EXTENDED MODEL ANSWER

Digital Communication II 2001 Paper 9 Question 3 (IAP)

POTS analogue modems

Synthesised audio tones that pass over the conventional telephone network.

Analogue between home and exchange, then digitised at the exchange for transport between exchanges. The line is digitised at 8KSamples/s at 8bit resolution using a companded encoding scheme (μ-law or a-law).

Only a single copper pair exists, and is used for both directions.

Most ISPs will connect digitally into the exchange, hence only one analogue segment. This is exploited by V.90 modems to enable provision of 56kb/s downstream bandwidth. Upstream bandwidth is limited to 34kb/s. In reality, the connection speed is likely to be lower due to line noise. The end systems go through a negotiation phase to determine a common standard they support, then go through a learning phase to determine line quality.

Advanced coding techniques are used to maximise the throughput achievable over the approx 4kHz bandwidth of the phone line. Current modem technology is not too far from the Shannon limit.

The POTS is ubiquitous, and likely to be the baseline access method for many years to come, particularly in developing countries.

In the UK, BT is generally the "incumbent supplier" of local-loop telephone service. Telephone usage is normally charged on a time metered basis, making it difficult for ISPs to offer Internet access without per-minute charges. The industry regulator is currently in the process of forcing BT to offer un-metered access to the local loop to third parties.

Cable modems

Tree of 75 Ohm coaxial emanating from the "head-end" which serves many thousands of customers. Simple repeaters are used to amplify and distribute the signals, many located in "kerb-side boxes".

Coax is a good transmission medium, capable of high bandwidths.

Due to the tree structure of the cabling, the network is best suited to downstream transmission from the head-end. The bandwidth used by a single television channel can be used to carry around 30Mb/s of traffic. This asymmetric nature is not a problem for current WWW traffic patterns.

Providing upstream connectivity is harder. Some installations utilise a conventional analogue telephone modem for this upstream path. Others (like those of NTL Cambridge) use the cable network for the upstream path. A different frequency band is used. Due to the

physically large network size (and hence propagation delay) schemes such as CSMA (used by Ethernet) would be very inefficient. Instead, transmission by clients is scheduled from the head-end using a reservation protocol (part of the DOCSIS standard). Peer-to-peer transmissions are not possible – everything must go via the head-end.

From the operator's point of view, cable modems provide a low-cost means of providing broadband service to widely distributed customer base. However, it may be necessary to segment the shared media into multiple segments as the user base increases in size (but this extra equipment can be funded from revenues).

Digital Subscriber Line (xDSL)

DSL utilises the existing copper pair between Customer Premise (e.g. home) and Central Office (exchange).

It poses a tricky transmission medium as it suffers from high frequency attenuation, crosstalk between pairs, reflections from impedance changes (due to wire thickness and material transitions) and electromagnetic interference. Furthermore, since there is only a single pair it needs to be used in both directions.

There are two major competing coding schemes. One employs a complex phase/amplitude modulation scheme with multi-bit symbols, while the other uses multiple simultaneous lower bit rate carriers with simpler modulation. Both schemes use complex equalisation to try to compensate for some of the medium's deficiencies.

NEXT (Near End crosstalk) occurs when the transmitter on adjacent pair couples on to a closely located receiver. FEXT (Far End crosstalk) occurs when a remote transmitter on an adjacent pair couples on to the receiver.

There are a range of DSL variants that offer different bandwidths over different distances from the exchange and different line qualities.

ADSL offers an asymmetric bandwidth service (e.g. 512Kb/s to 2Mb/s downstream, 128kb/s upstream) that suits current WWW traffic patterns.

Some DSL variants also enable the wire to offer conventional PSTN phone service concurrently. Low-pass filters must be installed to block the high frequency digital data signal from being heard on the analogue telephones.

Before installing DSL, the operator must remove "load coils" and "bridge taps" if any are present on the line. Not all lines will be sufficiently close to the exchange or of a high enough quality to provide service.

Local Loop Un-bundling is the process whereby 3rd parties (ISPs) are to be given the ability to provide DSL services over the incumbent Telco's copper plant. It raises thorny issues, such as the siting of 3rd party equipment in exchanges, responsibility for maintenance of the copper plant, reliability of "Life Line" telephone service, and possible electromagnetic interference problems.

Fixed wireless

Most fixed wireless system require line-of-sight between the node and base station. This avoids the tricky problems caused by multi-path reflections, and enables use of lower transmission powers. There is no need for base station hand-overs or other problems associated with mobile wireless. Rooftop antennas are generally employed, with the base station being on the tallest building possible.

Both free-space laser and microwave schemes exist.

Free-space laser schemes offer bandwidths in the 2-155Mb/s range. Some new schemes are employing WDM to improve on this.

Microwave schemes are being designed in the 2, 28 and 40GHz bands. Higher frequencies offer greater bandwidths, but are harder to work with due to the high-speed electronics required.

"rain fade" attenuation is a serious problem. Adaptive coding schemes are required to detect this condition and switch to lower bandwidth (more robust) coding schemes, and perhaps increase the level of FEC protection.

Fixed Wireless provides a cheap way for an ISP to offer coverage to many clients in an urban area from the top of a tall building. Dependency on prevailing weather conditions may make it less suited to some regions.

Optical fibre

Today's optical fibre has the potential to carry huge amount of bandwidth (many terabits). Were fibre installed into the home the link bandwidth could be upgraded for many years to come simply by changing the termination equipment.

Optical fibre is cheap to manufacturer, in some cases, cheaper per metre than copper UTP. Termination costs have traditionally been expensive as they have required precision manufacturing. Lasers have typically been expensive too. However, these costs have dropped dramatically for systems of 150Mb/s or less. (In some cases LEDs can be used in place of lasers, further reducing costs).

Installing fibre (in conduits) into newly built properties is certainly economically viable. However, digging up the road to provide fibre to existing homes is very expensive and not currently favoured.

One compromise is to lay fibre to a "kerb side box" from which UTP or coax already exists into the home (with a run of 200m or less). Many cable companies already have such a wiring infrastructure, which should be able to provide high bandwidths into the home.

Satellite

Two main type of satellite exist, Geostationary and Low Earth Orbit.

A single GEO satellite can be used to provide coverage to a region. However, at a height of 36,000km the round-trip-time is of the order of 240ms. This may not be good enough for some interactive applications e.g. virtual reality.

LEO satellites are typically in 1,500km (2 hour) orbits. A constellation of over 20 is typically required to provide coverage to any given region (though a large %age of the earths service will then be covered). Latency is typically sub 100ms.

Different schemes are proposed for providing the bulk relaying of data back to the ground. Some employ satellite tracking stations distributed over the globe, while others use inter-satellite communication to relay the data back to some small number of ground stations.

Launching satellites is an expensive and risk-prone business. Particularly for LEO systems, incremental deployment is typically not possible; the whole constellation must be in place before continuous service can be provided to any one area.