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Data Communications

INTRODUCTION

Data Communications

COMMUNICATION

- What do we mean?
- First some definitions…

Process

APPLICATIONS

- Made up from one or more **processes**
- Processes are independent:
  - They run separately
  - Progress at different rates (they are asynchronous)

Message

MESSAGES

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

Communication

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PROCESSES COMMUNICATING BY SENDING MESSAGES

The End!

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QUESTIONS?

How?

Image courtesy of Colin Kinner

HOW DOES IT WORK?

- We want to understand how this works
- So, some more definitions…

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

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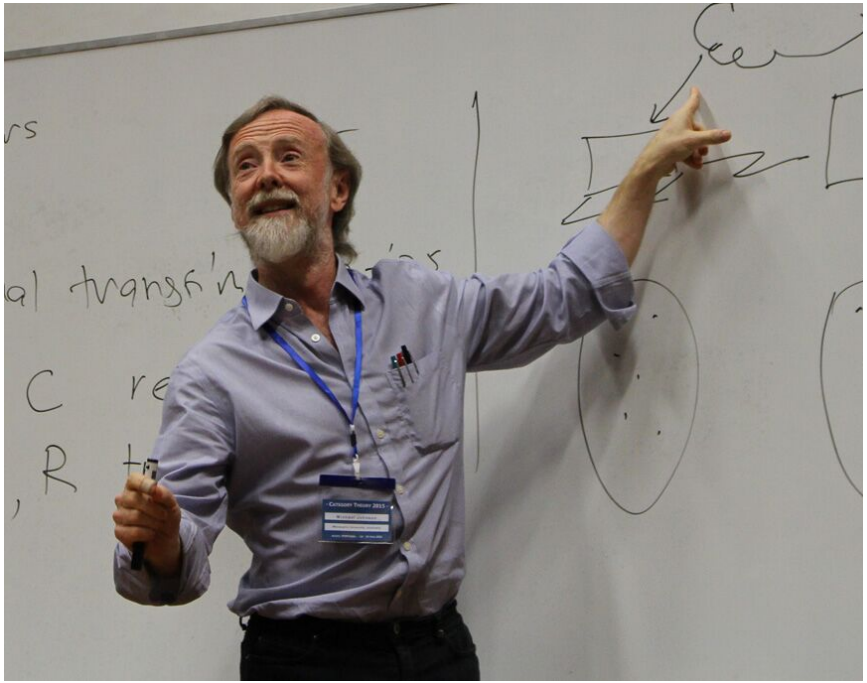
I WANT TO SEND A MESSAGE TO A COLLEAGUE:

“Let’s grab a coffee after the lecture”

Example



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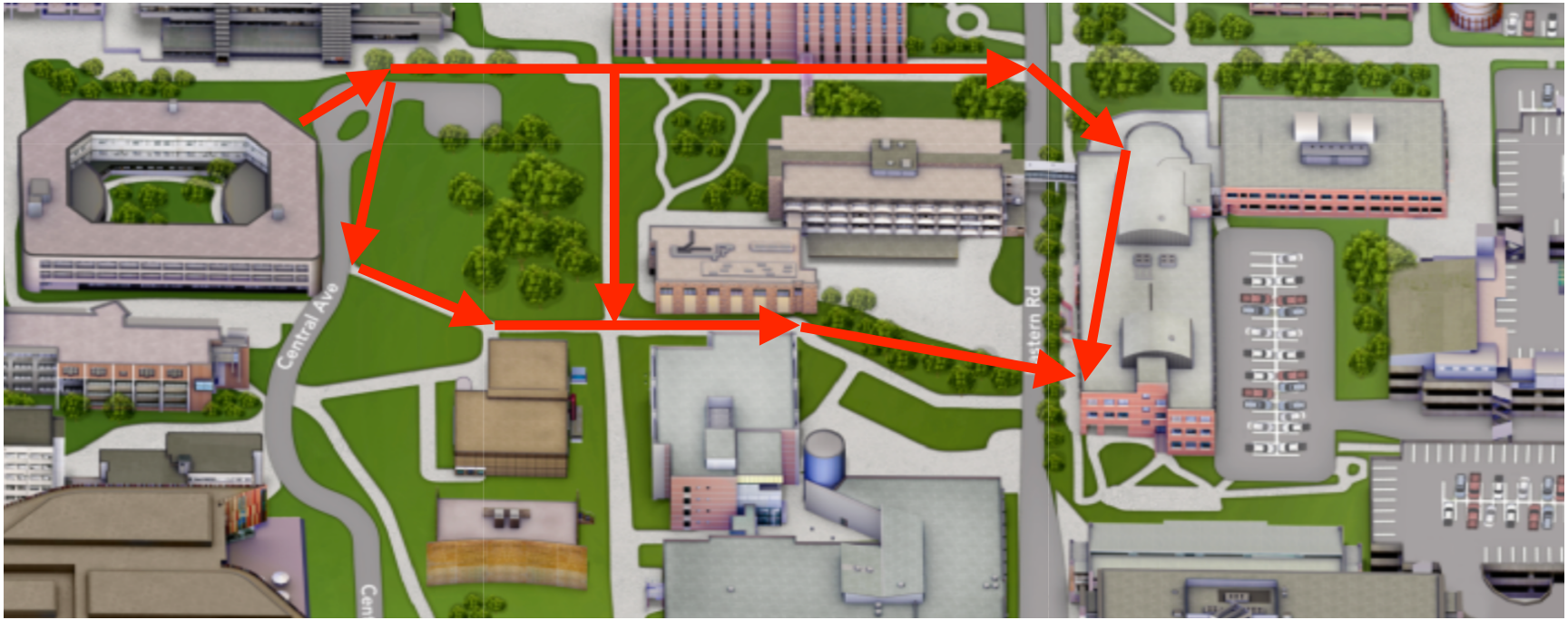
Example



So

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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?

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FOUR THINGS CAN GO WRONG — MESSAGES CAN GET

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

What is a Network?

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network | ˈnetˌwərk |

noun

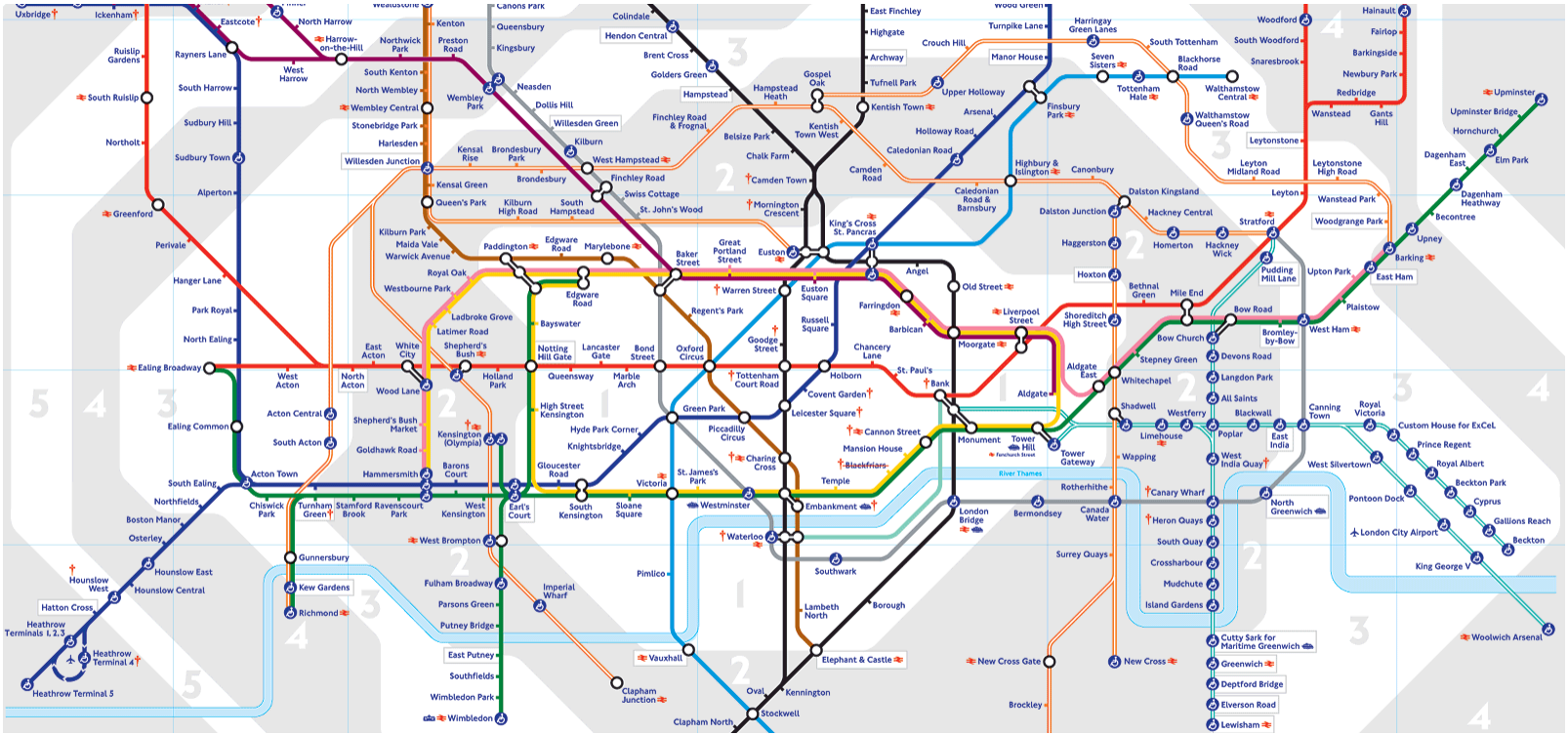
1 an arrangement of intersecting horizontal and vertical lines

- 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


Uxbridge
Ickenham
Eastcote
North Harrow
Harrow-on-the-Hill
Northwick Park
Kenton
Preston Road
Canons Park
Queensbury
Kingsbury
Colindale
Hendon Central
Brent Cross
Golders Green
Hampstead
Hampstead Heath
Gospel Oak
East Finchley
Highgate
Archway
Tufnell Park
Kentish Town
Kentish Town West
Crouch Hill
Turnpike Lane
Harringay Green Lanes
South Tottenham
Blackhorse Road
Walthamstow Central
Woodford
South Woodford
Snaresbrook
Hainault
Fairlop
Barkingside
Newbury Park
Redbridge
Wanstead
Gants Hill
Upminster
Upminster Bridge
Hornchurch
Elm Park
Dagenham East
Dagenham Heathway
Becontree
Upney
Barking
East Ham
Plaistow
West Ham
Bromley-by-Bow
Bow Road
Bow Church
Devons Road
Langdon Park
All Saints
Poplar
Blackwall
Canning Town
Royal Victoria
Custom House for ExCeL
Prince Regent
Royal Albert
Beckton Park
Cyprus
Gallions Reach
Beckton
London City Airport
King George V
Woolwich Arsenal
Pontoon Dock
West Silvertown
Ruislip Gardens
South Ruislip
Northolt
Greenford
Perivale
Hanger Lane
Park Royal
North Ealing
Ealing Broadway
Rayners Lane
West Harrow
South Harrow
Sudbury Hill
Sudbury Town
Alperton
Wembley Park
Neasden
Dollis Hill
Willesden Green
Kilburn
West Hampstead
Finchley Road & Frognal
Finchley Road
Swiss Cottage
St. John's Wood
Brondesbury
Brondesbury Park
Kensal Rise
Kensal Green
Willesden Junction
South Kenton
North Wembley
Wembley Central
Stonebridge Park
Harlesden
Queen's Park
Kilburn High Road
South Hampstead
Chalk Farm
Camden Town
Mornington Crescent
Belsize Park
Camden Road
Caledonian Road
Caledonian Road & Barnsbury
Holloway Road
Arsenal
Finsbury Park
Manor House
Seven Sisters
Tottenham Hale
Upper Holloway
Highbury & Islington
Canonbury
Dalston Kingsland
Dalston Junction
Hackney Central
Hackney Wick
Homerton
Haggerston
Hoxton
Shoreditch High Street
Old Street
Angel
King's Cross St. Pancras
Euston
Great Portland Street
Warren Street
Euston Square
Farringdon
Barbican
Moorgate
Liverpool Street
Aldgate
Aldgate East
Whitechapel
Shadwell
Westferry
Limehouse
Wapping
Rotherhithe
Canary Wharf
Heron Quays
South Quay
Crossharbour
Mudchute
Island Gardens
Cutty Sark for Maritime Greenwich
Greenwich
Deptford Bridge
Elverson Road
Lewisham
North Greenwich
Canada Water
Bermondsey
London Bridge
Tower Gateway
Tower Hill
Monument
Fenchurch Street
Bank
St. Paul's
Chancery Lane
Holborn
Covent Garden
Leicester Square
Cannon Street
Mansion House
Blackfriars
Temple
Embankment
Charing Cross
Piccadilly Circus
Green Park
Oxford Circus
Bond Street
Marble Arch
Goodge Street
Tottenham Court Road
Regent's Park
Russell Square
Baker Street
Marylebone
Edgware Road
Paddington
Warwick Avenue
Maida Vale
Kilburn Park
Royal Oak
Westbourne Park
Ladbroke Grove
Latimer Road
Bayswater
Notting Hill Gate
Lancaster Gate
Queensway
High Street Kensington
Holland Park
Shepherd's Bush
East Acton
White City
Wood Lane
North Acton
West Acton
Acton Central
South Acton
Ealing Common
Shepherd's Bush Market
Goldhawk Road
Kensington (Olympia)
Barons Court
Hammersmith
Acton Town
South Ealing
Northfields
Boston Manor
Osterley
Hounslow East
Hounslow West
Hounslow Central
Hatton Cross
Heathrow Terminals 1, 2, 3
Heathrow Terminal 4
Heathrow Terminal 5
Turnham Green
Stamford Brook
Ravenscourt Park
Chiswick Park
Gunnersbury
Kew Gardens
Richmond
West Brompton
Fulham Broadway
Parsons Green
Putney Bridge
East Putney
Southfields
Wimbledon Park
Wimbledon
Imperial Wharf
Earl's Court
West Kensington
Gloucester Road
South Kensington
Sloane Square
Victoria
St. James's Park
Westminster
Waterloo
Pimlico
Vauxhall
Clapham Junction
Clapham North
Stockwell
Oval
Kennington
Lambeth North
Southwark
Borough
Elephant & Castle
New Cross Gate
New Cross
Brockley
River Thames

Example

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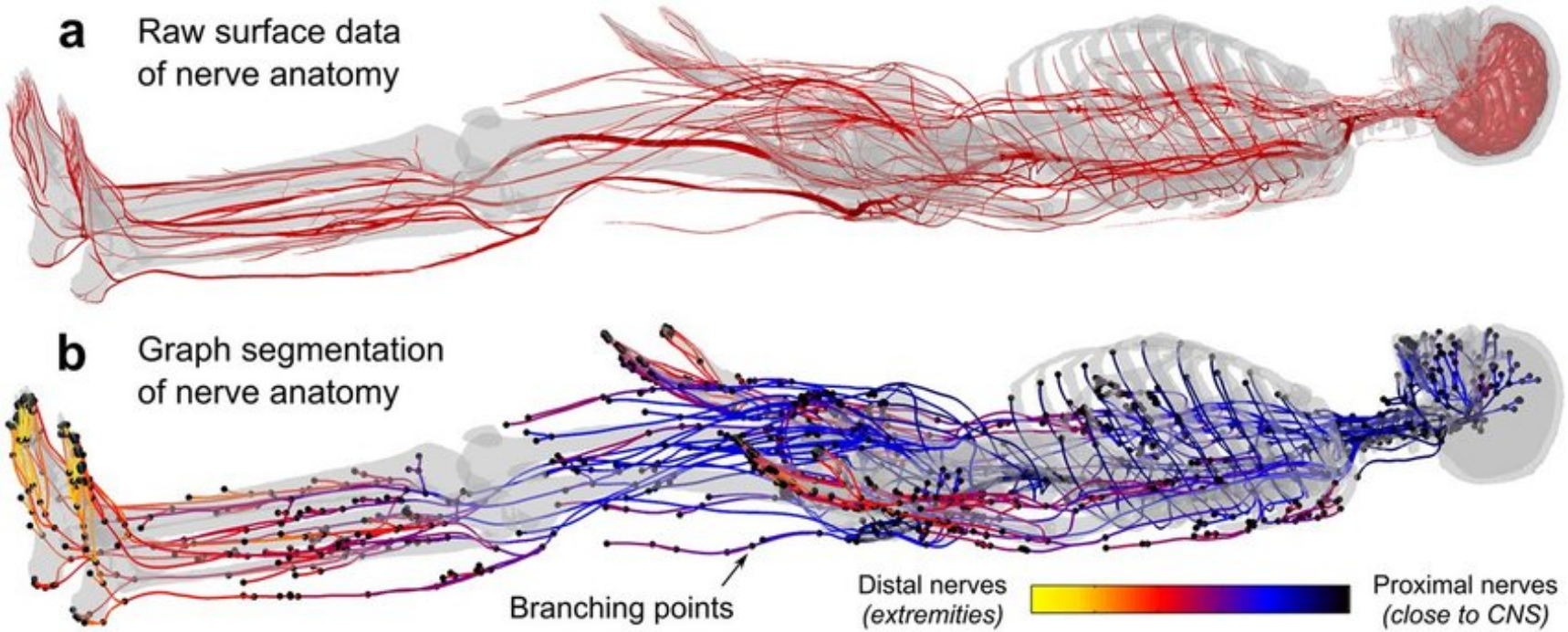

Computer Networks

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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.

Classifying Networks

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WE CAN CLASSIFY NETWORKS IN MANY DIFFERENT WAYS SUCH AS:

- How they operate
- The geographic area they cover
- The “shape” of the network — its *topology*

Kinds of Networks

OPERATIONAL CLASSIFICATION

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CIRCUIT SWITCHED

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

PACKET SWITCHED

- Multiple paths
- No setup
- Shared
- Data networks

Kinds of Networks

GEOGRAPHIC CLASSIFICATION

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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

BACKBONE NETWORKS

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

METROPOLITAN AREA NETWORKS

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

WIDE AREA NETWORKS

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

Kinds of Networks

TOPOLOGICAL CLASSIFICATION

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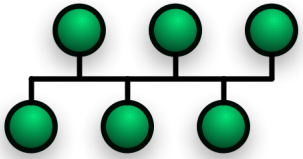
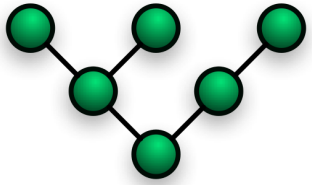
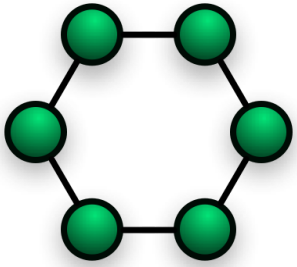
Point-to-point



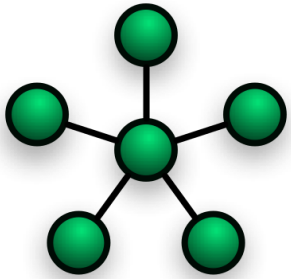
Bus (multi-drop)



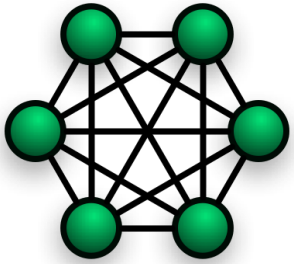
Tree



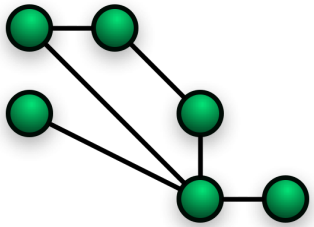
Ring



Star



(Full) Mesh



Partial mesh

Physical Layout

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Abstract Layout

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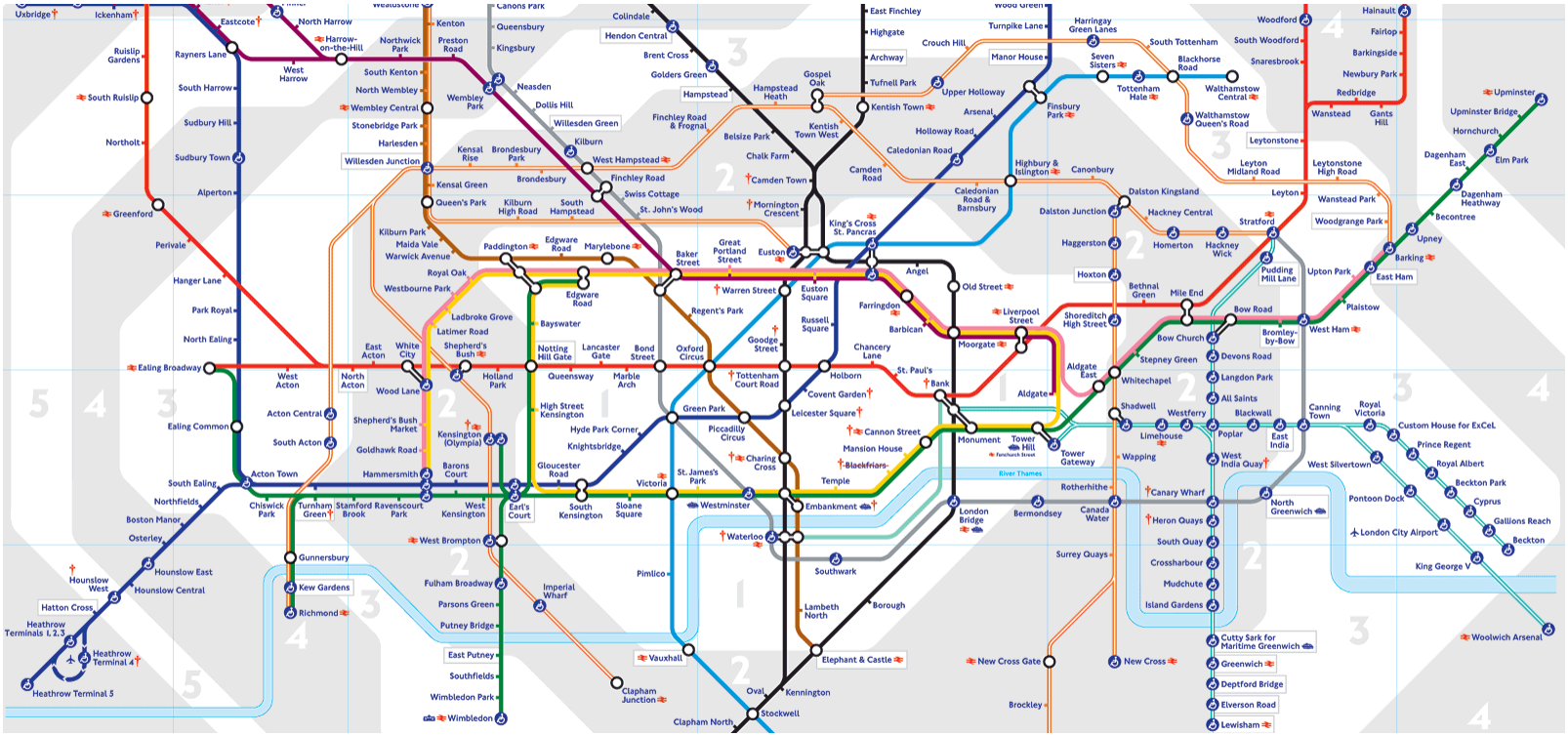

Kinds of Networks

TOPOLOGICAL CLASSIFICATION

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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

PACKETS CONSIST OF 2 THINGS

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

Metadata

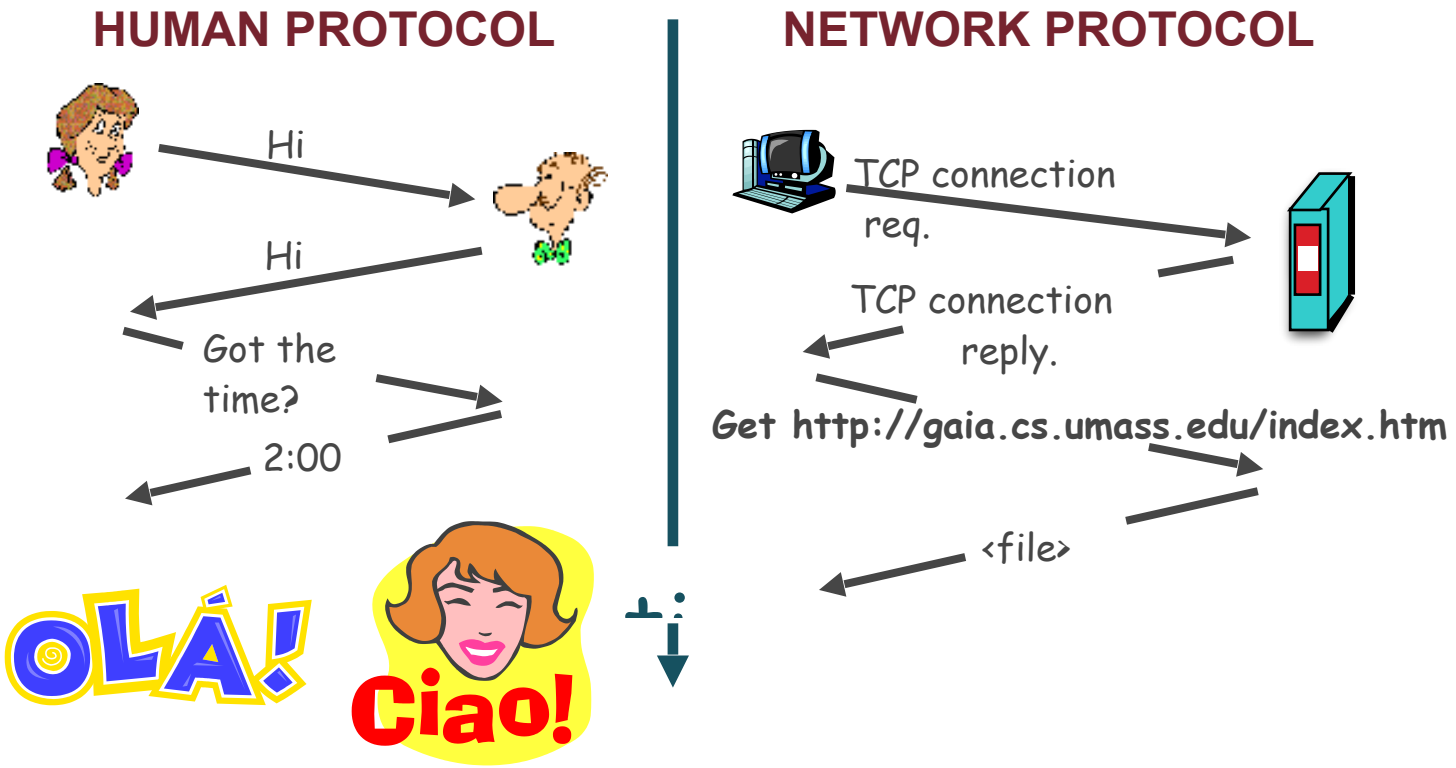
DATA ABOUT DATA

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

Can you think of other examples of Metadata more generally?

Protocols

OPERATIONAL CLASSIFICATION



Protocols

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HOW PROTOCOLS WORK

- 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

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HOW MANY PROTOCOLS?

- 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

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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

Protocol Stacks

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PROTOCOLS WORK TOGETHER

- 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.

OSI Reference Model

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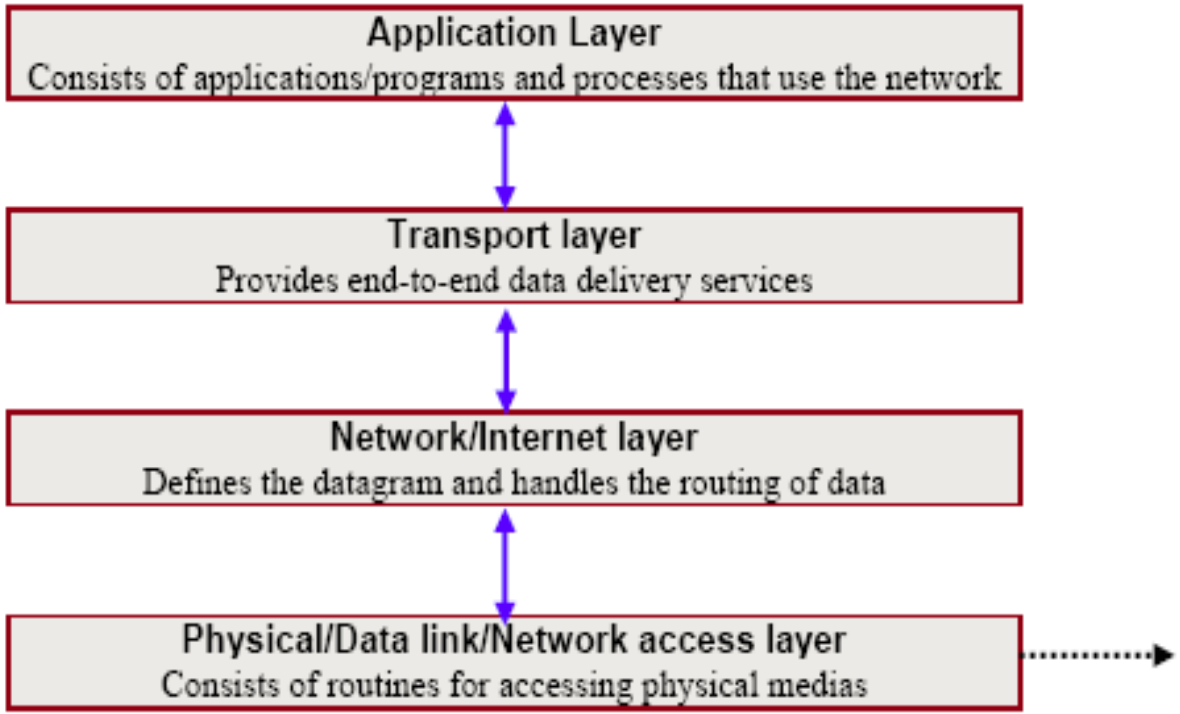
layer 7 application	Applications and application interfaces for OSI networks. Provides access to lower layer functions and services.
layer 6 presentation	Negotiates syntactic representations and performs data transformations, e.g. compression and code conversion.
layer 5 session	Coordinates connection 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.

Internet (TCP/IP) Model



Protocol Headers

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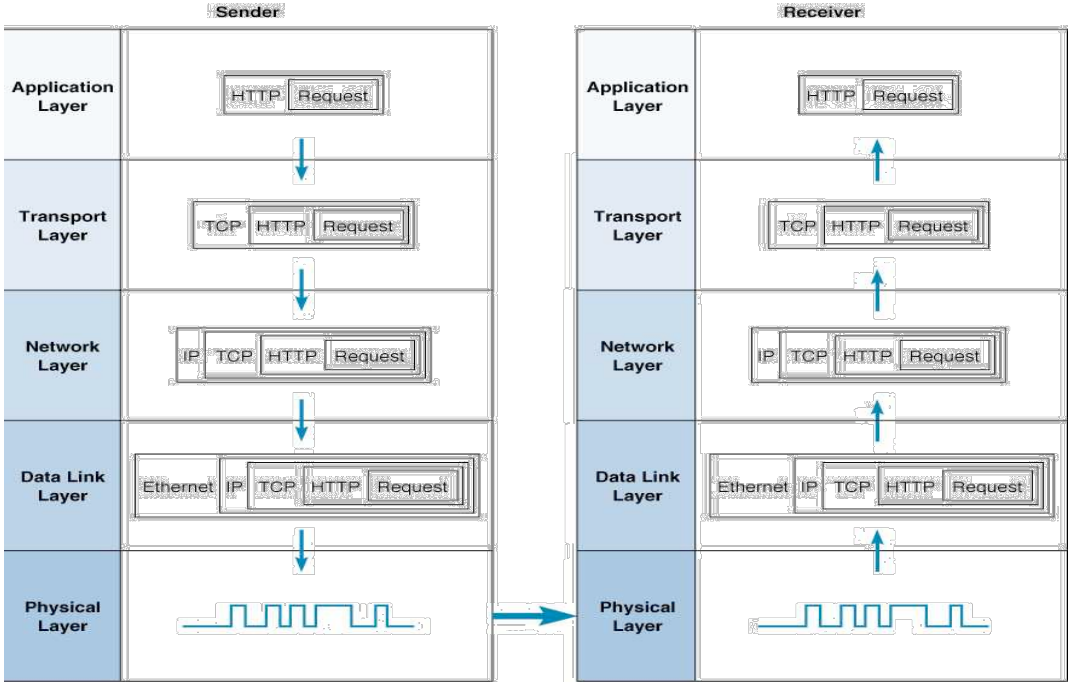
EACH LAYER ADDS ITS OWN HEADER

- 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

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)


Sender
Receiver
Application Layer
Transport Layer
Network Layer
Data Link Layer
Physical Layer
HTTP Request
TCP HTTP Request
IP TCP HTTP Request
Ethernet IP TCP HTTP Request

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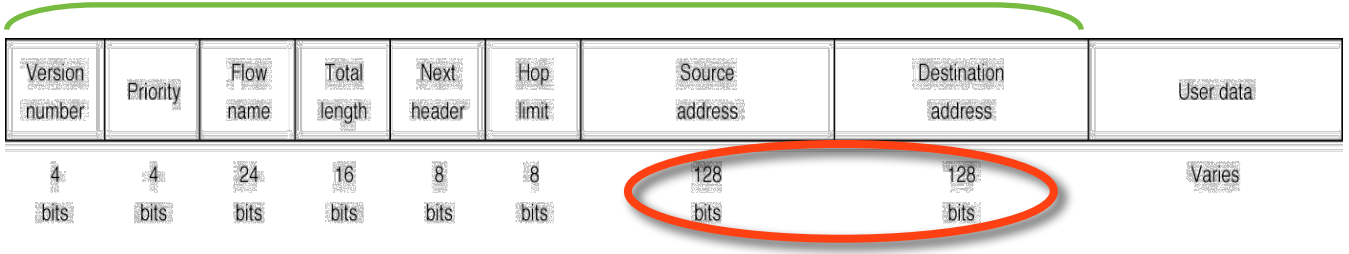
IPv4 Header: 192 bits

IPv6 Header: 320 bits



Protocols and Standards

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A SYMBIOTIC RELATIONSHIP

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

Standards

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WHO SETS THE 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

Addressing

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WHO'S WHO ON THE NETWORK?

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

Addressing

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Layer	Address Kind	Computer Representation	Human Representation	Example
Application	Application Dependent HTTP - URLs	String	String	http://www.mq.edu.au/...
Transport	Port - destination application	16 bit field	Number 0-65,535	24
Network	IP Address IPv4 IPv6	32 bit field 128 bit field	4 decimals 0-255 8x4 hex digits	134.57.33.2 4534:4EF3:4AFD:A43F:4567:E34F:236B:453F
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 other!	N/A	N/A	Bits are broadcast on link, i.e.., flood.

Addressing on the Internet

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WHO'S WHO ON THE INTERNET?

- 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

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WHO'S WHO ON THE INTERNET?

- 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