Application Sharing in The Virtual Classroom

Solutions Investigation Analysis Framework

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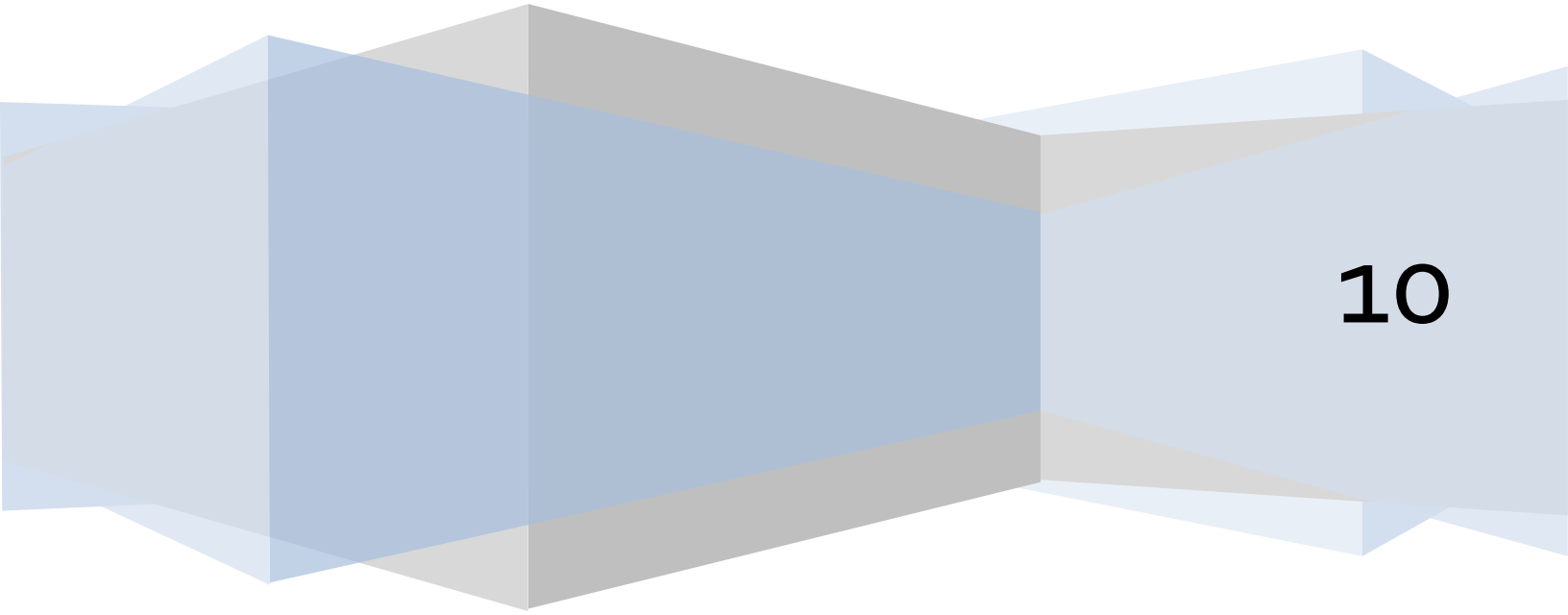

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Application and Screen Sharing Solutions Investigation Progress Update

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1. Background

The Computer Science department at Rhodes University is providing distance courses to the Computer Science department of the University of Namibia, to help with staff research capacity building there. The teaching takes place over the Internet in a virtual classroom.

There is a need for application sharing, a feature important in any advanced virtual classroom taking into account constraints such as the actual bandwidth on the link used for the connection and its level of reliability.

2. Introduction

This project will investigate all alternatives to support application sharing. Once the alternatives have been explored, the system deemed most suitable to the circumstances of the teaching at Rhodes will be implemented, most likely within the Mobicents environment.

The investigation would not go into allot of technical design details of screen and application sharing system as to be used in development, but would look at system architectural design issues in terms of usability, performance, integration, scalability and adaptability. The ideal solution for the application sharing would have the following features:

- ✓ Real-Time response and Light on bandwidth
- ✓ Be able to work on unstable network connections
- ✓ Be able to handle different processing speeds and capabilities of participating hosts
- ✓ Perfect synchronizing and intelligent sync recovery functions. Also Flexible
- ✓ Minimal visibility of the of the solution on screen and real time connection and sync status update
- ✓ Integrates well into conferencing technologies having either a central controlling system or also work as peer-to-peer
- ✓ Can work on different platforms or operating systems
- ✓ If in a restricted environment such as behind firewalls and NAT, should be able to communicate

As part of the research into application sharing for the virtual classroom, different existing tools and solutions have been investigated. These tools include web conferencing systems, screen and application sharing system and teaching systems.

3. Application Sharing

Application sharing is part of the umbrella Collaborative Software. It is also commonly referred to as Desktop Sharing or Screen Sharing. When applications are shared during a video conference or perhaps an online web conference, it would sometimes be referred to as Data Conferencing. Some of the implementations or solutions would broadcast the whole screen while others allow the option of only sharing specific application windows. Some other solutions allow only viewing of screens of the presenter and not allow remote participants to perform any task onto the shared application.

4. The Virtual Classroom

Porter (1997, p. 24) noted that "A virtual classroom should not be much different from a real classroom." In a virtual classroom one would like to have the same teaching and learning experience as close to as it would in the real classroom as possible. The difference only that with the use of technology a "virtual place" is created that can be any distance or geographical location. The virtual place would connect teachers and students which are not necessarily in the same geographical location. This would allow for the possibility for students to participate in courses which they otherwise could not have participated in. This research concentrates on the Live Virtual Classroom meaning that classroom activity take place in real-time.

To better understand and cover all issues one can categorize the virtual classroom into different types and setups. The types would be according to the functionality or experience in the virtual classroom in comparison to a real classroom. The virtual classroom setup would be as per arrangement of technology equipment such as the computers and network connections.

4.1. Types of Virtual Classrooms

The virtual classroom is evolving in three categories of classrooms which one can classify as the perfect classroom, semi-perfect classroom and the limited classroom

4.1.1. Perfect Virtual Classroom

In the perfect classroom the environment is fully virtualized with technologies such as augmented reality, virtual reality or maybe even holograms. The experience for the teachers and students would be as same as being in a real classroom where each person can see each other fully, not only the face and also the black board and other equipment as if they were place physically in front of them. In this classroom, people would not even have to only look at a computer screen and the images or projections would not be only flat or two dimensional, but be viewed in three dimensions.

4.1.2. Semi Perfect Virtual Classroom

In the semi perfect classroom the bandwidth and equipment are sufficient for video and audio transmission to all participating classrooms and participants. In this type of classroom the teachers and students can see each other on a computer screen or projector but perhaps on the face of the participants. This research would look into the semi perfect classroom.

4.1.3. Limited Virtual Classroom

In the limited classroom the participants sits in front of the computer and has limited bandwidth and may only be able to have voice in addition to the application sharing. It would not be possible to have a teaching session without voice.

In all classrooms the participants or classrooms may be scattered geographically which is the very reason for having to create a virtual classroom.

Ultimately the presenter or instructor should only give the presentation once in the real classroom and be visible to all virtual classrooms where students experience as if they are in the real classroom no matter the geographical locations.

5. Virtual Classroom Setups

One may also have to look at different arrangement of the classroom in guiding the choice of implementation of the application sharing system. In terms of the arrangement of the computer and other equipment such as the projector, video cameras, speakers and microphones, there are three possible arrangements at this point. One should note that the setup of the computers at each physical location like the Universities do not form a virtual classroom at these respective locations, but all of the instructors and the students at the different locations connected together with the different equipment over the Internet form one virtual classroom.

5.1. Setup 1: Two Cloned Computers for Exclusive Teaching Use

In this setup, there would be two computers having identical hardware, software and configuration.

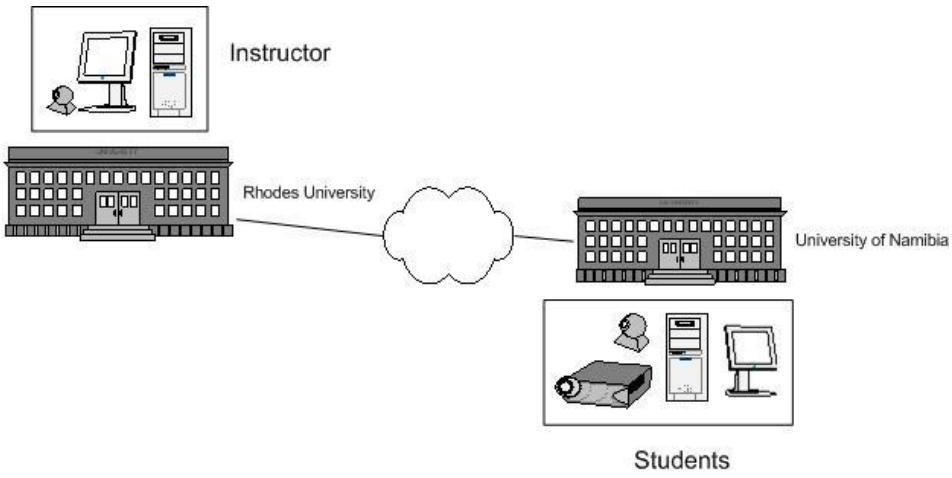

Figure 1: Virtual Classroom Setup 1

One computer in the remote classroom having a projector, camera, speakers and microphone connected to it. The other computer would be on the side of the instructor have a small camera, microphone and speaker attached. The two computers would be completely synchronized to the lowest level of the operating system and the use of these computers would only be for the purpose of teaching.

5.2. Setup 2: Multiple Computers in Same Geographical Location (Students)

In this setup, each participant would be sitting in front of their own computer in the same room or building connected with a Local Area Network.

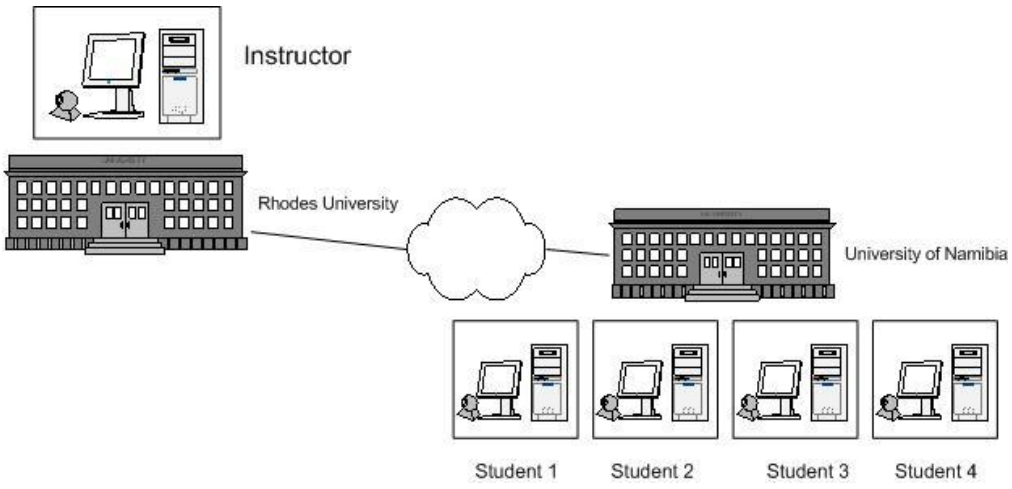

Figure 2: Virtual Classroom Setup 2

Each participant would have a camera, microphone and speakers/headset attached to their computer. The operation system for a little simplicity now would have the same operation system installed, but it may not be at the same state (*example; Service Packs*) and may not have the same number of other programs installed on it. The file system may also be totally different from each other.

5.3. Setup 3: Multiple Computers in Different Geographical Locations (Students)

This setup would be the same as above in setup 2, but this time the computer would not be in the same location connected by a LAN, but in different countries or continents connected through the Internet.

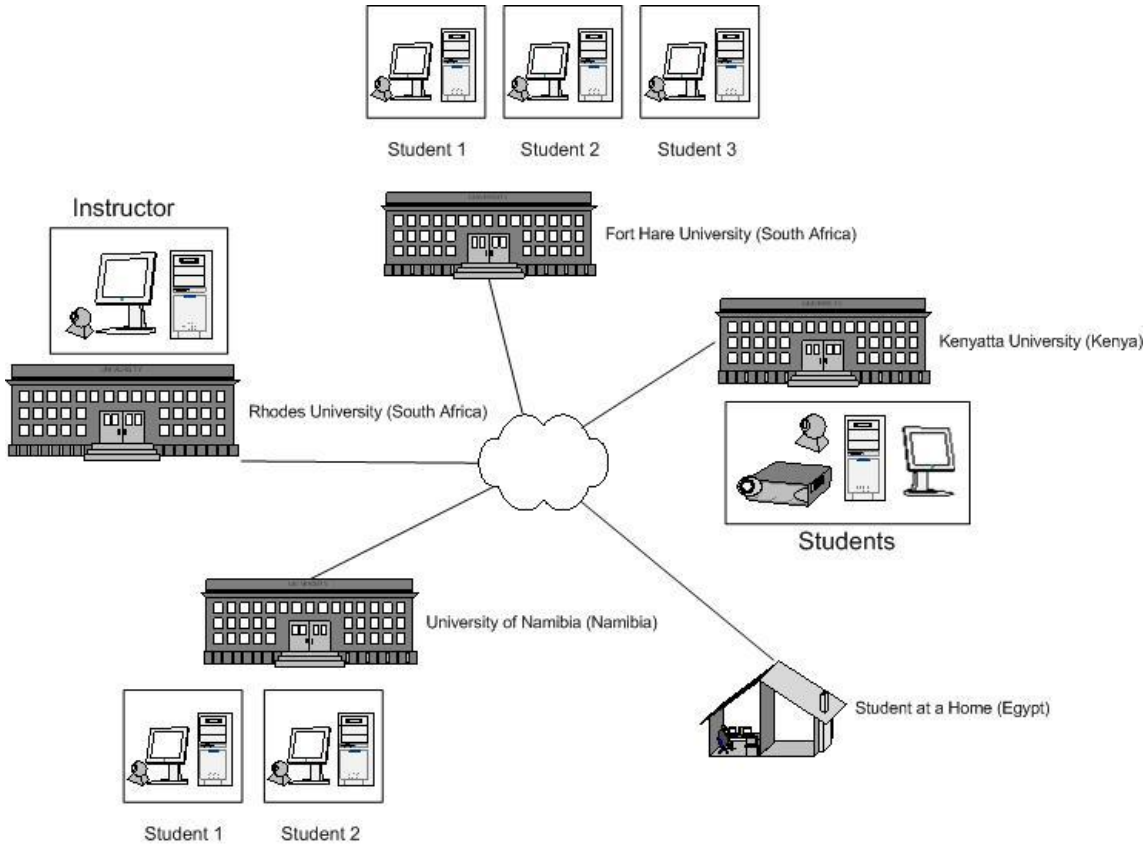

Figure 3: Virtual Classroom Setup 3

There may be a mixture of students and even perhaps students connecting from their homes as long as they have the necessary network connection and computer equipment.

6. Scenarios and Issues

There would be three scenarios of assumptions so that one can put focus at particular issues to considered and solved. One can classify them into issues concerning the classroom, the software and the network. The division into the different issues does not suggest that each would be tackled separately in isolation, but is rather just a way to identify all possible issues in the different levels and functional domains.

6.1. Scenario 1: Classroom Issues

Assumptions: Good Software Performance and Good Network Connection.

The ultimate objective in a virtual classroom is to have an experience as close to the traditional face-to-face classroom as possible.

In terms of a classroom, the instructor would like to have the participants pay attention, the participants being able to interact like asking questions and have engaging discussions. The classroom

is the most important issue to master and the software and network should be transparent and or invisible.

Here one would further investigate the concepts of Pedagogy, which is the study of being a teacher or the process of teaching and how this can be incorporated into the software. There may be some challenges as the teacher does not have the students in the same room and may also not see their mood and whether their paying attention to mention some challenges.

One of the issues in application sharing is late comers, that is people to join the screen and application sharing session after it has already started. Depending on the software architecture, the degree of it being a problem would be very different. In the replicated architecture it would be quite a challenge as all application messages have to be replayed to the late comer, but with the centralized architecture the late comer would just continue from the point he/she has joined and require less effort to synchronize.

6.2. Scenario 2: Software Issues

Assumptions: Good Classroom Management and Good Network Connection

6.2.1. Latency

Latency is the time delay between the moment something is initiated, and the moment one of its effects begins or become detectable. In the screen and application session systems, it is the delay between when the presenter initiates an activity, such as mouse click or cursor move on the screen and when a participants or student observes the same action on their computer. The shorter the latency, the more real-time experiences the participants would have.

6.2.2. Smoothness

A smooth experience is one that flows easily with a minimum of choppiness. In screen and application sharing, what underlies a smooth experience is often a high frame rate, where the screen is able to produce a high number of unique consecutive images (frames) on a per second basis. High frame rate means that the experience of seeing a video or graphically rich presentation during the classroom session is more similar to watching television, where audio and video are synchronized, also where images are clear. Smoothness may also improve focus of participants or students and reduce distraction by technology glitches or imperfection.

6.2.3. Fidelity

Fidelity denotes how accurate a copy is to its source. When screen sharing, presentation with perfect fidelity looks identical to both the presenter and attendee. When graphics, shapes and colors are truer and more consistent, the classroom session experience is improved and also reduces the risk of participants misread and misinterpret something.

6.2.4. User Interface

In terms of the user interface, the main aim is in sharing and teaching the shared application, so the software handling the management of the application sharing should be invisible as far as possible. The user interface should not add more complexity in terms of performing an action so that participants and

students would have focus on the learning and not be distracted in trying to find a menu or not know where to click. Little focus should be needed to operate the software during the session.

It would also be helpful to have some monitoring of the status of the network connection and quality.

6.2.5. Architecture

An application sharing system can be categorized into two architectures in terms of how it handles the shared application, namely The Centralized Architecture and the Replicated Architecture. The key difference is the instances of the shared application during the session.

In the centralized architecture, there is only one instance of the shared application where as the replicated architecture requires each participant to run locally his/her own copy of the shared application.

There may be some obvious advantages and disadvantages of each of the architecture in choosing which to use in which situation. Starting with the Centralized architecture, some advantages that can be listed at the time of this research:

- ✓ As only one copy on the host is running, this eliminates the need of first installing the software on each participating computer. This provides for financial gain if the software is to be bought and eliminate complexity of installation for the students.
- ✓ Further advantage would be the ability to show case new software requiring only the time it takes to make the connection between the computers which is great for eliminating the process of procuring the necessary software before preview.

Some disadvantages of the centralized architecture that can be listed at this time are as follows:

- ✓ As the screen has to be transmitted to the viewing computers, which is transmitted as graphics, one can expect a high volume of data to be transmitted, therefore a need for a high bandwidth for the system to be usable

Some techniques have been devised in solving the problem of bandwidth consumption in the centralized architecture, one of which is adding compression of screen images before transmission.

Another technique is to only send the parts of the screen that changes rather then send the whole screen. This technique is widely implemented as the Run Length Encoding (RLE) in the Remote Frame Buffering (RFB) protocol, which is used in Virtual Network Computing and X11 Windows System for example.

In the replicated architecture each participating computer has a copy of the shared application running locally and only event messages are broadcast between the instances. Some of the advantages to such a system at this point would be as follows:

- ✓ As only event messages are broadcast, one would expect very low data need to be transmitted over the network; therefore the system should work well over low bandwidth. The study at the

HP Labs claim to be able to use a 3D CAD system over as low as 56kbps connection, which sound extraordinary.

- ✓ Having the shared application running local, one would have the files on your local hard drives produced during the shared session after the session ends.

Some disadvantages in using the system with replicated architecture:

- ✓ As each computer needs to have a local copy of the shared application running, each have perhaps have to purchase the software.
- ✓ There is also the complexity of having to install the software first and have fully working before a shared session can begin.
- ✓ The operating system environment may not be exact for each participating computer, making it difficult to keep application synchronized as instances may behave differently.

Some techniques have been devised to tackle the problem of synchronization in the replicated architecture, which is the major issue under the replicated architecture. This may many times be caused by the problem of determinism. One suggestion of tackling the issue of determinism is discussed in a paper from IBM Research Lab by a system called the Zipper system. This system introduces basically the idea of isolation the shared application messages and variables from the external environment, which is the operating system.

6.2.6. Platform

Some of the application sharing system use either Graphic User Interface (GUI) or is web based. One might immediately think that if a system is web based then the platform or browser is irrelevant, but this is not the case. The system would need to capture or intercept the screen updates of the computer sharing its screen and for this to happen a component needs to be installed on the local machine to be able to access the system VGA drivers. This may also contribute to security concerns. All solutions would therefore not work on all operating systems or web browsers.

Depending on the architecture, the application sharing software intercept the screen update messages at different levels. The components for web based application sharing system are normally Java Applets or Active X objects. Other times the web based services needs a small GUI interface installed.

6.2.7. Synchronize

One issue of synchronization in the screen and application sharing is mentioned above in the classroom issues are the late comers. Another important issue to synchronize is the application response inline with the voice. If the voice and action of the application being shared is mismatched, it may be confusing for the viewer. It would be much like watching a movie where the sound and picture mismatch, you would see the actor say something and only hear his voice later at which time something else is shown on screen. It is not very pleasant to watch such a movie and also confusing to follow.

6.2.8. Other Issues

One of the issues of the application sharing software would be memory usage and processor load. It would need to be determined whether this has a significant difference amongst application sharing software with reasonable modern hardware. The application sharing software itself would have a system requirement before it can be installed and therefore the need to consider very old hardware is not needed.

Another keys issue would also be the handling of the audio and video streaming by the system.

The time it takes to start a session may also be important where time is always of essence. Some of the web based application sharing system doesn't take much time for installation or configuration to start a session.

7. Scenario 3: Network Issues

Assumptions: Good Classroom Management and Good Software Performance

Here the issues in the network have to be investigated such as the bandwidth speed and network latency. As application sharing is a real-time application which requires at least voice in addition, the network latency is very important and not only the download and upload speeds. A key factor to keep in mind in terms of bandwidth is to consider the upload speed of the sharing computer as many people would only think about the download speed.

Other network issues are network stability, firewalls, Network Address Translation (NAT) and multicast support. Multicasting may be very useful in a classroom setup where more then one computer is connected through a LAN to better utilize the internet connection as mentioned in the classroom setup 2. Also a beneficial factor to investigate is the support of UDP packets across a network.

In a discussion with a fellow classmate which manages servers with web based remote terminal services, it has become apparent that the proxy server may significantly affect the network latency when using web services. The network latency using the ICMP protocol is not affected by the proxy server and may be misleading as the HTTP protocol passes through the proxy and is affected. It has to be determined how much the proxy server affects network latency.

SSH is the one connection that is allowed to happen directly without passing through the proxy on the Rhodes network. SSH Tunneling is also a popular technique to run application sharing solutions for direct connections between host computers to overcome the restriction of needed TCP port not being allowed trough the firewall. It has to be investigated how much the ssh protocol affects the performance of an application running over ssh tunneling. One can also investigate whether it is possible to disable encryption when using ssh to boost the application sharing system performance.

Some web based application sharing solution try to use UDP packets when transferring media such as the screen updates where possible to form a direct connection to the other computers. This is a better use of bandwidth, but if that fail, they would use HTTP relaying data through a central server which is not a good use of bandwidth. It may therefore be important to test solution in both situations.

7.1. Protocols

Other issues to investigate here would also be the protocol, which are the session protocols and the media protocols. The session protocols would be responsible for the making the connection, monitoring the status and closing the session. This would happen on an application layer and does not describe the TCP protocol. It would include protocols such as SIP for example. Application sharing protocols such as RFB, RDP, NX are popular amongst existing application sharing solutions.

The protocol the application sharing system uses would determine its ability to be integrated with other systems. If a system uses an open standard protocol, it may be much easier to communicate with other systems. Using open standard protocols would also make it easier to integrate an application sharing system into Mobicents.

Sometimes some protocols may perform better then others affecting the overall performance of the application sharing system significantly. Another key issue with the selection of protocol is scalability of the protocol. This can be better understood in the scenario of web based system usage when having a single international network connection as describe below in figures 4 and 5.

Another key factor in the choice of protocol is to deal with network restrictions such as firewalls. Many networks only allow traffic such as HTTP and are very reluctant to open other ports such as for SIP or RDP due to security concerns. An application sharing system using the HTTP protocol with HTTP Tunneling would easily work in any network, but has a serious problem in terms of bandwidth usage and scalability as described below.

7.2. Physical International Connection

In the classroom setup 2, the default connection may cause a great waste of bandwidth and not be scalable at all. The internet connection would need N*bandwidth where the bandwidth is equal to the bandwidth needed for one computer to share an application or screen and N is the number of computers in the session. This is even worst when using web based services hosted on another continent.

Let us assume that there are three students on a University of Namibia premises and an instructor at Rhodes University. Let us also assume software using the VNC protocol such as RealVNC is used having desktops settings with simple imagery and reduced colour resolution, which would require 128kbps.

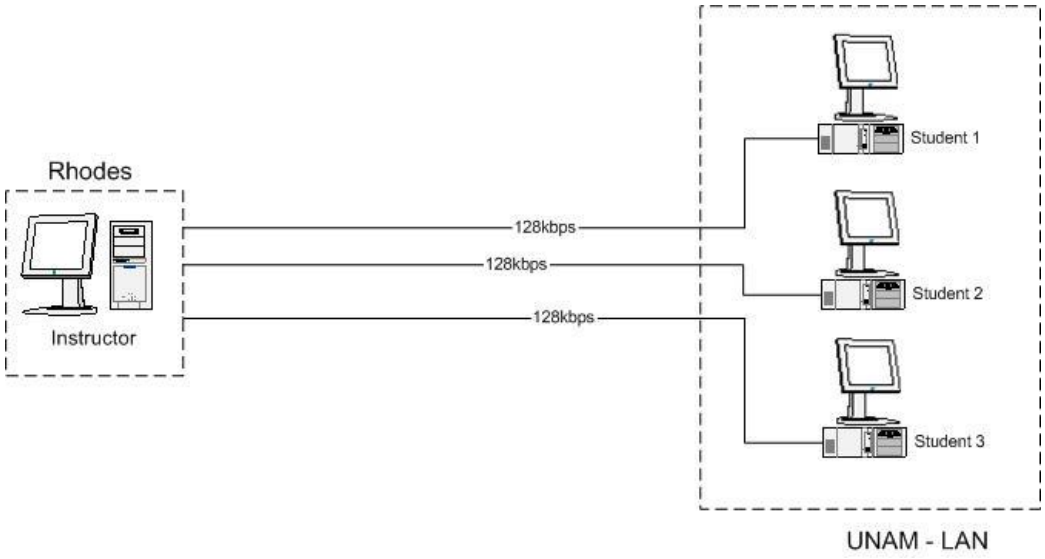

Figure 4: Virtual Classroom Setup 2 Bandwidth Default Scenario

As shown above, the Internet connection would need to be 3 times the required speed for three students, which is not scalable at all. One should note that as the screen is broadcasted to all participants, the same data gets send over the internet connection three times. A better usage of bandwidth would be to have the data spread by multicast on the LAN at the students end. The situation would be worst when it is a web based service and the same international link is used as illustrated below in figure 5.

It may be different situation if the session is started by one of the students. Everybody else would then connect to that student and control of the desktop can be handed over to the instructor if the software allows change of presenter feature. The only person connecting over the internet would then be the instructor and the data for the students would be broadcasted over the LAN. The student which would start the session would however need to have a public IP address and should also be able accept incoming connections and have good upload speed.

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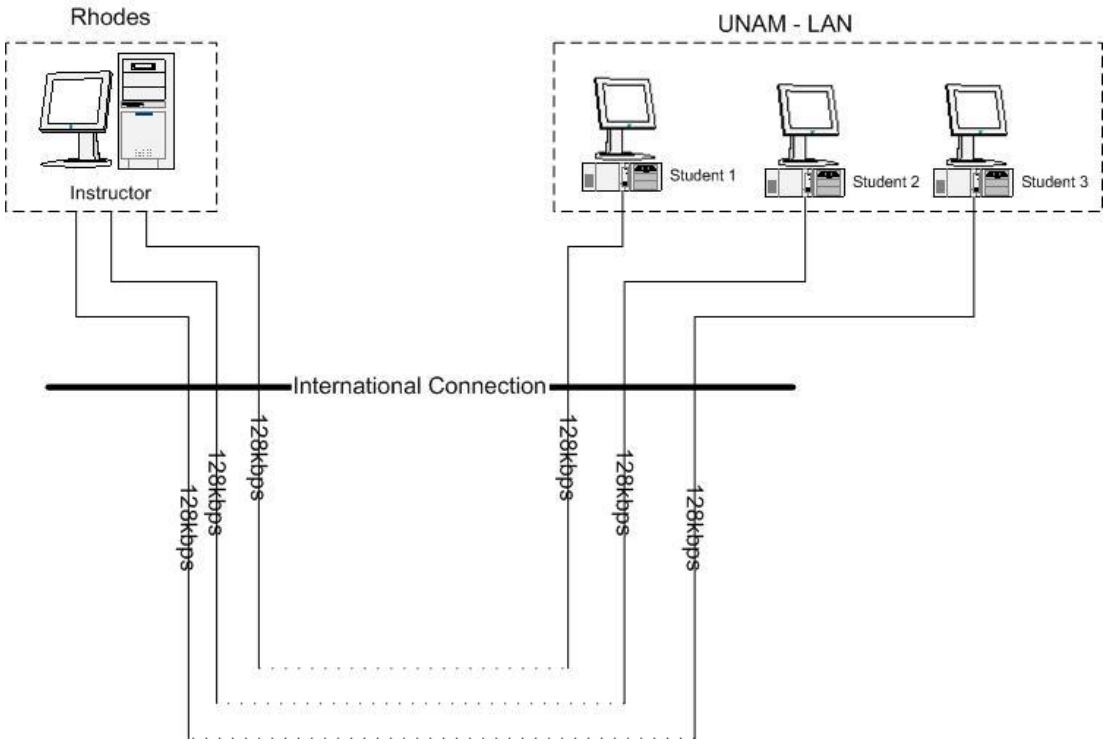

Figure 5: Web Based Service Hosted in USA

When having one international link, which might be the case with the link of Africa to Europe and USA, the traffic passes twice over the connection for each computer connected. In the example shown above, the international connection requires six times the required bandwidth of the screen sharing application for 3 students.

The use of multicasting, relay or rebroadcasting techniques can be very useful in efficient use of bandwidth. The use of relay may be helpful when having situations such as perhaps a student wanting to connect from their home in the same country. If we have the university already connected and we expect local connection when in the same country to be good, then the internet traffic can just be relayed from the university to the student connecting from home.

With web application one may argue that the performance may be different at different time as less people may be connected at certain times. The problem however may be that because the service is global, people from different time zones connect, so when it is very late for some it may be early for others. It may be so that a constant average number of people would be connected to this service and at which time one connects would not even matter.

8. Use Cases and Complications

There may be some complications when the application sharing software is to be use in the Rhodes and UNAM virtual classroom project. The project would be teaching courses such as Real-time Multimedia

and below are some of the software to be used and task that need to be performed. This software adds some complications.

The choice of application sharing architectures, replicated versus centralized plays a big role in having to deal with these complications later in the research. One may even have a hybrid architecture where the software would have both replicated and centralized architecture and have the ability to switch between the two as the need arise.

8.1. WireShark

Wireshark is a packet sniffing software that enables analyzing all LAN network packets to which the respective computer is connected. This software thereby would need physical access to the network interface card (NIC) on the respective hosts.

One of the complications is that, in an application sharing session, the computers are in different geographical locations and connected on different networks and therefore the network setup and network packets observed at each computer would not be the same. One might try and replicated the network, but this would add complexity to the learning process as there would be the need to control network traffic from other devices connected to the network in order to have the same output on the screens.

This however would have different results as per the two different architectures mentioned above.

In the replicated architecture, each would see the network packets on their respective network and these may not be the same as the other students and the teacher participating in the session. There is also the problem of a mismatch between the LAN bandwidth and the Internet connection bandwidth.

There might be the solution of the application sharing software have a still image exchange functionality, which is the exchange of the screen captures of the presenter's screen as to share the screen displaying the captured network packets of the presenter to other participating students and teacher.

In a centralized architecture however, all students and teacher may only be viewing the network packets captured by one person's computer. To view the other participating people's captured network packets screen, the still image exchange functionality may be used or presenters may be changed to see a live capture.

8.2. VOIP Softphone

When calling from a VOIP soft phone, the audio would need to broadcast to the other participants. As the soft phone is software which would be part of the application sharing, the broadcast may need to be coordinated carefully not as to echo the audio back and forth between participants when using the replicated architecture. It may also need to be streamed separately.

8.3. Audio and Video Playback

There may also be a need to playback an audio or video clip during a teaching session. Depending on the architecture, this may be handled differently.

In the replicated architecture, in case the file is not on all computers already, the file would have to be copied to each computer and these files are normally very large and require very high bandwidth for all participants for it to be feasible. This would also result in a time delay as participants have to wait for the file to be finished copied. In a centralized architecture the audio and video would need to be streamed which also need high bandwidth. This can also be done using a separate streaming system such as Mobicents.

9. Methodology

In this phase of the study, I produced a spreadsheet with information about existing application tools which I whish to investigate. At this stage, the study is more about functionalities of the different applications sharing solutions. The columns and the relevance of each of these columns are shown below.

9.1. Free

The interest whether the software is free is to determine access to the tools. Some tools are only accessible by a limited days subscription, so there is a time limit when doing the testing with the trail versions of these software.

9.2. Open Source

It is also an aim to not reinvent the wheel. If a solution have appropriate feature that can be used, these parts of source code could just be copied and adjusted appropriately.

9.3. Web based or GUI based

This column is to see whether the software runs locally on the computer or over the internet. Application offered online is likely not available for download.

9.4. Programming Language

This is just for information sake and not so much determines choice of software. It may also aid when having to mix modules from different software.

9.5. Architecture

An application sharing system can be categorized into two architectures in terms of how it handles the shared application, namely The Centralized Architecture and the Replicated Architecture. The key difference is the instances of the shared application during the session.

9.6. Remote Control

Some application sharing systems only allow viewing a shared application and allow nobody to edit onto the shared application. This column shows whether the application sharing system would allow for remote participants to edit onto the hosted application.

9.7. Share Specific Application

At any one point in time the participants may be having a number of windows or application on their computer and not want all to be seen. Participants in a session may want to look at other documents or search on the internet on a discussion or subject during the interactive session. It may also be very inconvenient for every window of one participant shown on the other people screen as it may be distracting.

9.8. Change Presenter

This column is to see whether the software allows the presenter position to be shifted of handed over to another participant. A presenter in this context we would regard as the person in control and whose screen is being broadcasts to others in the session.

9.9. Live Cursor

This column shows whether the every movement of the cursors would be visible on all participating computers. A protocol for handling the cursor during application sharing is specified in RFC2862.

Most of the information above is collected by visiting the websites for each solution and going through the features page. Other times the solutions needed to be trialed by downloading and installing it or registering for a new account and give it a test. All information is then entered into a spreadsheet.

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