Some ICT Resources Management Strategies for Cost-effective Internet-Based ODL

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Abstract

Internet-based Open and Distance Learning (ODL) promises to extend education beyond the traditional boundaries of regional and economic constraints. The pervasiveness of the Internet allows educational providers the flexibility to tailor contents to suit specific target groups. The possibilities seemed endless, limited only by the capability of the content designers. In practice, however, the possibilities are somewhat tempered by the limitations imposed by the ICT infrastructure at the two ends – at the content provider's end and the receiver's end. Also, although information and communication technology (ICT) infrastructure is the backbone of Internet-based ODL delivery, it is expensive. ICT resources must therefore be managed optimally to ensure cost effectiveness. Prudent management of ICT resources can provide good learning experience for most students, from those with broadband connections to those with dialup connections. It also helps the ODL institution to make limited resources go further. This paper will look at some issues that can affect Internet-based ODL delivery as well as some simple conservation techniques to ensure optimum resources can be made available for ODL delivery.

Introduction to Open University Malaysia

The Open University Malaysia (OUM) is a new university (established in August 2001) that practices the open and distance learning (ODL) pedagogy. OUM practices the blended approach to ODL where learning can take place via three channels: printed modules, face-to-face interactions and online support. Students attend fortnightly face-to-face sessions at 62 learning centres spread throughout Malaysia. Part-time local academics support these face-to-face sessions. Student also access online resources such as courseware and the digital library. In addition, the students are also required to carry out discussions among themselves as well as with their tutors online. The tutors and examiners submit coursework and exam marks online. In order to facilitate this web-based teaching-learning process and also to ensure timeliness in completion of administrative processes OUM places great emphasis on high availability access to web-based services. ICT resources must be properly managed to ensure cost effectiveness in the provision of high availability access.

The OUM ICT Services Department practices prudence in the acquisition and management of ICT resources. Whenever possible, software applications are developed in-house. This means that changes can be implemented very quickly. Major hardware, such as servers and storage must be scalable so that from a conservative start-up, new, small units can be added as required.

The eLearning Implementation Process.

Successful ICT planning for eLearning means that the ICT specifications must be such that all the eLearning objectives for the planned duration can be met. The infrastructure must also be scalable to cater to unexpected requirements. To ensure that the ICT infrastructure to be put in place can effectively support eLearning it is necessary that a set of clear and detailed eLearning objectives be formulated BEFORE the ICT requirements are specified. Note, however, that in the happy situation where budget is not an issue the above does not apply. The best over-specified ICT infrastructure can always be provided to cater to any eLearning

eventuality that may arise. Usually, however, budget is limited and judicious management of ICT resources is required to provide passable eLearning environment cost effectively. There is always a compromise between what the eLearning content developers want to deliver and what the prevailing ICT infrastructure can allow.

ELearning Objectives from the Perspective of ICT Provision

Although eLearning objectives depend on the provider, a generic set of objectives in the context of ICT requirements can be stated as follows:

- To integrate ICT in the provision of education and training.
- To exploit ICT potential for improving quality.
- To exploit ICT potential for innovation.

These objectives imply that ICT is the enabler, the invisible highway where learning can proceed beyond its traditional boundaries without obstacles. This in turn means that in order to support eLearning, the ICT infrastructure must be reliable and must allow easy access to eLearning contents. Thus, a working specification for ICT infrastructure to support current and the near future eLearning needs would be:

- High availability ICT services.
- Sufficient bandwidth
- Scalable infrastructure.

This specification is broad enough to cover most requirements.

In most ODL implementations the ICT infrastructure was already in place before ODL pedagogy strategies were formulated. The ICT infrastructure is therefore a given and the educationists must work within the capabilities of the existing ICT infrastructure. And there are many limitations: the bandwidth to the Internet is never large enough, the allocated email storage space is too small, etc.

Bandwidth – how big is big enough?

Bandwidth determines the time taken to download content – the bigger the available bandwidth the faster the download speed. The bandwidth of the connection to the Internet determines how many concurrent access to a certain content over the Internet is possible or how fast a certain content can be accessed for a certain number of concurrent users. Bandwidth, thus determines whether a service over the Internet will be queued or not. With sufficient bandwidth there will be no queues for services, resulting in almost instant access. In other words, bandwidth directly determines the quality of service of ODL delivery.

Experts differ on what is an optimum download time. Many so-called rules of thumb quotes 10 seconds over a 56 kilobits per second (kbps) modem as the threshold; faster than this gives a better user experience and vice-versa for slower. All these rules of thumb are based on studies carried out by Nielsen (1999). More recently S. Galbraith and N. Davidson (2005) carried out a survey to measure the relationship between the perceived user frustration levels with the speed of web page downloads. All users download using 56 kbps modems. The results of this survey indicate that frustration develops after a second or so of waiting. If a user is required to wait between 5 and 15 seconds there is a significant chance that a user will abandon a website rather than wait for the information. Any wait beyond that is highly likely to cause the user to abandon the site. There appear to be agreement between the results of the two studies.

It must be remembered that all these studies concern general sites with non-specific target audiences, the so-called casual browsers. ODL sites usually have very definite target

audiences (the students and staffs) and the web is used for information as well as to obtain services and carry out transactions. The perception of acceptable download times may differ in this context. These focused users may be more tolerant of slight delays. Still, the rule of thumb should be kept in mind and where possible, bettered. The download time can be taken as a measure of the quality of service.

Factors affecting available bandwidth.
Bandwidth is a two-way issue: the bandwidth of the content provider and the bandwidth at the student end. While the institution can provide adequate bandwidth, a student accessing the institution via dial-up connection can, at best, get the maximum bandwidth of his modem. Thus, all applications that are to be made accessible over the Internet must take into account the lowest possible bandwidth at the receiving end.

(i) Concurrent usage
The number of concurrent or simultaneous usage determines the bandwidth. The maximum bandwidth required to supply a certain content is determined by the total bandwidths of all those trying to access the content concurrently. For example, if it is estimated that 50 students will access the contents via dial-up modem with bandwidth 28.8 kilobit per second (kbps) and another 50 over 56 kbps modem the total bandwidth required at the delivery end to ensure no queuing is
(50 x 28.8 + 50 x 56) kbps = 4240 kbps = 4.24 Megabit per second (Mbps).

This is the theoretical bandwidth assuming no other traffic exist while the concurrent session is in progress. In practice there will be other traffic such as emails, instant messages and Internet searches and downloads going on concurrently. The actual bandwidth required is therefore larger than calculated. Calculations similar to this can be used to estimate the bandwidth required for conferencing or streaming videos to many concurrent audiences.

(ii) File size
An uncompressed 8-bit (256 colour) picture of size 640 x 480 pixel is 307.2 kbyte or 2.46 Mbit. This is a full-screen (or quarter-screen if very high resolution monitor) colour picture of passable, but not very good quality. Over a 56 kbps modem, this single picture will require 43.89 seconds to download! Imagine the wait over 28.8 kbps dialup. This is for just a single picture. Videos and animations are made up of many pictures revealed quickly in a short time. Full motion video with large graphics is thus not realistic over dial-up connection. The picture size and colour level must be reduced. The images can also be compressed to reduce the size.

(iii) Learning contents
Certain contents, such as videos and fancy animations, can place heavy demand on bandwidth and may not be accessible at all over dial-up connections. Streaming of media, be it audio or video, can optimize available bandwidth by performing continuous downloads ‘behind the scene’ while a fully downloaded content is being shown (or heard). This technique is often used to provide video content to low-bandwidth users. While it is true that streaming can reduce bandwidth requirement, if used with high quality full-motion videos, this technique may still require large bandwidth at the user end for satisfactory experience. It is still the question of how much data is needed to be downloaded per second. Full motion video, although good to look at, may not necessarily provide more educational content than a similar video of more moderate quality. In most cases a low bandwidth courseware consisting of a combination of streamed audio and animated graphics can prove effective. Streaming servers can help in situations of insufficient bandwidth availability, but the content must be carefully tailored to suit the slow accessibility of most users. Unless this is done, the experience may prove unsatisfactory.

Another approach is to allow full downloads of contents. The downloading process can take some time to complete, but once completed the downloaded files can be accessed with no

delay. Copyright and licensing issues may have to be considered with complete downloads. Of course, contents can also be placed on CDs and distributed to students. Contents with large areas of text, such as PowerPoint presentation, with a small window for video or 'talking head' may be better suited to online delivery compared to those with full-motion, full-screen video. Compressing videos and reducing the colours can dramatically reduce the bit-rate required for satisfactory viewing. All delivery options must be considered if ODL were to be made available to everyone.

Managing ICT Resources

One important (and usually expensive) resource is bandwidth. When it comes to bandwidth no amount is large enough. There will always be applications that can use up all available bandwidth. Peer-to-peer file sharing services that allow sharing of very large files (some of several gigabytes), usually movies and song albums are notorious bandwidth hogs. All file uploading and downloading services must be scrutinized to prevent abuse. Denial of service attacks (DDOS) can also use up bandwidth. Thus, to make available the most bandwidth for use by ODL all "frivolous" usages must be identified and prioritized or managed carefully.

Prudent bandwidth management means that only legitimate traffic is allowed on the available bandwidth. This means that undesirable traffic such as inappropriate downloads (music, videos) and malicious contents (viruses, worms and spams) must be actively blocked.

(i) Optimize graphics

Graphics usually make up the bulk of the total home page size. Reducing or optimizing the graphics content can help to reduce the page size.

For most web pages with graphics content, the following can serve as a general rule:

(i) Use the fewest images with the smallest byte size that is appropriate to achieve an acceptable download speed. Large images slow Web page downloads, especially for users with slow Internet connections. Breaking a large image into several smaller images will decrease download times, but if too many small images appear on a page, download times will still be problematic.

(ii) All Web graphics should be optimized. Optimizing reduces the bit depth (or colour depth) of the image, resulting in a smaller byte size. Further size reduction can usually be obtained by converting GIFs to the more compact JPEGs and using the most optimum compression ratios on existing JPEGs with minimal image quality loss.

(ii) Prioritize traffic

At OUM access to all known peer-to-peer file sharing services as well as downloading and uploading of certain file types are blocked as a matter of policy. Blocking frustrates attempts to access these services and after a short while no more attempts are made. There is also active monitoring of sources of heavy traffic. Through prudent bandwidth management OUM has been able to maintain average bandwidth usage to about 20% of the total. There is therefore ample headroom to cater to near-term peak demands with the expected increase in student enrolment.

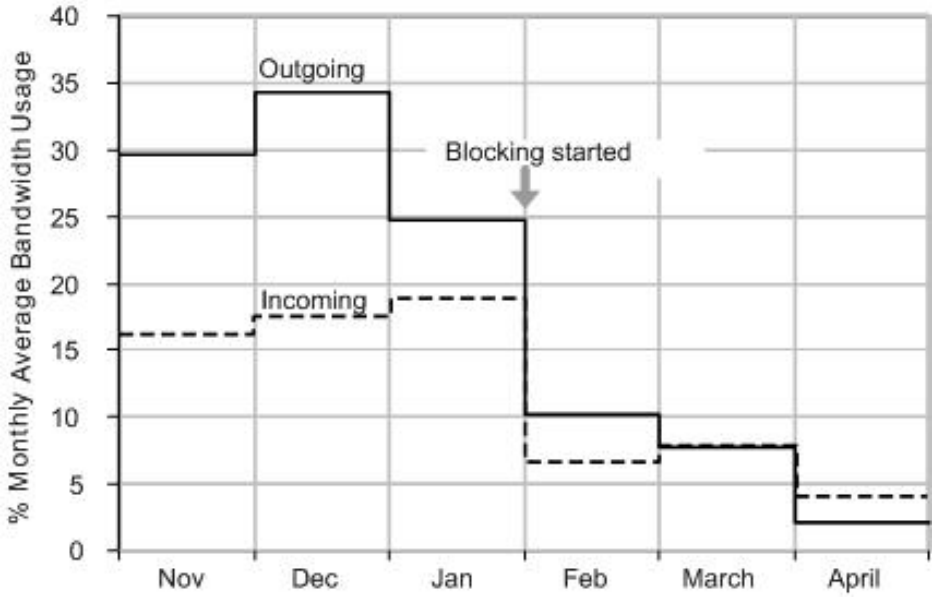

Figure 1: Effect of blocking on average bandwidth usage

Managed network traffic blocking at OUM was started in mid-January 2003. During this time there was a proliferation of peer-to-peer applications, denial of service attacks and massive widespread of e-mail viruses. Access to contents was difficult and there were a lot of complaints from students about this. OUM has sufficient bandwidth but most of the bandwidth was used up by illegitimate traffic. An improvement in accessibility was observed after the blocking exercise.

Figure1 shows the dramatic effect that appropriate traffic blocking can have on available bandwidth. Before the blocking exercise, about 17% of available bandwidth was used up by incoming traffic and about 30% by outgoing traffic. As soon as peer-to-peer traffic and certain file types were blocked, total average traffic reduces to about 20%. With further fine tuning the prevailing average used bandwidth is now about 10 – 15%. This trend of bandwidth has continued; with on average about 60% bandwidth headroom always remaining free. The immediate result of the blocking exercise is that more bandwidth can be made available for learning contents. Another, not so obvious result is improved security brought about by reduced spasm and viruses incidences.

Blocking of undesirable sites is one option. Another option is to block certain file types. Movie files (avi, mov, mpeg etc.) can fill up about 2 CDs, that is, more than 1 GB of data. Also, music files (wav, mp3), though at about 4 – 5 MB is not substantial in comparison to movie files can still clog up bandwidth when many are downloaded concurrently.

(iii) Optimise homepage download times

If eLearning services are to be provided via the portal then great care must be taken in the design of the portal to ensure speedy delivery of service. Although attractiveness is important, more important perhaps is the download time. As discussed previously for general sites one should strive for less than 10 s to complete download over a 56 kbps dial-up modem. However, since most open university home pages are service portals meant for their own students a bit more than 10 s may be acceptable. Although the students must still access the services no matter the speed of the connection, quick download times can give the impression of being friendlier. An important factor in student retention for all open universities!

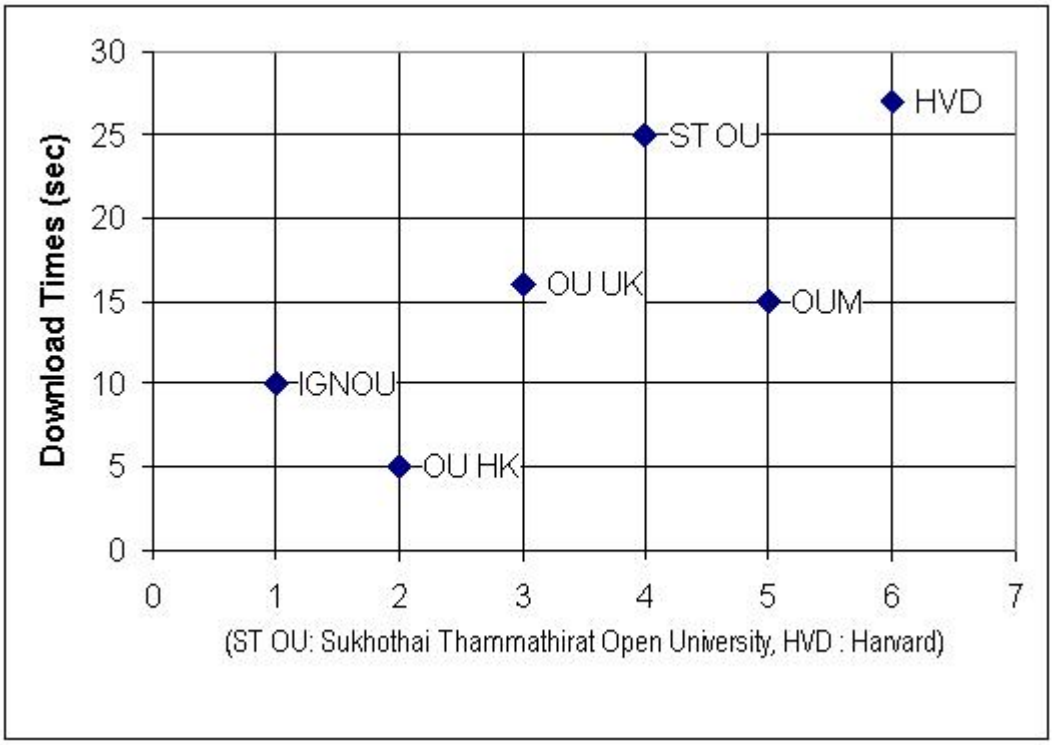

Figure 2: Download times of some Open University homepages.

Figure 2 shows the time taken to completely download the home pages of several open universities and one "traditional" university, over a 56 kbps modem. At first glance it is surprising that the download time for the Harvard (HVD) home page is a bit on the high side considering that the design is quite simple. However, the page is graphics heavy. The total page size for the Harvard home page is about 170 KB with graphics making up 150 KB! In comparison the total page size of the OU HK home page is just 470B.

The importance of portal download times should not be underestimated. A few tens of seconds more or less here can mean the difference between a good or unsatisfactory eLearning experiences.

The above only hints at what can be done to make more bandwidth available for use of eLearning. By freeing up more bandwidth for eLearning better quality contents can be made available for more effective teaching-learning.

(iv) Bandwidth at the Learner End

As mentioned previously, bandwidth is a two way affair. The maximum download speed for the Learner is the bandwidth of his connection to the Internet. For the majority this would be the dial-up connection over the phone line. The speed is dependent on the condition of the wiring as well as usage in the particular area. Since dialup is a best effort (or shared) service, if more people use the connection in the neighbourhood then the speed will drop accordingly. All learning contents accessible over the Internet must take into account this best effort service.

The students of the Open University of Malaysia reside in both the very urban and very remote areas, with the majority in semi-urban areas. The connection to the Internet also varies from large bandwidth leased-line and domestic broadband to very slow dial-up. The numbers for 2005, usually quoted for Malaysia are "Just 8.6 million or 35 percent of Malaysians regularly connect to the Internet, and only 0.5 percent utilize broadband"

(www.**connect**withcanopy.com/ index.cfm?canopy=cs.story&aid=318). The majority of OUM students must therefore access the Internet via low-speed, dial-up connections. A study is currently underway to determine the Internet connectivity profile of OUM students.

The type of contents for eLearning must therefore take into account this spread in accessibility. Most of the contents over the Internet are tailored to suit the majority accessibility, which is 56 kbps dial-up modem. This narrow bandwidth rules out direct access to interactive, media-rich content over the Internet. Other approaches must be looked at if this type of content must be made available over the Internet. One method of delivery that is being tested at the OUM, that can give good interactivity and access to media-rich contents, in spite of the low bandwidth at the Learner's end, is the hybrid Internet and CD-ROM approach. Media-rich contents are stored on CD-ROM. Links and explanatory texts to contents on the CD-ROM are provided over the Internet. To use this material the Learner access the relevant web page and inserts the CD-ROM containing the linked material into his CD-ROM drive. Graphics and animations are obtained from the CD-ROM while instructions and learning managements (monitoring and assessments) are carried out online.

The project, REMOTE - Leonardo da Vinci Program, is based on an integrated fat/thin delivery mechanism similar to the above. The low-bandwidth content from the central server provides updates to contents, enables assessments and tutor support. All media-rich contents are supplied to students on CD-ROMs (Radu Vasiu et.al., 2004). Indeed, if so designed, this technique can provide media-rich interactivity even over low-bandwidth dial-up connections.

(v) Use Peer-to-Peer Technology

Although peer-to-peer sharing is the bane of all IT Administrators because of their capability to very quickly use up all available bandwidth, they may also hold the promise of future viability of ODL. With the expected rapid growth in enrolment and more ambitious contents, it is imperative that new approaches to providing ODL be explored. The time may be fast approaching when it will no longer be possible to provide the best quality of service from a central location. It may be prohibitive financially to provide sufficient bandwidth to meet all expectations. Also there is a limit to the largest bandwidth that can be provisioned. Peer-to-peer sharing may perhaps be the answer for future ODL content delivery. In this scenario each students who download contents can be a provider for others seeking the same content. Thus, the more students who download contents the better the content distribution! The bandwidths of the students uploading contents constitute the bandwidth of the institution. Thus, the more students the better. The promise of harnessing this technology has been mentioned previously, for example, Cross, J. (2002), but the actual implementations in the ODL context has not been as widespread as expected. OUM is currently exploring pilot trials of content distribution using this technology.

(vi) Outsource High Traffic Services

Recently the OUM has switched email services from its own in-house one to a popular offering of one of the giant providers. The change was carried out after very careful studies of the various email services available were carried out. We had to make the change because of the change in student expectations. They are used to very large email storage (2 GB at least!) and very good spam and virus filters and all these for free. We were only giving our students 50 MB each and we were struggling to keep out spam and viruses. Outsourcing the email services has enabled OUM to meet students' expectations and at the same time has freed up resources: the technicians maintaining the email services as well as the associated servers and storage can be redeployed elsewhere.

Conclusion

ICT infrastructure for eLearning must be reliable and must be able to support all the requirements of the teaching and learning processes. Expensive resources must be optimally utilized to ensure cost-effectiveness. The available infrastructure determines the type of contents that can be accessed online and directly, the quality of the online experience. Through careful planning and prudent management, the available resources can be stretched further to continually meet greater expectations in service delivery. All available options to improve service must be looked at before any decisions to purchase additional resources are made.

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