Networking  
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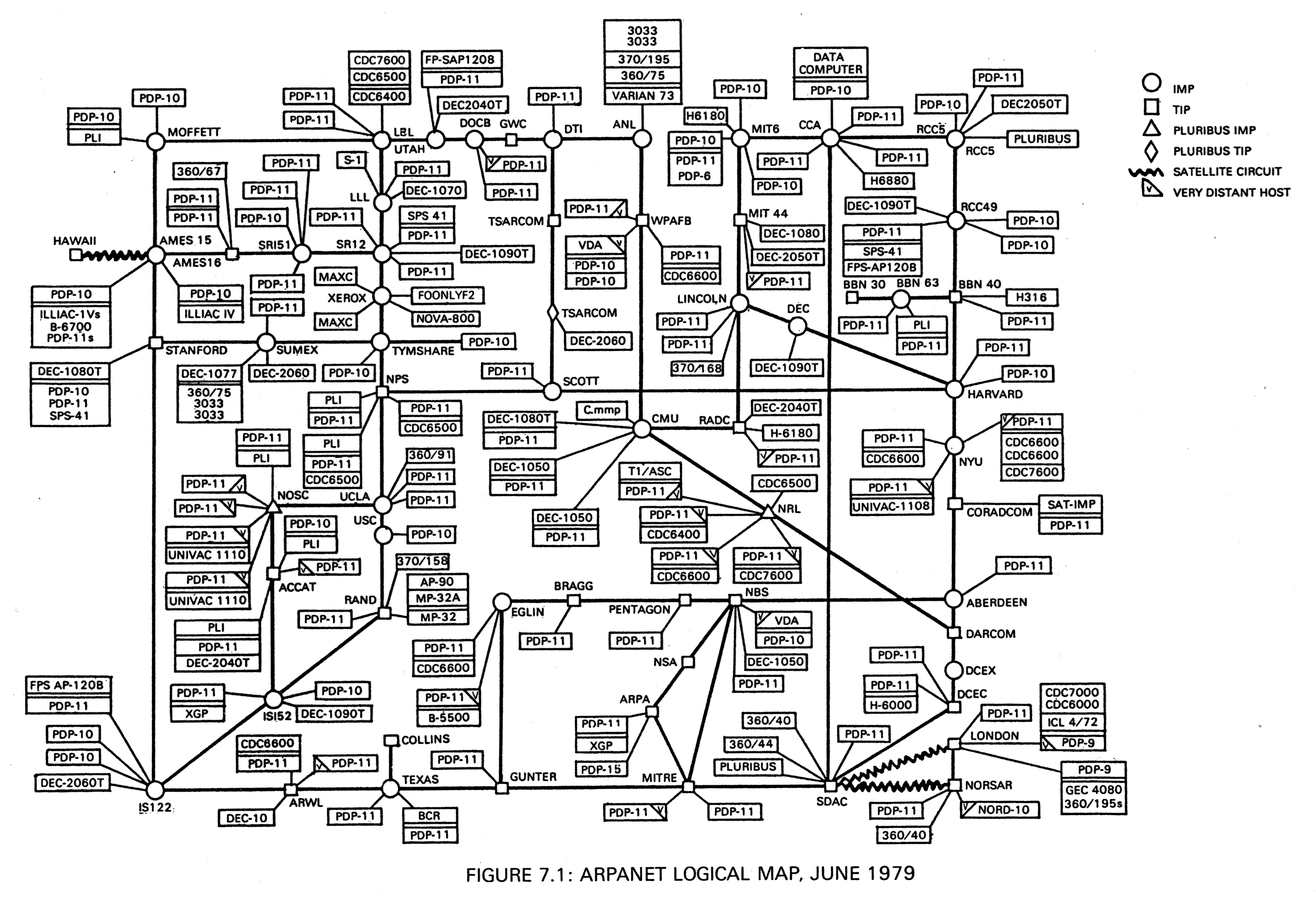
### 1. Networks

#### History

* Email and discussion groups are immediately popular
* 1973 Internet reaches London
* 1974 TCP/IP replaces NCP

### 2. Networks

#### History



Arpanet in 1979, from “Computer Networks, Fundamentals, Practice”; Bacon, Stokes, Bacon, 1984

### 3. Networks

#### History

* 1980s 1000s of machines on the Internet
* Domain Name System arrives
* 1980/90 Original ARPANET decommissioned and replaced
* Commerce arrives
* Other networks based on other protocols are replaced by the Internet
* 1992 1,000,000 hosts
* Gopher
* Tim Berners-Lee invents the Web

### 4. Networks

#### History

* The Internet starts to enter the home
* Microsoft gives up on its own network and falls into line
* The Dot Com boom
* The Dot Com crash
* Broadband to the home
* Large commerce over the Internet

### 5. Networks

#### History

* Mobile revolution
* “Social” media
* Internet of Things (IoT); blockchain; etc.
* …what next?

### 6. Networks

Already this decentralised and packet nature has implications on how the Internet must work

* how to chunk the data into packets?
* how are route(s) the packets use to get to their destination found?
* how do we reconstruct the original data as packets might be arriving in any order?

And higher level decisions like how we shall choose and build these multiple routes; what hardware to use, and so on

### 7. Networks

A packet doesn’t know how to get to its destination

Even the source host doesn’t generally know a route to the destination (only if the destination is on the local network)

A packet is like a postcard with the address written on it: it relies on the *routers* it passes though to make the right decisions

“Please forward me to <www.youtube.com>”

It is not like a car driver with their own map making their own decisions!

The question now becomes: how do the routers know what to do? More on this later

### 8. Networks

#### Protocols

To ensure maximum interoperability, the Internet relies on *standards* and *standardised protocols*

The use of standards means that machine A will be able to communicate with machine B even if A and B are made by completely different companies, are of completely different technologies and have never previously interacted

It is clear that you must have standards for interoperability in hardware: you can’t plug a electrical plug into an optical socket

But you must have standards in the software too, as becomes clear when you try to use a Web page authoring tool that doesn’t produce standard HTML

Thus we must have standards for the protocols

### 9. Networks

#### Protocols

This is somewhat akin to people agreeing all to use English (for example) to communicate

A pair of random people meeting can talk if they both know English

If not, the chances are that they share their native languages are quite small

### 10. Networks

#### Protocols

The Internet has a collection of specifications called *Request for Comments*, or *RFC*s

RFCs are freely available on the Internet for everyone to read and implement

The RFC philosophy:

Be as close to the RFC as possible in what you do yourself, but be as liberal as possible regarding what you accept from others

**Continuing Exercise** When a topic is covered in lectures, read the relevant RFCs

### 11. Networks

#### Protocols

There are several bodies that oversee the structure and working of the Internet and the standards

* Internet Society (ISOC); oversees the Internet standard development processes
* Internet Architecture Board (IAB); ISOC committee that oversees the technical and engineering development of the Internet, particularly IETF and IRTF
* Internet Engineering Task Force (IETF); IAB committee that develops standards and publishes RFCs
* Internet Engineering Steering Group (IESG); executive sub-committee of IETF that has final say over RFCs

### 12. Networks

#### Protocols

* Internet Research Task Force (IRTF); IAB committee that does long-term research and development of Internet technology
* Internet Research Steering Group (IRSG); sub-committee of IRTF that manages the research groups
* Internet Corporation for Assigned Names and Numbers (ICANN); nonprofit internationally-organised organisation to oversee (sets policy) for global resources such as names and numbers or other identifiers
* Internet Assigned Numbers Authority (IANA); an affiliate body to ICANN that actually manages the domain names, IP addresses and other things, currently run by a company named “Public Technical Identifiers”

### 13. Networks

#### Protocols

IANA delegates management of various things to *Regional Internet Registries* (RIRs), e.g., domain names and addresses

Current RIRs:

* African Network Information Centre (AfriNIC); Africa
* American Registry for Internet Numbers (ARIN); North America and Antarctica
* Asia-Pacific Network Information Centre (APNIC); Asia, Australia, New Zealand
* Latin America and Caribbean Network Information Centre (LACNIC); South America
* Réseaux IP Européns Network Coordination Centre (RIPE); Europe, Russia, the Middle East, and Central Asia

### 14. Networks

#### Protocols

These are geographical, not political, regions

The RIRs further delegate things like management of domain names to commercial companies

E.g., 123-reg, GoDaddy and hundreds of others

**Exercise** Trace the movement of money up this hierarchy

### 15. Networks

#### Protocols

Outside ISOC, others important specification bodies include

* IEEE Institute for Electric and Electronic Engineers; hardware like Ethernet and Wi-Fi
* ISO International Standards Organisation; e.g., XML standards
* IEC International Electrotechnical Commission; e.g., Digital Living Network Alliance (DLNA)
* ITU-T Telecommunication Standardization Sector of the ITU (International Telecommunication Union); e.g., DSL standards
* lots more national and international institutions, such as the British Standards Institution (BSI)

### 16. Networks

#### Protocols

There is quite a lot of overlap in what these institutions cover

Sometimes one institution will take a standard from another institution and put a new cover sheet on it and give it a new name or number

For example, the JPEG standard, from the Joint Photographic Experts Group, is the same as ISO standard 10918-6:2013 and ITU-T T.872

**Exercise** Investigate these standards bodies

### 17. Networks

#### History

Anyway, we need a common “language” (the protocols) for a network

For the Internet, this common language is called the *Transmission Control Protocol/Internet Protocol* (TCP/IP)

This name is more historical than accurate, but to see what it means we need to think of *layers*

### 18. Networks

#### Layering Models

What do we need to make two computers communicate?

We need to connect them, so there must be some kind of physical (electrical, optical, radio or other) thing between them

So they must be compatible on voltages, how bits are represented as electrical or optical signals, etc.

And they must agree on how to represent data as bits: recall the different ways of representing signed and unsigned integers; similarly there are several ways of encoding alphabetic characters as bits

And the same problem for all other kinds of data: how to represent that sound or that shade of blue?

### 19. Networks

#### Layering Models

And technical requirements we have of the network

Such as do we make sure data arrived safely and didn’t get lost or corrupted in transmission?

And a lot of other problems that only become clear when you try to build a network

Getting this right all at once is very difficult

### 20. Networks

#### Layering Models

So how should we implement a network system?

First we need a standard to follow

So how should we design a network standard?

The standard must address all the issues (and more) mentioned previously

### 21. Networks

#### Layering Models

This is too big a problem to be tackled all at once

How about chopping the design into chunks, each chunk having a well-defined functionality?

Note this is just the way we approach writing large programs

Except we are not writing a program here, we are designing a standard

So we slice the problem into nice, bite-size pieces, called *layers*

### 22. Networks

#### Layering Models

So what should the chunks be?

A *layering model* for a system is a suggestion on how you might want to slice up the problem of designing it all

An oft-misunderstood point is that a layering model is *not* a networking standard

It is a recommendation on how you *approach the design* of the standard

After you have written the standard, you can then make implementations

### 23. Networks

#### Layering Models

So:

* We pick a layering model
* We use this to guide us in making a standard
* We use the standard to direct the implementations
* We can then use the implementations

Note that there will likely be several differing implementations

But, if it is a comprehensive standard, and *if all the implementations follow the standard*, they will interoperate

### 24. Networks

#### Layering Models

For networks, there are two main layering models in use: the ISO Open Systems Interconnection (OSI) Seven-Layer Model; and the Internet Four-Layer Model

That is: two popular recommendations on how to design a networking standard

The OSI model is widely used while the Internet model is not, despite closely mirroring the Internet standard