COMS3100/7100

Introduction to Communications

Lecture 29: *Telephone & Internet*

This lecture:

1. History of Telephony.
2. Pulse Code Modulation.
3. Digital Multiplexing.
4. Computer Networking & the Internet.

Ref: CCR pp. 495–499, 526–541, Couch pp. 552–559, Technology in Australia 1788–1988, ch. 8, Australia & NZ Telecommunications Profile, Brisbane's Early Telephone Exchanges, A Brief History of the Internet in Australia.

History of Telephony

In order to understand why the telephone system is the way it is, it's necessary to learn something of its history.

Electric Telegraphy

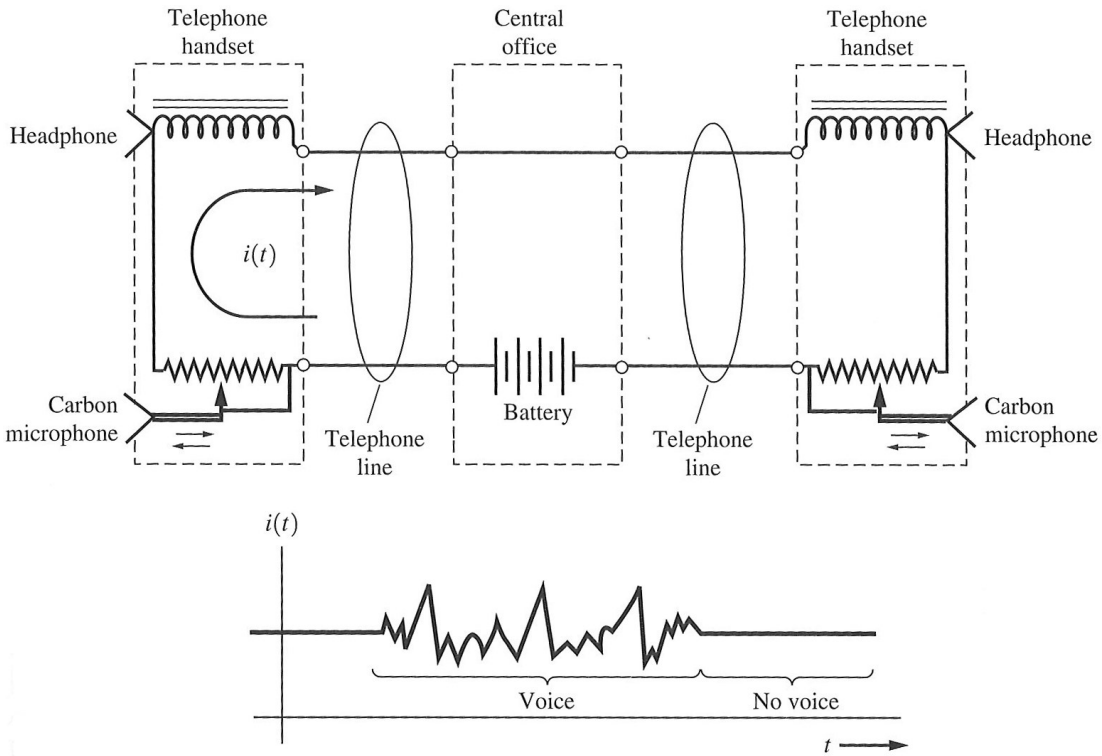
The age of electrical telecommunications began with the electrical telegraph (succeeding Napoleonic-era semaphores).

- First entered commercial service on the *Great Western Railway* in the UK in 1839 (patented 1837).
  - First use in Australia in 1854 from Melbourne to Williamstown.
  - Queensland followed in 1861.
  - Thus began the network of poles and wires still in use today.
- Governments worldwide moved to create or protect monopolies in telecommunications, especially in the British Empire.
  - In the Australian colonies, the telegraphs came under the control of the newly amalgamated Post Offices (SA 1869, Qld 1880).

Birth of the Telephone

In 1876, *Alexander Graham Bell* beat a host of others to a key US patent on the telephone and gave a successful demonstration.

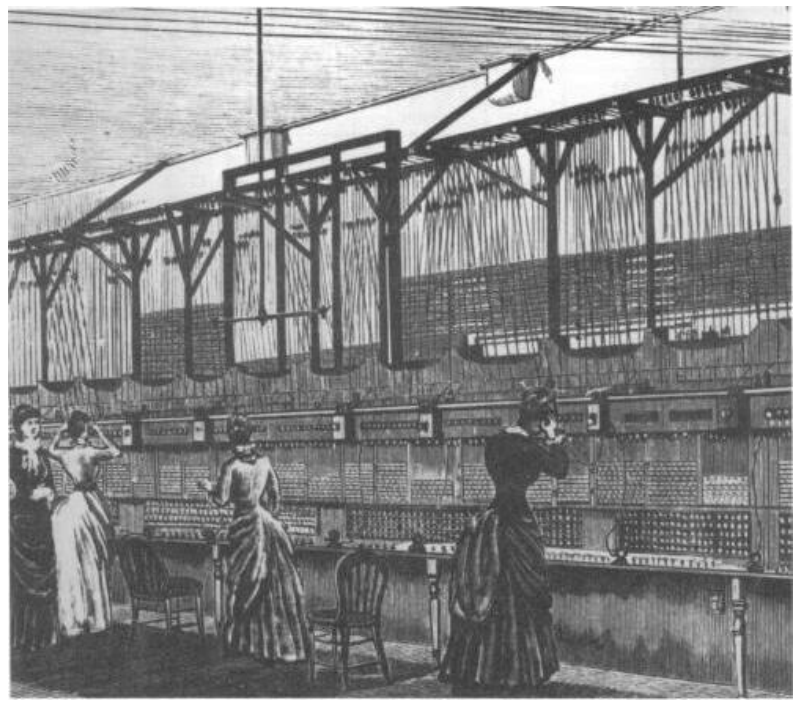
- In 1877, the carbon microphone was invented by *Thomas Edison* (the patent was hotly contested).
- The first services were point-to-point until the invention of the *exchange*, first installed in Connecticut in 1878.



Early Telephony in Australia

Bell's publications in 1877 led to widespread experimentation and imitation in Australia.

- Point-to-point operation between Melbourne and South Melbourne began in 1879.



Switchroom at Melbourne Telephone Exchange 1886. Source: Technology in Australia, 1788–1988

- In 1880, Queensland installed a telephone system & exchange.

Telephony Goes Transcontinental

Because of its early history, the telephone system was originally known as the *Post Office Telephone System (POTS)*.

- As the popularity of telephony increased through the 1880s, exchanges were connected together via *trunk lines*.
  - In 1888, Adelaide ↔ Semaphore, Hobart ↔ New Norfolk.
- In 1891, the first *automatic* exchange operated in Indiana.
  - First in Australia was Geelong, 1912; Brisbane in 1925.
- In 1901, with Australian federation, control of telephony passed from colonial Post Offices to the new *Postmaster General (PMG)*.
  - Originally accounted for 90% of the new federal bureaucracy!
- Trunks were extended gradually to be transcontinental.
  - First US transcontinental call was 1915: New York ↔ San Francisco.
  - In Australia: Sydney ↔ Melbourne 1907 ↔ Brisbane 1923 ↔ Perth 1930.

Telephony Goes Intercontinental

In 1927, the first public intercontinental phone call was made, via radio: USA $\leftrightarrow$ UK.

- In 1930, a public radiotelephone service connected UK $\leftrightarrow$ Australia $\leftrightarrow$ NZ.

Emergence of Digital

- The foundations for digital transmission of voice, *pulse code modulation (PCM)*, were laid in a series of patents by Alec Reeves in 1937–1939.
- The practical transition to digital began during WWII with the SIGSALY system for encrypted telephony (using PCM).
  - One of only a few such units was installed in GHQ SWPA for Gen. Douglas MacArthur in Queen St., Brisbane.
- Digital telecommunications gradually worked its way into the mainstream.
  - For the 1956 Melbourne Olympics, some international cable traffic was upgraded to digital.

Telephony Goes Digital

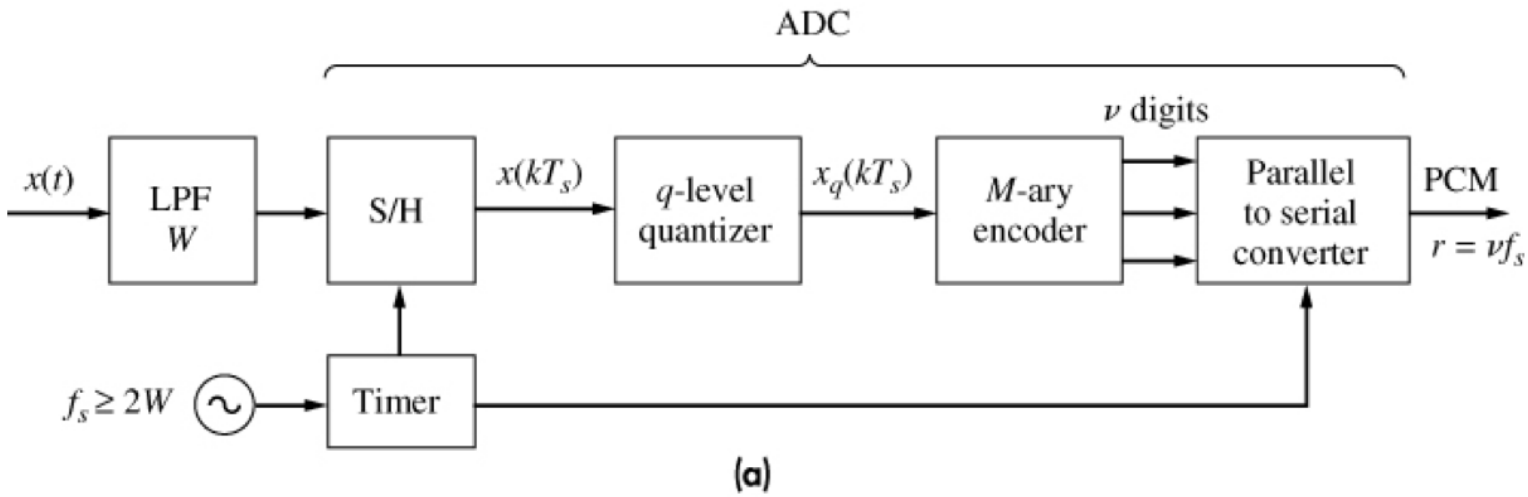
- In 1962, the *T1* system was deployed in the USA for digital trunking using PCM.
  - In Australia, the *Datel* service was introduced in 1969, for data services on voice-grade lines.
  - Beginning in 1977, *Telecom* (PMG having split into two in 1975) began gradually upgrading trunk lines to PCM.
- Following rapid development from the 1960s, optical fibre became suitable for long-haul telecommunications in the mid-1970s.
  - Melbourne $\leftrightarrow$ Ballarat link completed in 1984.
  - In 1988, the first intercontinental optical-fibre cable *TAT-8* entered service between the USA, UK and France.
- In 1992, *digital subscriber lines (DSLs)* were first standardised (in *HDSL*) allowing data rates of 1.5 Mbps or higher from the home.
  - ADSL first offered in Australia in 2000.
- Starting in 2004, *Voice over Internet Protocol (VoIP)* has been offered commercially (more on this later).

Pulse Code Modulation

In a series of inventions in the 1920s and 1930s, British engineer Alec Reeves discovered a means for digital transmission of voice.

- His invention, *pulse code modulation (PCM)*, is a digital transmission system using an *analogue-to-digital converter (ADC)* on input and a *digital-to-analogue converter (DAC)* on output.
- In PCM for modern telephony, a voice signal is first bandlimited to 4 kHz or less by an *anti-aliasing filter* (LPF).
- It is sampled at 8 ksps with 8 bits per sample.
- The bits are sent serially using a suitable line code at 64 kbps.
- At the receiver, the bits are re-assembled into samples.
- The samples are then used to reconstruct the original voice signal through the DAC.

PCM Transmitter



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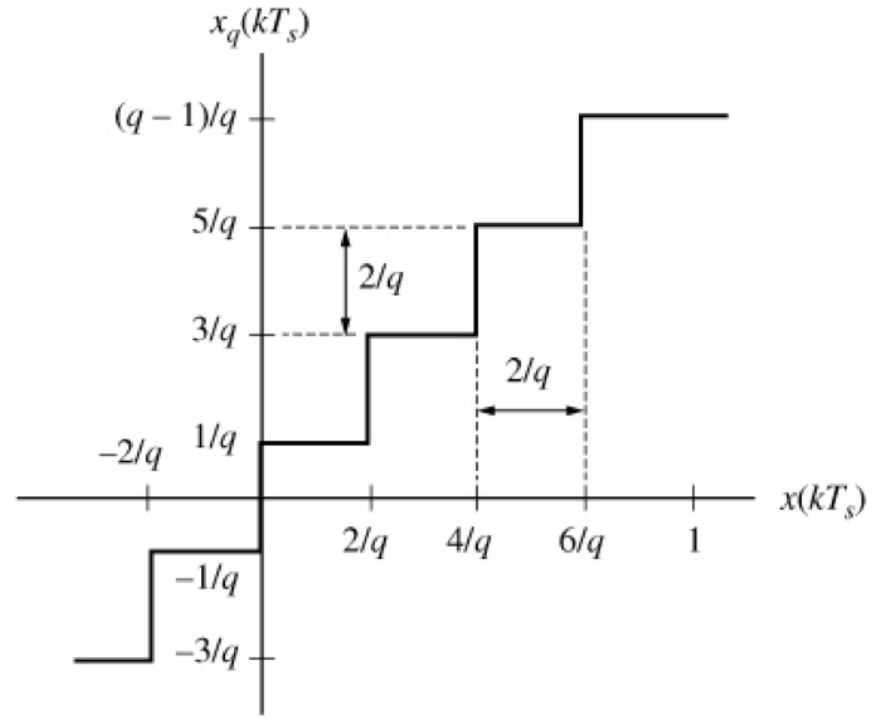

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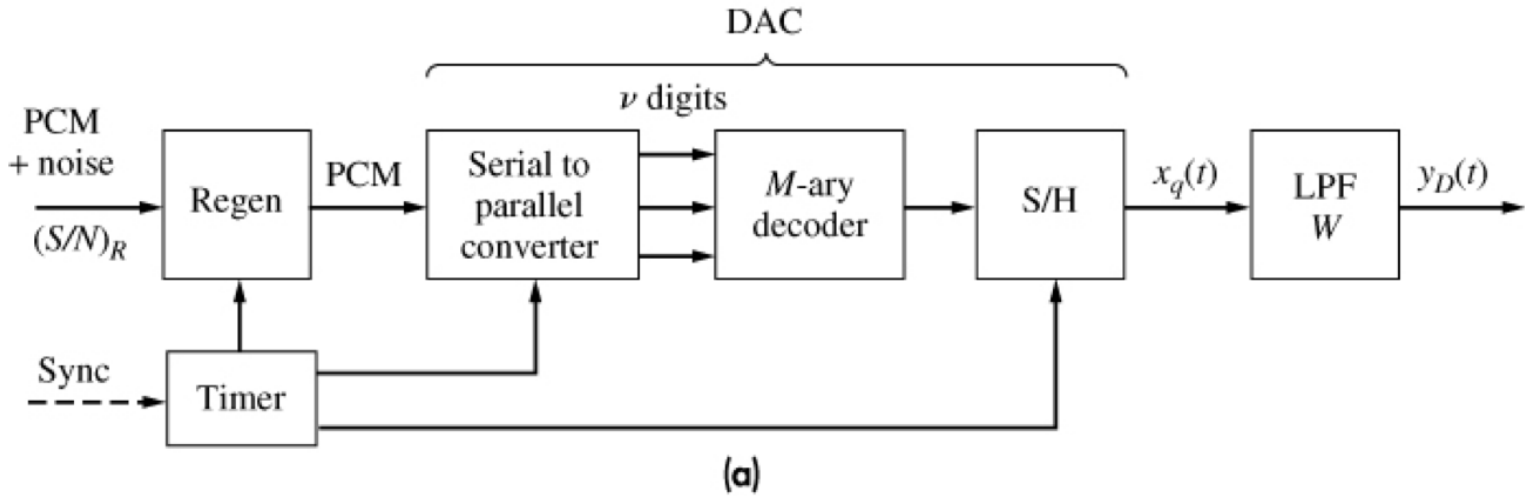
PCM Receiver



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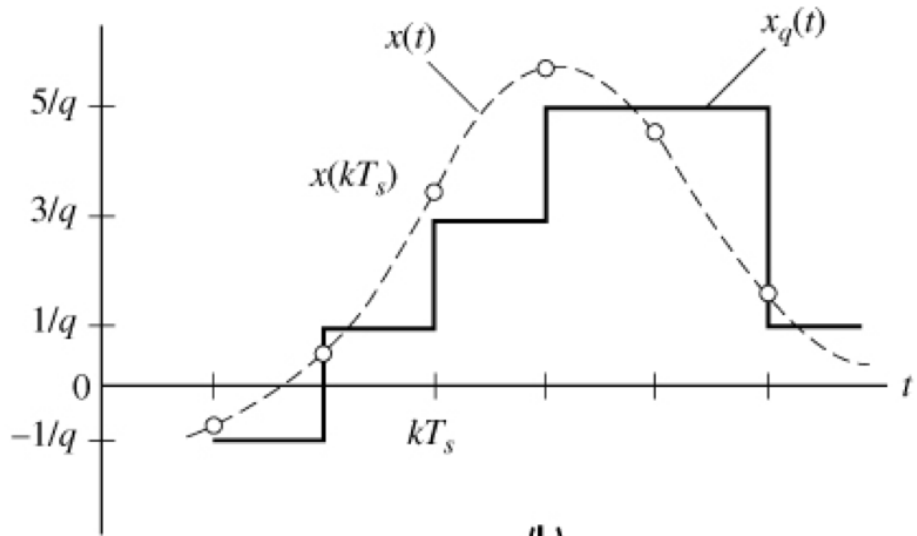

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Digital Multiplexing

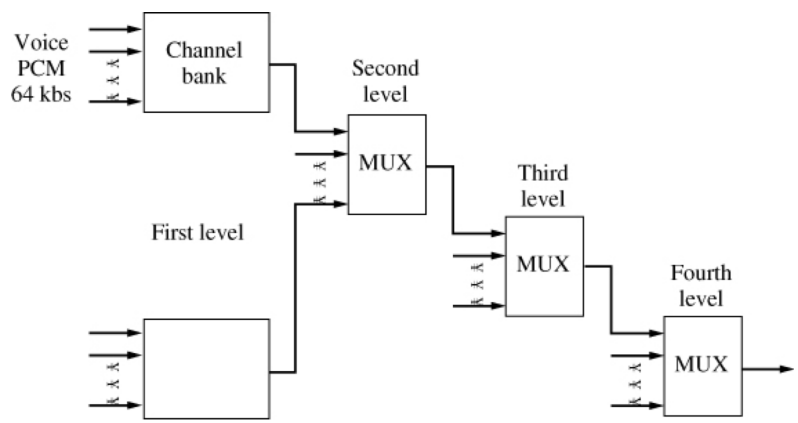
In Lecture 17/18, we examined the problem of *multiplexing* in communications.

- There are a number of different possibilities, *e.g.*, PAM/TDM and FDM.
- We could apply these techniques directly to digital data also (and sometimes we do exactly that), but we now have an alternative.
- Digital multiplexing (especially in the *public switched telephone network, PSTN*) is based on *interleaving* bits from two or more sources.
- A MUX usually must perform the four functional operations:
  1. Establish a *frame* containing at least one bit for each input.
  2. Assign to each input unique bit slots in the frame.
  3. Insert control bits.
  4. Make allowance for any variation of input bit rates.

Plesiochronous Digital Hierarchy

The *plesiochronous digital hierarchy (PDH)* was the first digital multiplexing hierarchy adopted worldwide for the PSTN.

- Implementation details vary: the *T1* system is used in North America, Japan, South Korea, but *E1* elsewhere.
- The basic unit is the *E0* 64 kbps PCM signal.
- 30 E0 signals can be multiplexed in a *channel bank* to create an *E1* signal which, with framing and signalling overheads, is 2.048 Mbps.
- E2, E3, *etc.*, each multiplex four channels of their predecessor.



Synchronous Digital Hierarchy

PDH is designed to cater for slightly different local clocks in its different sources (the origin of *plesio* in its name).

- Therefore, PDH sometimes has to add *stuff bits* to a frame if the clock of one of the sources is running too slow.
- The newer *SDH* has tightly controlled atomic clocks distributed to all sources.
- Designed for transmission over optical fibre.
- Lowest level is *STM-1* which multiplexes 63 E1 lines.
- Standards defined for STM-4, STM-16, STM-64, *etc.*
  - STM-64 carries 10 Gbps.

Circuit vs. Packet Switching

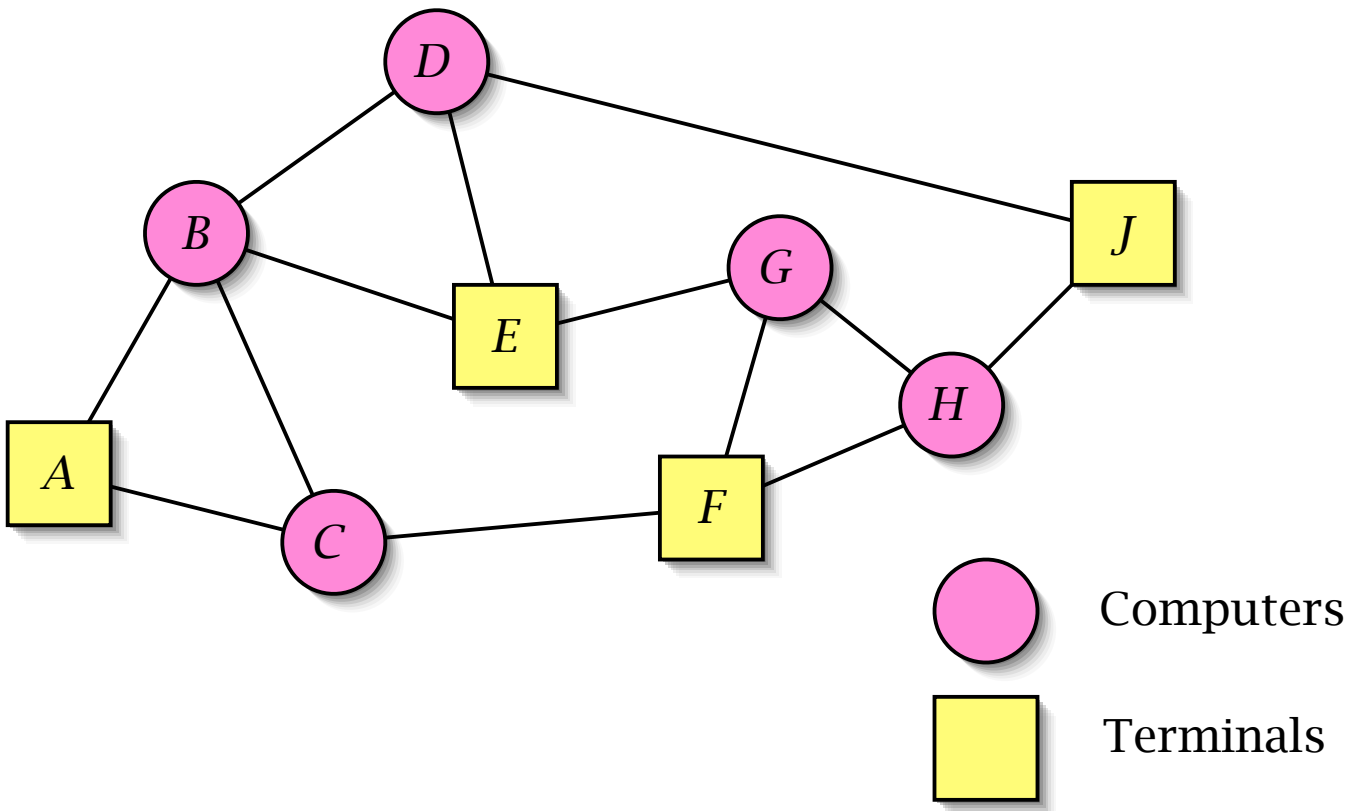
The PSTN is traditionally a *circuit-switched* network.

- This means a dedicated path is set up between transmitter and receiver with a guaranteed, constant bit rate.
- Works great for voice, but can be inefficient for other sorts of data.
- In a *packet-switched* network, each link is used only so long as needed to deliver a packet from one node to the next.
- This is more efficient, but nodes may need to temporarily store/delay packets if the required line is already in use.
- Such delays are quite acceptable in some applications yet intolerable in others.
- The Internet is a prime example of a packet-switched network.

Computer Networks

In 1969, the *Advanced Research Projects Agency (ARPA)* of the US Department of Defense established the *ARPA network (ARPAnet)*.

- Consider a model of five computers and four terminals.
- Each *node* can transmit, receive and store data for packet-switched routing.



History of the Internet

In Australia, there were twin developments in the early 1970s.

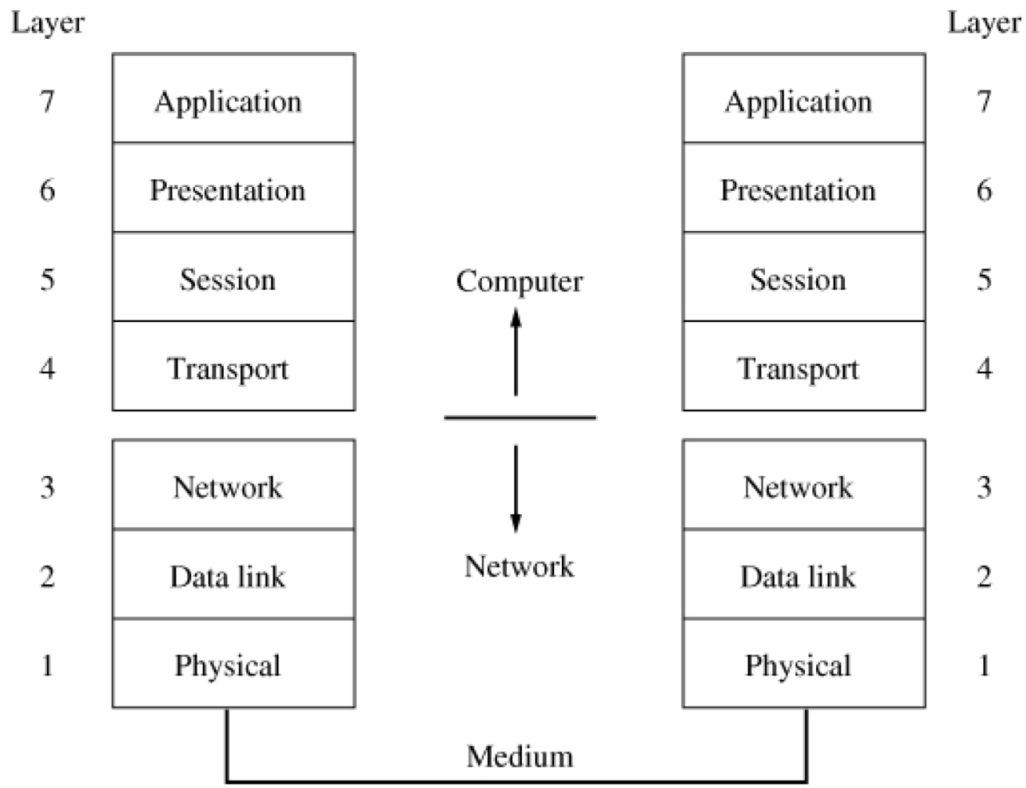
- The *Australian Computer Science Network (ACSnet)* used dial-up modems between universities to store and forward.
- The *CSIRO Computing Network (CSIROnet)* was an experimental packet-switched network.
  - In fact, ACSnet used CSIROnet for interstate links.
  - *X.25* was the first international standard (1976) to govern packet-switched networks, implemented on CSIROnet.
- The term *Internet* was coined in 1974 by Vinton Cerf, and the protocols bearing its name were standardised in 1981.
  - A permanent connection between ACSnet and ARPAnet was established in the early 1980s.
  - 'Full' internet arrived in Australia with the *Australian Academic & Research Network (AARnet)* in 1989.
- Recently, the internet has become an attractive network for transmission of voice (VoIP).

OSI Model

Open Systems Interconnection

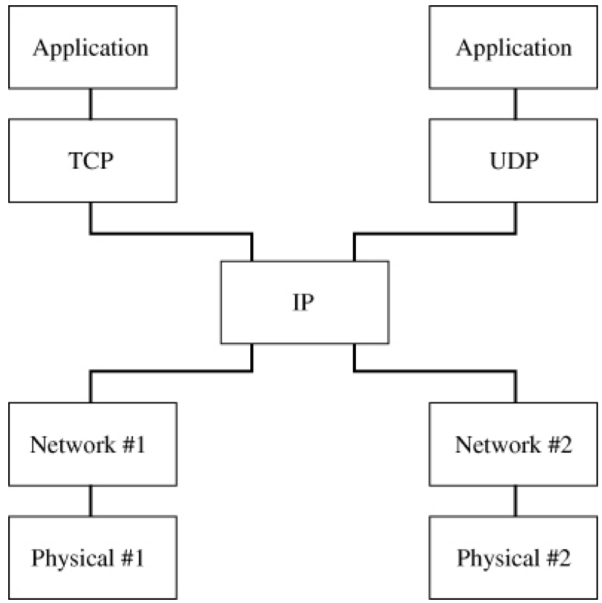
The *Open Systems Interconnection (OSI)* model was developed in the late 1970s by the ISO.

- 'Open' means any two systems can communication if they adhere to the model.



TCP/IP

The *Transport Control Protocol/Internet Protocol (TCP/IP)* was developed in conjunction with ARPAnet and preceded OSI.



- The *Internet Protocol (IP)* concerns how packets should travel across the network(s), *i.e.*, how they should be *routed*.
- The *Transport Control Protocol (TCP)* sits above this, ensuring reliable transmission of packets in the correct order.
- A simpler, lower-overhead but less reliable alternative is the *User Datagram Protocol (UDP)*.