Data Communications

LECTURE: INTRODUCTION AND CONCEPTS

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Data communications

WHAT ARE WE LOOKING AT?

What do we mean by data communications?
How can we use these / plan these?
Some quick definitions to help us…

Data communications

“PROCESS”

Applications are made up from one or more processes

Processes are independent:

- They run separately
- Progress at different rates (they are asynchronous)

Data communications

"MESSAGES"

Messages provide **synchronisation** between processes, as well as exchange of information.

Data communications

"COMMUNICATION"

Processes communicating by sending and receiving **messages**

The end!

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Questions?

Data Communication

HOW?

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What we'll look at in this unit are some ways of managing the "how" we can communicate. Including:

- Sending messages over different networks
- What could go wrong when sending a message
- Core principles of computer networks
- Kinds and topologies of networks
- The "Things" we send are called "Packets"
- Protocols, encapsulation, and a few other concepts.

Concept

SENDING MESSAGES

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We Need three things:

- The contents of the message
- The identity of the recipient
- How to get the message from the sender to the recipient

Example

SENDING MESSAGES

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I WANT TO SEND A MESSAGE TO A COLLEAGUE:

"Let's grab a coffee later today"

Example

SENDING MESSAGES

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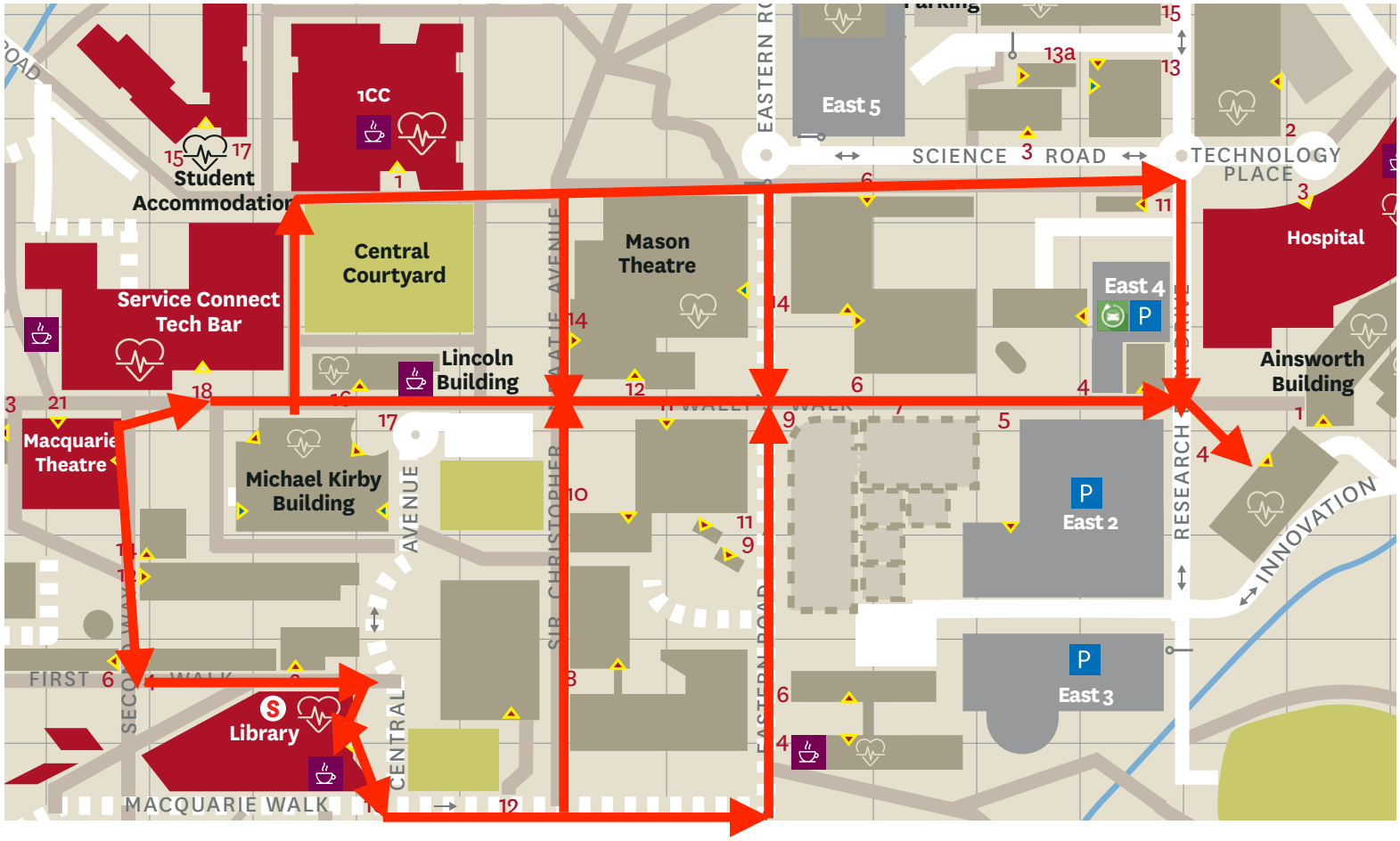
Areas of Expertise

- Software and Systems Engineering
- Pedagogy and Learning / Teaching Approaches
- Algorithms, Data Structures and Programming
- Robotics ans Embedded Software
- Information Systems and Computer Networks

"Let's grab a coffee later today"

Example

SENDING MESSAGES



What we have so far

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AS FAR AS USER OR THE PROCESSES ARE CONCERNED

- Message
- The recipient

THE NETWORK IS CONCERNED WITH MESSAGE

- The route – how the message gets there

What could go wrong?

SENDING MESSAGES

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FOUR THINGS CAN GO WRONG — MESSAGES CAN GET

- Lost
- Delayed — causing out-of-order delivery
- Corrupted
- Duplicated

Concept

WHAT IS A NETWORK?

network | ˈnetˌwərk |

noun

1 an arrangement of intersecting horizontal and vertical lines

- a complex system of roads, railroads, or other transportation routes: *a network of railroads.*

2 a group or system of interconnected people or things: *a trade network.*

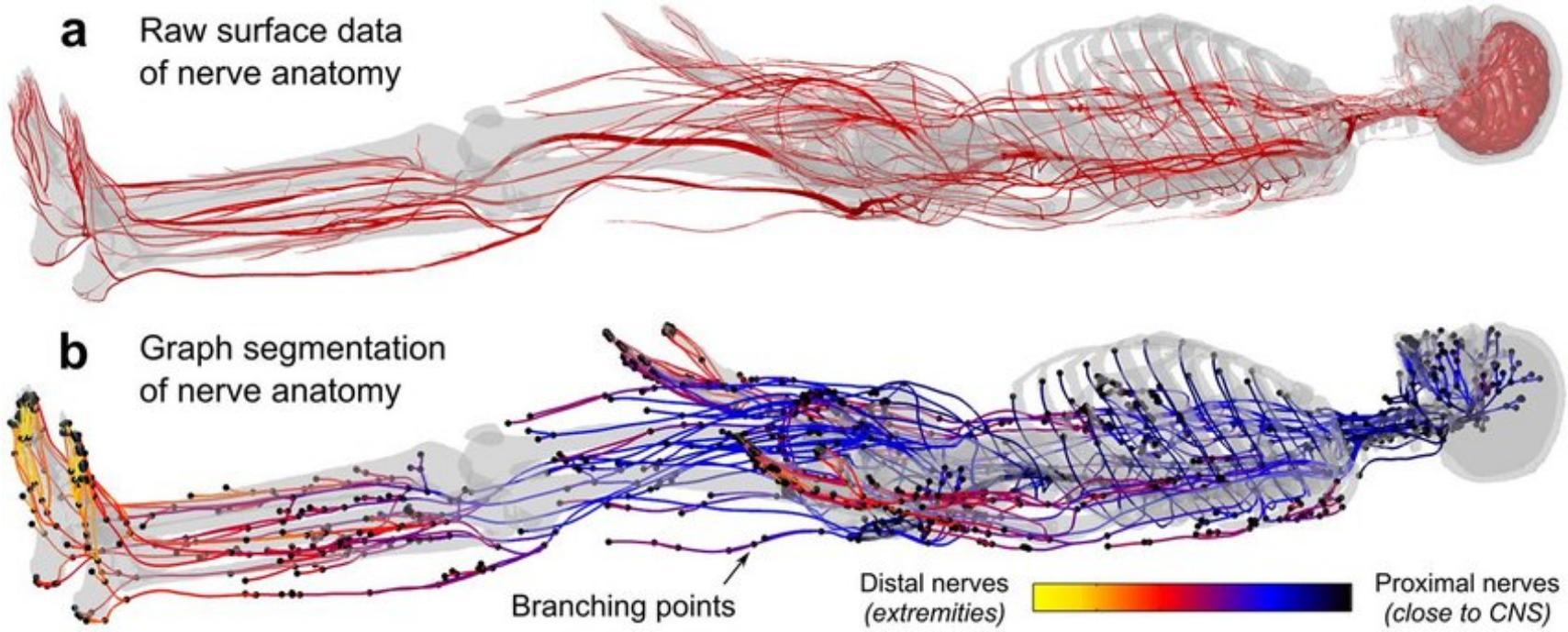
- a group of people who exchange information, contacts, and experience for professional or social purposes: *a support network.*
- a group of broadcasting stations that connect for the simultaneous broadcast of a program: *the introduction of a second TV network* | [as modifier] *: network television*
- a number of interconnected computers, machines, or operations: *specialized computers that manage multiple outside connections to a network* | *a local cellular phone network*
- a system of connected electrical conductors.

Example

NETWORKS

Example

NETWORKS



Thinking about computer-based networks

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MANY OF THE PRINCIPLES AND CONCEPTS ARE THE SAME

- Entities
- Connections — between entities
- Transporting
  - Messages — high level
  - Bits — low level

Network Components

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ABSTRACTLY NETWORKS ARE COMPRISED OF THREE THINGS:

- **Node:** each computer system in a network
  - Some nodes are end-points, the termination points of communication,
  - Others are intermediary systems, forwarding traffic between links
- **Link:** connects one node to an adjacent node, with no intervening nodes.
- **Path (route):** A group of links that allows a message to move from its point of origin to its destination.

Example

HELP ME SEND A MESSAGE TO “BOB”

Classifying Networks

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WE CAN CLASSIFY NETWORKS IN MANY DIFFERENT WAYS:

1. How they operate
2. The geographic area they cover
3. The "shape" of the network — its *topology*

1. Operational classifications

"KINDS OF NETWORKS"

CIRCUIT SWITCHED

- Point-to-point
- Creation and termination
- Exclusive
- Telephone network

https://upload.wikimedia.org/wikipedia/commons/5/50/Telephone_operators%2C_1952.jpg

PACKET SWITCHED

- Multiple paths
- No setup
- Shared
- Data networks

2. Geographic classifications

"KINDS OF NETWORKS"

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LOCAL AREA NETWORKS

- Nodes are near to each other
- Generally a single building, or
- More commonly a single floor of a building

METROPOLITAN AREA NETWORKS

- Connects networks together across a single metropolitan area
- Normally operated by a communications provider

BACKBONE NETWORKS

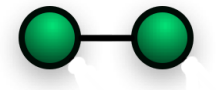
- Connects LANs or other networks together
- Normally constrained to a single organisation

WIDE AREA NETWORKS

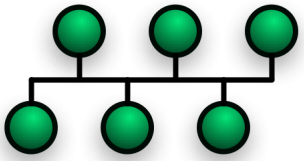
- Connects networks together at a larger scale
- Scales from between cities to between continents

3. Topological classifications

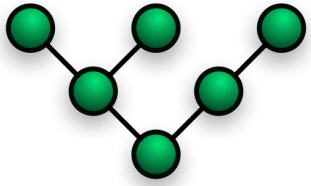
"KINDS OF NETWORKS"



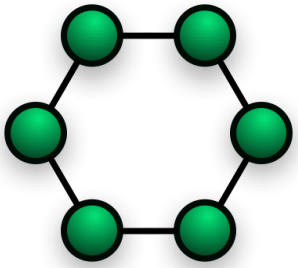
Point-to-point



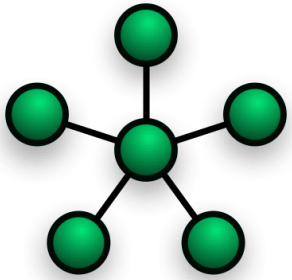
Bus (multi-drop)



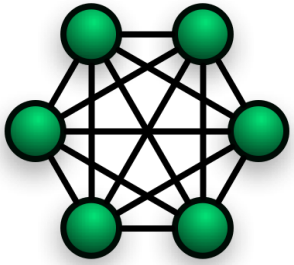
Tree



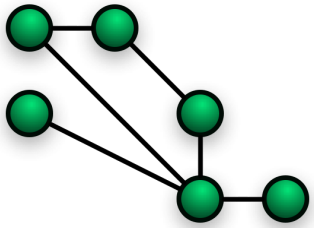
Ring



Star



(Full) Mesh



Partial mesh

Network Layouts

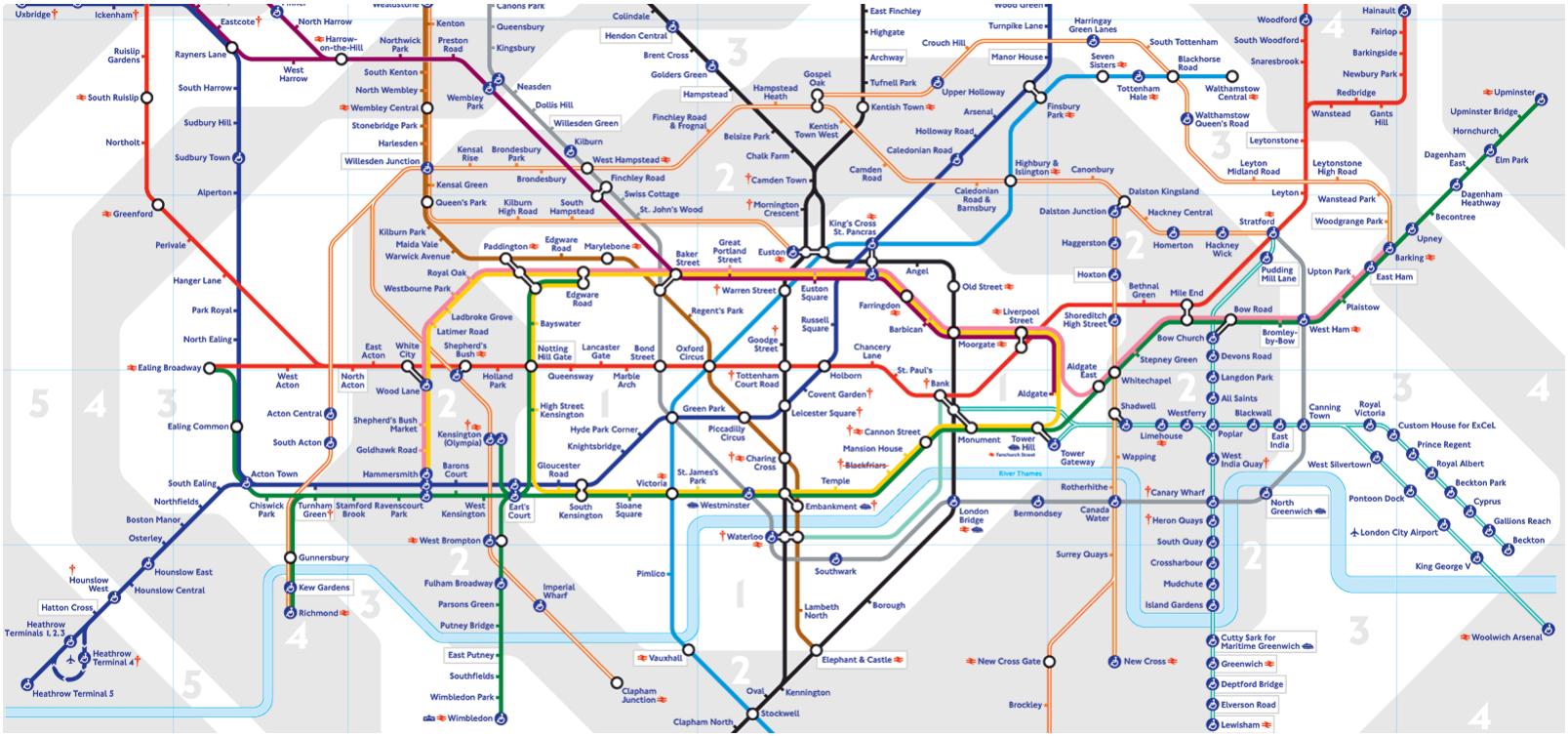
LOGICAL VS PHYSICAL REPRESENTATIONS

Physical Layout

EXAMPLE USING A TRAIN NETWORK

Logical / Abstract Layout

EXAMPLE USING A TRAIN NETWORK



Representations

"KINDS OF NETWORKS"

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LOGICAL TOPOLOGY

- How it operates
- Algorithmic
  - The "logic" of operation

PHYSICAL TOPOLOGY

- How it looks
- How does it "plug together"

WE WILL TAKE A CLOSER LOOK AT THIS IN THESE TWO TOPICS:

- Local Area Networks
- The data-link layer

As Previously Mentioned

NETWORKS CAN BE EITHER BE

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CIRCUIT SWITCHED

- Like a telephone conversation
- An exclusive pathway is established between the two end-points.
- Simultaneous conversations can occur but only between strictly separate pairs of end-points

PACKET SWITCHED

- Like the postal service
- Items of varying sizes are passed between multiple pairs of end-points over a shared network
- For this to occur we must break our communication into discrete chunks called packets

“Packetisation”

WE CAN’T SEND EVERYTHING AT ONCE - SO BREAK IT UP

PACKETS CONSIST OF 2 THINGS

- A Header which contains Metadata
- A Payload or Body which contains Data

Metadata

"DATA ABOUT DATA"

What would a courier need to know about the packet to work out what to do with it?

Metadata

"DATA ABOUT DATA"

What are some other metadata examples for packets

- What is the destination
- What time was is sent
- Who sent it?

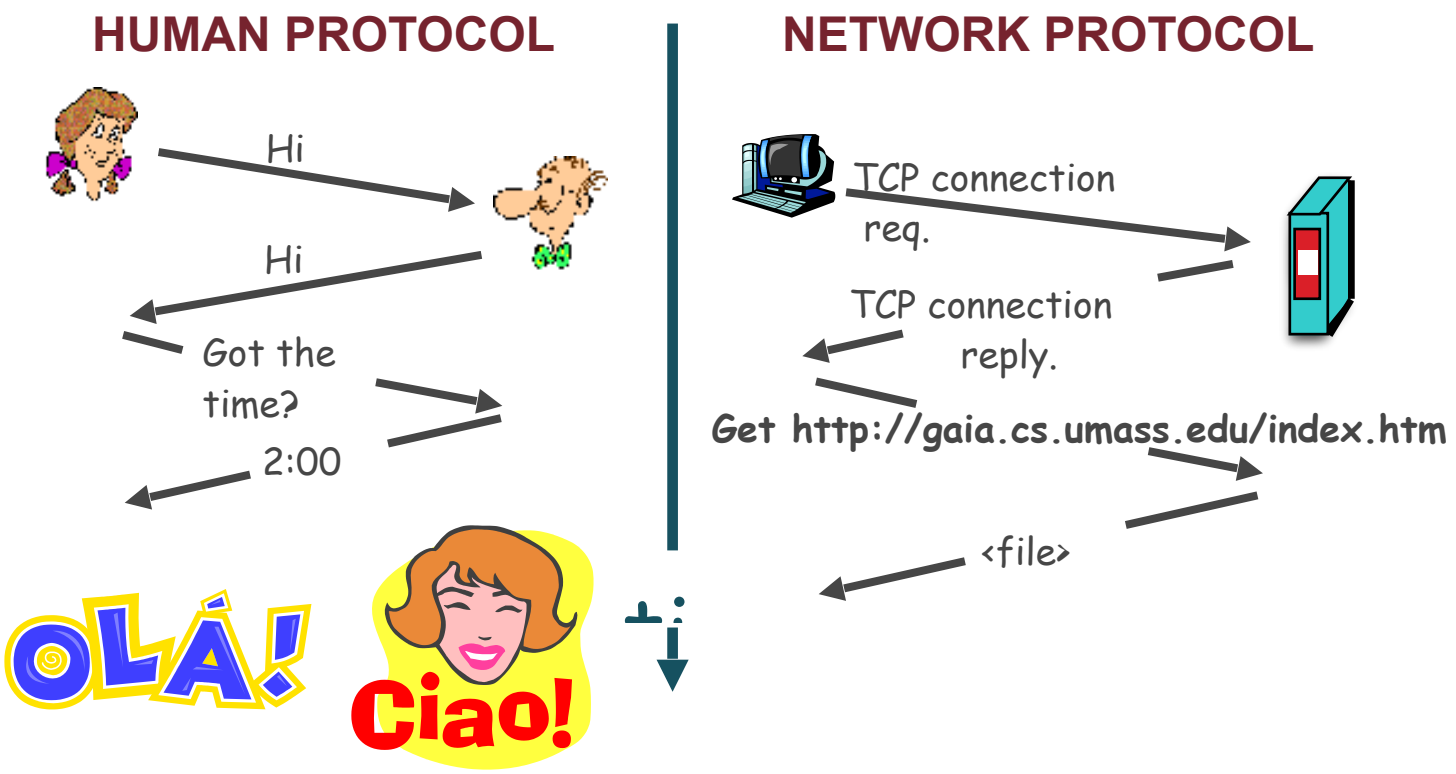
Can you think of other examples of Metadata more generally?

Protocols and Standards

IN DATA COMMUNICATIONS

Communicating (protocol)

"OPERATIONAL CLASSIFICATION"



Protocols vs Standards

WHAT IS THE DIFFERENCE

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KEY DIFFERENCES:

- Level of detail
  - step-by-step vs
  - broad guidelines
- Development
  - individual companies/groups vs
  - recognised organisations
- Implementation
  - Directly implemented on devices vs
  - definition on how to implement protocols

Protocols

HOW DO THEY WORK?

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At the sending computer, the protocol:

- Breaks the data into smaller sections, called packets, that the protocol can handle.
- Adds addressing information to the packets so that the destination computer on the network will know the data belongs to it.
- Prepares the data for actual transmission through the network adapter card and out onto the network cable.

Protocols

HOW MANY PROTOCOLS ARE THERE?

- Communicating computers need to send a lot of information to each other, for example:
- are you still there?
- this message is to be sent to X
- the last message was in error
- the number of bits in this message is N
- we could use a single protocol to carry all the necessary information
- not a good idea - the implementation would be large and difficult to maintain

Protocol Layers

BREAK THE "ROLES AND RESPONSIBILITIES INTO LAYERS"

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PROTOCOLS WORK TOGETHER

- Sending data from one node to the next along a single link is a different problem than sending data from one building to another, which is a different problem to sending data to the other side of the world
- Good engineering practice, take a large complicated problem and break it into smaller problems which can be more easily solved.
- Different protocols solve different problems

These layers form a “Protocol Stack”

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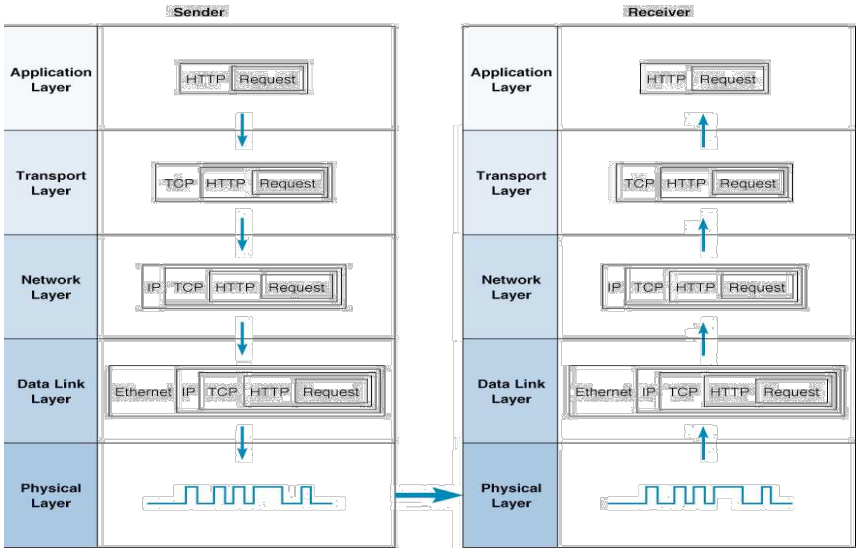
- A protocol stack is a combination of protocols arranged in a layered format.
- Each layer specifies a different protocol for handling a function or subsystem of the communication process.
- Each layer has its own set of rules.
- Standard Protocol stack – examples
  - OSI model
  - Internet (TCP/IP) protocol stack.

Protocols and Standards

A SYMBIOTIC RELATIONSHIP

- A protocol is embodied in a standard
- A standard specifies a protocol

A standard can describe one protocol in one layer, a standard can describe an entire stack…



Standards

WHO SETS THESE STANDARDS?

- The lowest layers in a protocol stack are generally defined by the IEEE
- The middle layers of the TCP/IP stack are defined by the IETF
- The upper layers may or may not be standardised
  - Example, the protocols that operate the web are defined by the W3C

Network Models

OSI AND TCP/IP

OSI reference model

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LAYER 1 CLOSER TO PHYSICS, UPPER LAYERS CLOSER TO YOUR APPLICATION

layer 7 application	Applications and application interfaces for OSI networks. Provides access to lower layer functions and services.
layer 6 presentation	Negotiates syntactic representations and performs data transformations, e.g. compression and code conversion.
layer 5 session	Coordinates connection and interaction between applications, established dialog, manages and synchronizes data flow direction.
layer 4 transport	Ensures end-to-end data transfer and integrity across the network. Assembles packets for routing by Layer 3.
layer 3 network	Routes and relays data units across a network of nodes. Manages flow control and call establishment procedures.
layer 2 data link	Transfers data units from one network unit to another over transmission circuit. Ensures data integrity between nodes.
layer 1 physical	Delimits and encodes the bits onto the physical medium. Defines electrical, mechanical and procedural formats.

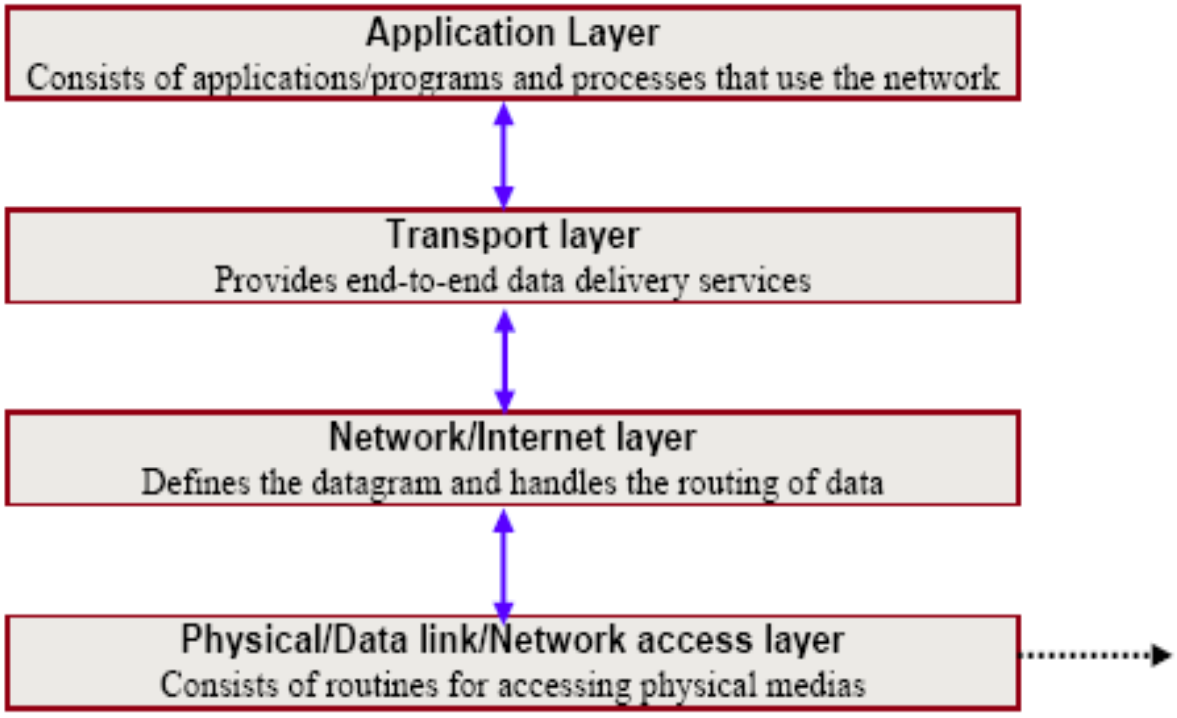
The OSI reference model

HOW TO REMEMBER THE LAYERS?

Please Do Not Throw Sausage Pizza Away

Internet Model

AKA TCP/IP MODEL



Side by side

OSI AND THE TCP/IP MODELS

FIGURE 1-3
Network models.
OSI = Open Systems Interconnection Reference

OSI Model	Internet Model	Groups of Layers	Examples
7. Application Layer	5. Application Layer	*Application Layer*	Internet Explorer and Web pages
6. Presentation Layer			
5. Session Layer			
4. Transport Layer	4. Transport Layer	*Internetwork Layer*	TCP/IP software
3. Network Layer	3. Network Layer		
2. Data Link Layer	2. Data Link Layer	*Hardware Layer*	Ethernet port, Ethernet cables, and Ethernet software drivers
1. Physical Layer	1. Physical Layer		

Network Models from the textbook, “Business Data Communications and Networking”, FitzGerald et al, 13 ed, pg 8

“Protocol headers”

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EACH LAYER ADDS ITS OWN HEADER

- Data in each header layer is only for corresponding layer at the receiver.
- Other layers may not (in general touch this information) – **encapsulation**
- In practicals we will analyse these headers (one week for each layer)
- This will help us understand what each layer does.

Encapsulation

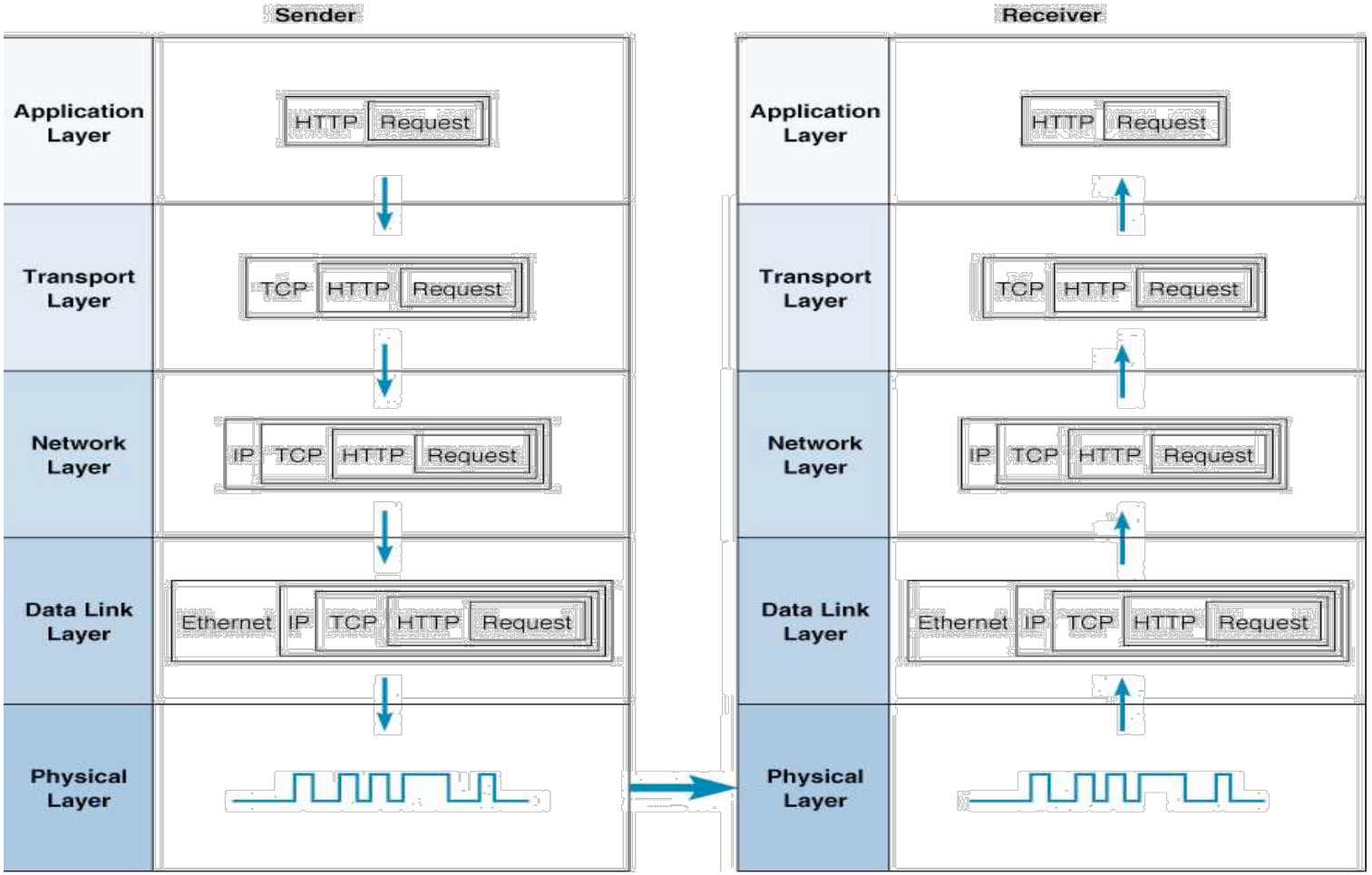
ENVELOPE INSIDE AN ENVELOPE INSIDE AN …

NESTING PACKET HEADERS

- The application layer contains the actual message generated by the application (or user)
- Each lower layer wraps the message with its own header (metadata)

Encapsulation

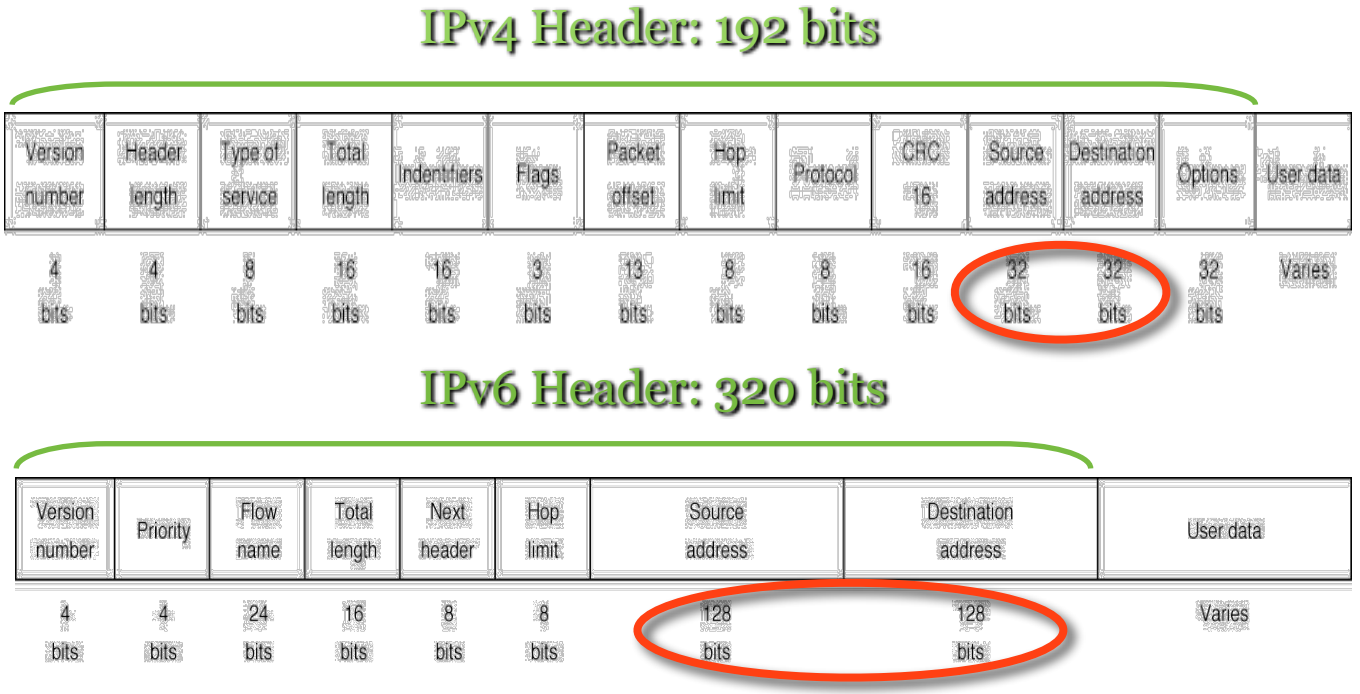
ENVELOPE INSIDE AN ENVELOPE INSIDE AN …



“Headers”

THE METADATA FOR A PACKET

…



Addressing

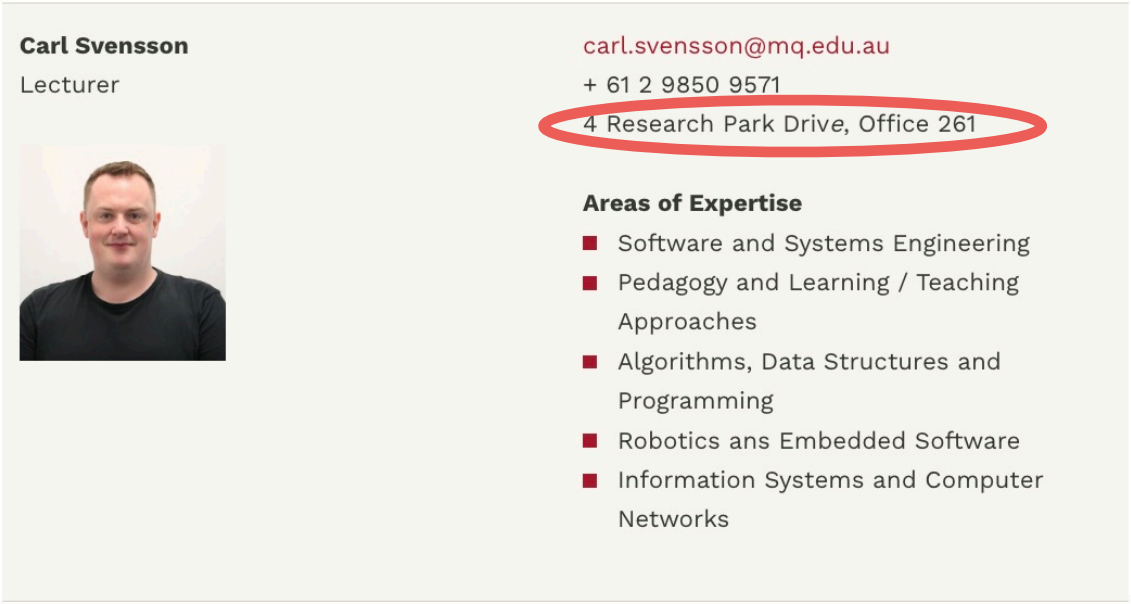
WHERE TO SEND THE MESSAGE TO?

Addressing

WHERE TO SEND MESSAGES TO

- In general to send anything to a destination we need an address
- We have several different kinds of addresses at different layers

Carl's address is one location, but what if the office number gets renamed? Is it still the same location?



Addressing in different layers

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Layer	Address Kind	Computer Representati	Human Representati	Example
Applicati on	Application Dependent	String	String	...
Transport	Port - destination application	16 bit field	Number 0-65,535	24
Network	IP Address IPv4	32 bit field	4 decimals	134.57.33.2
Data Link	MAC address (Ethernet)	48 bit field (6 octets)	6x2 hex digits	AE:56:23:F4:65:D3
Physical	Bits put in one end come out the	N/A	N/A	Bits are broadcast on link, i.e.., flood.

FIGURE 5-8
Types of addresses

Address	Example Software	Example Address
Application layer	Web browser	www.kelley.indiana.edu
Network layer	Internet Protocol	129.79.127.4
Data link layer	Ethernet	00-0C-00-F5-03-5A

Types of addresses in different layers, Textbook, page 120

Addressing on the Internet

WHO'S WHO ON THE INTERNET?

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- Every computer needs a unique address
- In the Internet this is a called an IP address
  - IP stands for Internet Protocol
  - IP is the network layer protocol for the internet, responsible for addressing and delivery of messages

IPv4 Addresses

WHO'S WHO ON THE INTERNET?

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- 32 bit (4 byte) addresses
- In the computer stored in binary, but for human convenience written in decimal
- A byte can hold values in the range 0-255
- Each byte in an IP address written separately
  - using so-called "dotted decimal" notation,
  - so an example IP address is: 127.97.201.4

Questions:
What is the maximum number of addresses IPV4 can support?

How many computing devices do we have on the internet?

Big Ideas from today

WHAT HAVE WE BEEN FOCUSING ON?

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Concepts: applications, processes, messages, packetising.

Views of a network (Logical, physical)

Network classifications:

- Circuit-switched, packet-switched.
- Local, backbone, metropolitan, and wide area networks.
- Topologies
- Layouts

Packets, Metadata, and packet headers
OSI and Internet models for layers
Addressing at different layers

After the lecture >>> Complete the Minute paper for Week 1 (see iLearn) <<<

Next week, we are going to cheat and look at how to add more IPv4 addresses without adding more IPv4 addresses :)
Also, if Carl were to move office, what would happen to the coffee message?