Networking & Internetworking

Topics for this lecture

- This lecture first introduces some fundamental knowledge and concepts:
  - **Types of networks**
  - **Underlying principles**
    - Packet transmission
    - Data streaming
    - Switching Schemes
    - Protocols
    - Routing
    - Congestion
    - Internetworking
  - Internet Protocol (TCP/IP)
  - UDP and TCP
  - Firewalls

The significance of this lecture

- DIS concepts to consider in the context of networking
  - Scalability,
  - Reliability,
  - Performance,
  - Mobility,
  - Quality of Service
  - Multicasting
  - And more..

This lecture aims to introduce those networking concepts that impact on DIS design and behaviour

Networking fundamentals

- There are many networks composed of many medias *(fibre, wireless, wire, etc.)*, many hardware devices *(routers, hubs, etc.)*, many software *(protocols, stacks, drivers, etc.)*
- These all affect the functionality of a DIS

Types of networks

- There are many different types of networks
- We are focusing on:
  - LANs (Local Area Networks)
  - WANs (Wide Area Networks)
  - MANs (Metropolitan Area Networks)
  - Wireless
  - Internetworks

	Range	Bandwidth (Mbps)	Latency (ms)
LAN	1-2kms	10-1000	1-10
WAN	Global	0.010-600	100-500
MAN	2-50 kms	1-150	10
Wireless LAN	0.15-1.5 kms	2-11	5-20
Wireless WAN	Global	0.010-2	100-500
Internet	Global	0.010-2	100-500

Taken from Coulouris et al, 2003

LANs

- Local Area Networks
  - Features
    - **High bandwidth / low latency**
    - Computers connect to a single medium
    - A **segment** of cable connects many computers,
    - Routing is not required since the computers have direct access
    - All computers share the bandwidth on segments
    - Other hardware, switches, hubs, etc. can be used to connect segments and are used for routing
  - Ethernet is the dominant technology
    - There are others token ring, slotted rings, etc.
    - Ethernet does not guarantee bandwidth or latency
    - However Ethernet is generally fast (low latency / high bandwidth)

WANs

- Wide Area Networks
  - Large range (satellites, optic fibres, microwaves)
  - **Lower bandwidth**, **increased latency**
  - Networks that are distributed over greater distances
  - They employ routers to direct signals between networks
  - Routing causes delays (latency)
  - Travelling potentially large distances also takes time
  - Example of the fundamental limitations of communication over large distances
    - Assume the speed of light, assume UK to Australia ~ 10000 miles
    - Europe to Australia will take at least 0.13 seconds
    - Europe to Australia via global satellite will take at least 0.2 seconds
    - SIMON: ERROR at END – LAN should be WAN!

MANs & WANs

- Metropolitan networks
  - Networks installed in cities, typically copper or optic fibre
  - DIS can use these networks
  - Many different technologies, Ethernet, ATM, etc.
- Wireless networks
  - Local area (150 metres or less)
    - Many types (IEEE 802.11, Bluetooth)
    - Generally connect local devices, printers, computers, laptops to other networks
    - Bluetooth is a personal LAN
  - Wide area (global)
    - Cellular networks
    - Slower than local area wireless networks
    - In the process of being upgraded

Internetworks

- Internetworks… a collection of networks joined together

"An internetwork is a **communication sub-system** in which **several networks** are **linked together** to provide **common data communication** facilities that **conceal the technologies and protocols** of the individual component networks and the methods used for their interconnection"

[Coulouris et al, 2003]

- Inter networks are open systems
- DIS need open systems thus need internetworks
- Can use a variety of LANs, WANs, etc. all knitted together
- Networks are connected together via gateways (routing computers) or dedicated routers
- A software layer is used to enable transmission and addressing

Networking key concepts

- Topics we are going to consider
  - Packet transmission
  - Data streaming
  - Switching Schemes
  - Protocols
  - Routing
  - Congestion
  - Internetworking

Packets

- Packet transmission
  - Messages are passed from computer to computer over networks via networks
  - Messages come in various sizes
  - Its impractical to send long messages as this would block the medium for others
  - Thus messages are sliced into small sections, known as packets
  - A packet is a sequence of data with a defined size
  - Each packet contains information about its addresses (source and destination)

Data streaming

- Data streaming
  - Multimedia applications require streaming
  - Requires the transmission of large amounts of data
    - Video plays at 24 frames/second, is a large streams, requires at least 24 frames/second
  - Buffering can help with anomalies
  - Another feature of data streaming is that it can also obtain a single route from start to destination and book resources on this route

Switching Schemes

- Transmitting information involves sending information between nodes
- This involves switching between networks
- This requires a switching scheme

- Switching schemes
  - Broadcast
  - Circuit switching
  - Packet switching
  - Frame relay

Switching Schemes (cont..)

- Switching schemes
  - Broadcasting
    - No switching is required as everything transmitted to everything
      - i.e. Ethernet, Wireless, etc.
  - Circuit switching
    - Physical connections (circuits) are made
    - Involves physically connecting wires
      - Old telephone network technology

Switching Schemes (cont..)

- Switching schemes
  - Packet switching
    - Store and forward technology
    - Computers receive, store and then pass on packets
    - Is now applied to audio and visual
    - Relies on sending information quickly
    - Store and forward introduces delays
    - They are additive
  - Frame relay
    - ATM networks
    - Examines only the first few bits of the message and passes the rest onwards
    - Much faster than standard packet switching

Protocols

- Networks rely on the use of protocols
- A protocol is '*a set of rules and formats that are used in communication*'

  - Protocol contains:
    - A specification of the sequence of messages
    - A specification of the format of the data

Protocols

- Why use protocols??
  - What happens if you expect a message in English and it arrives in French? Can you read it?
  - Computers too have to worry about the format of the messages and sequence of messages!
  - Protocols promote openness as they standardise development.

- Some real world example
  - Telephone conversation protocol
    - Simple protocol 'hello' 'goodbye'
  - Telephone banking
    - 'Hello', 'bank details', 'security check', 'transactions'

Layers

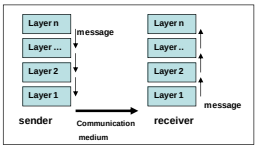
- Layers help to reduce complexity in systems
- Layers help to reduce dependencies

- Real world example of a restaurant
  - Customer Layer (east foot, places orders)
  - Waiter Layer (delivers food, takes orders)
  - Chef Layer (prepares food)

- Network protocols are also layered

Protocols and layers

- Network protocols are layered
  - Layering promotes openness
  - Layering separates responsibilities
- How does it work?
  - Messages descend layers from sender
  - Before ascending layers at the receiver

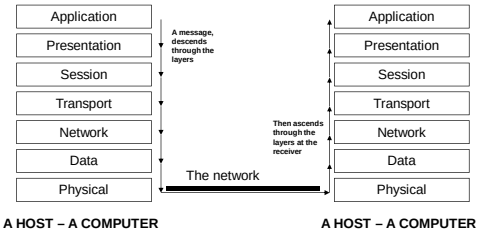


Protocol suites (OSI)

- Protocol suites
  - A protocol suite or protocol stack is complete set of protocol layers
  - The OSI model (Open Systems Interconnection) is a commonly used example of a protocol suite
  - The OSI model is a reference model

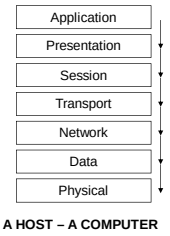
Protocols suites (OSI)

- The OSI model



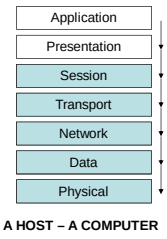
Protocols suites

- Layering
  - Simplifies
  - Generalises
  - Promotes openness and scalability
  - However layering affects performance
- Consider the OSI model
  - 6 messages are required for an application message to reach the physical layer



Protocols suites (cont..)

- Protocols
  - Protocol suites
    - A complete set of protocol layers
    - The OSI model is a complete stack of protocol layers
    - Layering protocols simplifies communication through interfaces
    - However, such layering costs performance
      - Messaging between layers takes time

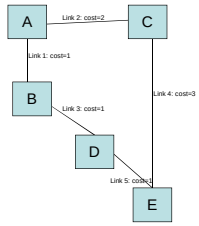


Routing

- Routing
  - Routing is required in networks that do not have direct access
    - Q. What type of network has direct access, i.e. broadcasting?
  - Adaptive routing is generally used in large networks
    - i.e. the best route is re-evaluated
  - Routing is achieved through routing algorithms
  - An routing algorithm has two sections:
    - 1. A decision about the route
      - Beware!! Too complex algorithms could degrade performance
    - 2. Gather some information about network traffic and configurations along its routes
      - Perhaps this is not so time critical

Routing algorithm

A wan (just routers in this diagram)



To	Link	Cost
A	Local	0
B	1	1
C	2	2
D	1	2
E	1	3

- **Column meanings**
- To column: The destination router
- Link: The link that should be used
- Cost: The cost of taking this route

= a router

Routing algorithm

A wan (just routers in this diagram)

Router A

To	Link	Cost
A	Local	0
B	1	1
C	2	2
D	1	2
E	1	3

Router C

To	Link	Cost
A		
B		
C		
D		
E		

Router B

To	Link	Cost
A		
B		
C		
D		
E		

Router D

To	Link	Cost
A		
B		
C		
D		
E		

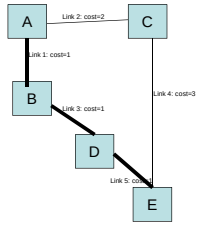
Router E

To	Link	Cost
A		
B		
C		
D		
E		

= a router

Routing algorithm

A wan (just routers in this diagram)



Router A

To	Link	Cost
A	Local	0
B	1	1
C	2	2
D	1	2
E	1	3

Router C

To	Link	Cost
A	2	2
B	2	3
C	local	0
D	4	4
E	4	3

Router B

To	Link	Cost
A	1	1
B	local	0
C	1	3
D	3	1
E	3	2

Router D

To	Link	Cost
A	3	2
B	3	1
C	5	3
D	Local	0
E	5	1

Router E

To	Link	Cost
A	4	3
B	5	2
C	4	3
D	5	1
E	local	0

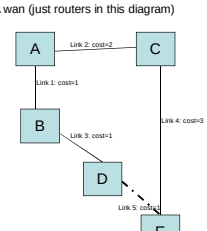
= a router

Routing algorithm

- Routing
  - Router information protocol (RIP) provides a summary to its neighbours sent as a packet
    - Every time a route table changes
    - This includes new routes, new costs, etc.
    - Faulty links are assign an ∞(infinite) cost
  - Cost could be based on something more meaningful, i.e. time for the route, distance, network traffic, etc.

Routing algorithm

A wan (just routers in this diagram)



Router A

To	Link	Cost
A	Local	0
B	1	1
C	2	2
D	1	2
E	1	3

Router C

To	Link	Cost
A	2	2
B	2	3
C	local	0
D	4	4
E	4	3

Router B

To	Link	Cost
A	1	1
B	local	0
C	1	3
D	3	1
E	3	2

Router D

To	Link	Cost
A	3	2
B	3	1
C	5	∞
D	Local	0
E	5	∞

Router E

To	Link	Cost
A	4	3
B	5	2
C	4	3
D	5	1
E	local	0

= a router

Routing algorithm

A wan (just routers in this diagram)

Router A

To	Link	Cost
A	Local	0
B	1	1
C	2	2
D	1	2
E	1	3

Router C

To	Link	Cost
A	2	2
B	2	3
C	local	0
D	4	4
E	4	3

Router B

To	Link	Cost
A	1	1
B	local	0
C	1	3
D	3	1
E	3	2

Router D

To	Link	Cost
A	3	2
B	3	1
C	5	∞
D	Local	0
E	5	∞

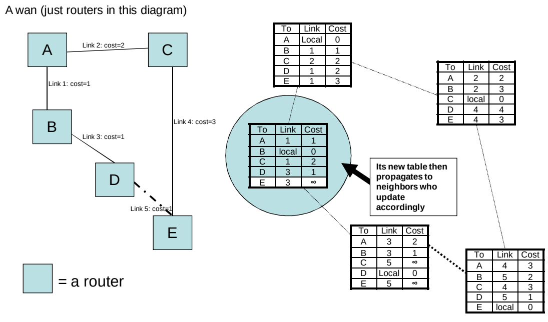
Router E

To	Link	Cost
A	4	3
B	5	2
C	4	3
D	5	1
E	local	0

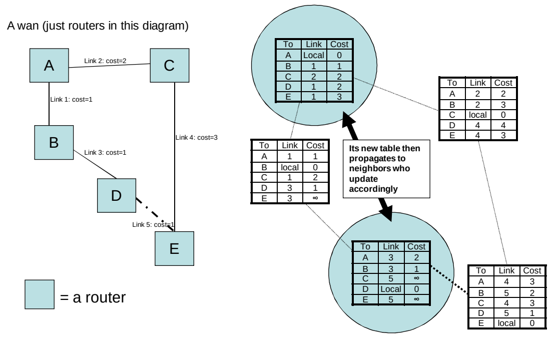
Its new table then propagates to neighbors who update accordingly

= a router

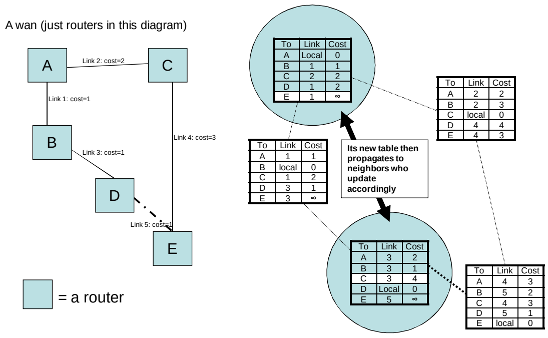
Routing algorithm



Routing algorithm



Routing algorithm



Congestion Control

- Congestion control
  - Network components have a finite capacity
  - When the capacity is full, queues occur
    - Queues can be stored in buffers
    - However buffers can also become full
  - Packet dropping
    - When full packets are ignored or dropped
    - Dropped packets have a ‘ripple effect’ wasting resources already used prior to the packet drop
  - **Congestion control** refers to a process whereby overloaded nodes inform other nodes that they are full
    - This way packets are not sent until the node is able to process them

Internetworking

- Internetworking
  - Many types of networks,
    - Q. How do we connect these subnets?
  - Requirements of internetworking
    - 1. A unified addressing scheme
    - 2. A protocol for handling packets
    - 3. Interconnecting the networks together
  - Example of the Internet
    - 1. IP address
    - 2. IP protocol
    - 3. Routers

TCP / IP

- What does it mean?
  - IP (Internet Protocol)
  - TCP (Transmission Control Protocol)
  - TCP/IP is a suite of protocols
- Many applications make use of TCP/IP
  - FTP, HTTP, SMTP, POP, NNTP and more
- Why is it good?
  - The Success of TCP/IP is derived from its independences from underlying transmission technology.
  - This promotes openness and scalability as networks are free to use different technologies.
  - Thus it accommodates heterogeneous systems

IPv4 and IPv6

- TCP/IP uses Internet Protocol
- IPv4
  - The most common standard (at the moment)
  - IPv4 has limitations
    - Limited address space
    - Limited security
- IPv6
  - Recent development
  - Aims to solve many of the problems of IPv4
  - Introduces large address space
  - Better security

IP and Internetworking

- Recall that internetworking requires three key things:
  - 1. A unified addressing scheme
  - 2. A protocol for packets
  - 3. Interconnection means
- Lets see how IP solves these problems

1. An addressing scheme

- IP address
  - Hosts are assigned 32BIT numeric identifiers
    - a network identifier
    - A host id
    - written as a sequence of four numbers (IPv4)
      - e.g. 111.222.333.444

2. A protocol for handling packets

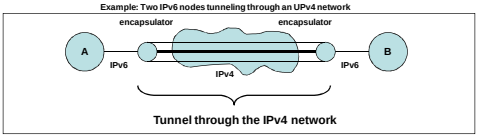
- IP protocol
  - best-effort/unrealisable delivery semantics
    - no guarantee of delivery.
    - packets might be dropped, delayed, duplicated and/or arrive out of sequence. Indeed
  - IP only provides checksums for the headers
  - IP layer transforms datagrams into network packets.
    - This involves resolving packet sizes
  - IP protocol contains a module to resolve addresses,
    - i.e. to convert internet addresses to network address.
  - IP protocol allows IP spoofing
  - Routing uses techniques similar to those discussed earlier, i.e. (simple RIP with IPv4 + route tables, IPv6 enhances these)

3. Connecting networks together

- Internetworking
  - Routers
    - Connect networks together
    - Can connect together through subnets
  - Bridges
    - Link networks of different types
  - Hubs
    - Connect hosts to the network for broadcasting
  - Switches
    - Used for connecting similar networks
    - Alleviates excessive broadcasting through hubs

3. Connecting networks together

- Tunnelling
  - A method of wrapping a packet so that it can pass through a network that it would not ordinarily be able to
  - Uses encapsulators at the entry / exit to the foreign network



TCP and UDP

- TCP and UDP
  - TCP and UDP are used by application programmers
  - TCP and UDP are the programmers view of TCP/IP
  - They provide simple process to process communication
  - Use ports
    - A port is a software defined access point to a host (Computer)
    - a port is a 16 bit integer number
  - UDP and TCP manage application process to process communication through the use of ports
  - IP receives packets and UDP or TCP and then distributes those packets to specific ports and thus specific process that are bound to those ports.

UDP

- UDP (Universal Datagram Packet)
  - UDP uses use datagrams encapsulated inside IP packets.
  - UDP contains a short header that includes source and destination ports, host addresses, length fields and checksums,
  - UDP is unrealisable – no guarantees
  - UDP datagrams could be sent to single hosts, point to point, or to multiple hosts at the same time through multicasting.
  - UDP is connectionless communication
- TCP (Transmission Control Protocol)
  - Maintains a connection throughout the communication
  - More reliable but not totally reliable
    - Can maintain the sequence of packets
    - Uses retransmissions to ensure correctness

Firewalls

- Firewall
  - connecting to the internet is dangerous
  - A firewall can protect intranets from attack
  - The firewall's role is to monitor and control communication into and out of an intranet.
  - It is implemented as a set of processes that act as a gateway to the intranet applying security policies as dictated by the intranet's organisation.

Summary

- This lecture first introduces some fundamental knowledge and concepts:
  - Types of networks
  - Underlying principles
    - Packet transmission
    - Data streaming
    - Switching Schemes
    - Protocols
    - Routing
    - Congestion
    - Internetworking
  - Internet Protocol (TCP/IP)
  - UDP and TCP
  - Firewalls

Now think about all this again

- DIS concepts to consider in the context of networking
  - Scalability,
  - Reliability,
  - Performance,
  - Mobility,
  - Quality of Service

END