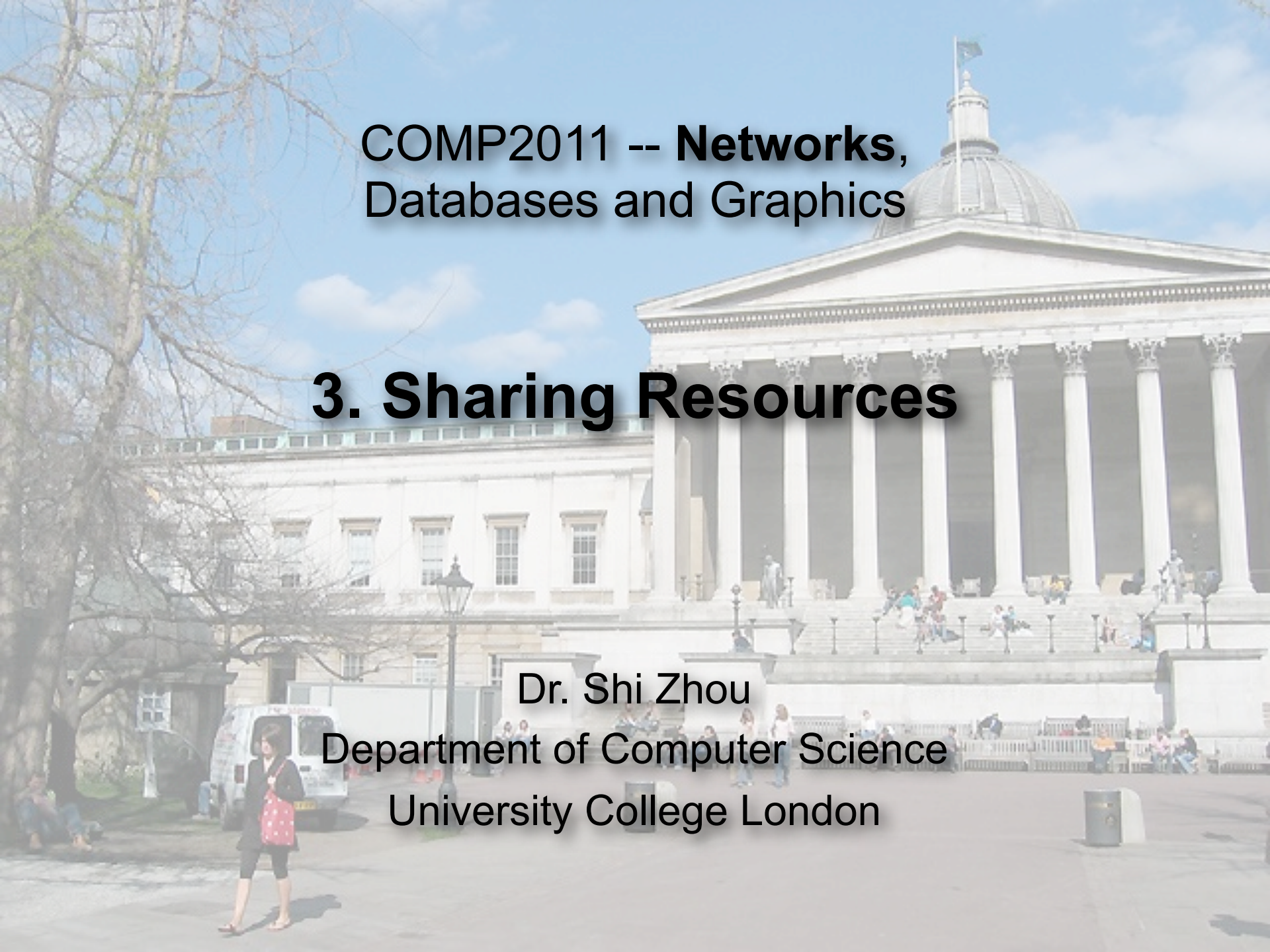

COMP2011 -- **Networks**,
Databases and Graphics

3. Sharing Resources

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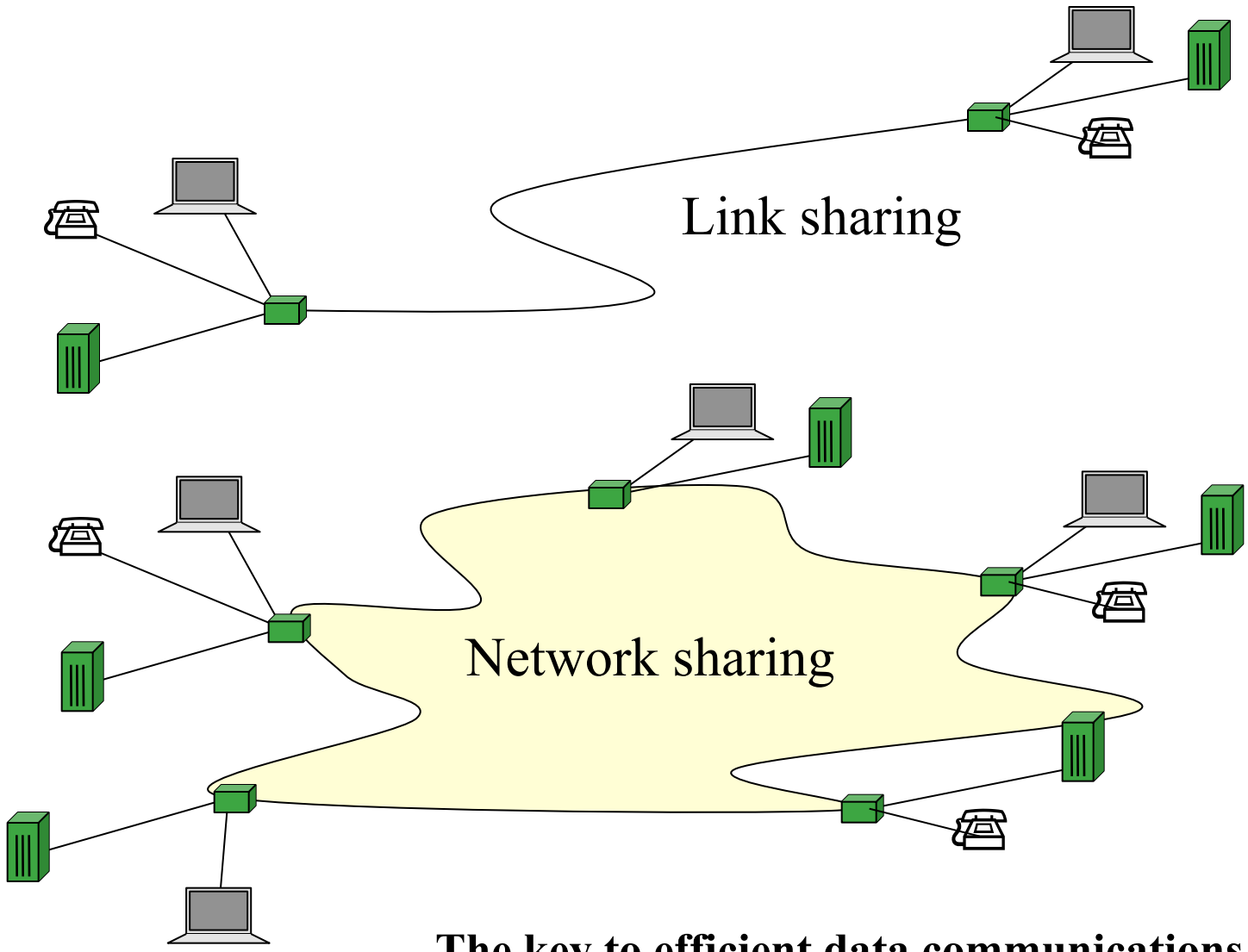
Sharing



The key to efficient data communications is the efficient sharing of physical resources.

A little history

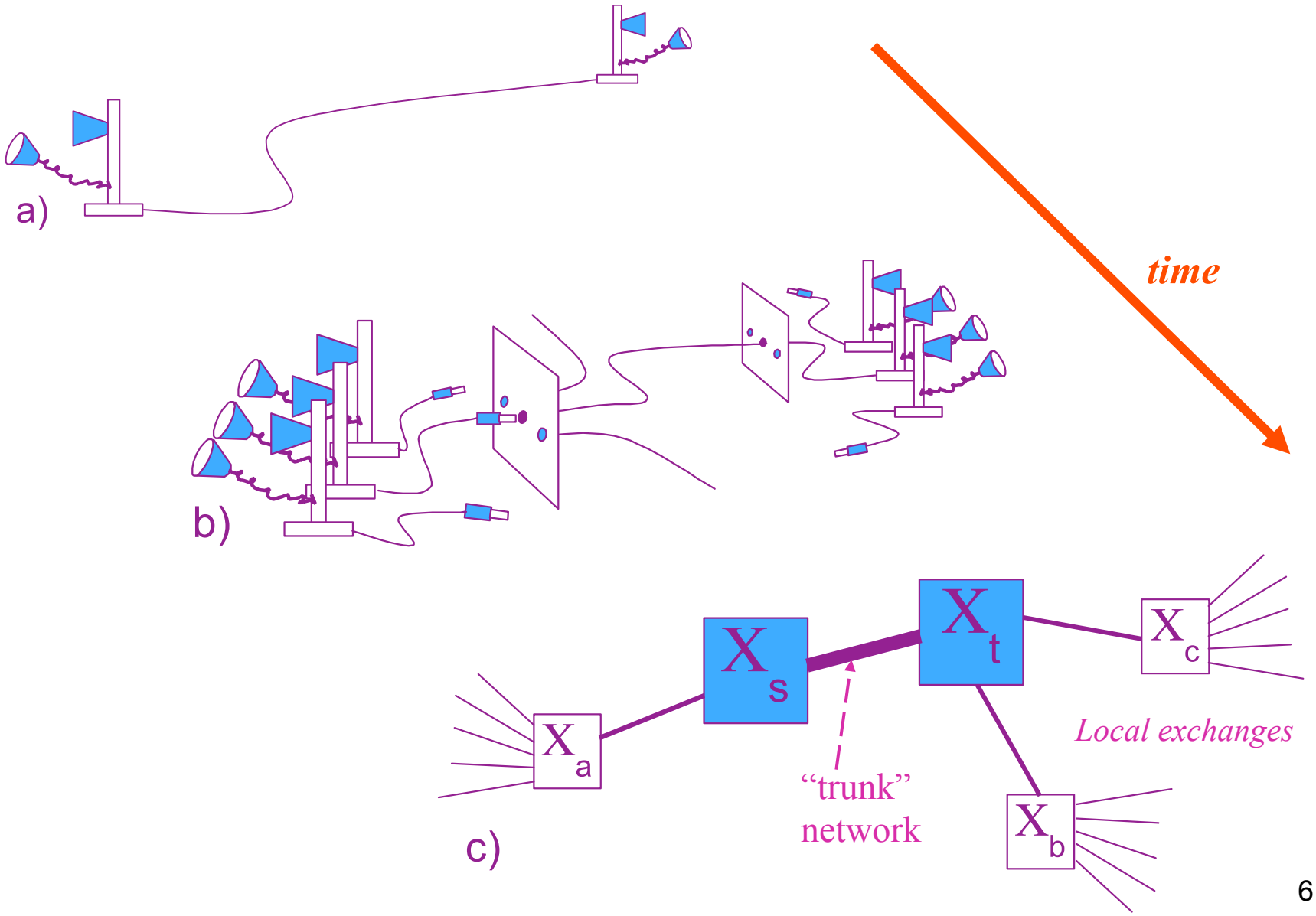
- 1837 the telegraph (Cooke and Wheatstone)
- 1838 Morse code (Samuel Morse)
  - Electronic digital communication
- 1843 Facsimile transmission
  - Data communication
- 1865 Commercial facsimile transmission
- 1876 The telephone (Alexander Graham Bell)
  - Analogue voice
- 1878 First commercial telephone exchange
- Analogue telephone network grew and grew …
  - Telecommunications

A little more history

- 1960s communication between computers
  - Over quite long distance, Wide Area Networks (WANs)
  - Used analogue telephone infrastructure (circuit-switching)
  - MODEMs (digital-over-analogue-channel)
  - Low capacity, noisy, error-prone
- 1961 Packet-switching
  - Kleinrock and Baran (US), Davies and Scantlebury (UK), and Pouzin (France)
- 1970s Mini-computers, 1980s Micro-computers (desk-top workstations and PCs)
  - Local Area Networks (LAN)
  - Share media network, independent of public network
- 1972 Metcalfe's Harvard PhD Thesis
  - Ethernet LAN and Metropolitan Area Network (MAN)

Part 1. Circuit-switching

Circuits and Circuit-switching

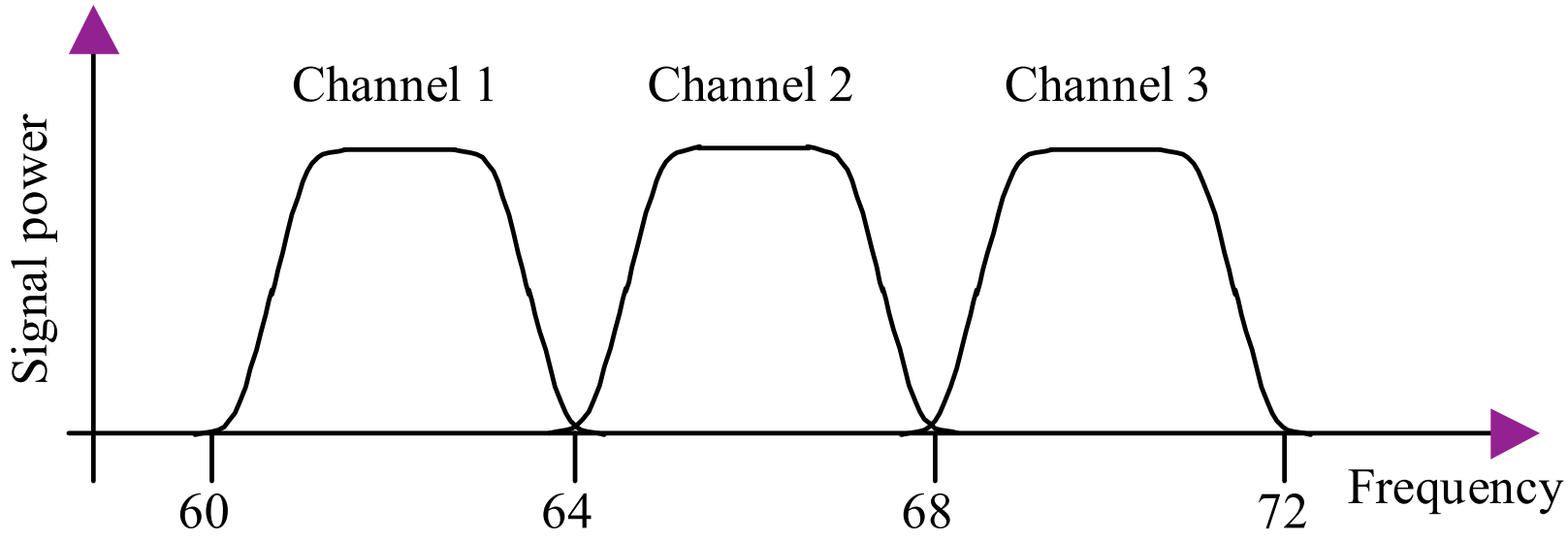


Eight characteristics of telephone service

1. Any telephone can communicate with any other telephone;
2. A telephone can only communicate with one other telephone at a time;
3. Other telephones may be "blocked" - unable to communicate because a wire they need is in use;
4. Communication between two telephones (once established) is unaffected by activity elsewhere in the network.
5. Whilst they are communicating, the two telephones have exclusive use of the wires that link them;
6. Words are delivered in the same order in which they are spoken.
7. Time intervals between words are preserved
8. We can distinguish three phases in the life of a circuit; setting it up, using it and tearing it down

Frequency Division Multiplexing (FDM)

- To provide sub-channels over a single piece of wire
- 12 carrier frequencies at 4KHz intervals
  - from 60 KHz to 108 KHz; carrier spreads ± 1.5 KHz
- Voice waves filtered to approx. 3KHz bandwidth
- Voice modulated on carrier



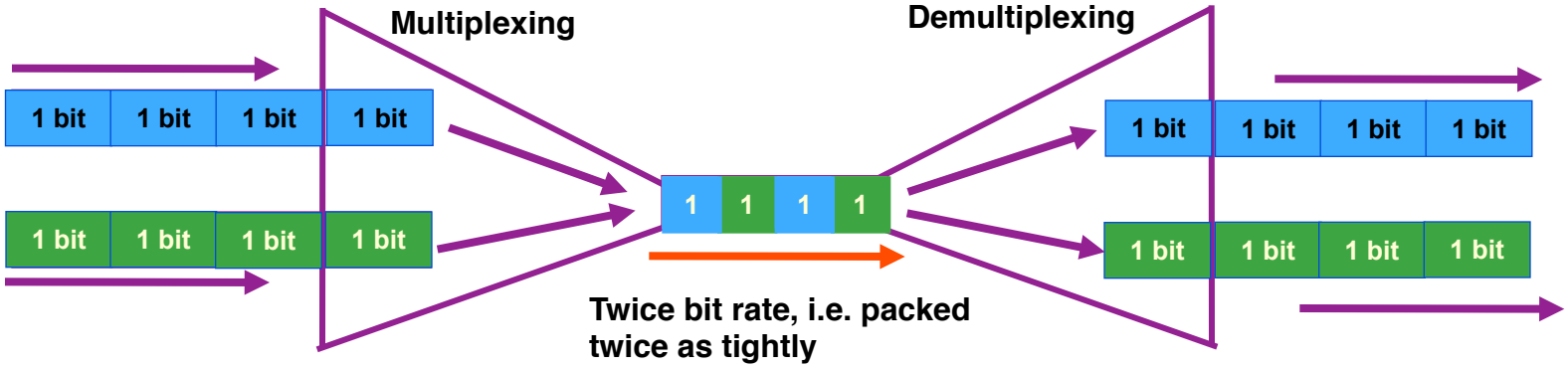
High “capacity” not High “speed”

- Higher speed vehicles travel faster
- Bits always go at the same speed
  - ~ 2×10^8 m/s in copper, ~ 3×10^8 in fibre
- “High-speed link” means more bits are injected and delivered in a given interval
  - It is really “high-capacity”

File transfer can complete more quickly over a higher capacity link!

Time Division Multiplexing

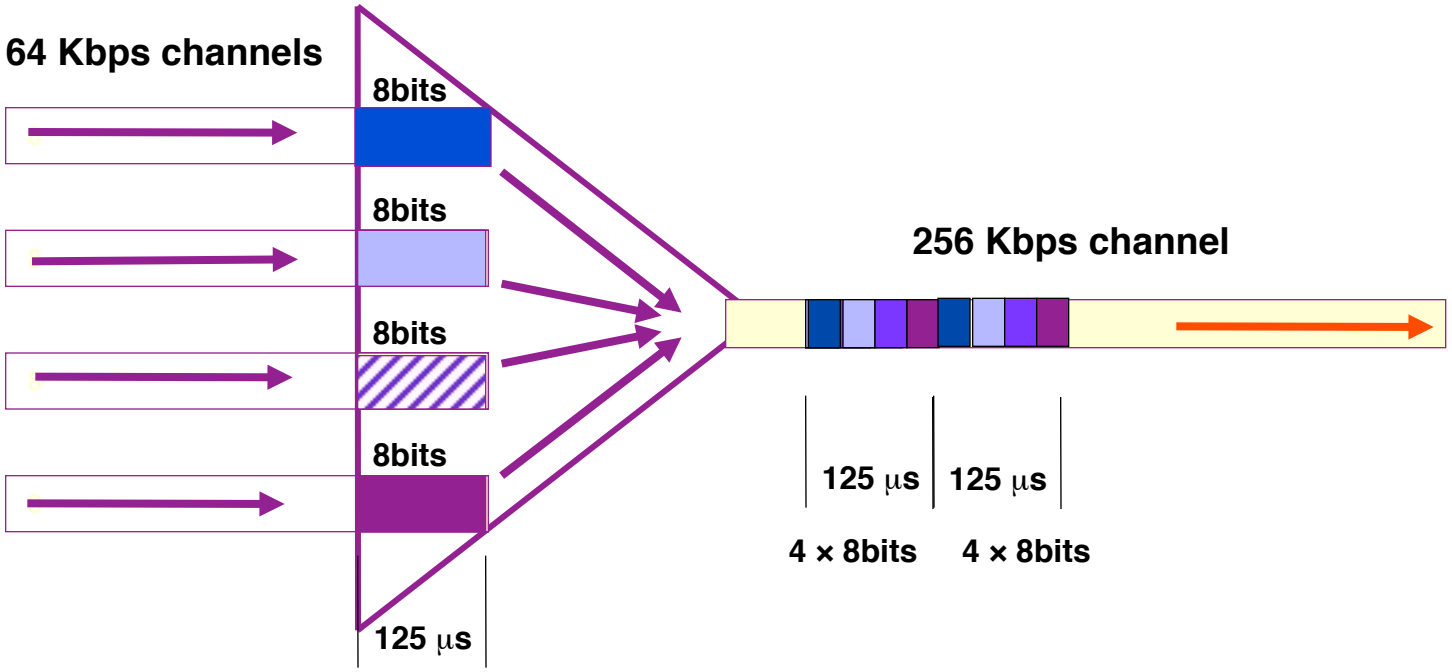
- TDM interleaves bits (sometimes bytes) from several streams onto a higher bit-rate stream



- Timings between bits of a stream are preserved
- The effect is as if there are two separate "bit-pipes"
- Easy to turn TDM system into a switch
  - to connect arbitrary inputs and outputs

Time Division Multiplexing

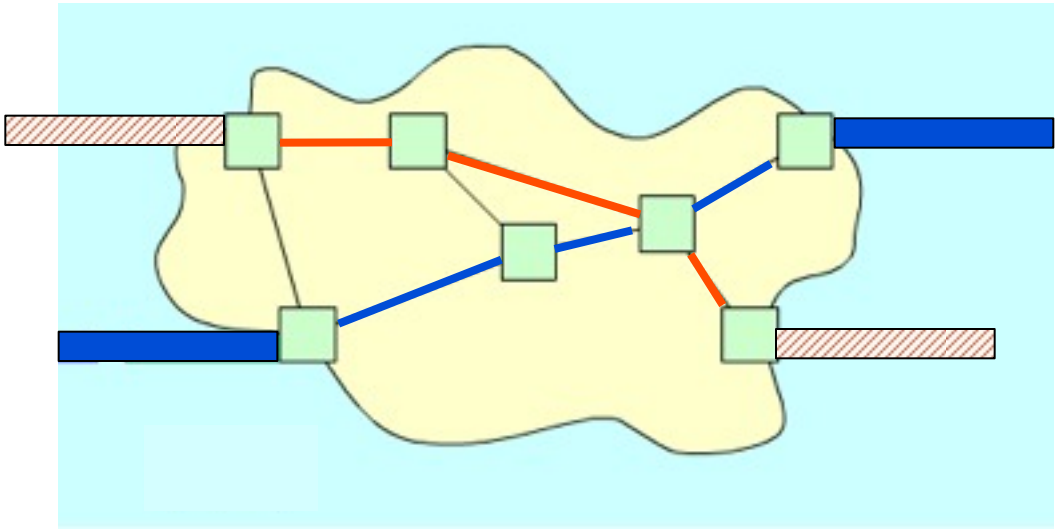
- Voice digitised by a CODEC
  - 64 Kbps pulse code modulation (PCM)
- Multiple digitised channels multiplexed on to “high capacity channel”
- Inevitable delays



Modern switched circuit

- Circuit – constant bit-rate pipe across network
  - Typically based on TDM through circuit-switches

1. Switched circuits
   - Set up dynamically using signalling protocols
   - Charges based on duration
   - Examples: PSTN and ISDN
2. Leased circuits
   - Leased lines
   - Set up “administratively”
   - Monthly charge



Circuit-switching is inefficient for data communications

- A host can only communication with one (or a small fixed number of) host at a time
  - But we'd like to to communicate with multiple computers concurrently
- Time intervals between bits are preserved
  - But we'd like to communicate between dissimilar devices
- The technology used to digitise calls inside a modern telecomm network results in a continuous stream of bits at 64Kbps
  - But data is "bursty", we then have to open a circuit with capacity sufficient for the peak data-rate, while for much of the time the opened circuit will be idle.
- Fixed allocations
  - If we want 65Kbps, we may have to ask for 128 Kbps
- **Data communication needs a different approach**

Part 2. Packet-switching

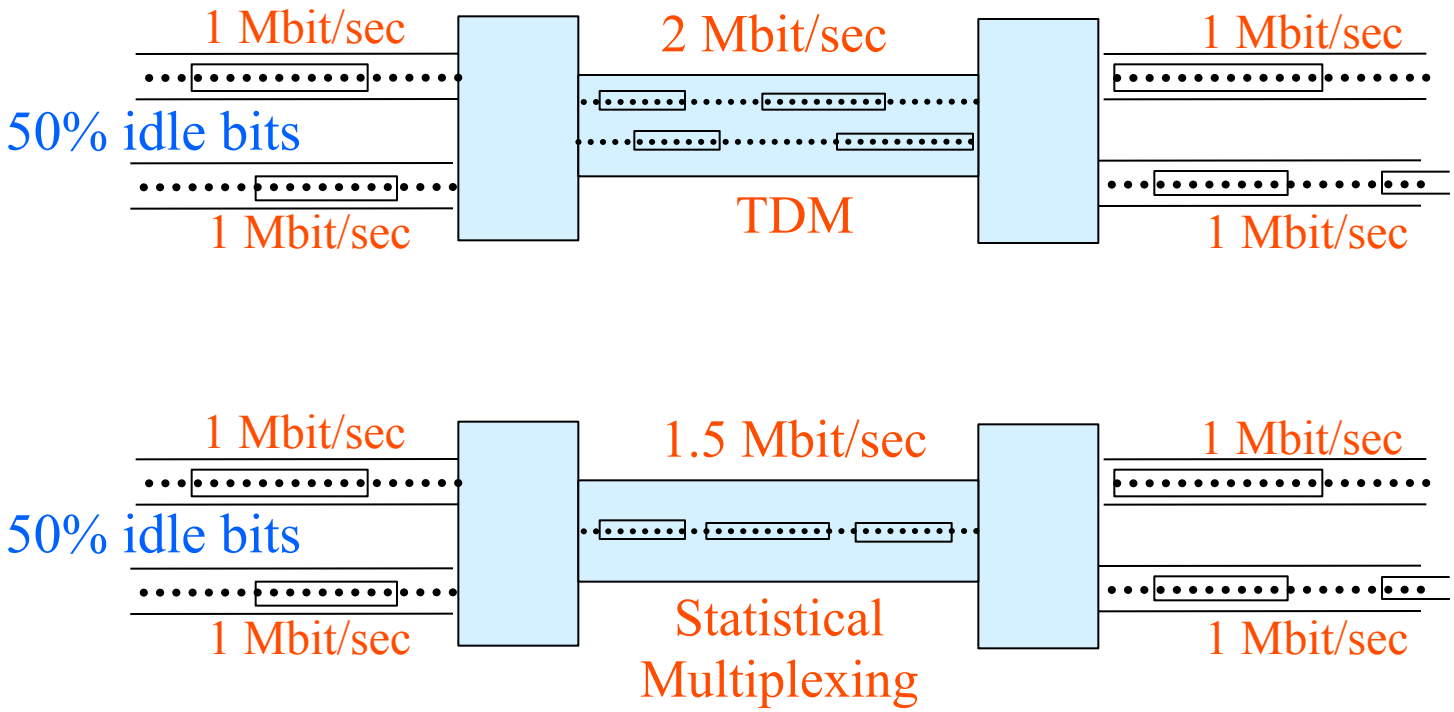
TDM

- TDM
  - works at bit (or byte) level
  - a stream of bits at a constant rate
- However,
  - most application generate data in bursts interspersed with periods of idleness.
  - in data communication not all bits are useful, e.g. idle pattern in bit-oriented synchronous framing

Statistical Multiplexing

- Data sent in “lumps” called “frames”, “packets” etc.
- Lumps may vary in size
- Inter-arrival times are random
- Statistical multiplexor: packet-switches, Internet routers
- Usually processing is FIFO (First In, First Out)
  – Quality of service (QoS) needed
- Can overload an output => queues needed
  – Data discarded and additional delay

TDM vs Statistical Multiplexing



- Statistical multiplexing treats the data bits and ignore the idle bits
  - lower link capacity requirement
  - higher utilisation rate

Delays in Statistical Multiplexing

- Statistical multiplexing has longer, more variable delays than TDM
  - A complete frame must be received before transmission begins
    - A frame of 15,000 bits has delay of 10ms for 1.5Mbps
  - Queuing to solve possible contention when two frames arrive simultaneously
    - Highly variable, cause jitter
    - A frame may be discarded, cause data loss
  - Additional overhead
    - Some bits in the frames must carry control information, e.g. to indicate to which channels they belong

- Still the best choice for most data communications
  - Major advantage: enhanced utilisation for bursty data

Packet

- Packet -- a collection of bits
  - Packet lengths vary
  - mostly less than 1500 bytes
  - objects often need to be split into a series of packets
  - carry control information, overhead

Packet-switching

- Based on statistical multiplexing
- "Packet-switches" – store and forward

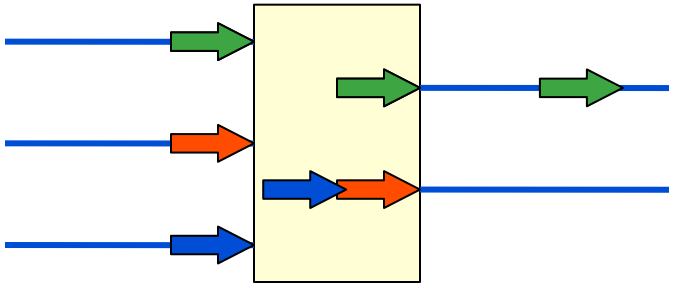
– packets from different sources are mixed on a link

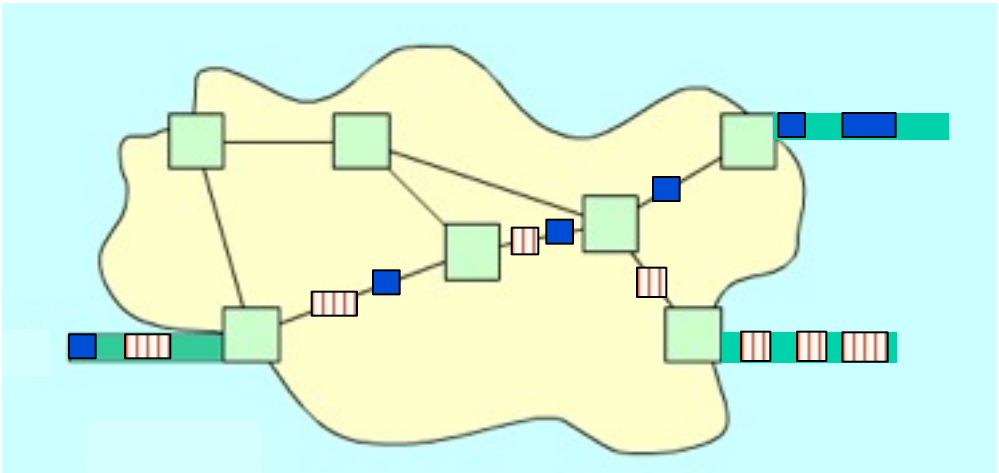
– packets multiplexed to many destinations

– only send a packet when there is data to send

– packets arrive at random intervals

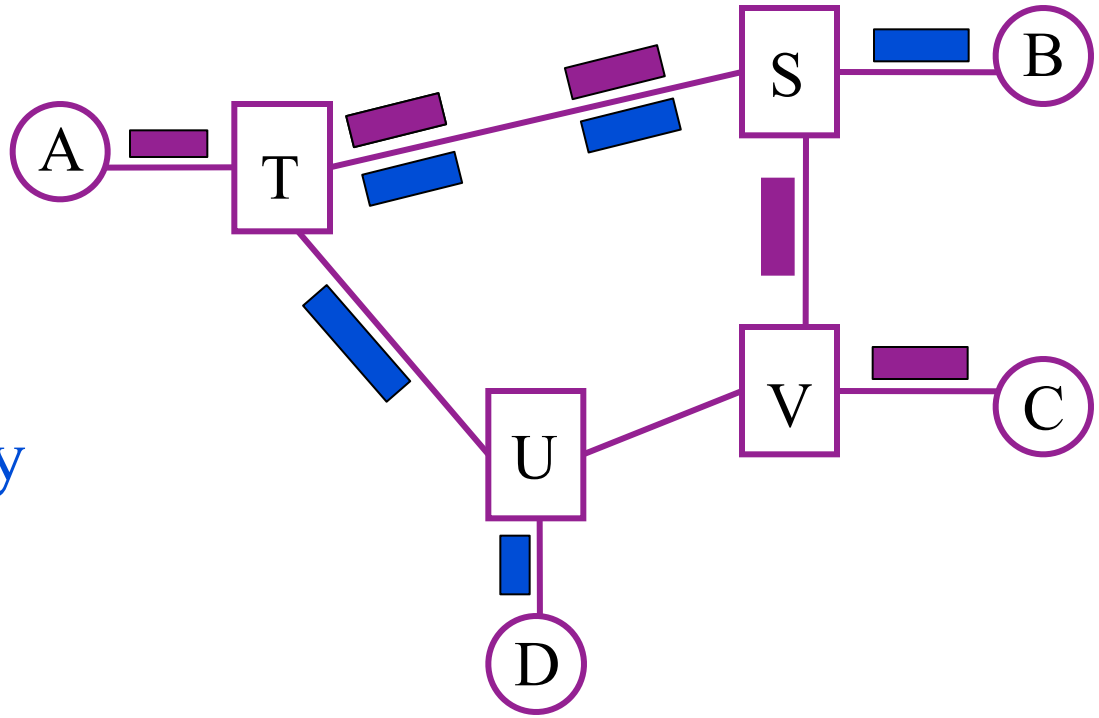
- Allocate network capacity on-demand with fine time granularity





Mesh-type packet networks

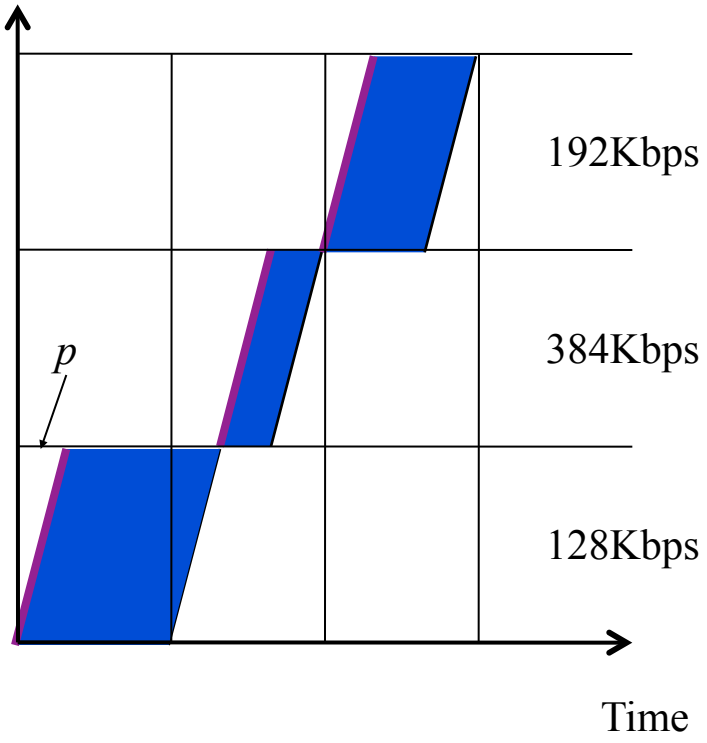
- Topology similar to circuit-switched network
  - "Packet-switch", "router"
  - Store and forward operation



- X.25
- Frame relay
- ATM
- Ethernet

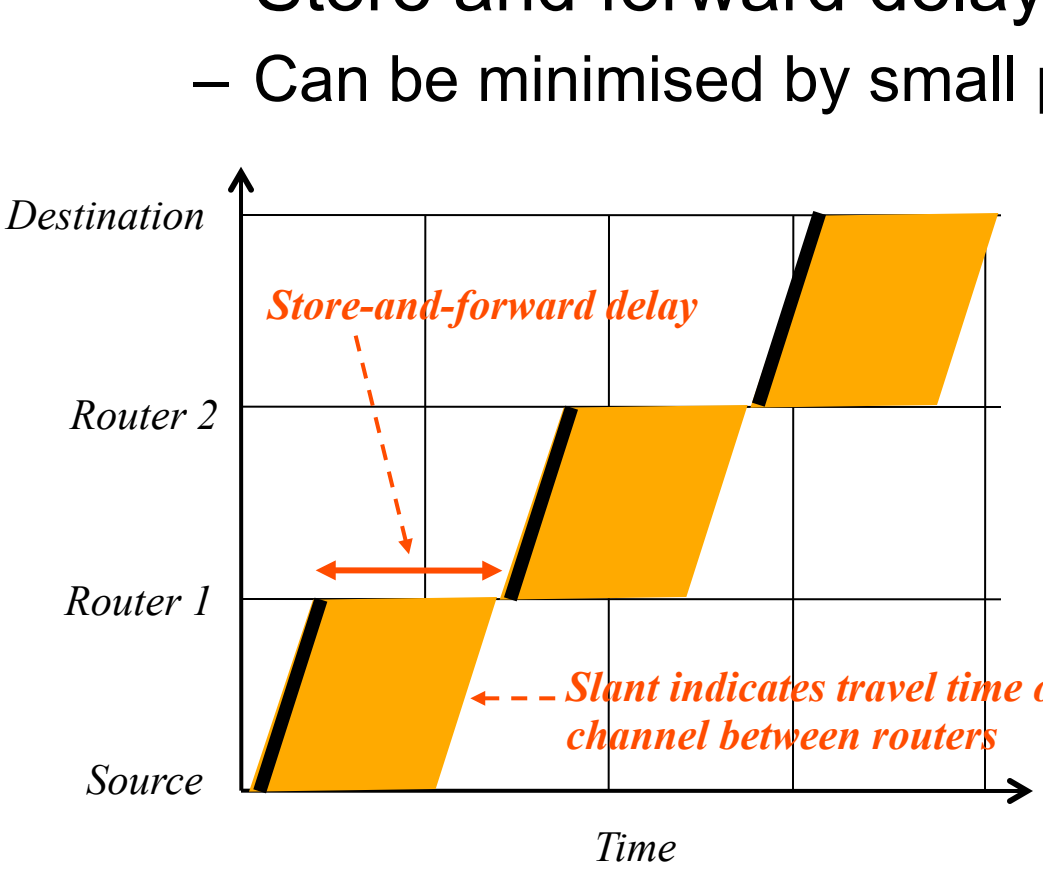
Packet-switching advantages

- Hosts with nothing to send send nothing
- Links are statistically multiplexed
- Easy for hosts to multiplex packets to many destinations
- Source and destination can operate at different bit-rates, as can intervening links

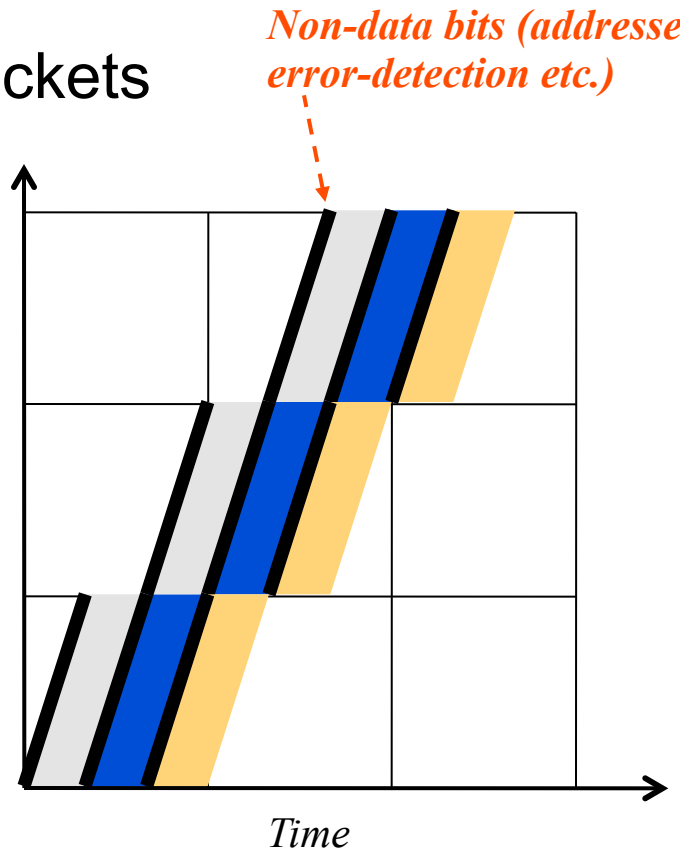


Packet-switching disadvantages (1)

- Store and forward delay
  - Can be minimised by small packets



a) A single large packet traversing 3 links with the same channel data rate.



b) Three small packets (containing the same data) traversing the same 3 links

Packet-switching disadvantages (2)

- Switches may become congested
  - Queues at packet switches
  - Queuing delay
  - Discard packets
- End-to-end delay is unpredictable
  - Jitter (variable delays in transmission time due to waiting in queues)
- Packet header overhead
  - Sequence numbers
  - Addresses
  - Connection identifiers

Packet variants

- Cell-switching
  - Cells: small, fixed-size packets (relatively large overhead)
  - Used in Asynchronous Transfer Mode (ATM) networks, 53-byte cell
  - Now used mainly inside switches (gigabit ethernet hubs)
- Frame-relay, frame-switching
  - Frames: unit of data transferred in data-link layer
  - Particular technologies transfer frames through frame-switches
- Message-switching
  - Email messages, files
  - Very large store and forward delay

Circuits or Packets?

	Circuits	Packets
1. Any host can communicate with any other host;	1: Yes	1: Yes
2. A host can only communicate with a small, fixed number of hosts at a time;	2: Yes	2: No
3. Other hosts may be "blocked" - unable to communicate because the wire they need is in use;	3: Yes	3: No
4. Communication between two hosts (once established) is unaffected by activity elsewhere in the network.	4: Yes	4: No
5. Whilst they are communicating, the two hosts have exclusive use of the sub-channel which links them;	5: Yes	5: No
6. Bits are delivered in the same order in which they are sent.	6: Yes	6: ?
7. Time intervals between bits are preserved	7: Yes	7: No
8. We can distinguish three phases in the life of a circuit; setting it up, using it and tearing it down	8: Yes	8: ?

For packet-switching, 2 and 3 are advantages; 4, 5 and 7 are potential disadvantages; 6 and 8 depend on whether we use “virtual circuits” or “datagrams” (to be discussed).

Sharing Summary

- Sharing links and networks
- Circuit-switching
  - Fixed allocations – FDM, TDM
- Packet-switching
  - Statistical multiplexing

The End