

# **BANDWIDTH MANAGEMENT POSITION PAPER**

## **Executive Summary**

The delivery of information over the Internet requires a chain of essential components:

- Content;
- Connection;
- Local infrastructure;
- Bandwidth management.

For many institutions in developing countries, the delivery chain continues to have weaknesses. Each link in the chain could be made to operate much more efficiently.

The chain metaphor is useful because effective delivery of content is bounded by the strength of the weakest link. The most effective approach to improve information access is to increase the quality of all the links in the delivery chain. There is only limited benefit gained by trying to compensate for deficits in one part of the chain by over-investing in others. At present, investment does not appear to have been evenly distributed.

Aptivate has been helping to develop the WHO's Health InterNetwork Access to Research Initiative (HINARI) and the UNFAO's Access to Global Online Research in Agriculture (AGORA) initiative, and has worked with the Tertiary Education Network (TENET) in South Africa, the Kenya Education Network (KENET), Ghanaian Agricultural Information Network (GAINS), the International Network for the Availability of Scientific Publications (INASP) and the International Centre for Theoretical Physics (ICTP).

Aptivate's work over the past three years suggests that bandwidth management is a particularly weak link in the delivery chain and a major barrier to effective Internet access. Improving bandwidth management will help unlock benefit from existing investments and ensure that future investment is more effective.

Managing bandwidth improves the performance of an Internet connection by removing unnecessary traffic. Bandwidth is like a pipe. It doesn't matter how big the pipe is, if the traffic in the pipe is not managed it will clog up with unwanted traffic and be hijacked by peer-to-peer traffic, viruses and other "malware."

"...improving bandwidth management is probably the easiest way for universities to improve the quantity and quality of their bandwidth for educational purposes".<sup>1</sup>

Bandwidth management is essential for any institutional network. In the North, budgets for managing connections are often far greater than the cost of the connection itself. Universities understand that if they had a much smaller capacity connection and managed it correctly, the Internet would still be accessible. However, if the connection was increased and the management removed, useful access to the Internet would decrease immediately and soon become impossible.

The main challenges relating to bandwidth management can be categorised as increasing awareness, improving skills and providing appropriate tools.

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<sup>1</sup> *African Tertiary Institutions Connectivity Survey (ATICS): Full Report*, Gakio; 2006.

## **Increasing Awareness**

Although there are technical issues relating to bandwidth management, the biggest challenge is to raise awareness of the importance of managing bandwidth. Bandwidth is a limited resource that needs to be shared. Bandwidth has a cost and policy should govern its use. Just as with a phone line, use of bandwidth should be monitored and managed.

## **Improving Skills**

Capacity building and skills development are fundamental to improving bandwidth management practice within developing world institutions. Institutions have put forward a strong demand for bandwidth management training, even amongst those institutions that have organised some form of training in the past.

The challenge is to provide comprehensive training on policy and the purpose of bandwidth management for managers, integrated with hands-on technical training for network administrators.

## **Providing Appropriate Tools**

In many institutions the necessary tools are not yet present, and if they are present they may not be used to their full extent.

Working with the above partner institutions, amongst others, Aptivate believes that further investigation would answer the remaining questions:

- Why are tools not being used at many institutions?
- are the tools appropriate for this audience?
- are there significant gaps in the functionality of existing tools?
- How can the most appropriate tools be integrated into a wider programme of bandwidth management and training?
- Can any existing tools be leveraged for use by small or overstretched IT teams?

This position paper provides an introduction to the field of Bandwidth Management & Optimisation; it summaries activities being undertaken at present and recommends a number of options that could be considered by partners to enable them to overcome some of the challenges in improving information access.

## INTRODUCTION

Effective Internet access requires an information delivery chain composed of four essential links: content, connection, local resources and bandwidth management.

- **Content.** Content must be in a form accessible by the user. Language and relevant information are important, but a key factor is also appropriate format. If users have little bandwidth available then content must be in a format that is readily accessible.
- **Connectivity.** A connection (bandwidth) is required to access content.
- **Local resources.** The institution needs resources to deliver the content to the user. These include the local network, computers, tools and the skills of the network administration team.
- **Bandwidth Management.** Without proactive management, network capacity fills with viruses and inappropriate traffic, problems cannot be diagnosed and the connection becomes ineffective.

The chain metaphor is useful because effective delivery of content is bounded by the strength of the weakest link. Significant improvements in efficiency could be achieved for each link in the delivery chain.

The most effective approach is to resource and improve the quality of all the links in the delivery chain. There is only limited benefit gained by trying to compensate for deficits in one part of the chain by over-investing in others.

This paper concentrates on bandwidth management. Our work suggests that bandwidth management is a particularly weak link, a major barrier to effective Internet access and has received the least investment. Improving bandwidth management will unlock benefit from existing investments and ensure that future investment is more effective.

## CONTEXT

It is not viable for a higher education or research institution to operate if it is not connected to the wider academic community. This means having good working access to the Internet. The Internet has become essential for access to the state of the art in any discipline, to undertake and publish research and therefore to attract funding. This is just as true for developing world institutions as it is for those in the North.

Many development agencies, foundations and funding organisations have recognised the Internet as a vital resource for developing country research and learning institutions. A number of initiatives have arisen to make publications freely available online, such as UNFAO's AGORA and WHO's HINARI projects, PERI, PloS and SciDevNet. Such resources are of high value to researchers as is evident from the user feedback they receive, and the immediate response if a system goes down at any time. Development agencies and organisations like the International Network for the Availability for Scientific Publications (INASP) are also involved in training initiatives to try to build an adequate skills base to utilise online resources. Donors are also providing ongoing support to institutions for upgrading their equipment and network infrastructure. This support is often channelled through local initiatives and organisations such as the African Virtual University, the African Association of Universities and National Research and Educational Networks such as South Africa's Tertiary Education Network (TENET) and the Kenya Education Network (KENET).

Developing country universities and their funders have made significant investments in Internet connections. Bandwidth is both absolutely and relatively much more expensive for institutions in developing countries than for those in the North. The University of Ghana spends roughly US\$10,200/£5350 per month for 1MB of bandwidth<sup>2</sup> NTL/British Telecom provides the same amount of bandwidth to individual home users in the UK for US\$28.50/£14.99 per month. Small businesses and other organisations in the UK generally receive 8 times as much monthly bandwidth as the University of Ghana at approximately 1/100th the cost.

**“This is one area that a lot of institutions are making considerable investment in, and have to have value for money.”** *Clement Entsua Mensah, Director, Institution for Scientific and Technological Information (INSTI), Ghana.*

Many institutions are finding that they still do not have reliable, usable Internet access for their students and staff despite considerable investment. A recent BioMedCentral survey<sup>3</sup> of health journal access programmes found that logging into some databases took so long that connections often timed out entirely.

An Internet connection necessitates such high investment from an institution that other resources will invariably suffer as budgets are displaced. It is crucial that institutions implement management of their connections to ensure that returns on investments are achieved.

Improving the performance of the information delivery chain is urgent if researchers and students are to benefit from the Internet and take part in the International academic community.

In 2006, Aptivate conducted a project to assess bandwidth management issues with the Kenya Education Network (KENET) and five of their member institutions. We found one institution limiting student Internet access to five hours a week, one that allowed use of the connected computer labs for computer science students only and another that had been forced to take the extreme measure of cutting off student access entirely, indefinitely. These drastic decisions reduce the impact that online access could have. Such desperate measures would not be necessary if bandwidth was being managed.

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<sup>2</sup> Securing the Linchpin: More Bandwidth at Lower Cost; Partnership for Higher Education Africa; 2004

<sup>3</sup> Access to electronic health knowledge in five countries in Africa: a descriptive study, BMC Health Services Research 2007, 7:72

Bandwidth management is not merely a coping strategy to be employed by those with poor infrastructure and low bandwidth connections: it is essential for any institutional network. JANET, which connects UK research and education institutions, insists that members employ bandwidth management and maintains a dedicated advisory service to help achieve this. The budget for managing the University of Cambridge's substantial connection is far greater than the cost of the connection itself. If the university had a much slower connection, Internet access would still function, however if the connection was increased and the management removed, useful access to the Internet would decrease immediately and soon become impossible.

The experiences of INSTI in Ghana demonstrate the dramatic differences achievable by managing bandwidth. The institution had already made a significant investment in the connection and was disappointed in the result. INSTI was therefore considering investing in an even larger connection in the hope of achieving reliable Internet access. This investment would have resulted in little or no improvement without addressing bandwidth management issues. Focusing on bandwidth management at INSTI increased the effective speed of the network from 30 kb/sec (an unusable connection for an institution) to just under 480 kb/sec (equivalent to a reasonable home broadband link in the UK), an increase of 16 times the bandwidth available. Through managing their bandwidth, INSTI found that their current bandwidth was sufficient, and that any further investment could then yield a real improvement.

## WHAT IS BANDWIDTH MANAGEMENT?

Managing bandwidth improves the performance of an internet connection by removing unnecessary traffic: "...improving bandwidth management is probably the easiest way for universities to improve the quantity and quality of their bandwidth for educational purposes".<sup>4</sup> Bandwidth is like a pipe. It doesn't matter how big the pipe is, if the traffic in the pipe is not managed it will clog up with unwanted traffic and be hijacked by viruses, spam, peer-to-peer file-sharing traffic and problems on the network will not be accurately diagnosed.

Bandwidth management requires three activities: Policy, Monitoring and Implementation. If any one of these activities is missing then the management of bandwidth is significantly compromised. The activities inform and reinforce each other.

"...it is not enough to right-size the bandwidth. In order to properly manage this scarce resource, IT departments need a complementary budget for supporting infrastructure and staff. Simply put, there is no point in spending millions each year on bandwidth, only to skimp and scrape to save thousands on cache servers, which allow for more efficient usage of bandwidth. In particular, adequate budget will be needed to enforce policies and to use technology smartly."<sup>5</sup>

Our experience suggests that the provision of training, tools and support for bandwidth management is not yet sufficient. Internet access will not improve in institutions until this is addressed.

### Policy

Individuals downloading music and other files for their personal use can absorb an institution's bandwidth. Frequently it is a minority that consume the majority of an institution's bandwidth. There is a material cost to this. It must be recognised that without an Acceptable Use Policy no amount of bandwidth will ever be enough to satisfy the demands of an unrestricted user community.

In this situation, user education is far more productive than technical solutions. The institution's policy needs to be understood and enforced. Network administrators need to be able to find out which users are not adhering to the policy and to interact with them on a face-to-face level.

### Monitoring

Monitoring is important for defining and enforcing policy. Network monitoring informs the process of creating an enforceable policy that reflects the actual needs of the user group. It is also a necessary part of enforcing policy. Furthermore, monitoring is an essential element to fault diagnosis and accurate troubleshooting on the network.

### Technical Implementation

There are a number of tools and techniques that help network administrators ensure that bandwidth is managed and the policy enforced. The key components are:

- Network analysers - for monitoring traffic
- Firewalls - for blocking malicious and unwanted traffic
- Anti-virus - for protecting the network
- Caches - for efficiently using bandwidth
- Traffic shapers - for prioritising and controlling traffic
- Quota systems - for managing user behaviour

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<sup>4</sup> African Tertiary Institutions Connectivity Survey (ATICS): Full Report; Gakio; 2006.

<sup>5</sup> A response to "A pedagogical and economic critique of student charges for Internet access", Pippa Moll, International Journal of Education and Development using ICT; Vol. 1, No. 2, 2005 .

## CHALLENGES TO EFFECTIVE INTERNET ACCESS

It is tempting to think of bandwidth management as a technical issue requiring a technical solution. This is not the case. Ensuring that bandwidth is available for students and staff requires policy, resources and commitment from all stakeholders.

Although there are technical issues relating to bandwidth management, the biggest challenge is to raise awareness of the importance of managing bandwidth. Bandwidth is a limited resource that needs to be shared.

The main challenges relating to bandwidth management can be categorised as increasing awareness, improving skills and providing appropriate tools.

### Awareness

The fundamental step change in effective bandwidth management is achieved by a change in attitude. Bandwidth should be considered a limited, expensive and essential resource that needs management. Bandwidth should be treated in a similar way to telephone calls. In a university, students and staff are not permitted to make unlimited calls to any location for any reason. Phone calls have a recognised cost and must be used appropriately to advance the mission of the institution. In the same way bandwidth has a cost and policy should govern its use. Just as with a phone line, use of bandwidth should be monitored and managed.

The importance of bandwidth management is not currently well understood. Throughout our work with African institutions, we have seen that bandwidth management is not practised effectively. "*59% of African universities practice little or no bandwidth management*, (ATICS: Full Report; Gakio; 2006). Our research suggests that bandwidth management is being viewed as a set of tools that need to be installed rather than as fundamental change in attitude that needs to be imparted to all stakeholders in the network.

Duncan Greaves of TENET has emphasised the point that isolating bandwidth management as a purely technical 'IT issue' will mean that any bandwidth management can only ever be defensive fire-fighting. IT staff often have no mandate from the institution that would allow them to deliver positive outcomes from their management by concentrating on prioritising academic usage of the Internet. Positive prioritisation of bandwidth requires 'strategic management: "an approach that connects the management of bandwidth as tightly as possible to institutional objectives, and is willing to sacrifice the lesser good for the greater".<sup>6</sup>

Technical quick-fixes will not be effective on their own. In surveying ten Kenyan institutions served by KENET, we found that most institutions report that they employ basic bandwidth management tools: 8/10 have proxy servers, 7/10 have caches and 7/10 say that they monitor their networks. However, 8/10 network administrators did not know who their top bandwidth users are. It is not uncommon for 5% of users to consume 80% of the bandwidth. In this situation, user education is far more productive than technical solutions.

This lack of awareness is reflected in the relatively low adoption of acceptable use policies. From our Kenyan survey we found that 8/10 either did not have policies defining the usage of their network or did not enforce them. We conducted a further survey of network administrators from across the developing world attending a bandwidth management conference at the Abdus Salam International Centre for Theoretical Physics. We found that 15/25 institutions did not have any policy on Internet use.

In a comprehensive survey of ICT management in Kenyan universities<sup>7</sup>, it was concluded that donors must fund ICT management and understand that it is as important as any technical issue. Effective bandwidth management is only possible with support from all stakeholders - especially funding bodies, institutional management and network administrators.

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<sup>6</sup> Making Strategic Decisions about Bandwidth: a discussion document; Duncan Greaves; Tertiary Education Network; January 2007

<sup>7</sup> Improving ICT Management in Public Universities in Kenya; GNW Wanyembi; Delft University Press Science; 2002.

## **Skills**

Capacity building and skills development are fundamental to improving bandwidth management practice within developing world institutions. In all the institutions we visited there was strong demand for bandwidth management training, even amongst those institutions that had organised some form of training in the past.

The challenge is to provide comprehensive training on policy and the purpose of bandwidth management for managers and technical training for network administrators. There are some excellent training programmes in place and these have had a very noticeable impact. However, many organisations that are providing training are doing so because they have recognised the great need, rather than because it is central to their remit. As such many trainers do not have the core skills to provide the depth of technical training required.

A computer is a relatively complex machine to maintain but a network of computers is much more complex. The skills required for network management benefit from a hands-on approach, but this does not simply mean being given a computer and shown how to use a tool. Hands-on experience of bandwidth management means observing and manipulating traffic flows amongst a network of computers. In our view this requires a simulated network environment, something we have not yet witnessed in bandwidth management training.

As with any training programme there is a challenge in transforming training into practice. If a skill learnt in training is not put to use then it generally fades rapidly. This is certainly true with bandwidth management. IT staff who attend bandwidth management training must be empowered and encouraged to use the skills developed during training. This will require support from the institution but also adequate infrastructure and resources.

## **Appropriate Tools**

In many institutions the necessary tools are not present, not used if they are present or not used to their full extent. It is unclear whether this is symptomatic of inadequacies in the tools available or different issues such as the need for further training or a lack of essential policy.

Open-source tools are often well-suited to the requirements of institutions for reasons of cost and their potential for tailoring them to the functions required. However, they currently lack graphical user interfaces, making them more difficult to use and interpret. While there are good Open Source monitoring tools at the large scale (network level) and at the small scale (individual packet level), we believe the most important scale for fault diagnosis is in the middle of these extremes at the individual computer (host) or connection level. There is a lack of good Open Source visualisation tools at these scales. While there are many proprietary bandwidth management tools, we are unaware of an appropriate proprietary solution working at the appropriate scale.

We have found that there is an unfulfilled demand for appropriate monitoring and management tools, an observation corroborated by the African organisations we have worked with, such as KENET and TENET. All of the network administrators we spoke with in Kenya requested monitoring tools with better visualisation that would allow them to understand their network usage in more detail.

Lack of monitoring was shown to be a consistent problem during our research into bandwidth management. Without monitoring, IT staff do not have a good understanding of the traffic on their networks and are not able to identify the root cause of many problems.

It is not clear what is the cause of the lack of monitoring - whether it be a lack of awareness, skills or suitable tools. Whatever the causes the effects are debilitating making this a priority area.



## **Wider Challenges**

### **Open Learning**

Many of the universities we have spoken to in Kenya and Ghana described plans to increase the number of connected computers and also to provide e-learning services. Both plans require well-functioning networks.

In addition to the frustration of students and staff attempting to access resources online, African universities will not be able to implement their future plans to improve upon and widen their educational services unless bandwidth is better managed. If performance problems are not addressed, effective use for students and staff will decrease in proportion to network expansion. The provision of additional distance learning services will prove impossible.

This becomes even more important when the open learning initiatives of Universities in the North are considered, such as MIT's OpenCourseWare initiative. There is a growing movement to share course material amongst universities, something that could be of great benefit to institutions in developing countries. This resource will only become accessible if the issues across the delivery chain are addressed. Aptivate is working to raise the issue of appropriate content formatting and delivery mechanisms with Northern universities.

### **Staff Retention**

Another challenge that is related to skills is staff retention. The African Universities Internet bandwidth task force (Band ITs) report on Uganda noted that:

"Currently, it is estimated by the author (based on graduation figures and allowing for migration) that there are less than 200 really competent ICT professionals for the public and private sectors."<sup>8</sup>

The author then estimates the number required - and comes up with 12,000, based on the number of universities, companies etc. This may suggest that there is a need to review how network administrators can be motivated and retained and the strategy behind investment in Internet accessibility.

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<sup>8</sup>*African Universities Internet Bandwidth Task Force (BAND-ITs): Uganda Report*, F F Tsubira; 2003.

## **CONCLUSIONS**

Bandwidth management is a serious challenge for many institutions. Lack of appropriate bandwidth management is preventing useful access to the Internet. Managing the bandwidth available would make the Internet much more accessible, especially for those with a very slow connection.

Throughout our research, it has been clear that more education on bandwidth management is needed. There is relatively little understanding about the importance of managing bandwidth for the health of the institution. This results in a deficiency of policy, monitoring and technical implementation.

All stakeholders, especially development agencies and funding bodies, senior management and network administrators, need to better understand the importance of bandwidth management before Internet accessibility can start to improve.

### **Training**

Some training programmes recognise the importance of training at management level. Continuation of this effort with greater support for all the other activities required for bandwidth management would help effectiveness.

Management need to appreciate what a difference bandwidth management can make to their institutions. This needs to be practical and specific, showing tangible improvements like INSTI achieved – increasing bandwidth by 16 times through the introduction of some basic bandwidth management.

By promoting, monitoring and supporting collaboration between technical staff and management it will be possible to demonstrate the very real benefits, financially and functionally, of adopting bandwidth management policies.

In response to requests, Aptivate supports hands-on, practical training. The key issue is that training relates to the actual situation faced by IT staff. Training environments need to be created that allow network administrators to solve likely issues themselves.

Aptivate advocates a pair-training approach. By training a pair of IT staff from each institution the impact on capacity and institutional learning can be much greater and more likely to be sustainable. Training should provide a simulated network environment, as close as possible to their actual network. Working on the network, staff could identify and fix problems and build a bandwidth management system that they can then take back to their institutions. It would be possible for administrators to build such a system from scratch and therefore develop a deep understanding of the tool.

### **Tools**

Investigation is required into monitoring and implementation tools. Why are they not being used? Are they appropriate for this audience? Are there significant gaps in their functionality? How should they be integrated into a wider programme of bandwidth management and training? Can any existing tools be leveraged for use by small or overstretched IT teams?

Training tools are certainly required, specifically a simulated network environment. This will demonstrate all the components of bandwidth management and allow practical training based on the resolution of real problems.

The development of a tool set that can be put together on a dedicated machine (a 'bandwidth management box') during training sessions would be a creative approach. This would be used to manage the simulated environment and taken back for installation in institutions afterwards.

An integrated training programme can be a very useful part of the tools research, showing why tools are used or not, what is good or bad about them and identifying any gaps. Training can then become a very useful part of the development cycle should further tools be required.

## **Support**

Offering on-going technical support before and after training is important. IT staff in institutions that form bandwidth purchasing consortia, as advocated by IDRC's Promoting African Research and Education Networking (PAREN) program, could form a natural peer group. This could provide an effective means of combining the value of bandwidth with the need for management and bring together a group interested in implementing policy, monitoring and technical tools.

## **Summary Recommendations**

**The following recommendations summarise the findings from the field:**

### **General**

1. Improving the delivery chain holistically will have a greater impact than ad hoc & piecemeal activities
2. Bandwidth should be viewed as a shared valuable resource that requires management
3. Investment in Bandwidth Management before investing in more bandwidth is advisable
4. Acceptable Use Policies at every institution assist greatly
5. Commitment from institutions for concrete deliverables and timescales around policy and implementation improves impact
6. Support networks should be encouraged with support available through:
  - remote email
  - phone
  - online forums
  - creating self help peer groups
  - direct "logging in" to bandwidth management box solutions for remote diagnosis and direct support
  - possible creation of local support entities
7. Peer group involvement in the monitoring of the deliverables aids sustainable interest

### **Training**

1. Integrated training (Management & Information Service Providers & IT Staff) is beneficial
2. Co-ordinated policy and technical training with some sessions involving both management and IT staff creates understanding
3. Training IT staff in pairs assists sustainability
4. Peer group of IT staff by cross-pairing during training with staff from other institutions provides ongoing support in future learning and development
5. Hands on, practical network training with highly skilled, technical trainers is preferred

6. A full simulated network environment can strengthen skills and build a deeper understanding
7. Provision of a dedicated bandwidth management computer for hands on construction and configuring of a "bandwidth management box" that can be installed within institutions is ideal
8. Institutions should be encouraged to sign up to long term deliverables on bandwidth management.

### **Tools**

1. The aim is to provide reliable email to help reduce the use of webmail during working hours (webmail absorbs 20-30% of bandwidth)
2. Employ farside email scrubbing (Remote Spam Filtering) to reduce unnecessary bandwidth absorption
3. Investment in Monitoring Tools pays off

### **Research**

#### **More needs to be learnt about:**

1. Factors affecting tools adoption and acceptance
2. Bandwidth sharing tools (e.g. BC Router)
3. Platforms for distributed open course-ware

#### Options available for consideration for future development

1. Enhanced BMO technical training programme, with greater emphasis on practical training
2. Tools acceptance research
3. The provision of remote filtering and email services
4. BMO box solutions, evaluation and further iterations
5. Network simulation and technical training environments
6. The use of Loband (<http://www.loband.org>) as a Proxy service with local proxy integration
7. Advocacy for content providers
8. Design guidelines for content providers