Make Room! Make Room!

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November 1995

ABSTRACT

The ever growing computing requirements of a medium-sized university are detailed. The problems of providing enough computers for student use are noted, and a potential solution in the form of a Cable-TV-based network is described.

1. Background

Brunel is now a medium-sized university, having recently merged with the West London Institute of Higher Education. The expanded institution has about 2000 staff and researchers, and about 15000 students. There are four campuses (campii?) all within 20km of each other.

2. Ubiquitous Computing

The original Brunel sites at Uxbridge and Runnymede have had a unified computing environment for several years. Every member of the University is entitled to a computer username: these are issued to students during the registration process, though staff still have to apply individually. The username is the key to a service which aims to provide location-independent computing services. Almost every PC and workstation is connected to the Brunel network, and as far as possible all machines are set up to present the same environment to the user. This level of transparency is particularly valuable to the students, who often live on one campus but take lectures elsewhere. It also allows for the most efficient possible use of the limited number of 'public' computers (less than 500 seats for 15000 students).

The demand for computer time increases constantly. The main driver so far has been wordprocessing - students know that they will get better marks for a printed report than for a handwritten one, and suggestions to the academic staff that costs would be lower if they *deducted* marks for wordprocessed reports tend to fall on deaf ears! More recently, demand for database access, Web browsing, and other information-related activities has risen steeply. To cater for this increased demand by conventional means would mean creating at least one new computing classroom every year. Finding the money for this is very difficult, but finding the space is almost impossible. Other solutions must obviously be found.

3. Scalable Solutions

There seems to be only one solution to this problem that will work in the long term: *Every person must provide their own computer and find their own space to work.* In practice this is likely to mean a great increase in the use of laptop machines, with all the cost and health problems that they bring. The advantages of this strategy to the University are considerable: students will find the money to buy the machines (probably by going further into debt) and they will also take away the machines when they become obsolete.

The University's problem then changes to providing the support infrastructure for 15000 mobile computers. This is a significant task, which will include network connections, software provision and licence deals, information sources, facilities for co-operative working, and probably backup services as well.

4. Network Provision

Most academic and administrative buildings are now wired for ethernet. The majority of these installations are over-stretched 10-Base-2 networks, with fibre between buildings and several large routers in the centre.

The next big growth area will be the Halls of Residence: about 500 rooms are now wired with Category-3 UTP, and plans are laid to expand this to a further 400 rooms over the next two years. The takeup rate for Hall connections will probably exceed 15% this year, and is expected to rise rapidly over the next few years. Costs are fairly low: an installation fee of POUNDS 60 provides a network card installed and tested by Computer Centre staff, and a connection fee of just over POUNDS 1 per week makes a contribution to equipment costs.

Unfortunately, less than 30% of Brunel's full-time students are in Hall. Part-time students are even more difficult to help. For the off-campus students and staff we provide a dial-up modem bank supporting terminal access as well as SLIP and PPP. Several hundred people are registered to use this service, but so far we have found that ten modems are enough to avoid the 'busy signal' problem. Changes in local call charges could have a significant effect on this: in Berkeley calls are free up to 12km, and UCB finds that 500 modems are not enough for their 30000 students.

Dial-up lines are limiting in other ways: the best PSTN modems currently achieve about 30k bits/sec. With compression this can sometimes be squeezed up to 60k bits/sec, but this is not enough for many desirable applications. ISDN is a little better: a basic rate of 64k bits/sec costs the same per minute as a phone call, and it is possible to combine two such channels to produce twice the throughput at twice the cost. In spite of these disadvantages, we expect the demand for dial-up services to grow strongly because the telephone is the only two-way service that reaches *everywhere.*

5. Cable-TV to the Rescue!

A Cable-TV network is a shared-bandwidth system: the same signals are sent to all subscribers. An ethernet is also a shared-bandwidth system, so why not combine the two...

For the past few months, Brunel and the local cable company (TCC) have been testing one such system. It is the Zenith Homeworks system, which uses two television channels to provide four 500k bits/sec ethernet-like networks.

5.1. Anatomy of a Cable-TV network

Cable-TV systems usually have the capacity to carry 40-50 TV channels. The networks are completely analogue, and they use the same modulation schemes as terrestrial TV transmitters. The wiring topology is usually a star or a tree, and recent systems often use optical fibre for the longer distribution runs. Connection to the home is always with copper co-axial cable.

TV signals are generated at the 'head end' and distributed through the network by broadband amplifiers. [Fig 1] A small number (two to four) of 'reverse' channels are available at the low end of the frequency range. These carry signals *towards* the head end, and are normally used for monitoring and maintenance. The signal-to-noise ratio is not as good on the reverse channels: there are more noise sources below 80MHz, and there are many amplifiers and mixers contributing noise even if they have no useful signal to send.

5.2. Equipment

The pilot network uses special network interface cards that fit in PC ISA slots, together with external cable modems powered from the PC. The connection to the University network is through a device with some of the features of a bridge: it has one cable interface and one ethernet interface, and it maintains queues of packets heading in each direction. Unfortunately it does not perform any filtering or address-learning so it must be connected to an ethernet that does not carry any other traffic.

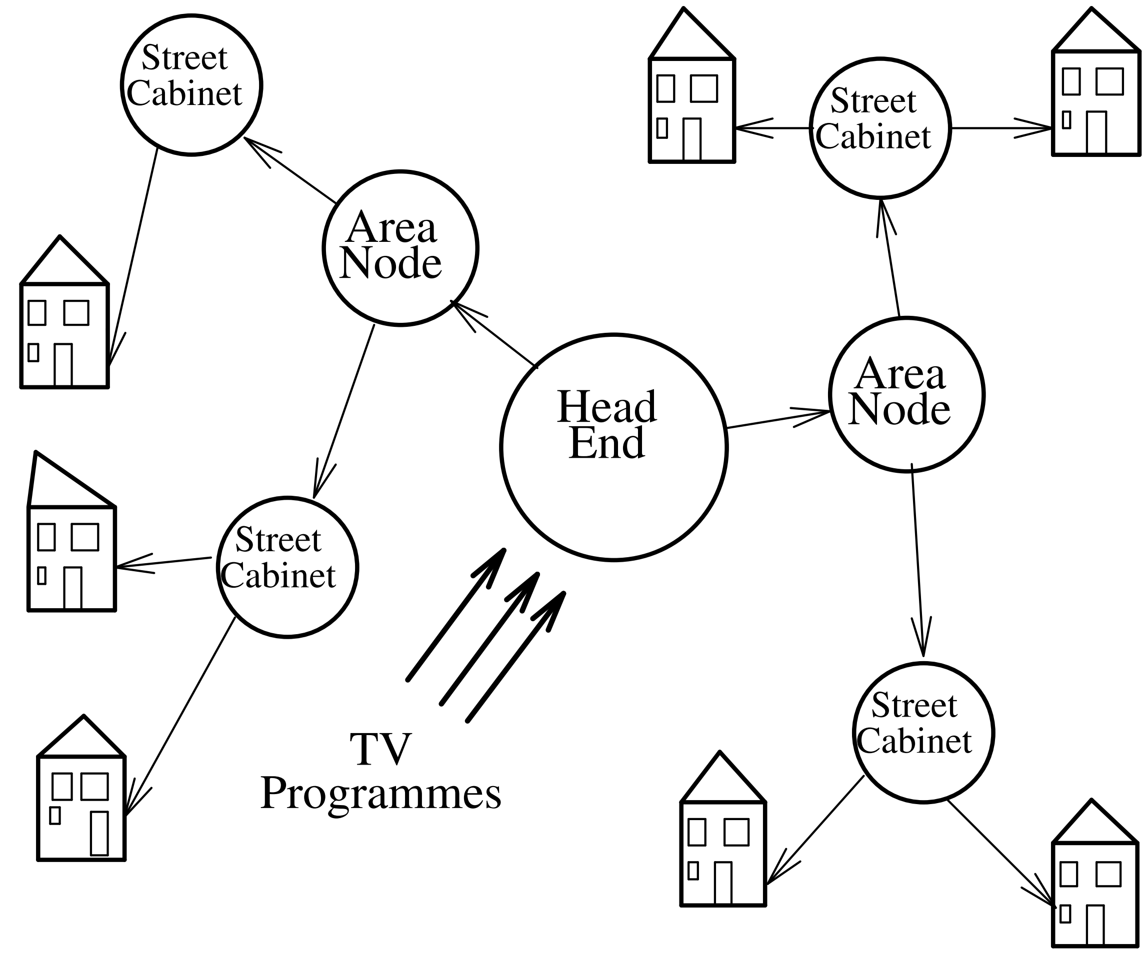

Figure 1: A Cable TV Network

A new development is the ‘Homeworks Universal’, which is a smaller version of the bridge-like box with a cable interface and a single RJ45 ethernet connection. This will allow machines other than desktop PCs to connect to the cable system. It also makes network management and user support rather easier because there is nothing to fit inside the user’s own machine. The cable link to the Universal box can be checked using SNMP from a support centre. If the user still cannot make their machine talk to the network they can simply bring it to the University and plug it into an ethernet for testing.

5.3. Cable Modems

The interface between the television network and the digital world is provided by a broadband modem. The Zenith Homeworks system has a basic data rate of 500k bits/sec using channels approximately 1MHz wide. The modems transmit on a low frequency (around 50MHz), and a frequency translator at the head end converts the signal to a high frequency (around 160MHz) for retransmission on the forward channel. [Fig 2] Four such digital channels will fit into one television channel (6MHz in Europe, 5MHz in the US). A newer product, Homeworks Elite, uses the whole TV channel for a single 4M bits/sec data channel. This is not a very impressive performance when compared with a telephone modem: a good V.34 unit can put almost 30k bits/sec onto a channel only 3kHz wide (though it does use almost 40MIPS of signal processing power to do it!). Recently proposed standards for cable modems will do better: prototypes achieving 10M bits/sec have been demonstrated, and 30M bits/sec is being talked of. These systems will probably be asymmetric: high speed towards the home and low speed towards the head-end on the noisier reverse channels.

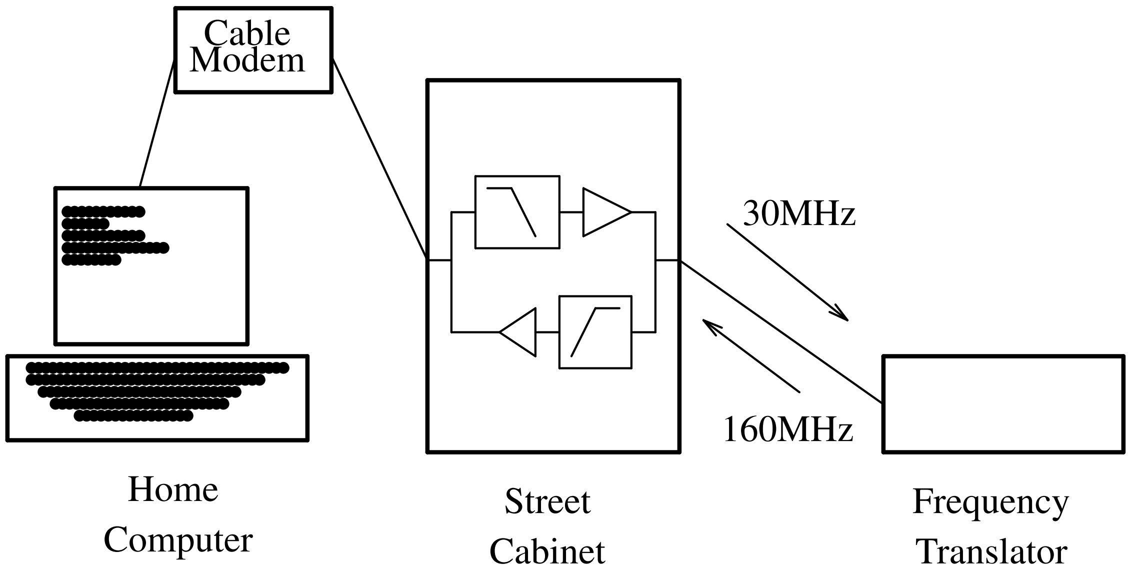

Figure 2: The Signal Path

5.4. Media Access Control

The maximum size of an ethernet is set by the need to detect a collision within the time taken to send the shortest allowable packet. This limits ethernets to a maximum of 2km diameter. Cable-TV networks are commonly 50km in diameter, which will obviously affect the collision-detection time. Further, on a broadband system a station cannot directly monitor its own transmission to detect a collision: the signal must travel to the frequency translator at the head end and back again before it can be checked.

The ethernet MAC protocol is specified in terms of a single bit-time so in principle it can be used on larger networks if the bit-time is increased. The change from 10M bits/sec to 500k bits/sec should allow the network to grow from 2km to 40km if the behaviour of the systems is otherwise similar. Unfortunately the analogy is not quite that close: the head end does not behave like a multi-port repeater, and there are many more ‘mixing segments’ than would be found in a normal ethernet.

Zenith describe their system as using a ‘modified ethernet protocol’ but have not indicated what the modifications are. Stations on the pilot network have shown an occasional tendency to hog the medium and lock out other users for long periods. This tends to suggest a degree of persistence in the MAC protocol.

5.5. Performance

The pilot network has five stations. The connection to Brunel’s network is through the bridge-like box described above. At present, only PCs running DOS and PCNFS are connected though we hope to obtain a ‘Universal’ box soon and try a Sun workstation. Home PCs are set up very much like staff office machines: DOS, Windows, and some applications are held on local hard disk, while the user home directory is NFS-mounted on drive H: and several groups of network software are mounted on other drives. One of the machines has been set up more like a classroom machine, with only enough on the local disk to boot it up and load the network software.

NFS throughput of 300k bits/sec has been observed to individual machines on a quiet network. This is roughly equivalent to 6M bits/sec on ethernet so a respectable percentage of the bandwidth is usable. Home machines can be used very much like office machines, though some applications are rather slow to start: there is certainly time to make the coffee while bringing up an X server from the network drive! The slowdown is nowhere near a factor of twenty though: PCs rarely achieve much over 1M bits/sec using NFS on ethernet.

Several people have experimented with X applications. The results have mostly been good, though there have been a few surprises: Xemacs is reported to be unusable and some CAD applications have very poor performance for example. Some of the blame for this is probably attributable to the PC (MSWindows) X server: it will be interesting to compare the results when we get a Unix machine onto the cable network.

5.6. Costs

Costing is not finalised yet, but the guideline figures we have are:

Homeworks kit	500
Homeworks Universal	600
Basic TV service	10 per month
Network service (extra)	15 per month

It is interesting to compare this with an ISDN installation:

Line installation	350
ISDN adaptor	400
Line rental	24 per month
Call charges	(normal phone rates)

A report from MIT[Eisner1995] gives some useful insight into these figures.

6. The Future

Shared 500k channels are a bit limiting. The cable company can improve the overall bandwidth by putting a multi-port bridge at the head end and running a leased 2M line to the Brunel network, but it is unlikely to want to split the network further. The relatively low bandwidth makes video-conferencing something to be avoided: it would work but one or two users could swamp the whole channel. For the same reason it may be best to avoid the use of NFS and regard the cable network as a very fast alternative to dial-up or ISDN rather than as a slow ethernet.

The higher-speed modems becoming available will open up other options, but as they use a whole TV channel we are unlikely to get the network to ourselves. If a good Internet provider starts to offer a cable-based service then Brunel could simply leave them to it and suggest that staff and students subscribe to the commercial service. In the longer term this will almost certainly happen. Another possibility would be virtual closed-user-groups, using a new IEEE 802 standard[IEEE1993] that permits ethernet frames to be ‘coloured’ so that they are only seen by stations of that ‘colour’. This would provide service isolation with bandwidth sharing: a difficult thing to manage perhaps?

Looking further ahead, it may be that the infrastructure needed for high-definition wide-screen television coupled with video on demand and other ‘superhypeway’ goodies will completely swamp our puny bandwidth requirements. Cable companies are already planning to deliver 27M bits/sec to the home using ATM: if this works it should finally make ATM affordable! The only worry is that the service may follow the traditional ‘fire hose’ view of so many information providers: they throw stuff down the pipe at you and the only thing that goes the other way is money. If they allow a few megabits per second to flow the other way the world may yet be saved...

References

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