NANYANG TECHNOLOGICAL UNIVERSITY

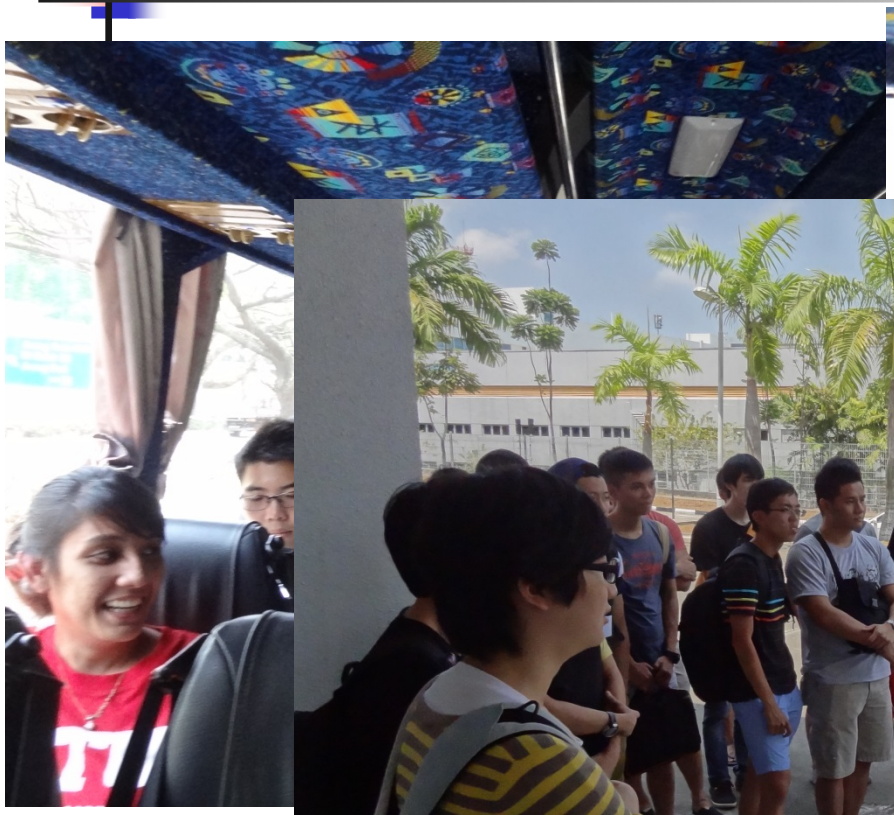
CE3005: Computer Networks

Module 2-1:
An Overview of Computer Networks and the Internet

Semester 1 2016-2017

School of Computer Engineering

Field Trip to Pacnet center



27 Feb 2014

Visit to Telstra Data Center, Paya Lebar
21 Sept 2015

Singapore tops global speed index for broadband links

PUBLISHED ON FEB 9, 2015 5:51 AM

The Singapore skyline at dusk. Singapore is now the world's fastest broadband nation, according to a global speed index watched closely by many international authorities and Internet service providers (ISPs). -- ST PHOTO: KUA CHEE SIONG

BY IRENE THAM TECHNOLOGY CORRESPONDENT

Singapore is now the world's fastest broadband nation, according to a global speed index watched closely by many international authorities and Internet service providers (ISPs). The US-based Ookla's Net Index - started in 2008 - shows that Internet users in Singapore have had the fastest broadband links, of around 104 Mbps, since December last year. Singapore edged out Hong Kong - which held the position for 19 consecutive months - to claim the top spot. Since then, Hong Kong with its download speed of around 95 Mbps has been in second position, followed by South Korea (80 Mbps) and Japan (67 Mbps). -

Government to get own telecoms network in smart nation push

PUBLISHED ON FEB 2, 2015 8:36 AM

BY IRENE THAM TECHNOLOGY CORRESPONDENT

A telecommunications network solely for public-sector use is being planned to drive Singapore's smart nation agenda.

This is a departure from the norm as the Government typically leases connectivity rather than own such networks.

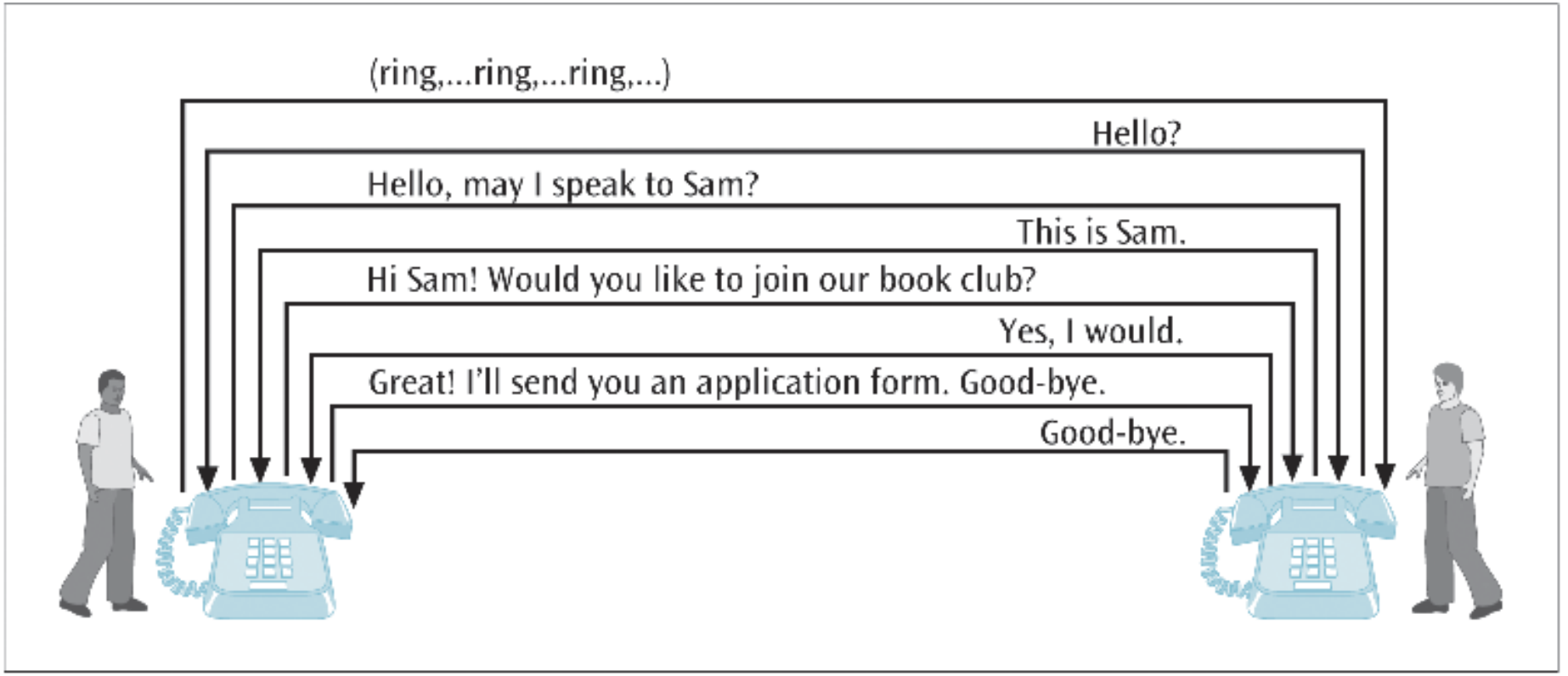
The new infrastructure will run the equipment for linking, among other things, a network of sensors slated to be rolled out islandwide this year.

The sensors - which can be in the form of computer chips or surveillance cameras - are for increasing round-the-clock surveillance in Little India and the Civic District in the heart of Singapore, for starters.

Other projects include monitoring the risk of flooding via sensors in drains and the safety of the elderly via sensors installed in their homes.

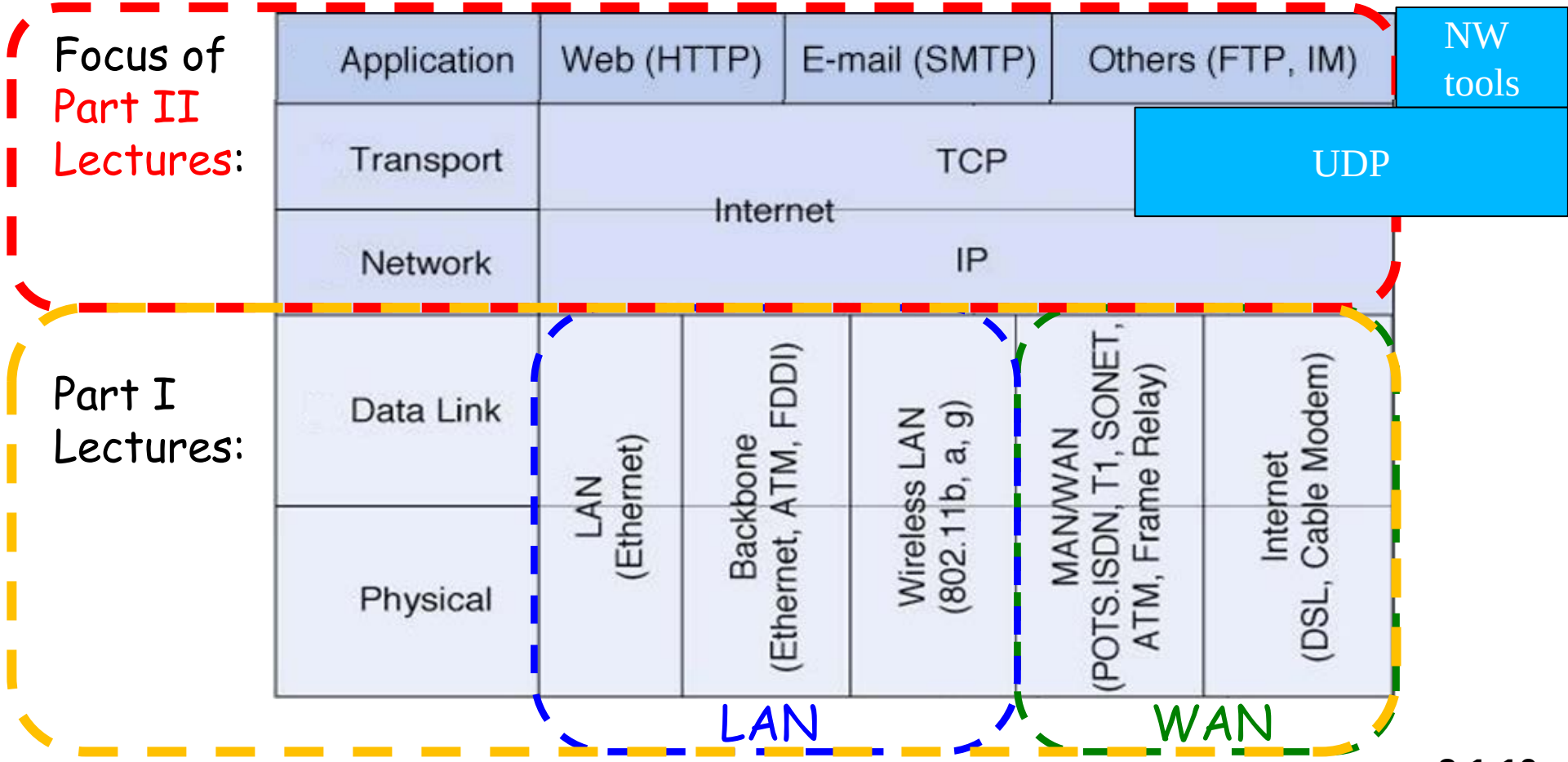
You've learnt the concept of a communication protocol, which is a set of rules defining the format and the order of messages exchanged between two parties.

When making a phone call, the recipient waits for the ring tone before answering. Then both will take turns to talk. This is a communication protocol.



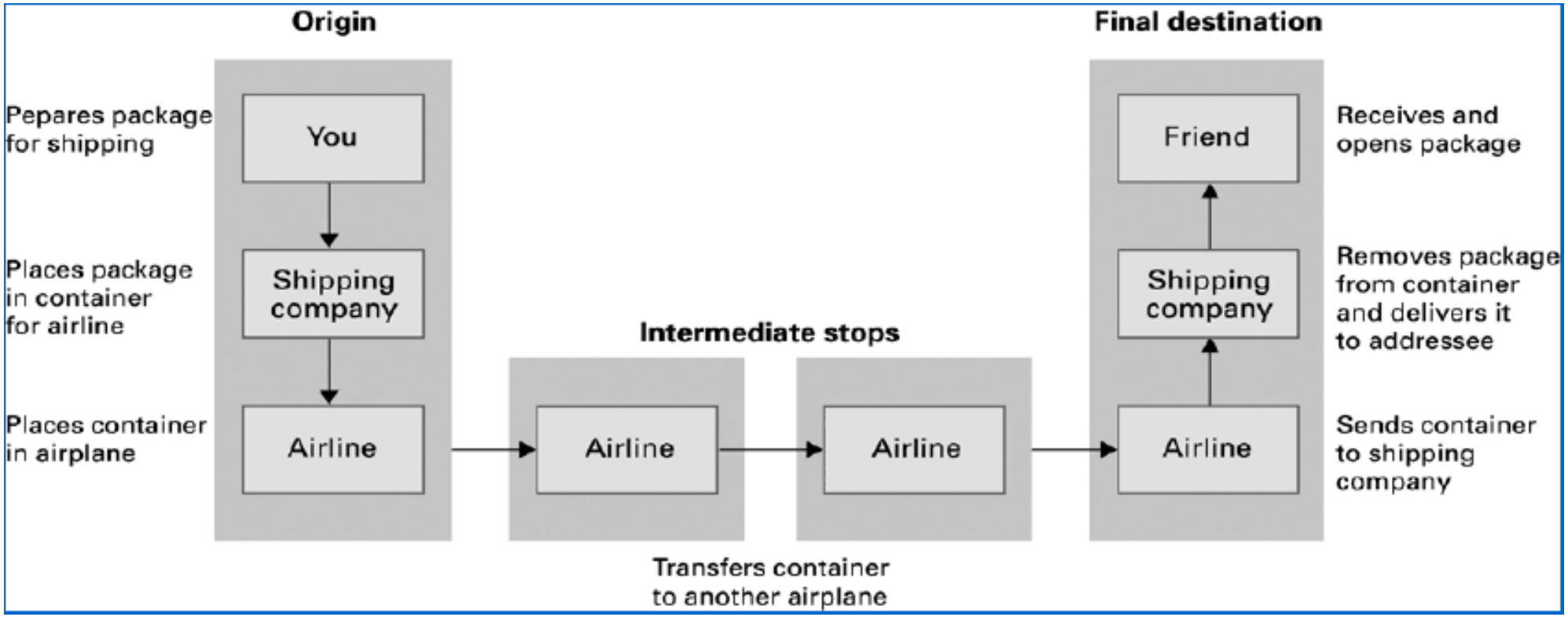
The complex task of computer networking is subdivided into layers called protocol stack. OSI is the standard but TCP/IP is in use, ie default standard.

For the learning of networking concepts, it is very useful to combine the merits of both OSI and TCP/IP and view the protocol stack/suite as consisting of 5 layers as follows:



The idea of layering is to make a complex task manageable - each layer performs a simpler subtask and uses the services provided by lower layers.

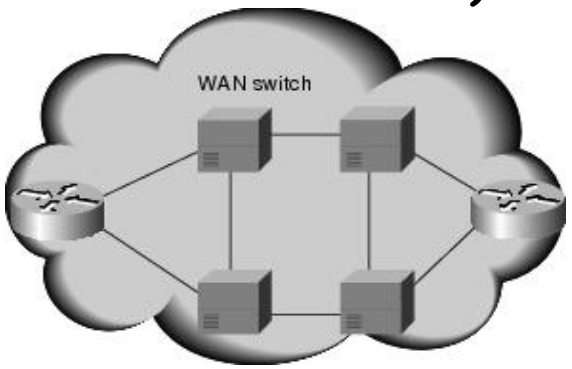
As an analogy, to send a package to an oversea friend, we only need to take care of packing/unpacking, and use the service of a shipping company, which in turn uses the service of an airline.



ENCAPSULATION occurs as information is passed from one layer to the next

Physically, computer networks may be broadly categorised into WANs and LANs.

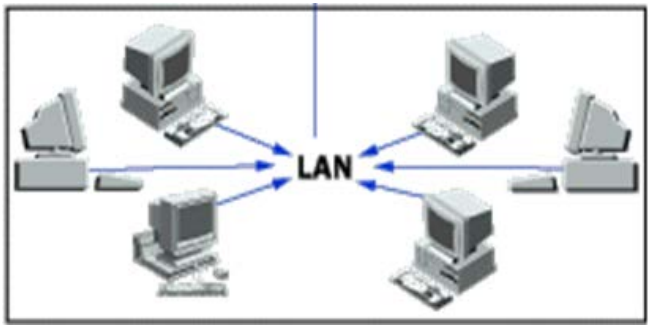
(Wide Area Network) WAN:



- Cover a large geographical area
- typically consist of switching nodes interconnected by point-to-point lines

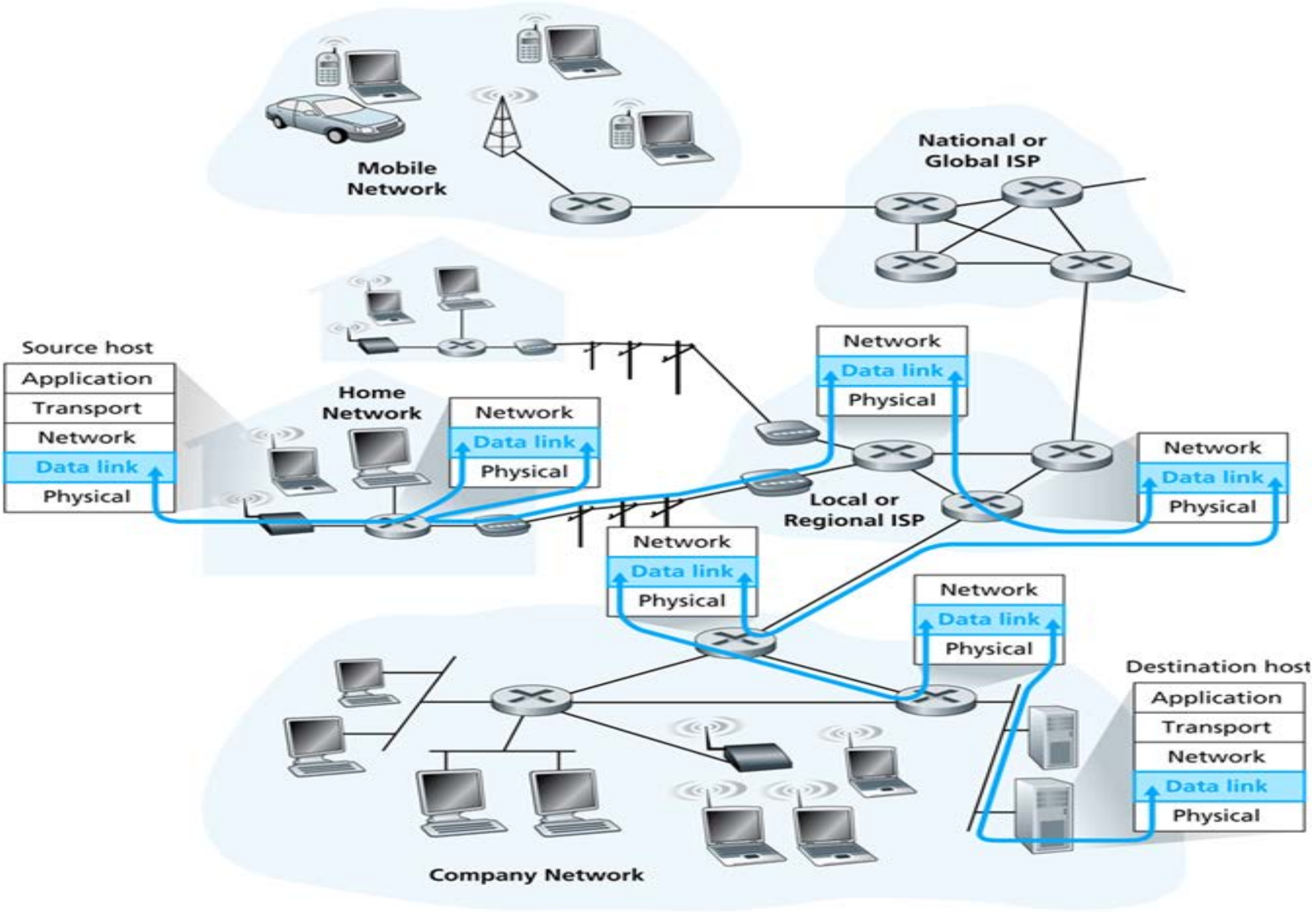
Metropolitan Area Networks (MAN) cover an area in between WAN and LAN. Nevertheless, their implementation technologies are typically similar to WAN.

(Local Area Network) LAN:

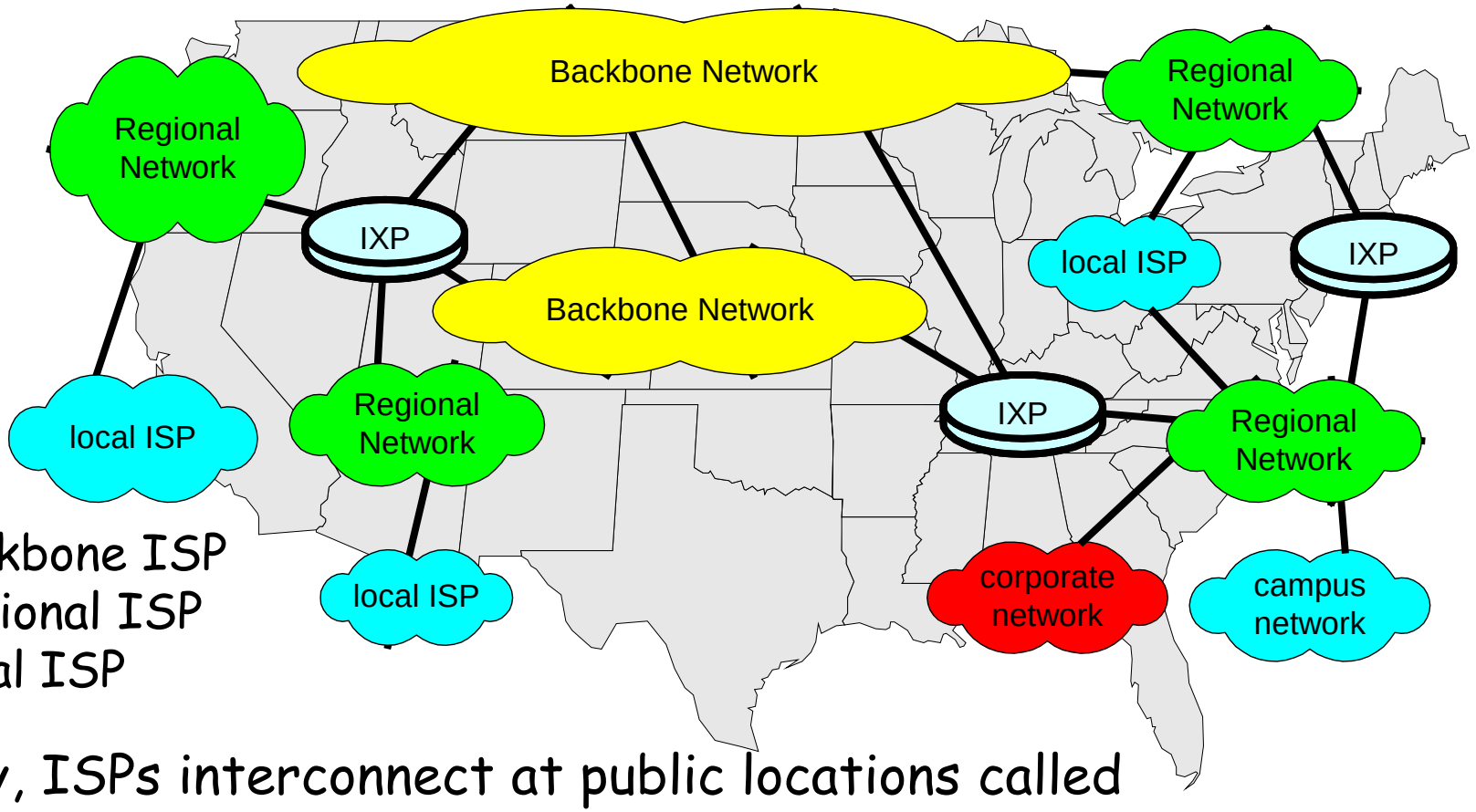


- Cover a small area like a room, a building or clusters of buildings
- typically consists of computers sharing common transmission medium
- nowadays, switched LANs are also getting common

Now, let's take a look at the Internet:



The backbones of Internet are the interconnections of many WANs of Internet Service Providers' (ISPs), which may be categorised as Tier 1, 2 or 3.



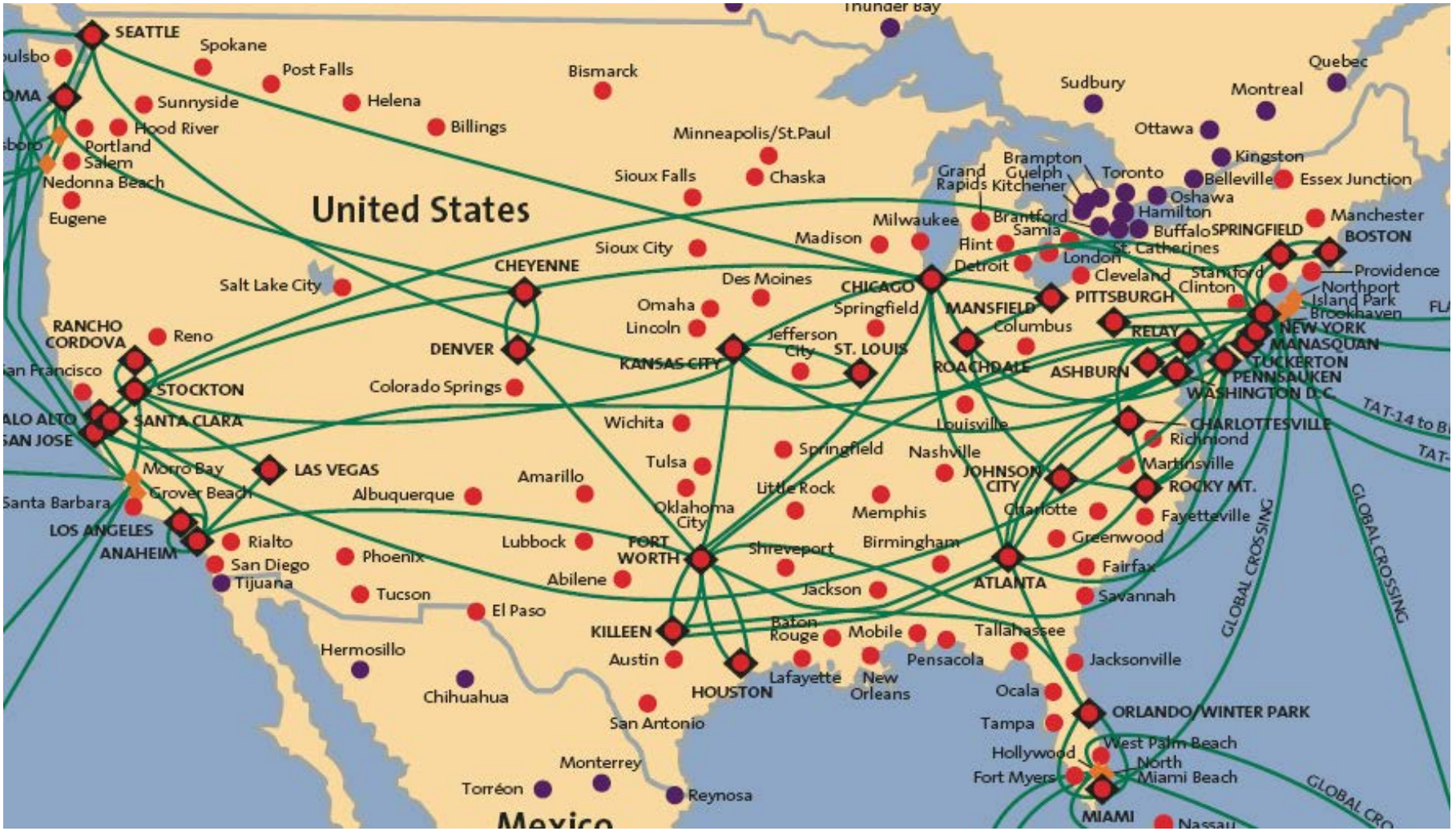
Tier 1 - backbone ISP
Tier 2 - regional ISP
Tier 3 - local ISP

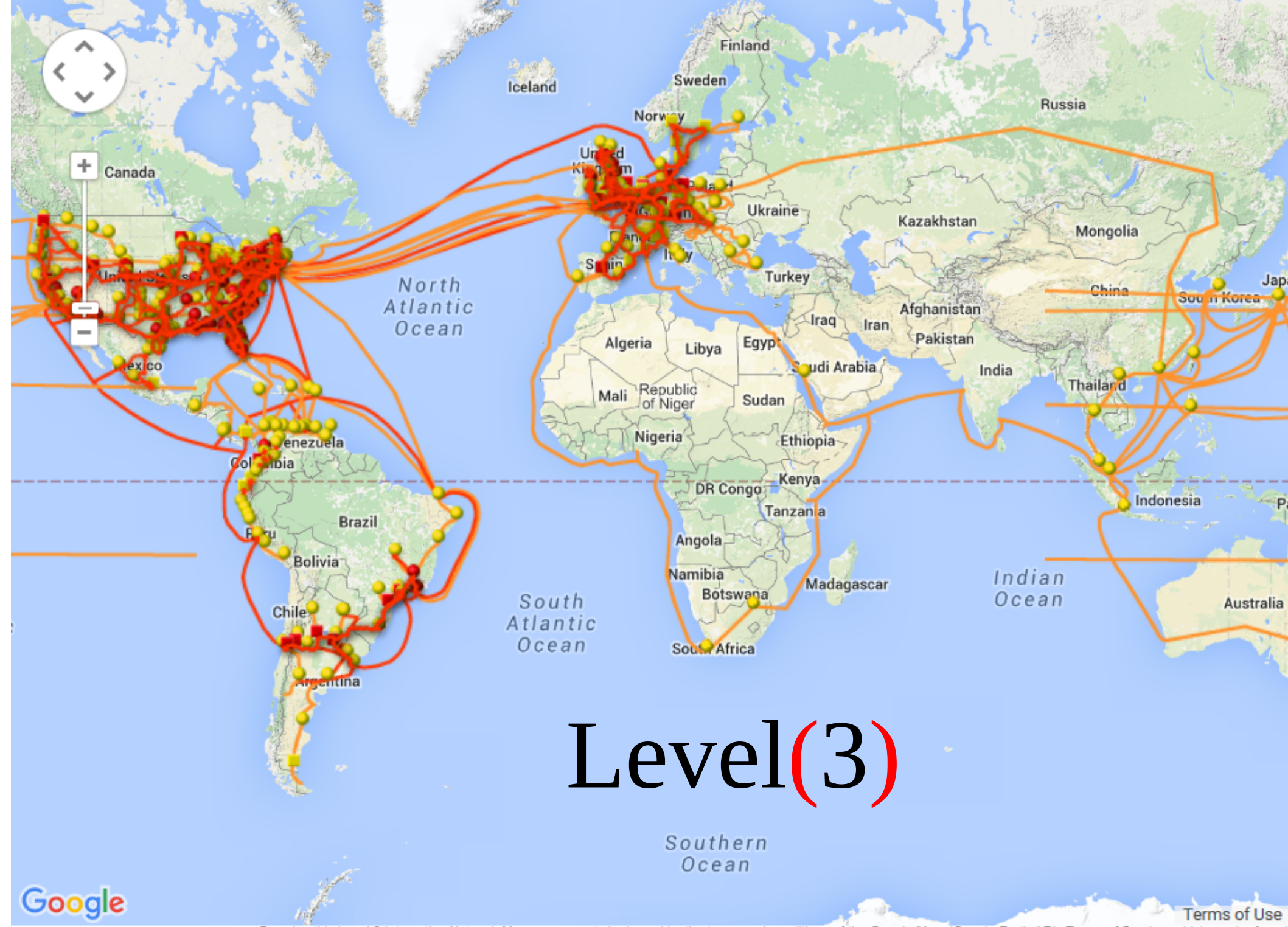
Typically, ISPs interconnect at public locations called Internet eXchange Points (IXPs) or Network Access Points (NAPs).

Alternatively, ISPs may interconnect directly on their own, called private peering.

An example of ISP is Sprint, a Tier 1 ISP in US. Note that an ISP usually has its own network of nodes interconnected by point-to-point links (WANs)

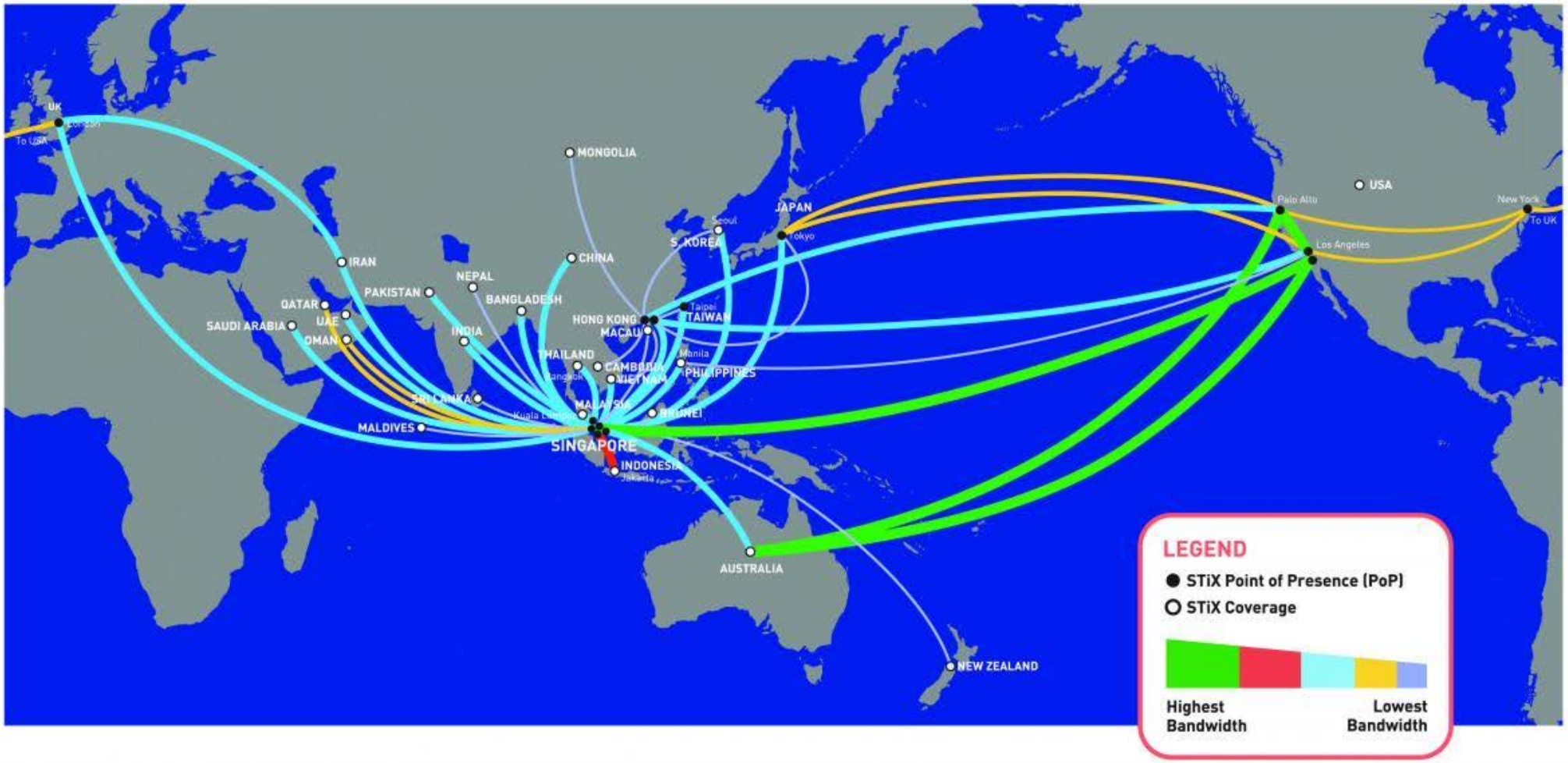
Sprint backbone network coverage:



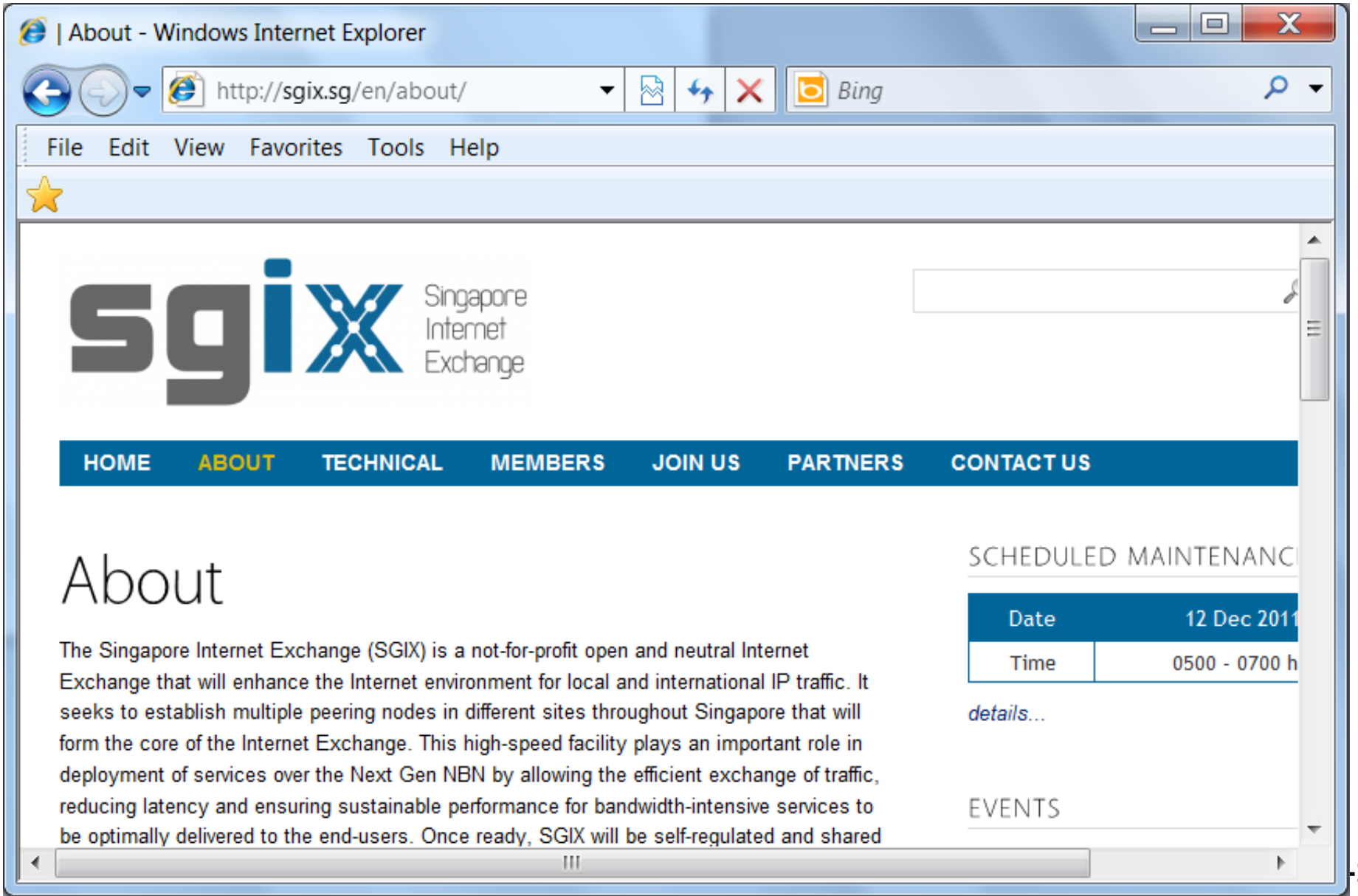


Another example of ISP is SingTel in Singapore, which may be considered as a Tier 1/2/3 ISP.

SingTel network coverage, which is called STiX:



An example of Open IXP is the Singapore Internet Exchange (sgix).



Help

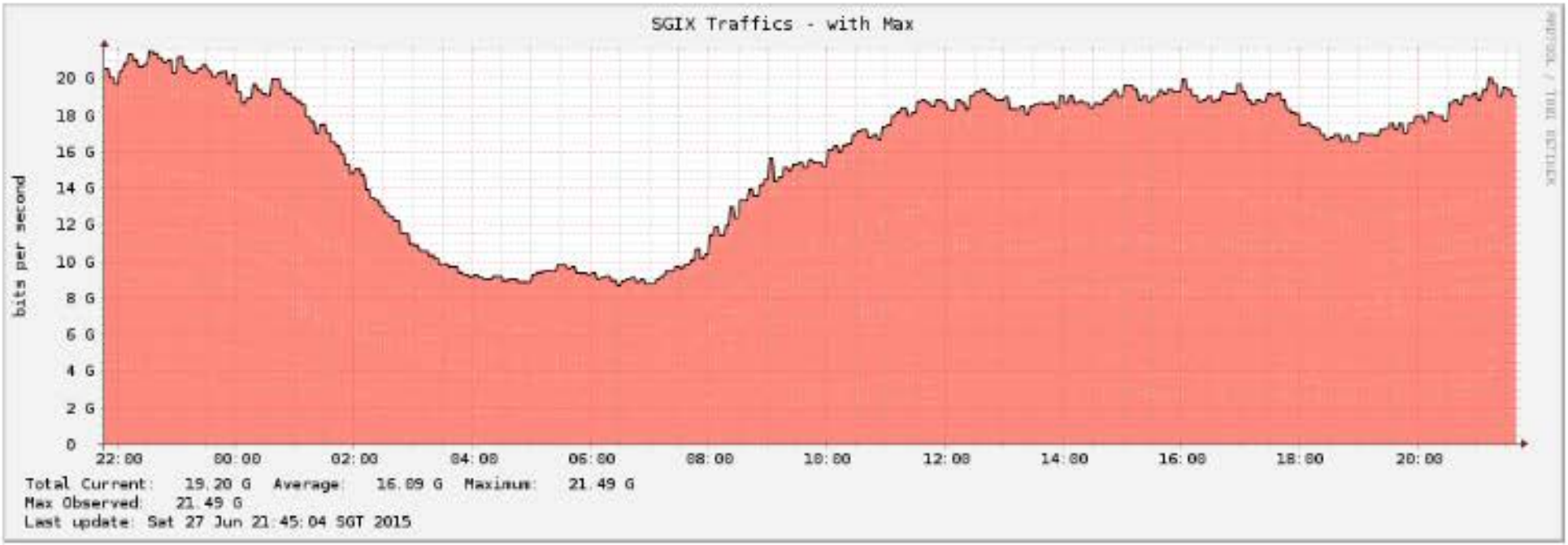
sgix Singapore Internet Exchange

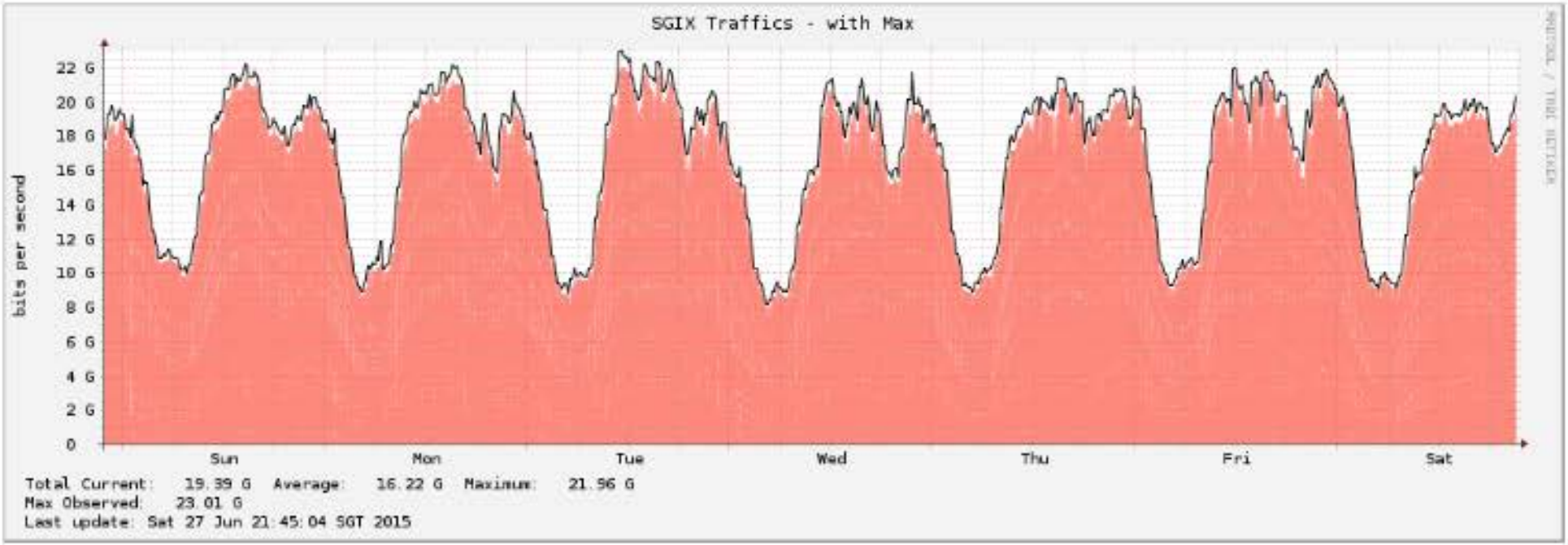
HOME ABOUT TECHNICAL MEMBERS PARTNERS JOIN US CONTACT US

List of Members

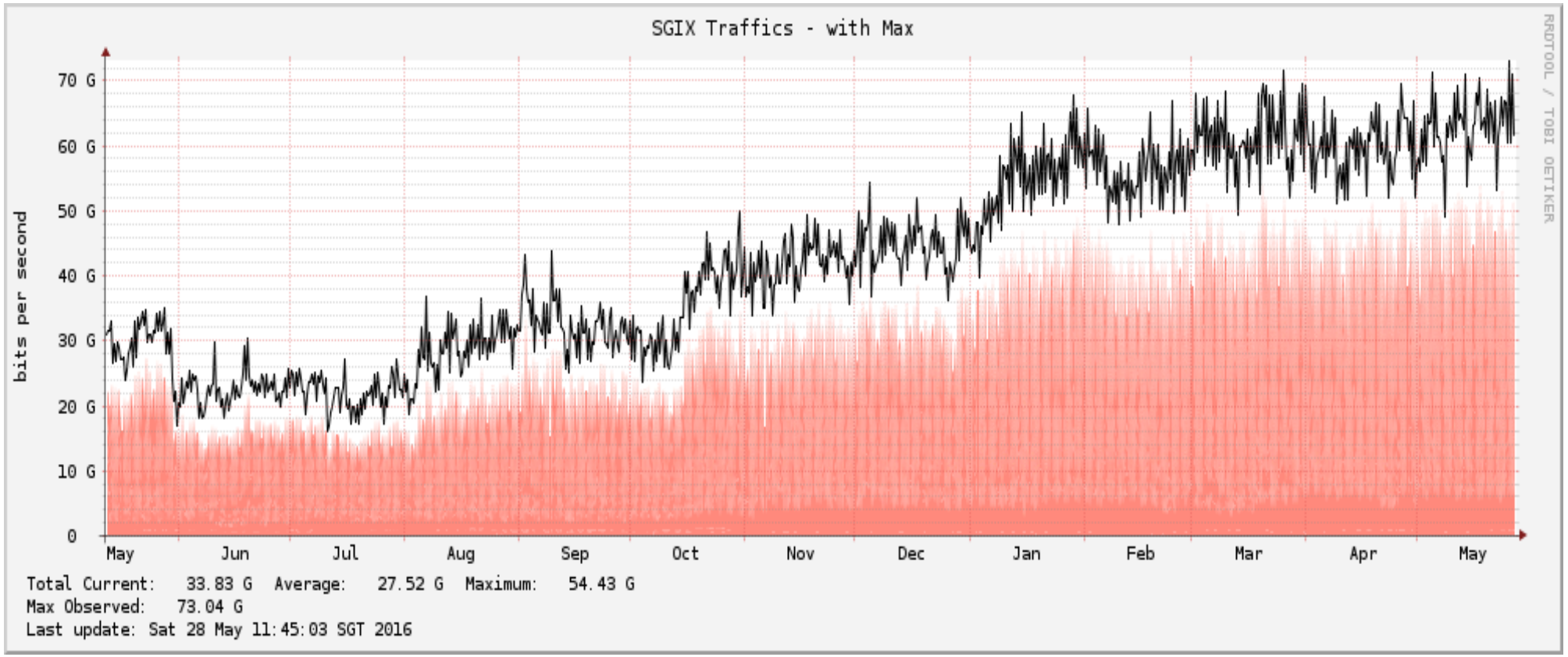
Member	ASN	Peering Policy	Peering Coordinator	Email	Port Speed	Location
PT Mora Telematika Indonesia	23947	Open	Tan Shao Yi	tansy /AT/ moratelindo.co.id	10G	GS
NewMedia Express Pte Ltd	38001	Open	Alan Woo Shian Loong	alan /AT/ newmediaexpress.com	100M	1-Net
Usonyx Pte Ltd	38532	Open	USONYX NOC	peering /AT/ usonyx.net	1G	GS
Microsoft	8075	Open	Microsoft Peering	peering /AT/ microsoft.com	10G	GS
SuperInternet ACCESS Pte Ltd	4844	Open	SuperInternet NOC	noc /AT/ super.net.sg	1G	GS
M1 Limited	4773	Selective	Peering	peering /AT/ m1.com.sg	10G	GS
SingAREN	23855	Selective	Stanley Goh	ccgohstanley /AT/ yahoo.com	1G	GS
PacNet	4628	Selective	Peering Co-ordinator	peering /AT/ pacnet.net	2x1G	GS
1-Net Singapore Pte Ltd	9226	Open	Lim Siu Po	siupo /AT/ 1-net.com.sg	1G	1-Net
Infocomm Asia Holdings	38540	Open	Joshua Aw Yong	joshua /AT/ iahgames.com	1G	GS

Peering Traffic

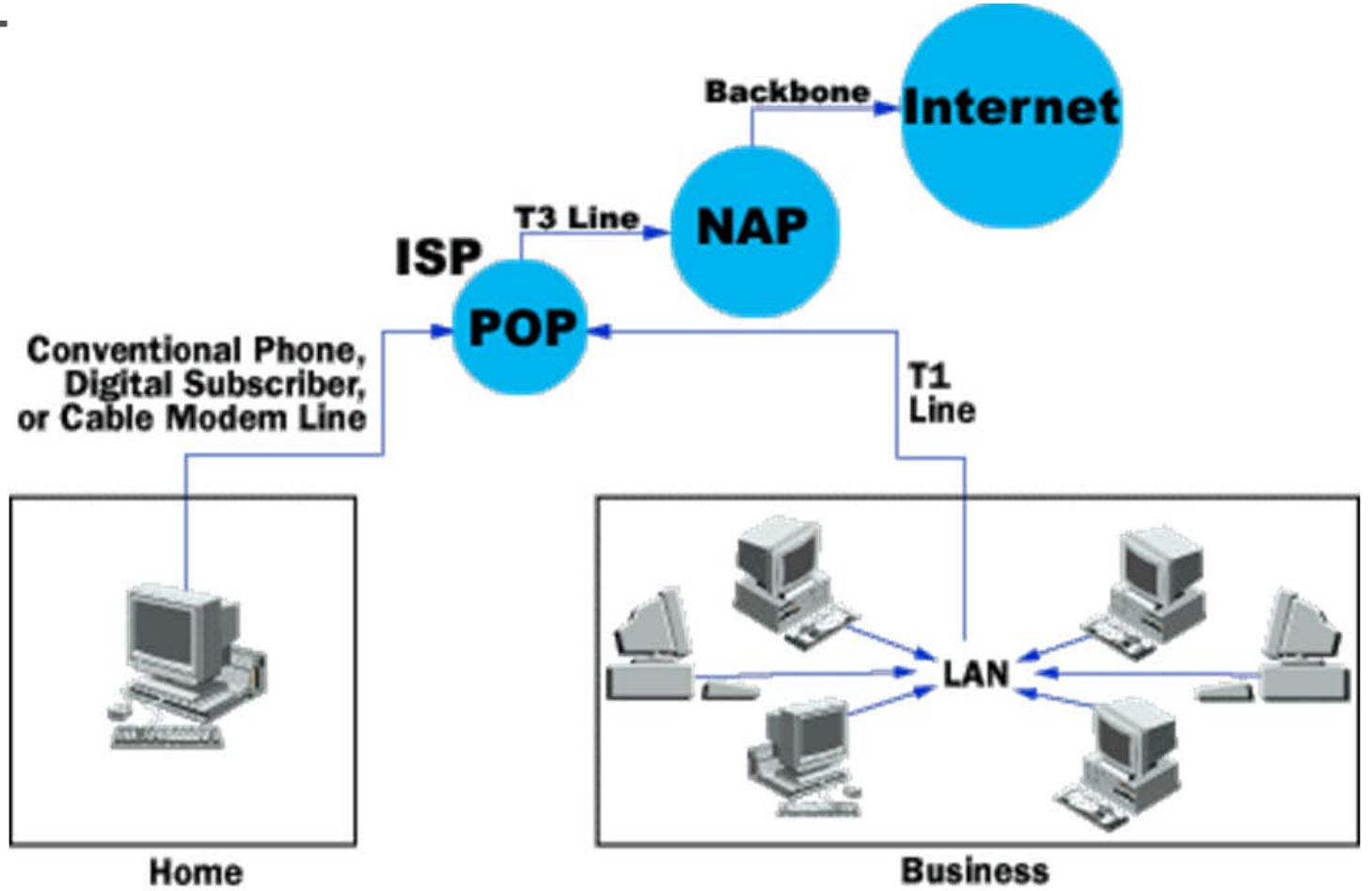




SGIX traffic
Long term trend

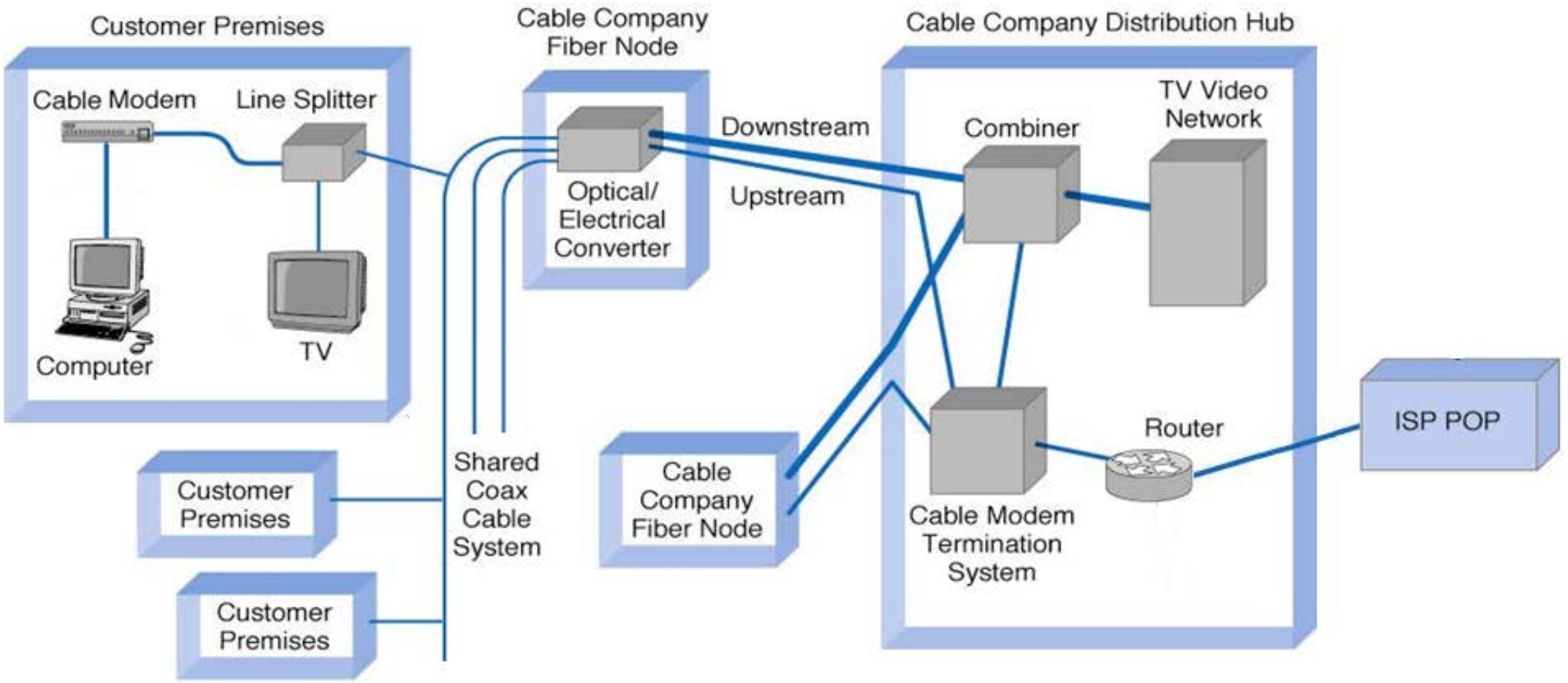


To enable subscribers to connect to the Internet backbones, ISPs usually set up Point of Presence (POP).



Point of Presence (POP) is the location where the ISP houses its network hardware (mostly routers) for subscribers to connect. Network Access Point(NAP) is interconnection points of ISPs

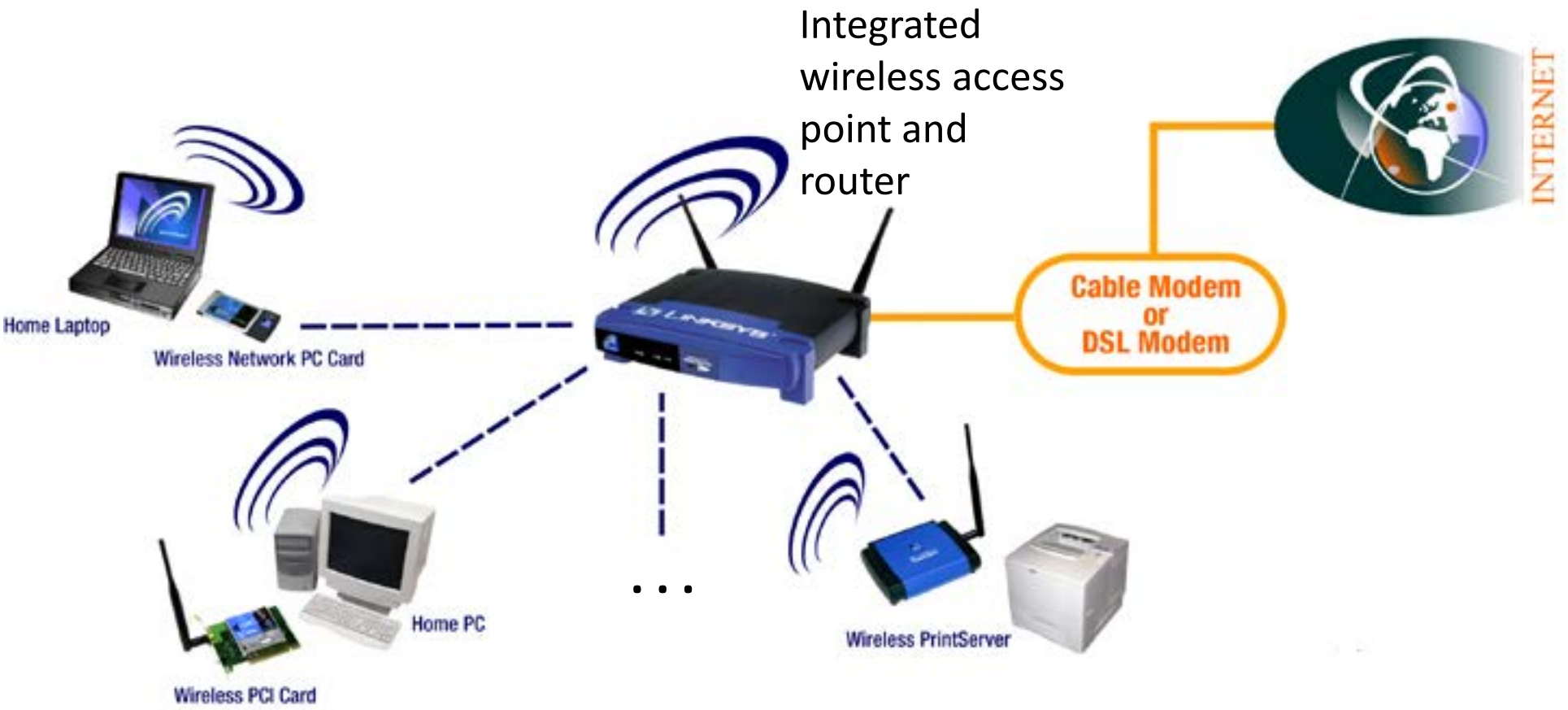
Similarly, to offer cable modem service (up to 100Mbps) for Internet access, cable companies have also linked their cable TV networks to POPs.



In addition, public locations (e.g. Libraries, etc) are installed with wireless LANs (called hotspot zones) connected to DSL/cable/ONT for Internet access.

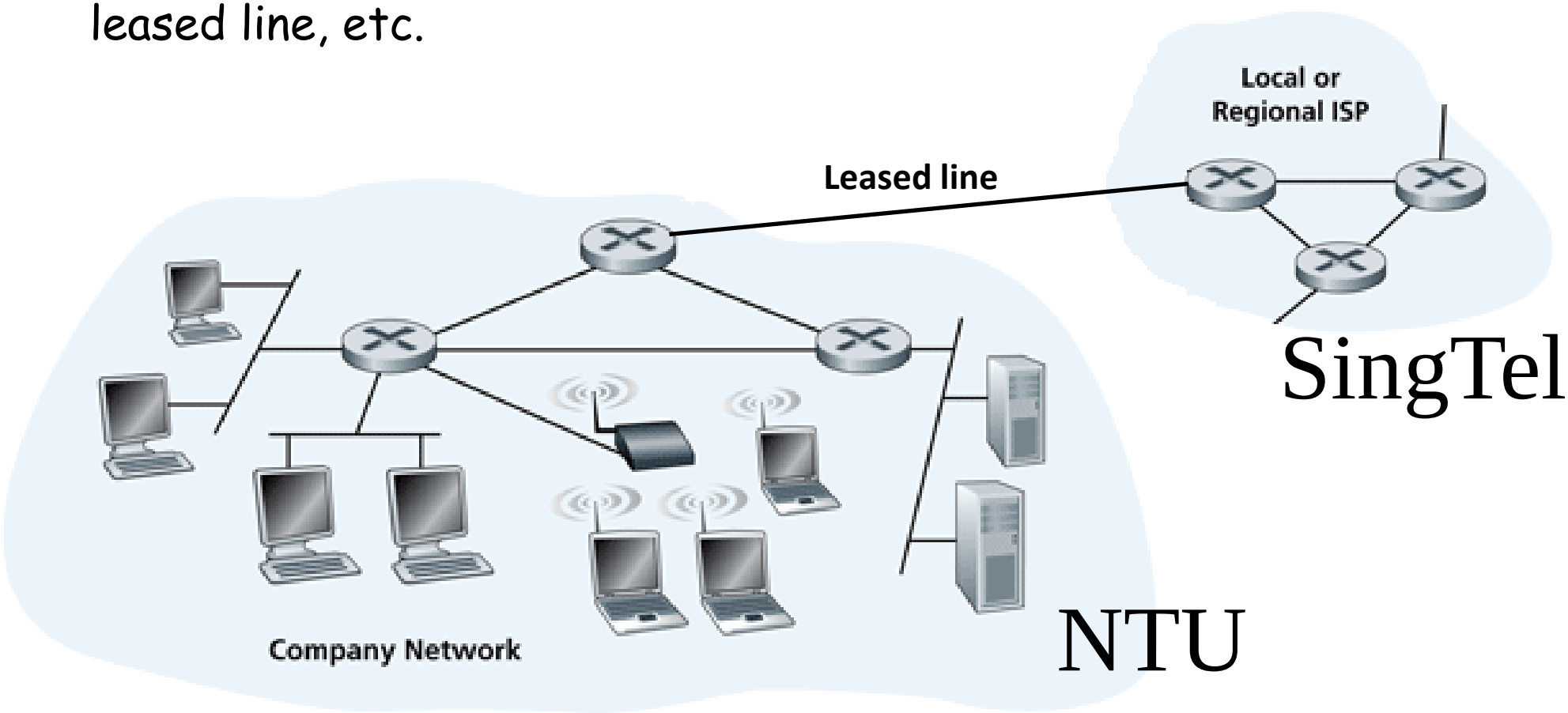
For example, also under iN2015 masterplan, around 5000 hotspot zones have been setup around Singapore under Wireless@SG programme, offering free access to Internet (up to 1Mbps).

At home, users may also setup their personal wireless LANs (usually Ethernet) which are then connected to DSL/cable/ONT for Internet access.

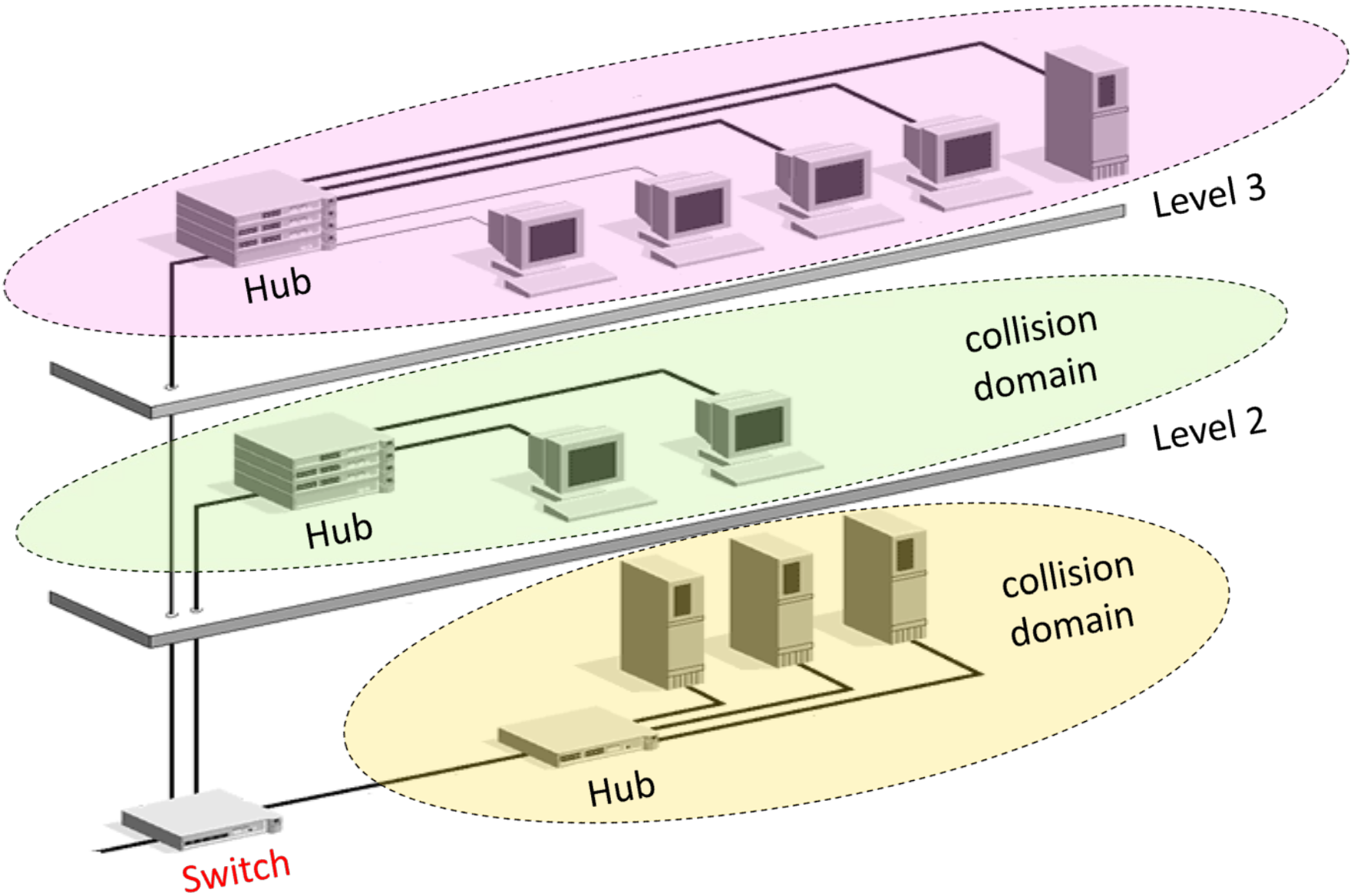


For large companies/organisations, private wired/ wireless LANs may be setup and linked via leased line to ISPs for Internet access.

Leased line is basically a permanent point-to-point connection with guarantee bandwidth. Depending on Telcos, various leased line services may be offered, e.g. traditional T1 line, new Internet leased line, etc.

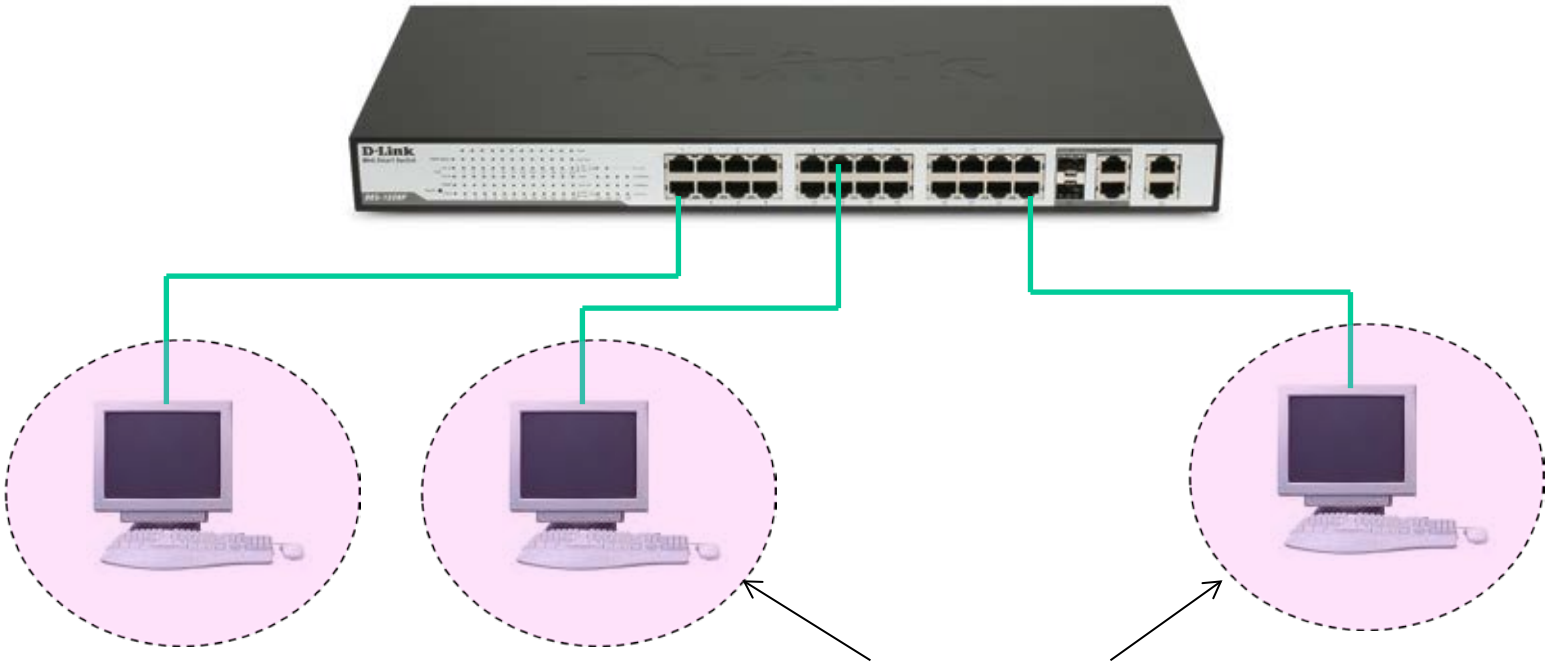


At the access and distribution layers, it's typical to interconnect hub-based 10BaseT Ethernets together by using a switch, hence called switched-Ethernet.

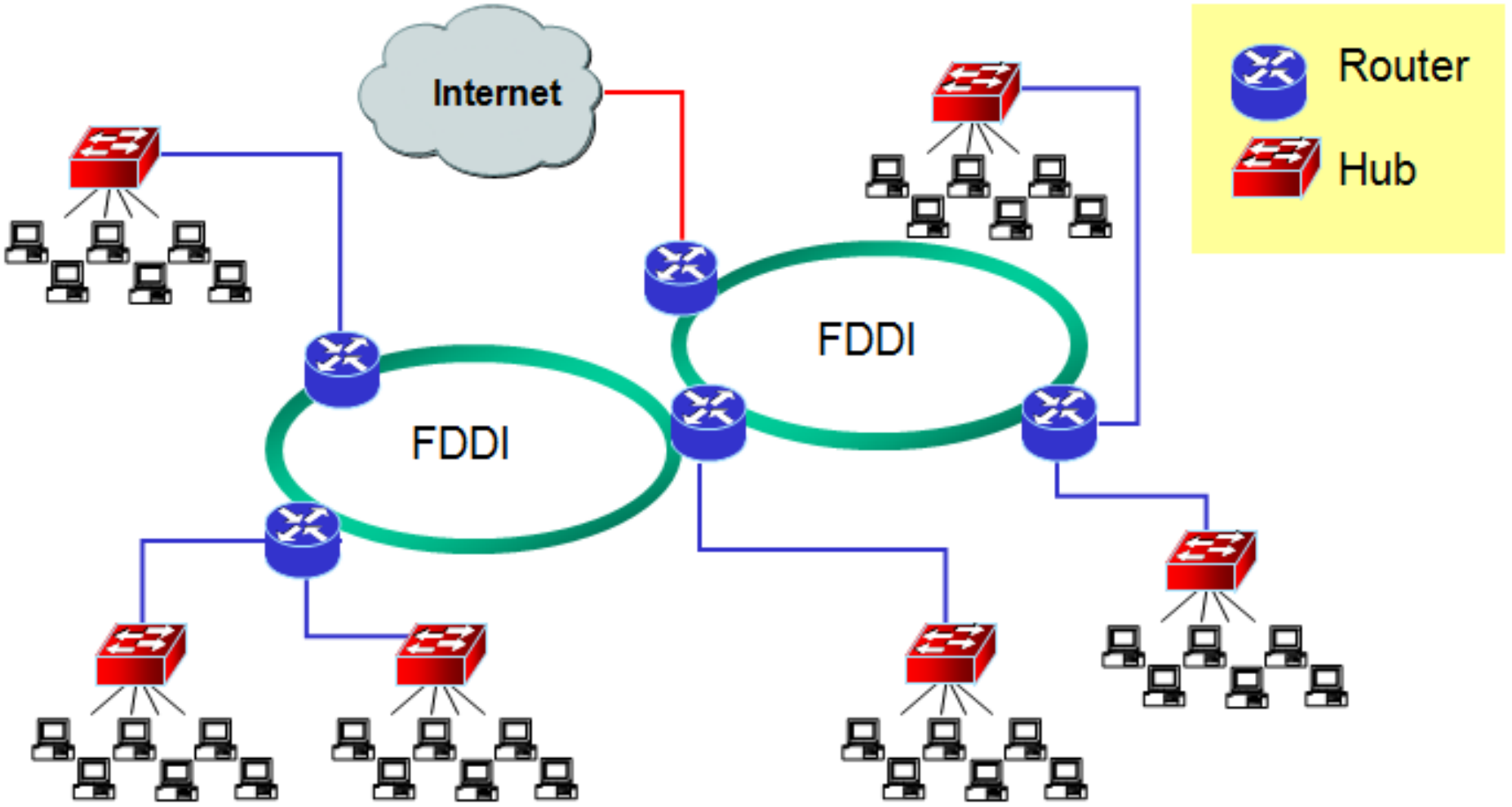


To improve performance, each station can even be connected directly to the switch at the access layer.

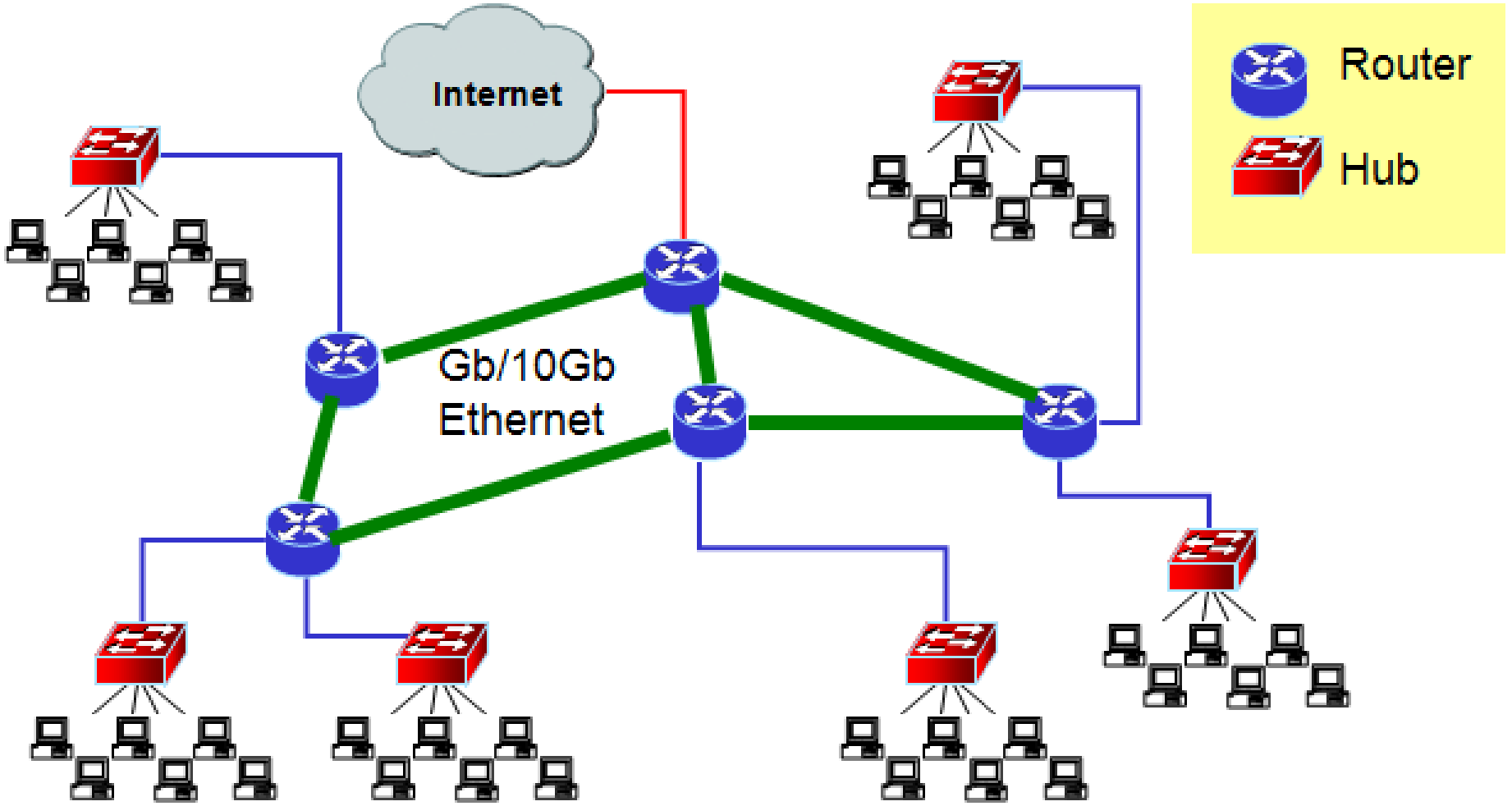
In this case, there is effectively only 1 station per collision domain, which means collision is non-existence. CSMA/CD, although still implemented, is now considered useless.



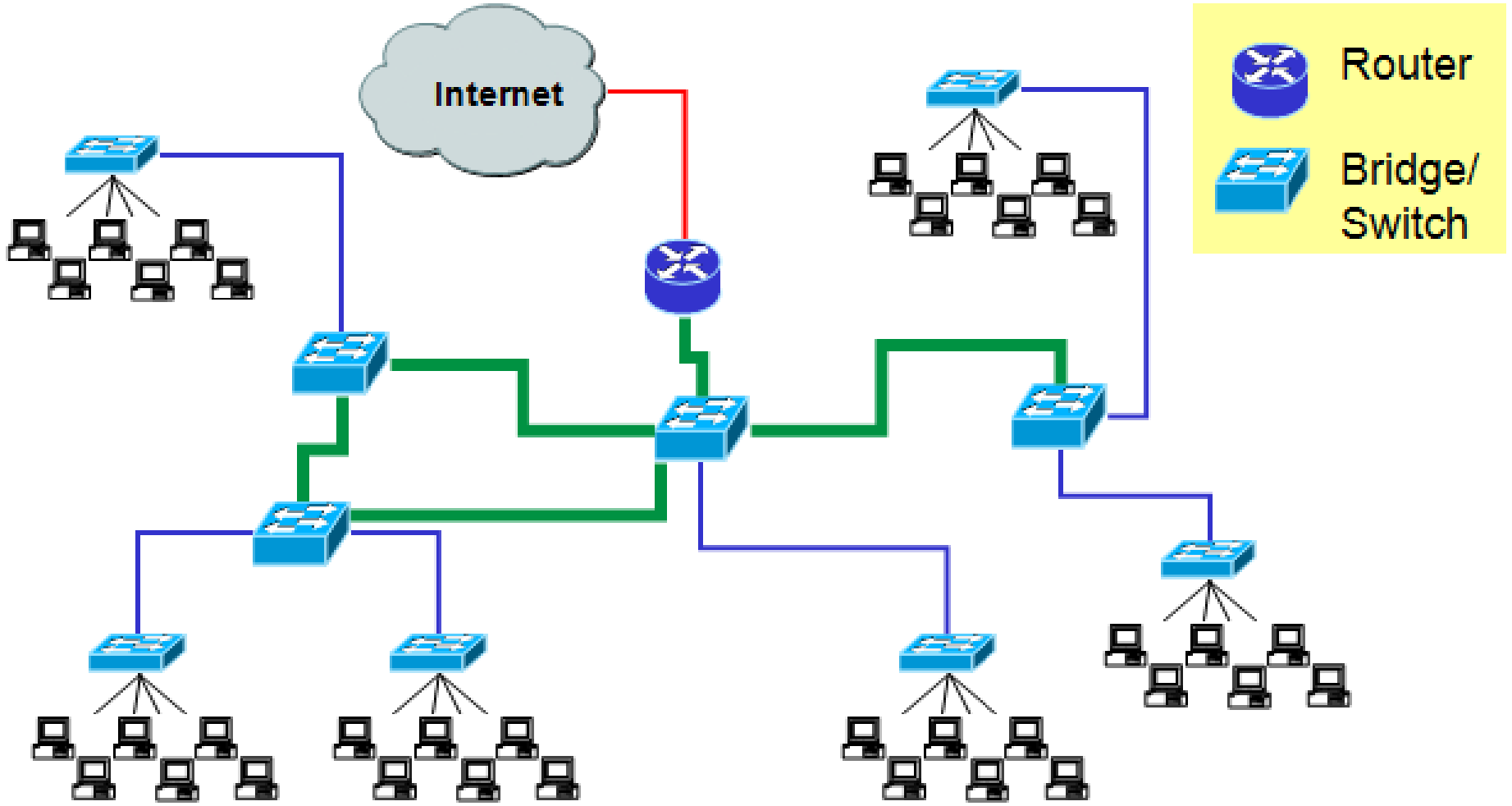
In the past, it's common to see other high-speed networks such as FDDI or ATM being used at the core layer to interconnect LANs.



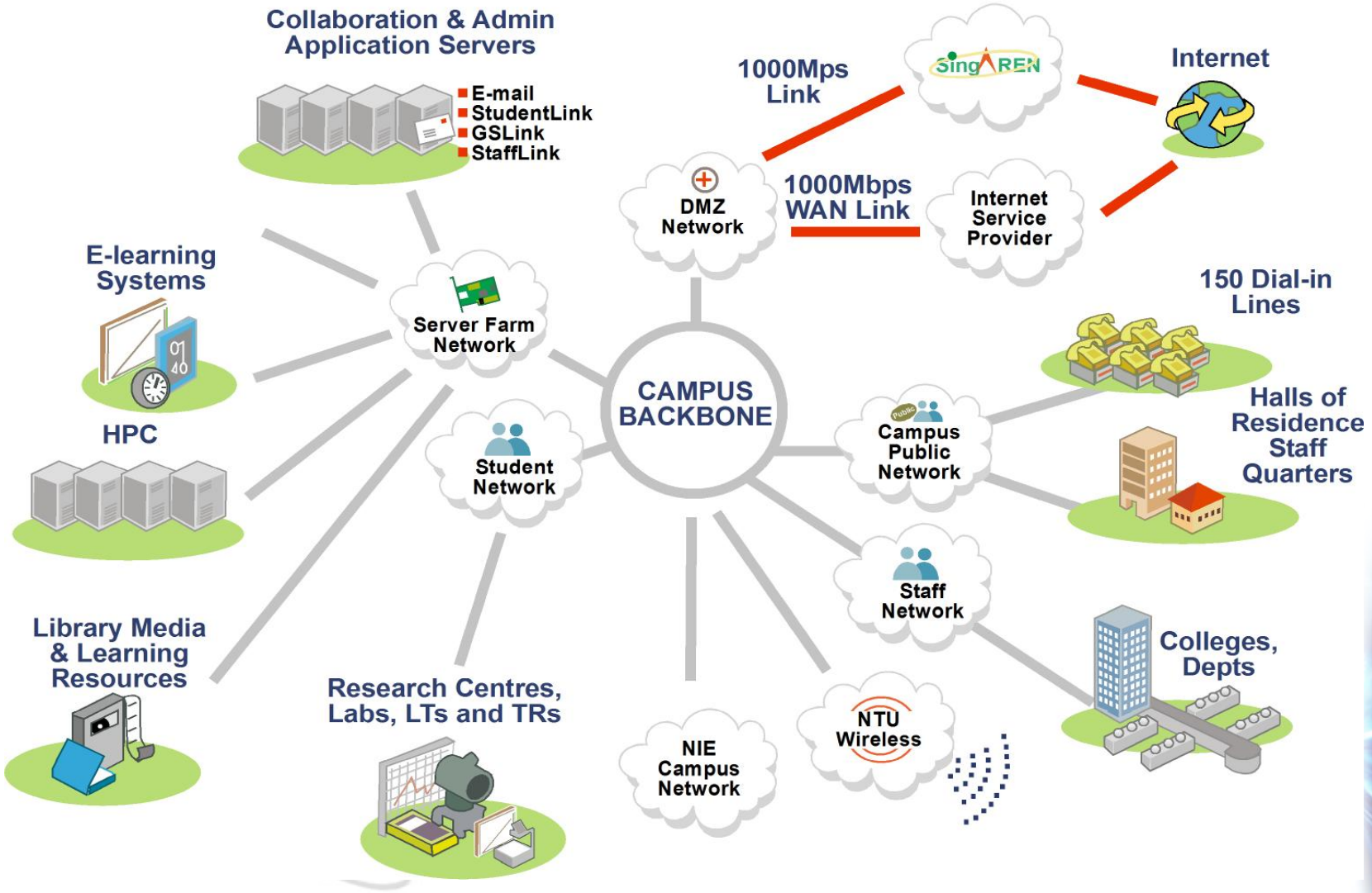
Nowadays, it's getting common to see Gigabit/10 Gigabit high speed Ethernets being used at the core layer to interconnect LANs.



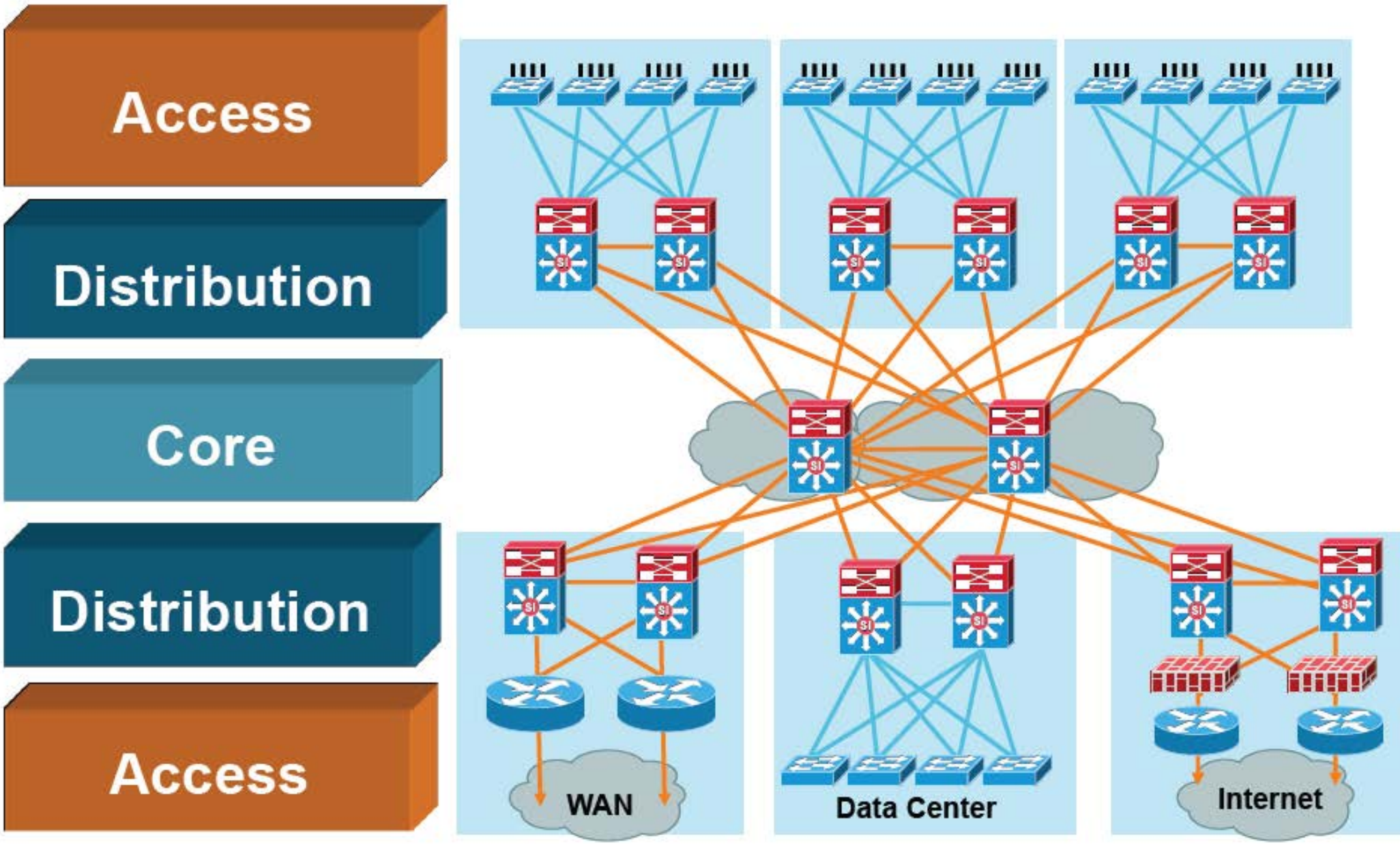
In addition, it's getting common to see a fully-switched network consisting of 10/100/Gb/10Gb Ethernets.



NTU IT Infrastructure



High-Availability Campus Design Structure, Modularity, and Hierarchy

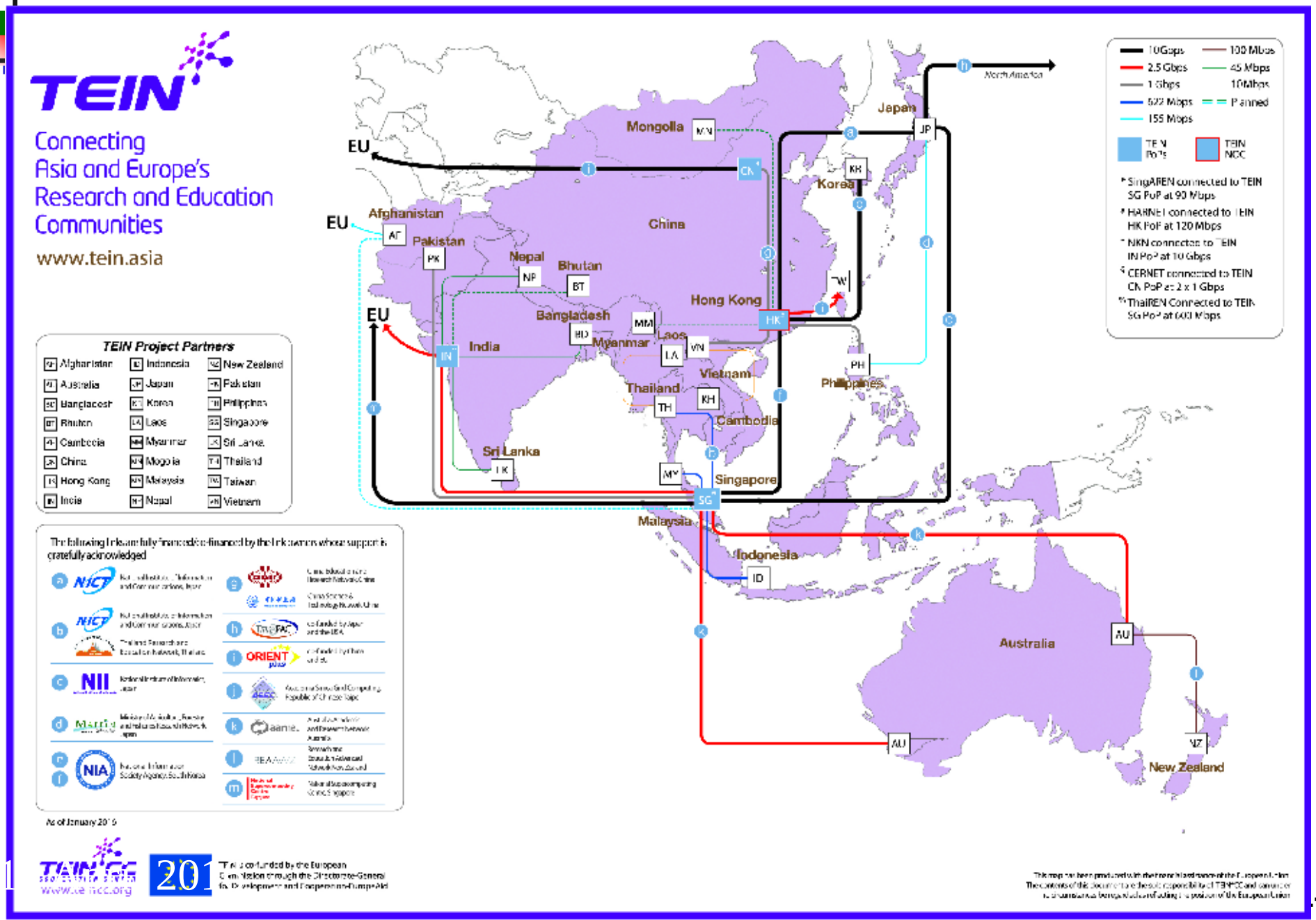


Case Study: SingAREN

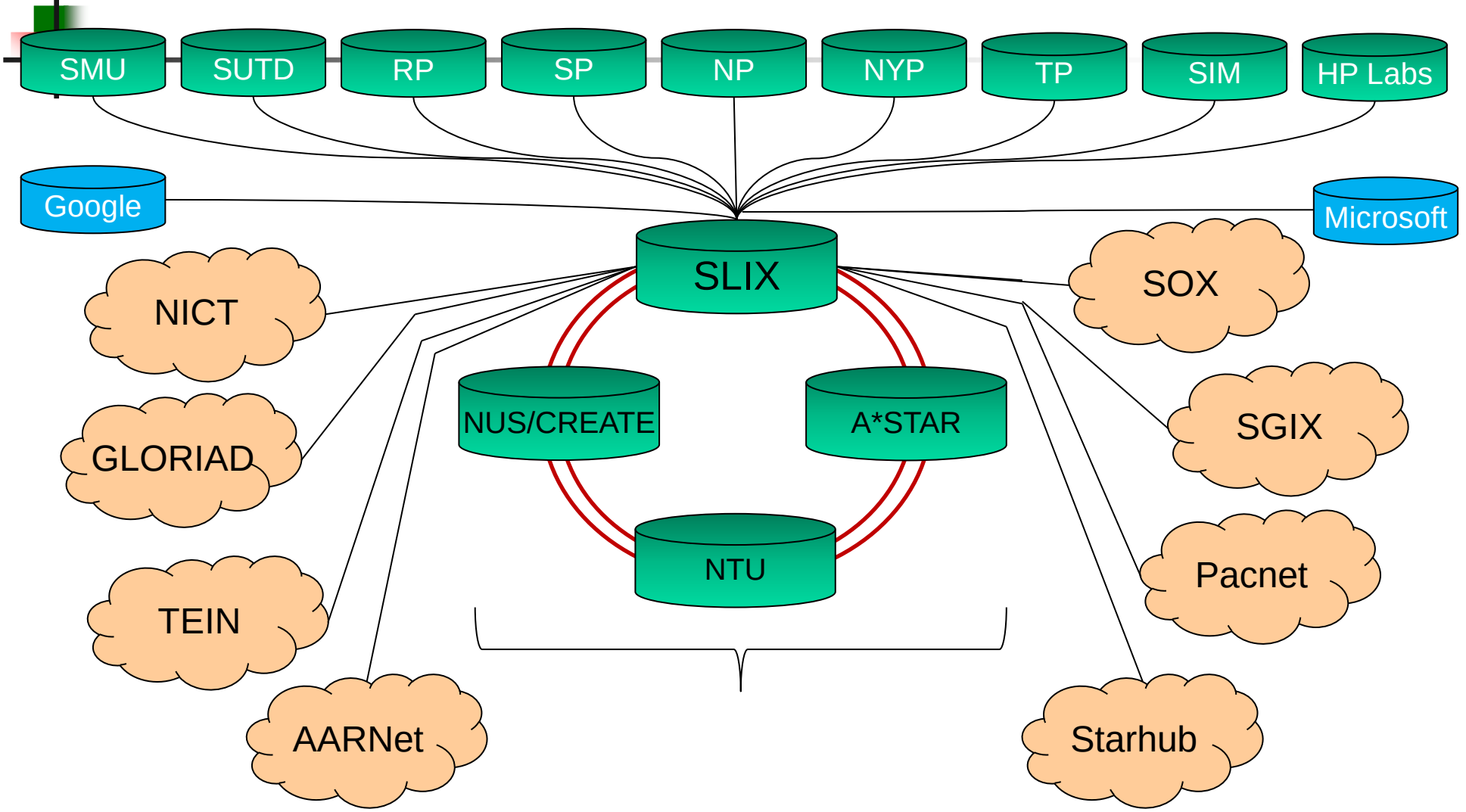
www.singaren.net.sg

TEIN4 Network Topologies

- As of January 2016 -

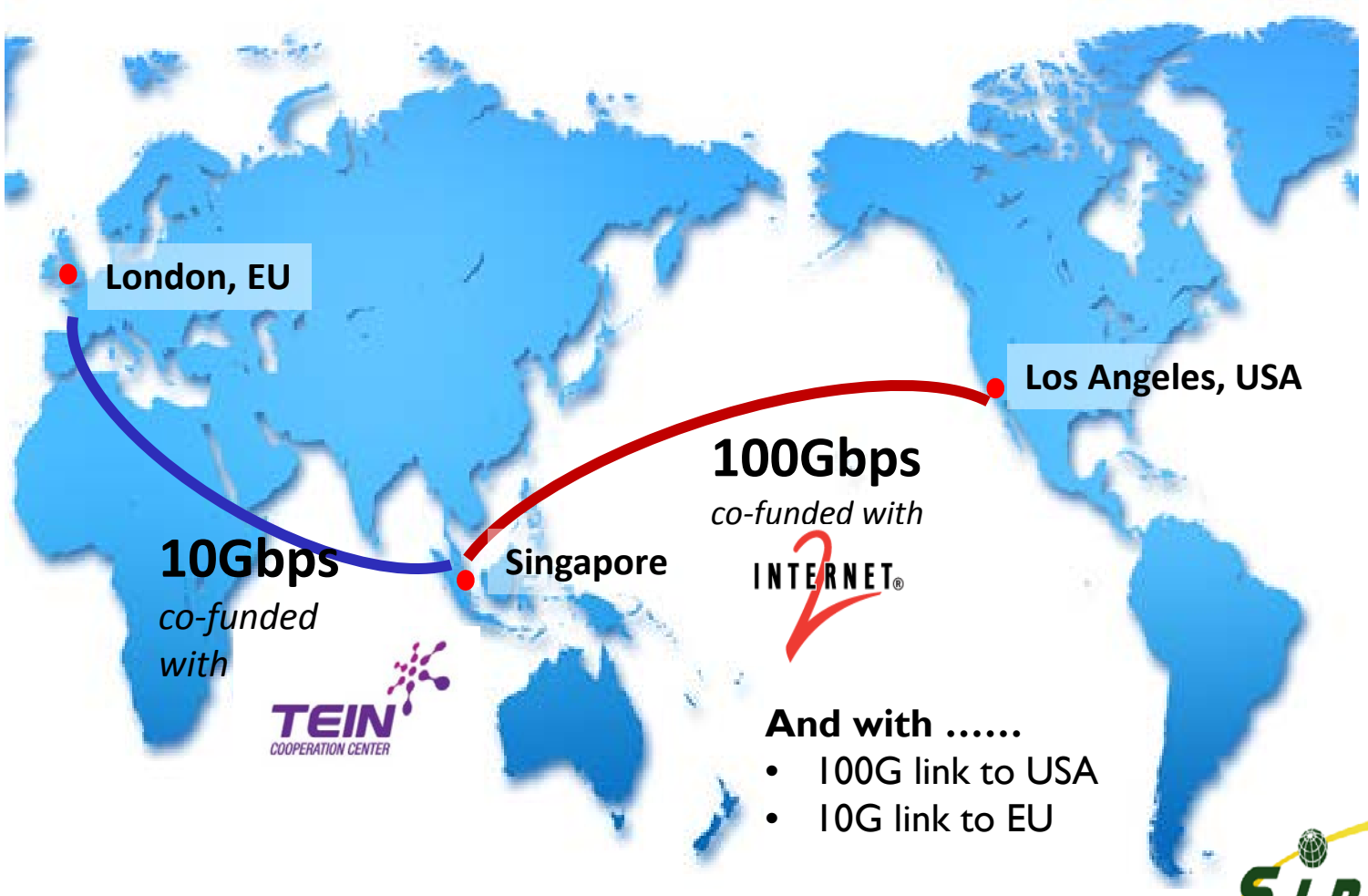


SingAREN-Lightwave Internet Exchange (SLIX)



SLIX backbone network running at 100 Gbps

Collaborations with National Supercomputing Centre (NSCC), SG and R&E partners:



SingAREN rack

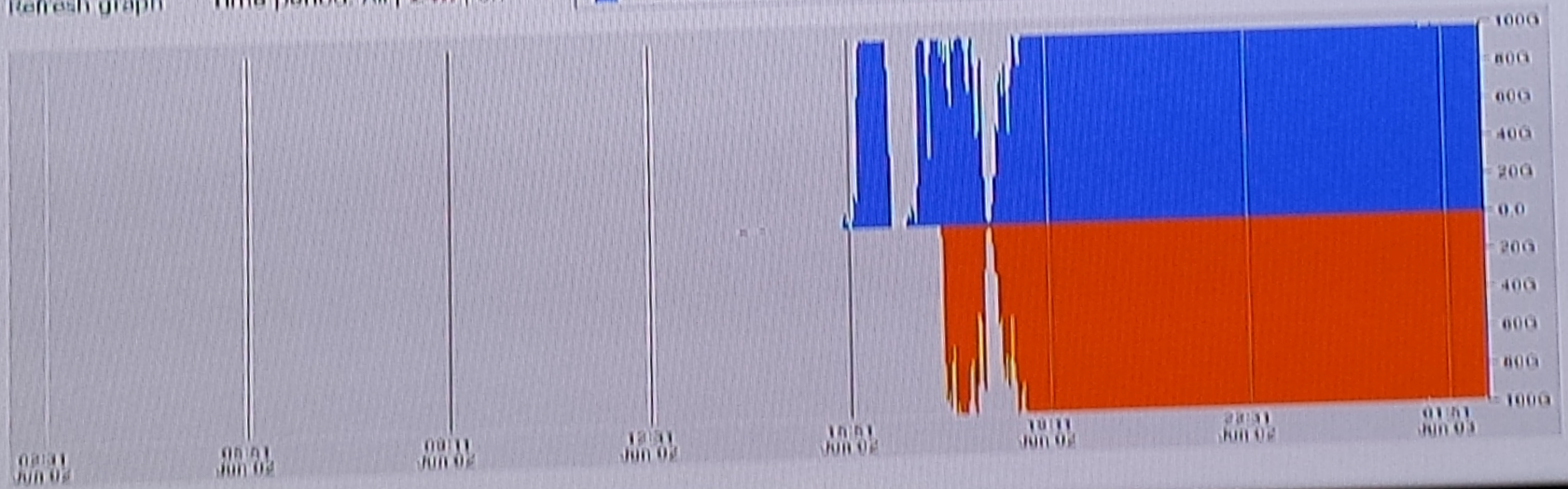
MAN LAN → AMS 90.92 Gb/s

AMS → MAN LAN 90.91 Gb/s

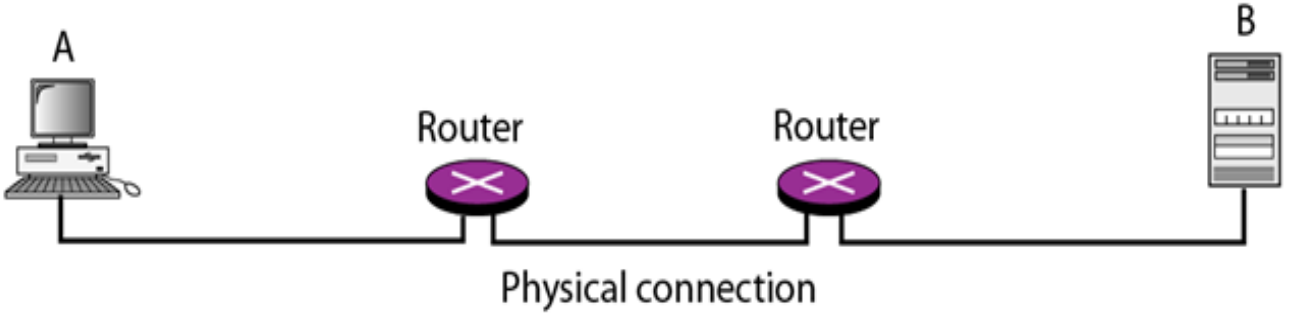
Data will refresh in 9 seconds.

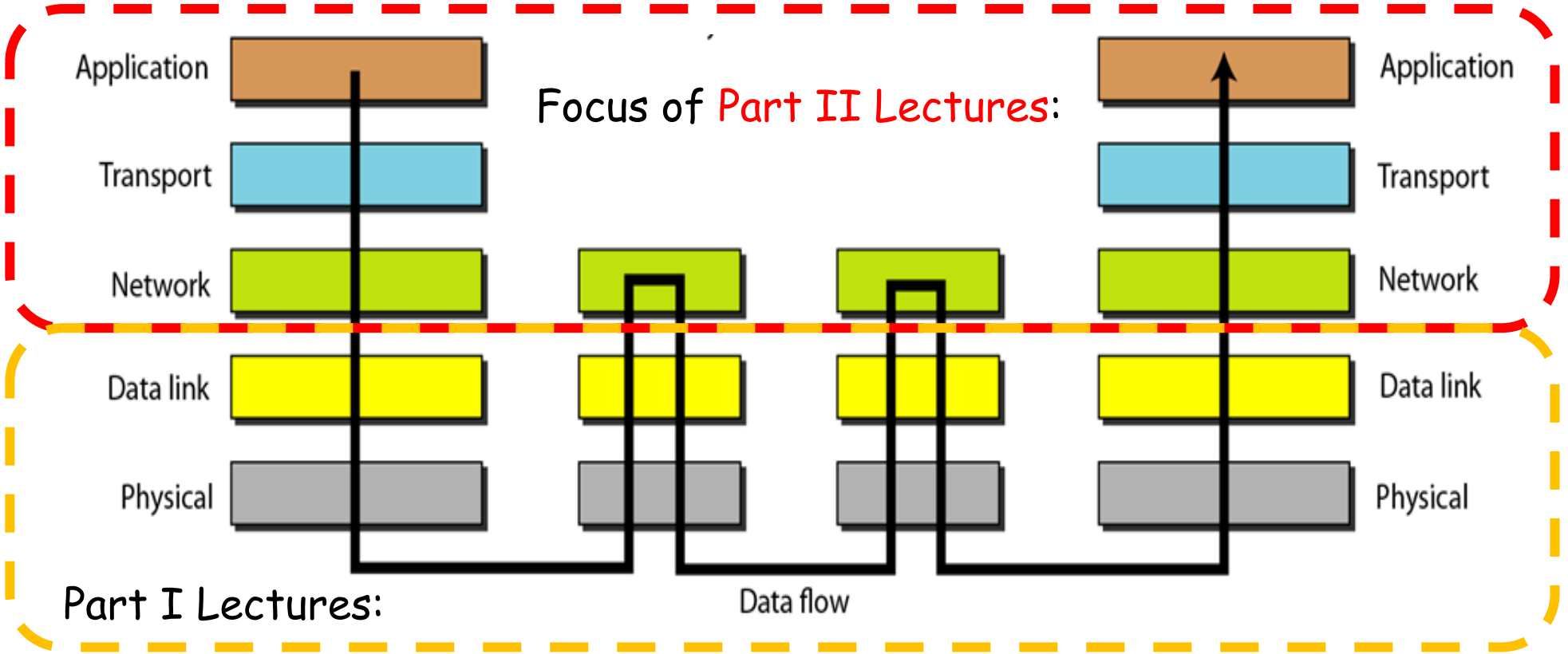
Transatlantic Traffic

Refresh graph Time period: All | 24h | 6h Amsterdam → MAN LAN MAN LAN → Amsterdam 2013-06-02 19:33



With so many different networks interconnected in the Internet, how can we achieve communications among them? – the TCP/IP protocol suite.





In computer networks, the rationale for having at least 5 layers can be appreciated by observing the functionalities of the different layers.

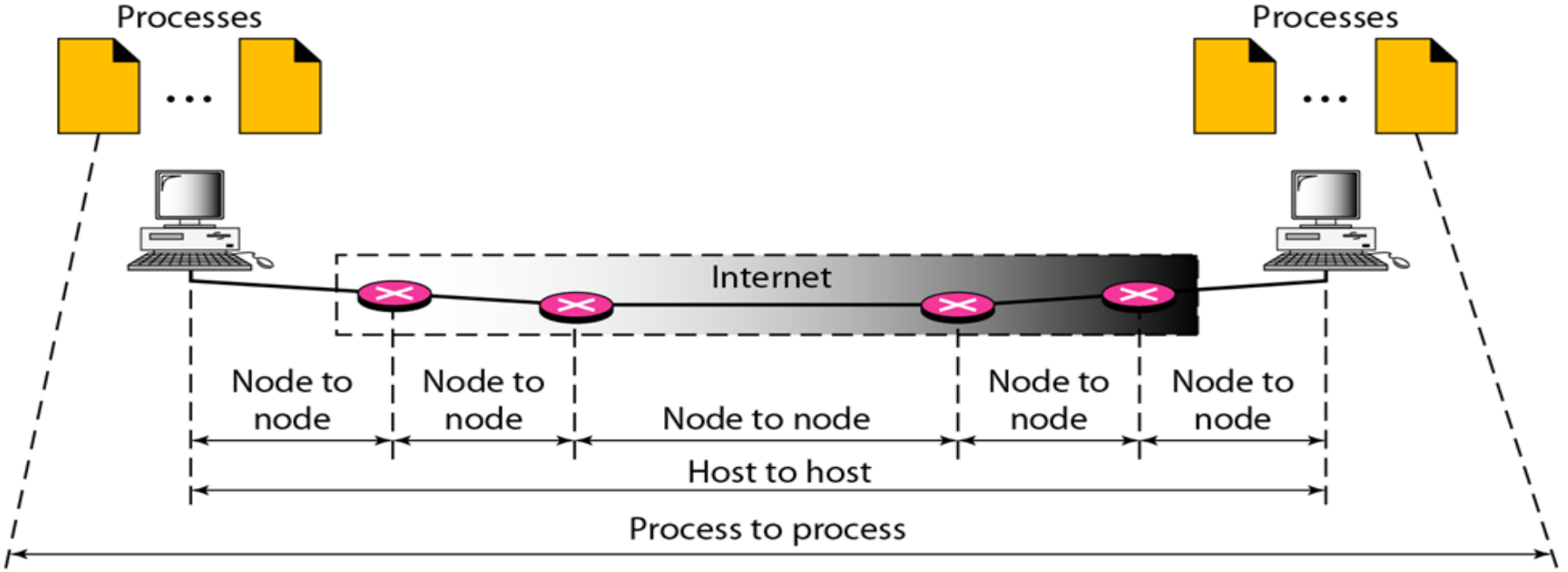
Application layer: concern with application requirement and simply use below services for communications

Transport layer: process-to-process communications

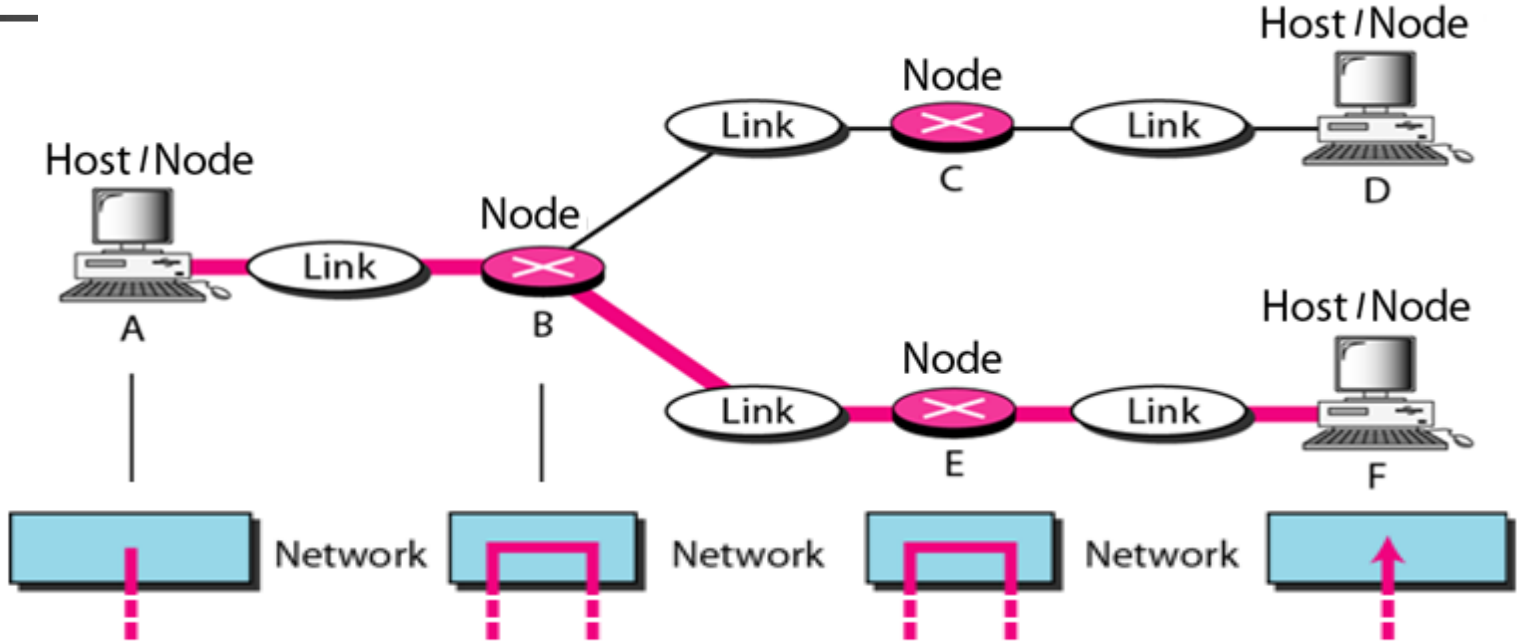
Network layer: host-to-host communications

Data link layer: node-to-node communications

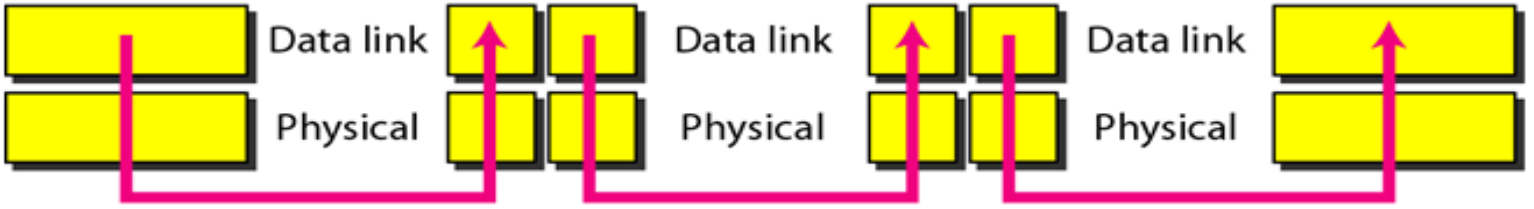
Physical layer: actual transmissions



The difference between host-to-host and node-to-node communications may be clarified by the following example:



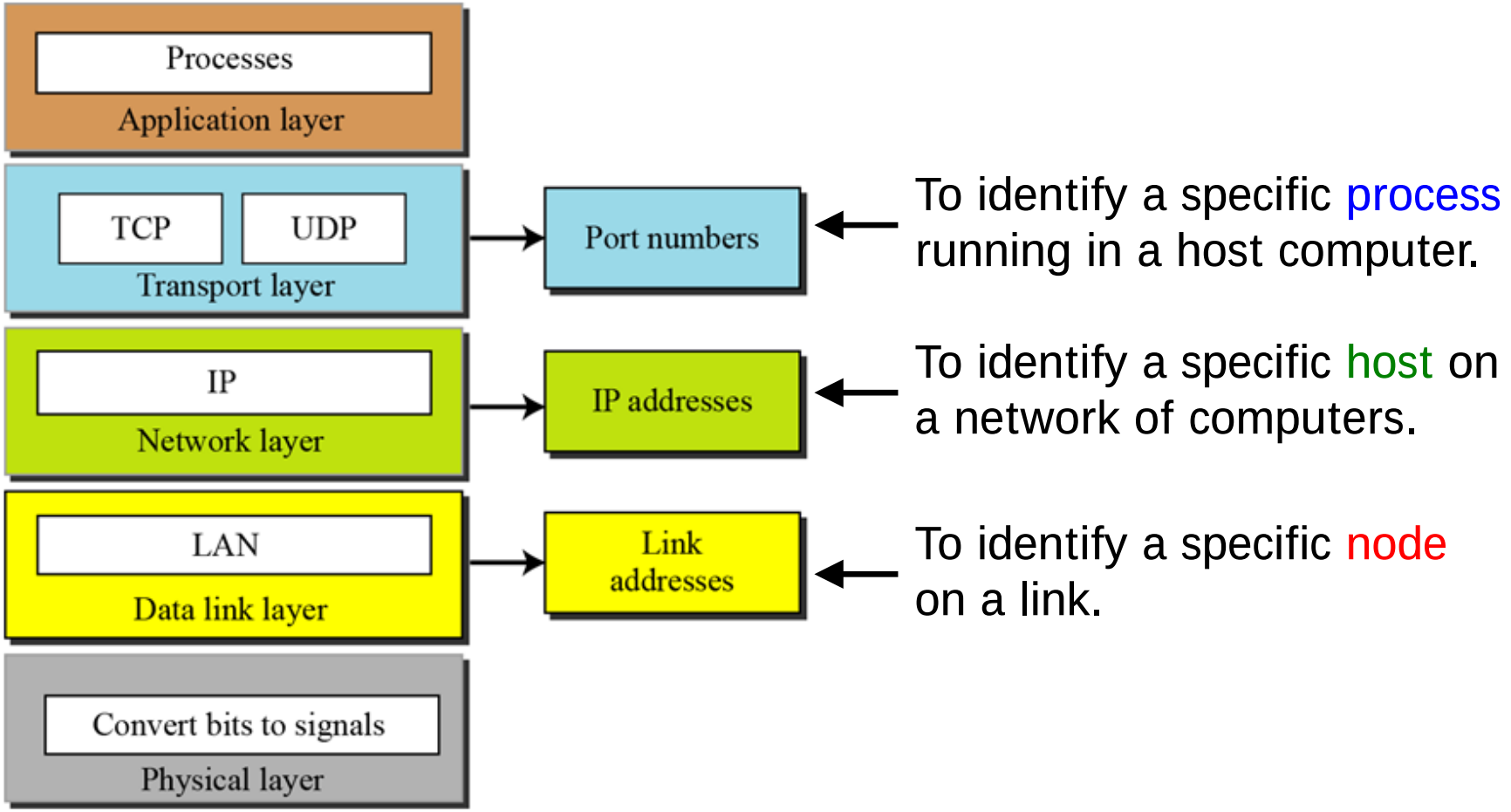
From host A to F, network layer at each node decides the next link/node to go in order to reach F; e.g. at node B, next go to E.



Then, data link layer at each node takes care of data transmission on individual link; e.g. from node B to E.

Since there can be many processes in a host, many hosts on a network, and many nodes on a link, we need addresses at different layers.

Hence, port numbers, IP addresses and link addresses are introduced to identify specific process, computer and node respectively:

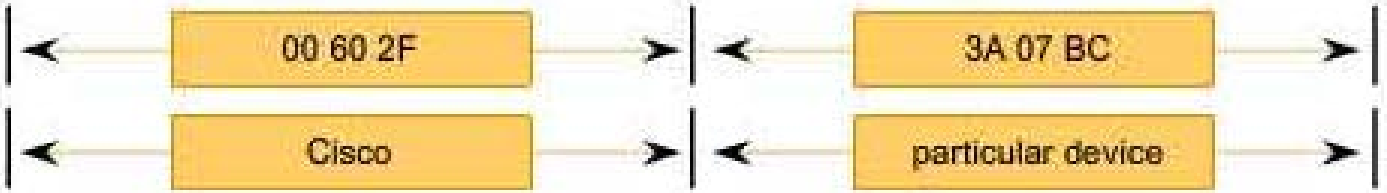


Consider Ethernet which is commonly used at the data link layer, the Ethernet/link/MAC addresses are assigned by vendors, and are 48 bits long.

The 48-bit Ethernet address is further divided into 2 fields:

- first 24-bit OUI which is assigned by IEEE, and
- remaining 24-bit which is assigned by the vendor

Ethernet address is commonly written in hexadecimal, e.g. 00:60:2F:3A:07:BC or 00-60-2F-3A-07-BC



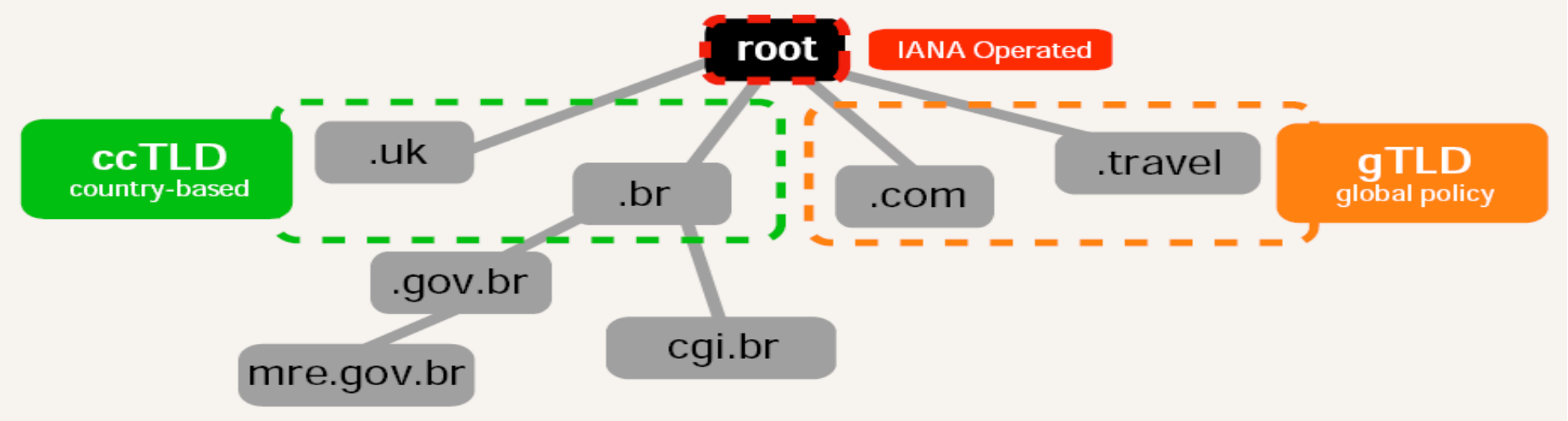
Note that the special address FF:FF:FF:FF:FF:FF is used as the broadcast address in Ethernet.

At the network layer, IP addresses are coordinated by IANA/ICANN, and distributed by five Regional Internet Registries (RIRs).

ISPs and large organizations/companies may join RIRs as members and obtain a block of IP addresses from them.

There are 2 types of IP addresses – IPv4 addresses are 32 bits and IPv6 are 128 bits long!

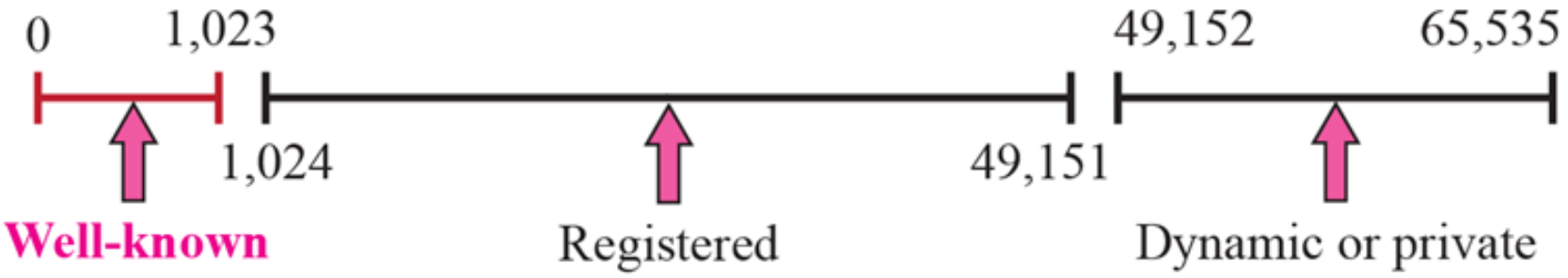
However, it's easier to remember names instead of numbers, so domain names are created and users may optionally buy them to map to their IP addresses.



Domain names are divided into gTLDs and ccTLDs, and commercial domain name registrars are accredited to sell them:

- generic Top-Level Domains (gTLDs): only IANA/ICANN-accredited registrars are able to sell domain names under gTLDs
- country-code Top-Level Domains (ccTLDs): delegated to respective countries, e.g. only (Singapore) SGNIC-accredited registrars can sell domain names under .sg

At the transport layer, port numbers are 16 bits long, and reserved ports from 0-49,151 are coordinated by IANA/ICANN to prevent conflicts in use.



- Well-known port: for common services such as HTTP (port 80), etc; must be registered with IANA
- Registered port: for vendor proprietary services such as Cisco P2P Distribution Protocol (port 4051), etc; must also be registered with IANA
- Dynamic/private/ephemeral port: typically for OS to allocate temporarily to client processes when needed

Now, we are ready to understand how the Internet works:

To reach an Internet resource, we need to specify:

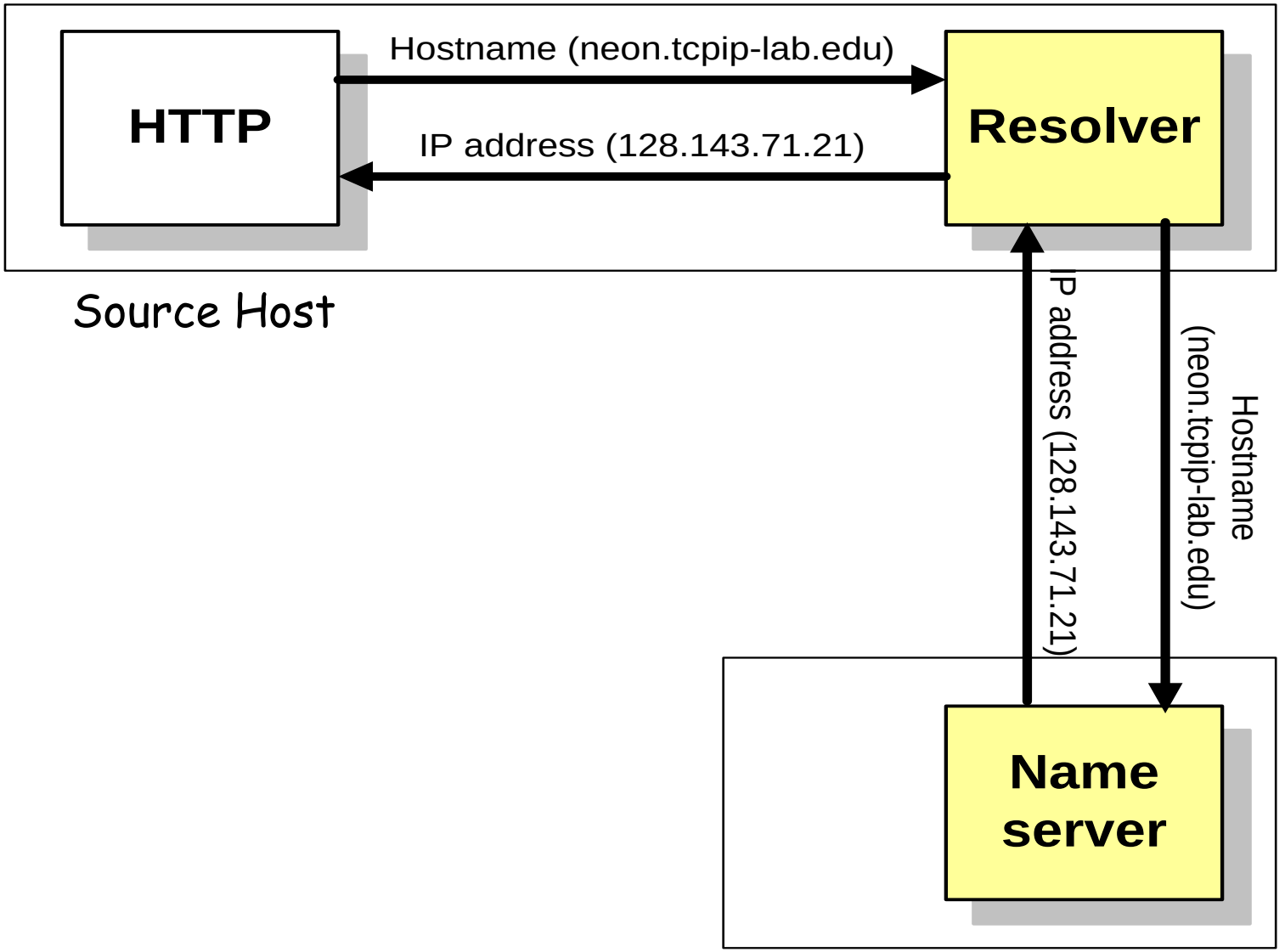
1. Method/Protocol used (application layer)
2. Host using IP address or domain name (network layer)
3. Port number (or none if using default well-known port) (transport layer)
4. Path and document name (application layer)

In practice, all above are concatenated into a single string called Uniform Resource Locator (URL)

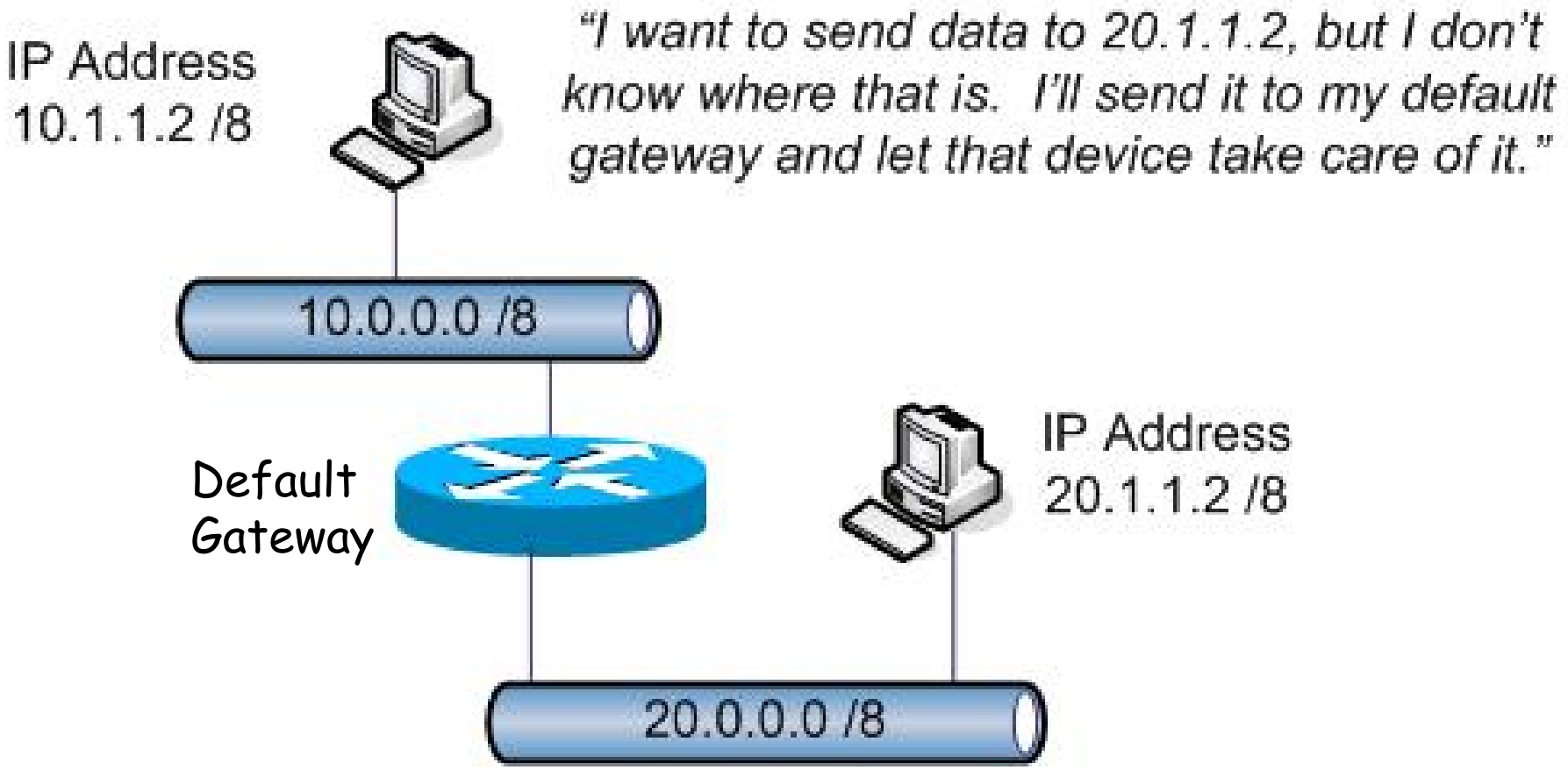
For example:

http://www.prenhall.com/reed/index.html

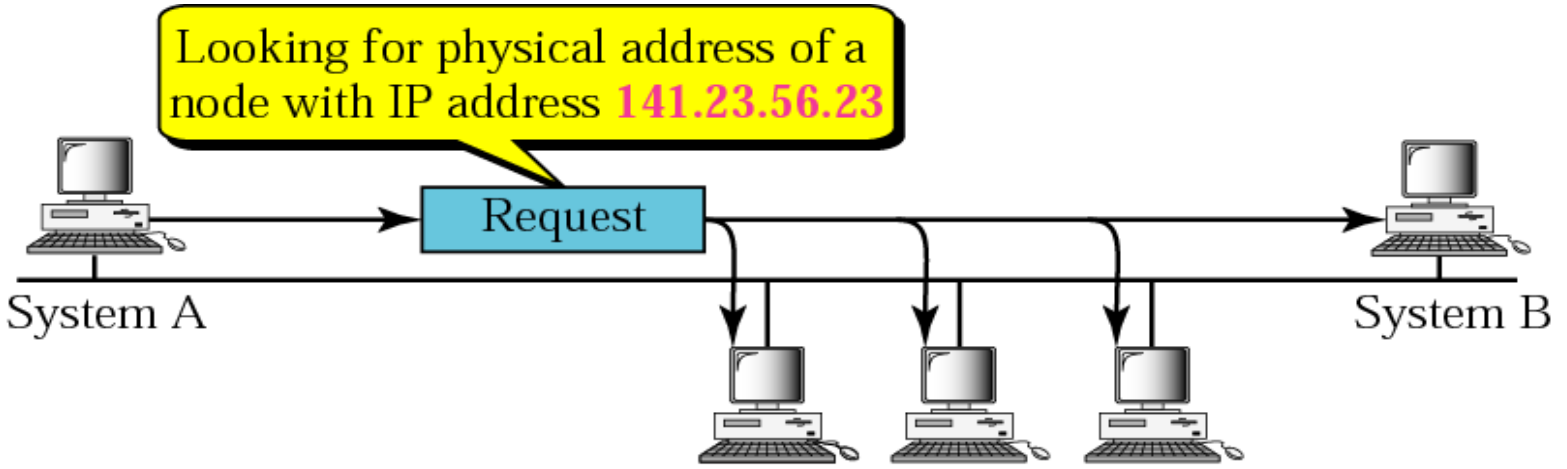
First, if domain name is used, the domain name will need to be resolved into corresponding IP address by using Domain Name System (DNS).



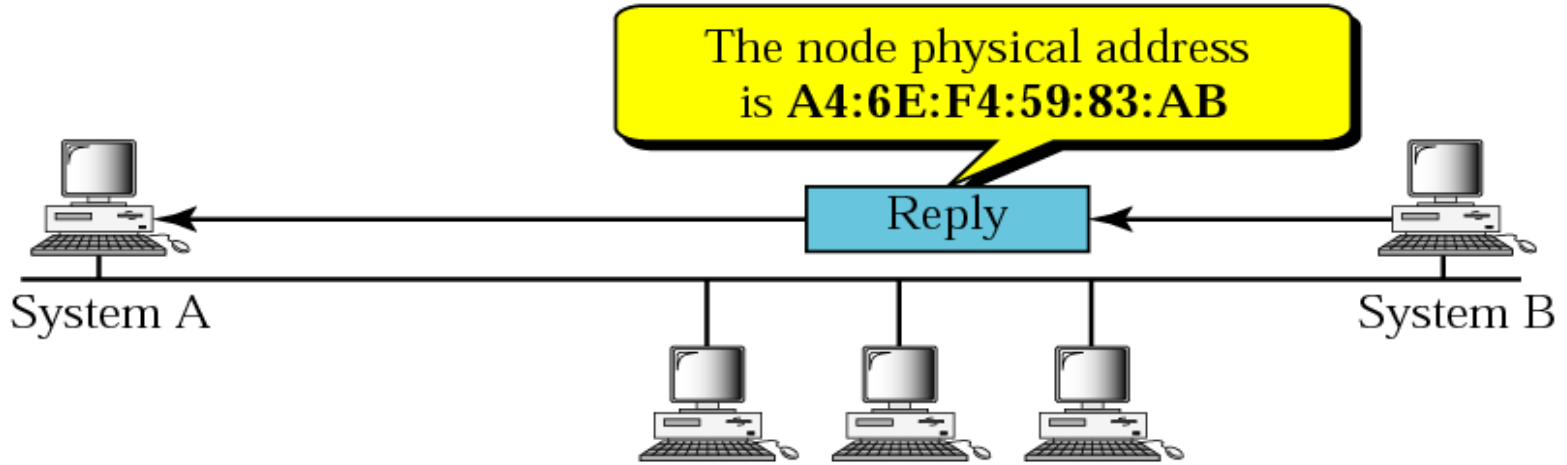
Next, if the destination IP address is on different network, the source host will ask its default gateway (router) to assist in forwarding the messages.



However, the source host may not know the link address of its default gateway. So, it uses Address Resolution Protocol (ARP).

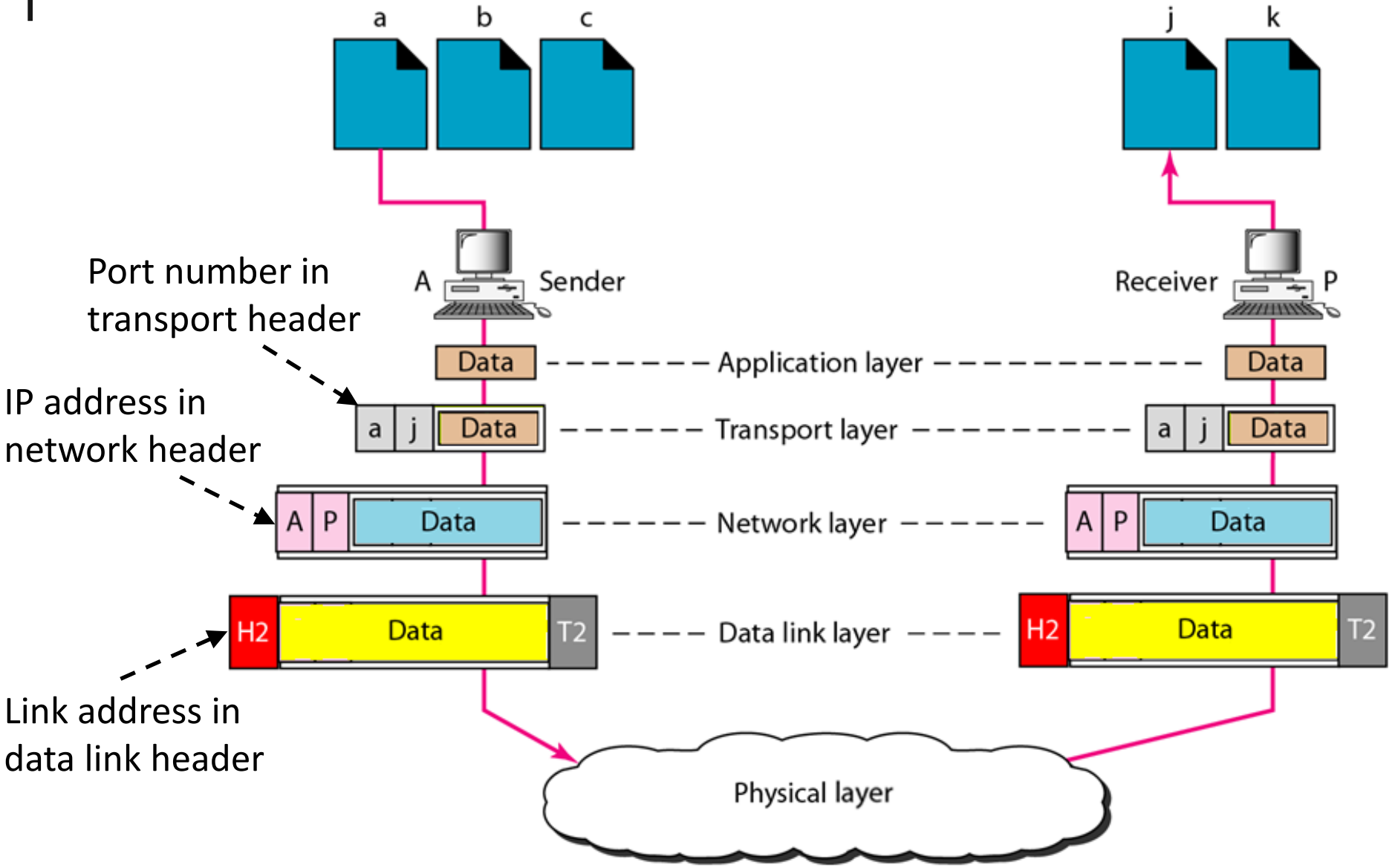


a. ARP request is broadcast

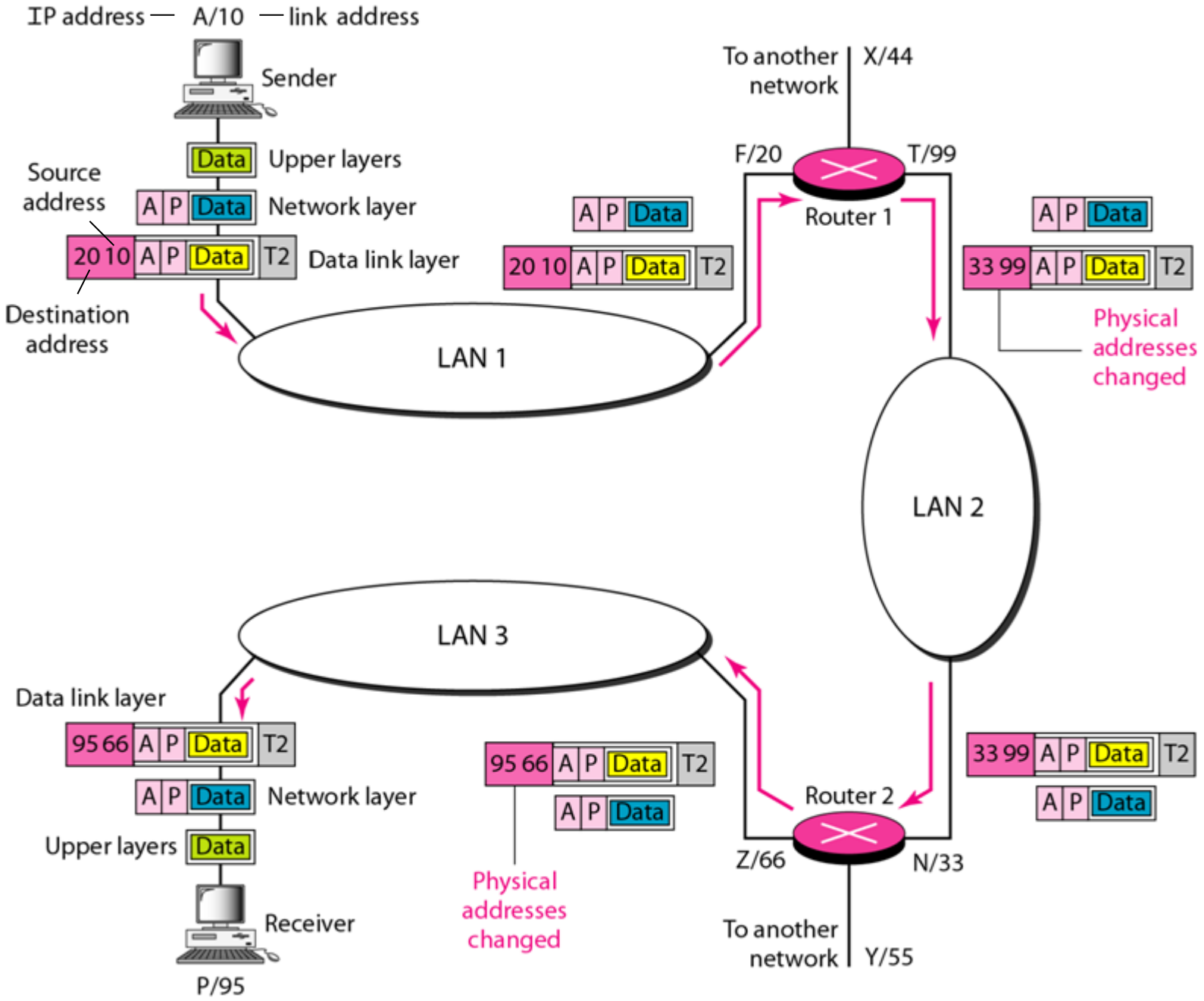


b. ARP reply is unicast

Now, each layer can encapsulate data from higher layer by adding its header with addresses, and the complete data is sent at the physical layer

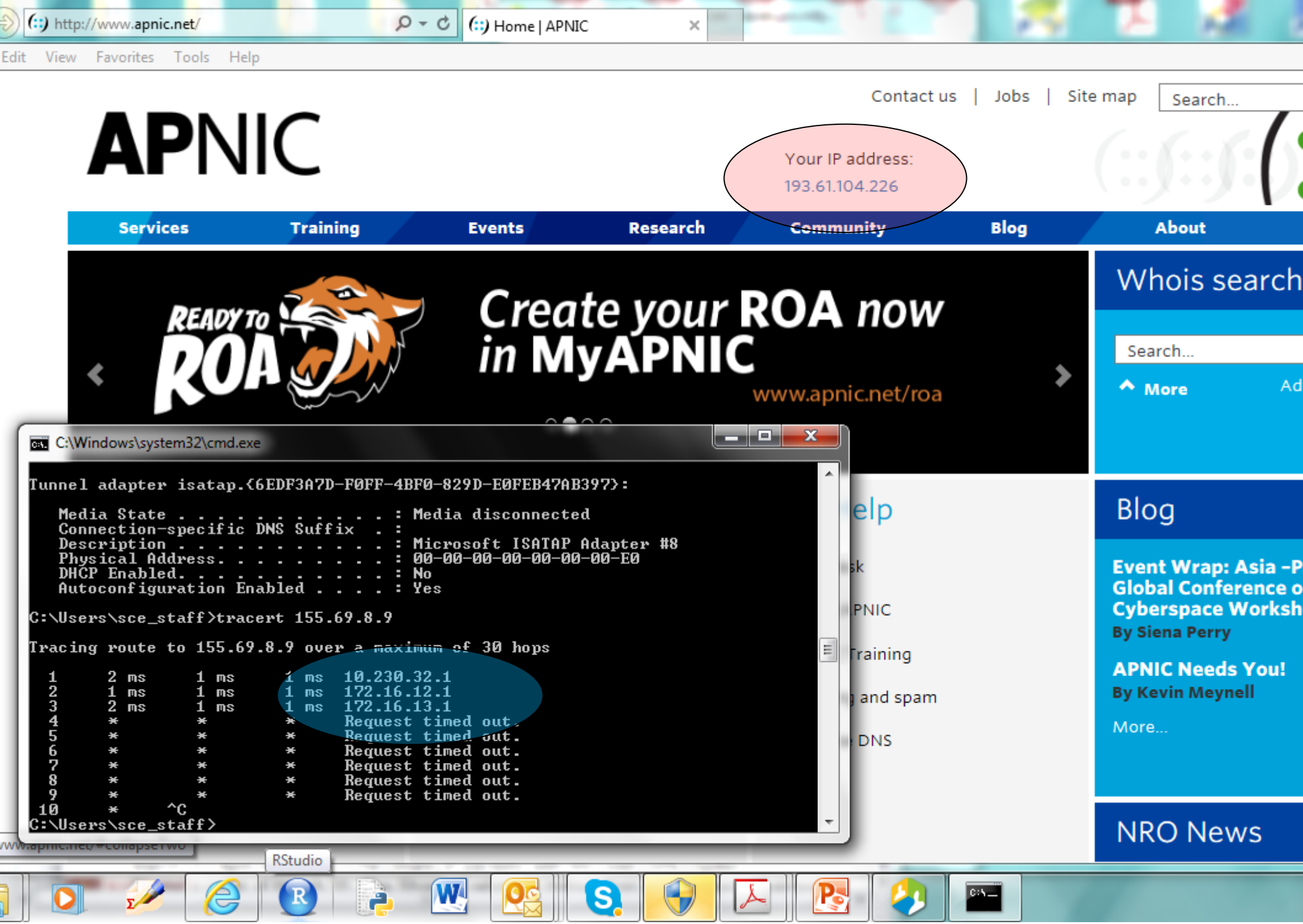


Finally, here's an overall picture of how computers communicate over the Internet:



Useful links

- http://www.speedtest.com.sg/speedtest.php
- http://www.tracert.org/bandwidth_meter/
- http://www.caida.org/home/
- http://www.apnic.net/
- http://en.dnstools.ch/ (good tool)
- https://www.ultratools.com/home
- http://ipinfo.io/ (Provide ASN # given IP address)


http://www.apnic.net/
Home | APNIC
Edit View Favorites Tools Help
Contact us | Jobs | Site map
Search...
APNIC
Your IP address:
193.61.104.226
Services Training Events Research Community Blog About
READY TO ROA
Create your ROA now in MyAPNIC
www.apnic.net/roa
Whois search
Search...
More
Blog
Event Wrap: Asia -P
Global Conference o
Cyberspace Worksh
By Siena Perry
APNIC Needs You!
By Kevin Meynell
More...
NRO News
C:\Windows\system32\cmd.exe
Tunnel adapter isatap.{6EDF3A7D-F0FF-4BF0-829D-E0FEB47AB397}:
Media State . . . . . : Media disconnected
Connection-specific DNS Suffix . :
Description . . . . . : Microsoft ISATAP Adapter #8
Physical Address. . . . . : 00-00-00-00-00-00-00-E0
DHCP Enabled. . . . . : No
Autoconfiguration Enabled . . . . : Yes
C:\Users\sce_staff>tracert 155.69.8.9
Tracing route to 155.69.8.9 over a maximum of 30 hops
1 2 ms 1 ms 1 ms 10.230.32.1
2 1 ms 1 ms 1 ms 172.16.12.1
3 2 ms 1 ms 1 ms 172.16.13.1
4 * * * Request timed out.
5 * * * Request timed out.
6 * * * Request timed out.
7 * * * Request timed out.
8 * * * Request timed out.
9 * * * Request timed out.
10 * ^C
C:\Users\sce_staff>
RStudio