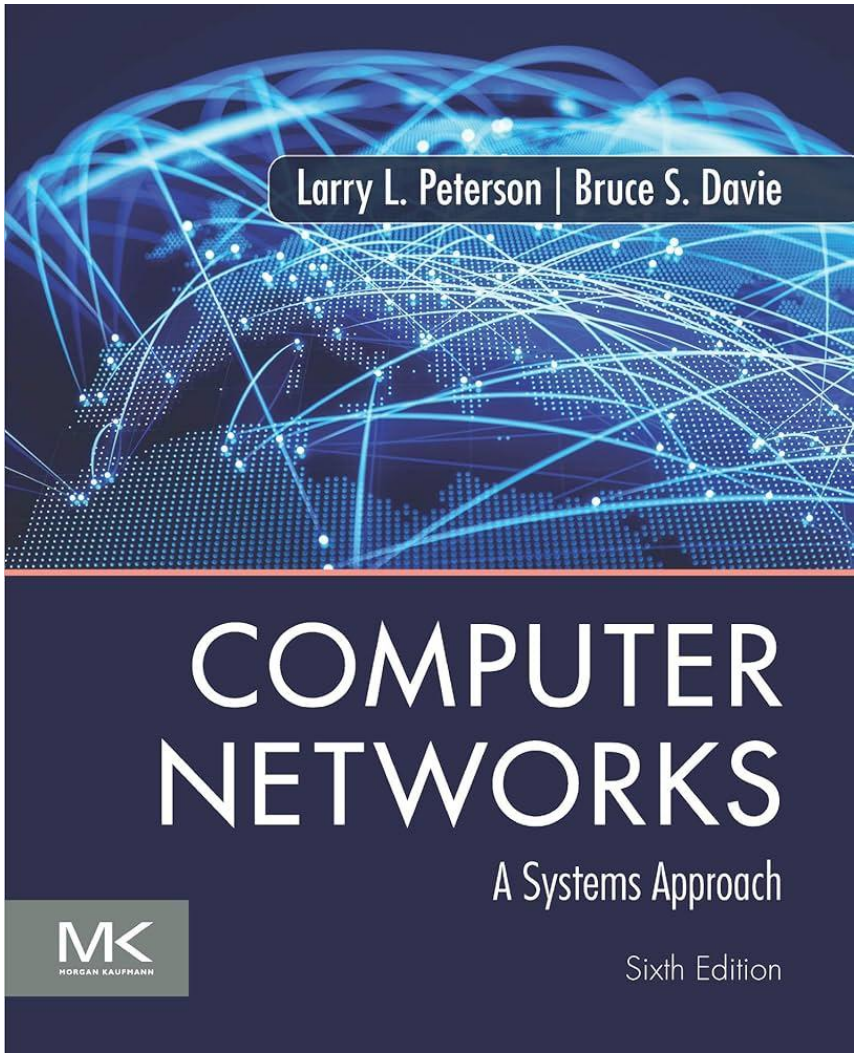
- The AS model decouples the intra-domain routing that takes place in one AS from that taking place in another.
- Thus, each AS can run whatever intra-domain routing protocols it chooses.
- It can even use static routes or multiple protocols, if desired.
- The inter-domain routing problem is then one of having different ASs share reachability information—descriptions of the set of IP addresses that can be reached via a given AS—with each other.

Session 6A: Summary

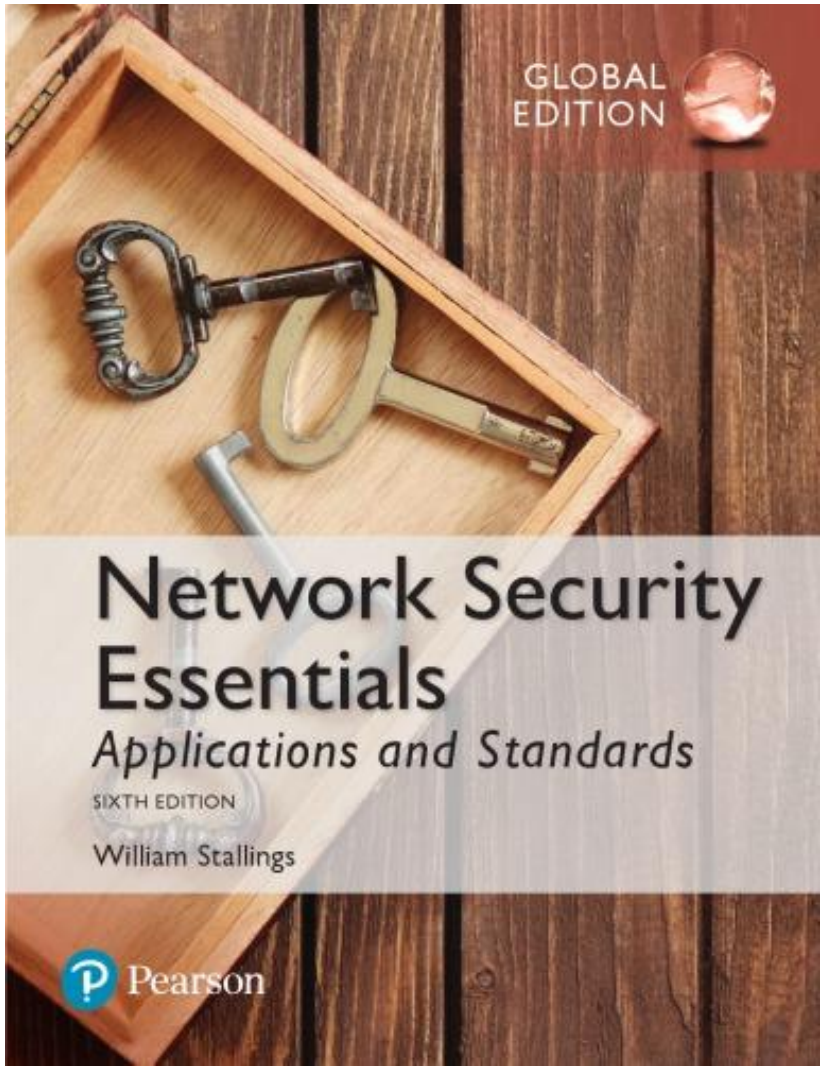
- Internet Domains
  - Internet Domain Structure
  - Stub and Transit Domains
  - Internet Exchange Points (IXP)
- Peering Relationships
  - Customer → Provider
  - Provider → Customer
- Routing Domains and Areas
  - Routing between Areas
- Autonomous Systems
  - Inter-domain Routing

Textbooks

Textbook 1

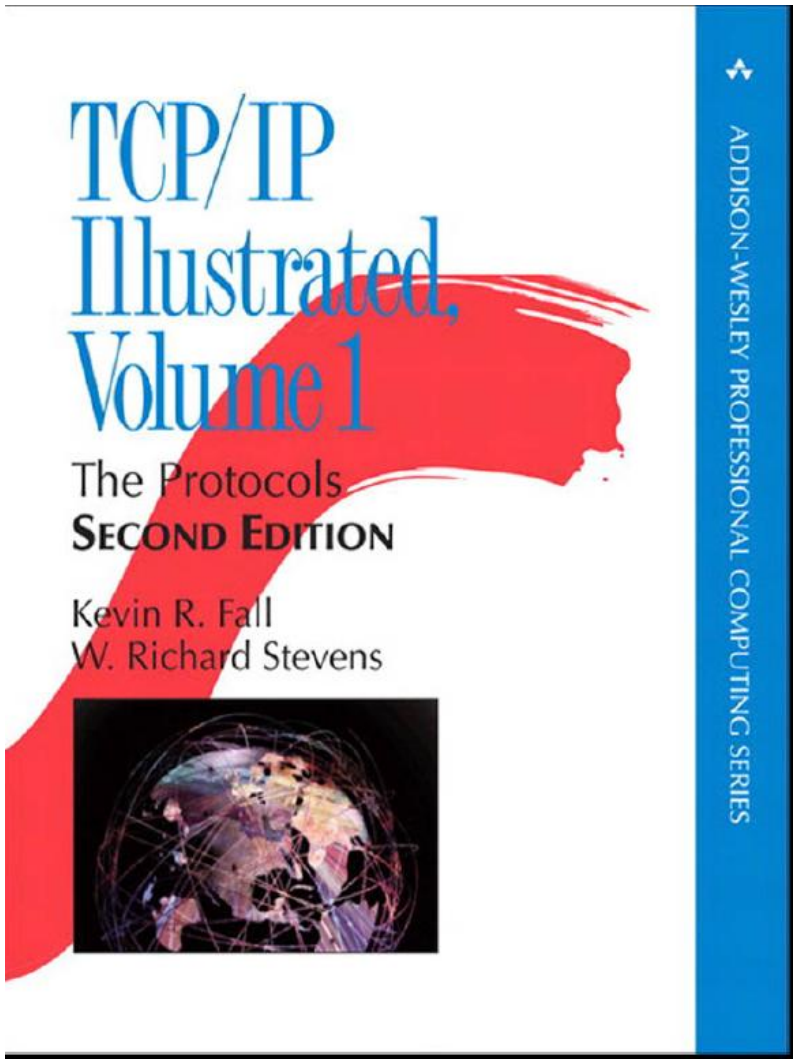


Textbook 2



References

Ref 1



Ref 2

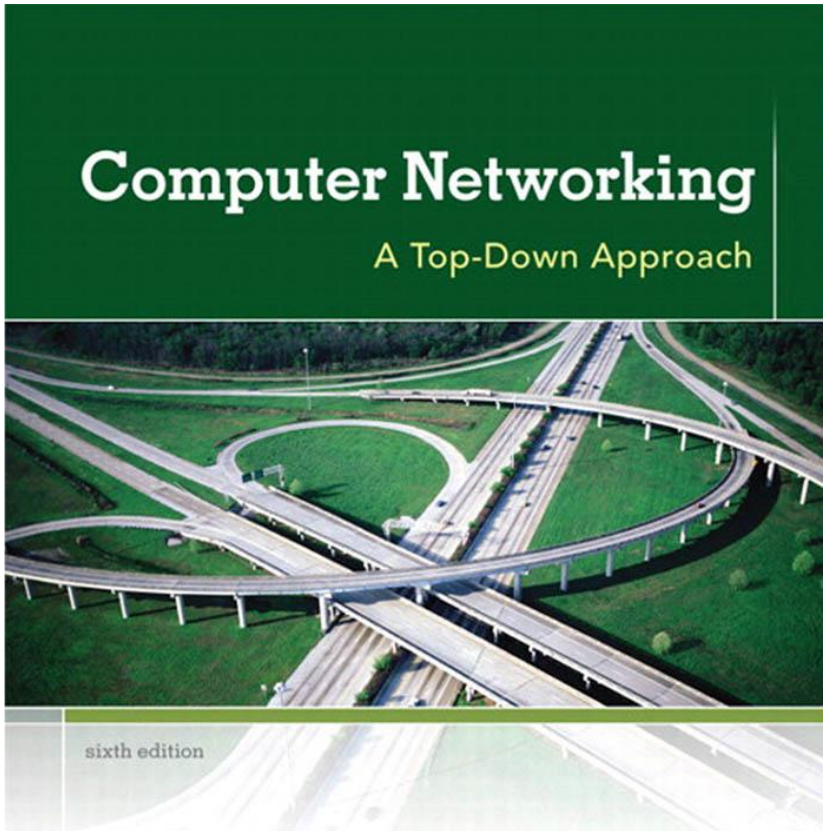
TCP Congestion Control: A Systems Approach

TCP Congestion Control: A Systems Approach

Peterson, Brakmo, and Davie

References

Ref 3



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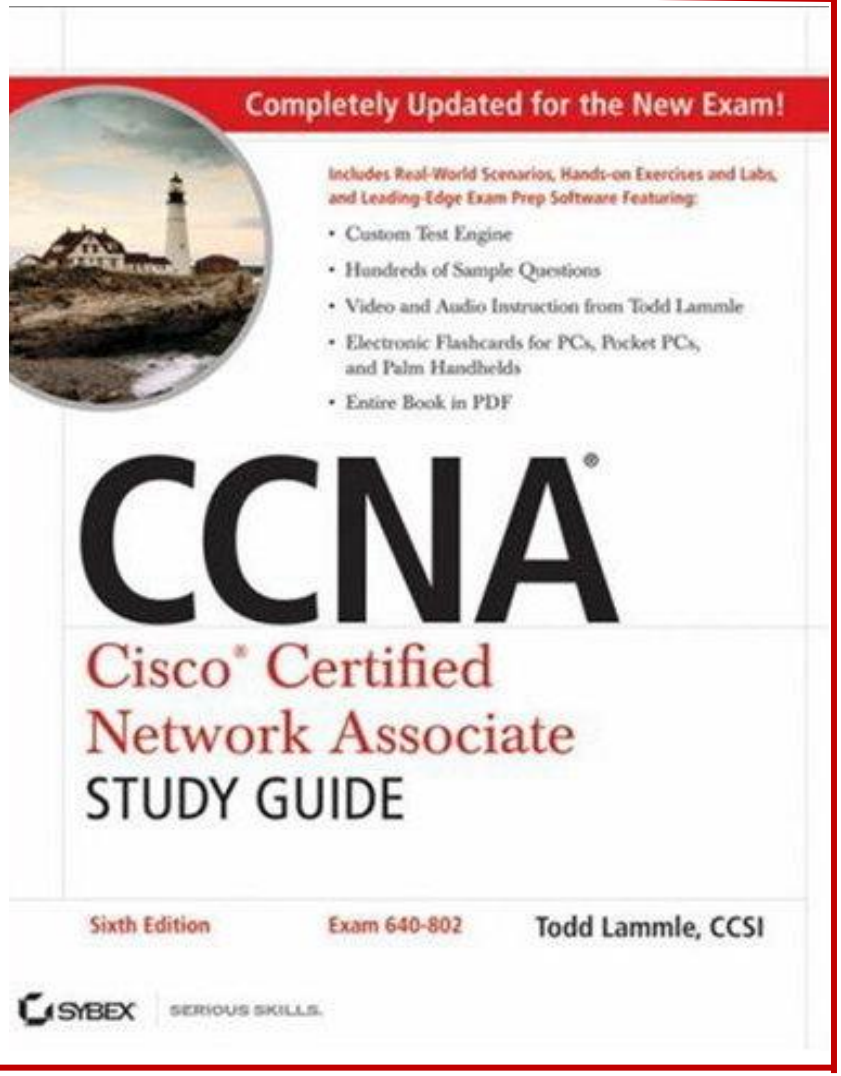

References

Ref 5