Private Dropbox
Final Report
COSC480

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Abstract

Private Dropbox is a file synchronisation tool designed to keep files in sync across multiple devices. It is decentralised, unlike many other file hosting services like Dropbox. My program is designed to run across any given network of computers. Configuration files allow the user to specify what files should be synchronised; to which machines; and how often to sync them. My program monitors the files being synchronised and the last time files were updated so that it knows when to sync with any other connected machines. Different machines may require different replication strategies, this makes it unique from other file replication tools.

Contents

1 Introduction

Dropbox is a well known online file hosting tool that will keep your data synchronised across multiple devices. I feel that there is a need for a private file synchronisation tool controlled by the end user rather than a corporation. In this section I will outline my project goals which explain how my program differs from Dropbox and others; give background information about the alternatives like Dropbox and what the problems with these solutions are; outline an example use case which shows why my program will be useful.

1.1 Project goals

The aim of this project was to develop a file synchronisation tool. Similar to Dropbox (and others) its main function should be to keep data synchronised between multiple devices. What makes it different however is it should:

- Support decentralised operation. It will not necessarily need to communicate with 'the cloud'. The program should not require a centralised server. However it should be possible to configure the system to behave like a centralised system if the user wants to. The system should be flexible in this regard.

- Allow file synchronisation between multiple clients not just point-to-point between two clients. Synchronisation between two clients however is the basis for multiple client synchronisation. Clients may be running different operating systems. Clients may be connected to different networks, with different costs of access, including being disconnected from the Internet at times.

- Permit the user to choose what to replicate and how often to do it within different sets of files. Choosing what to replicate could be done based on file name, file types, file size *etc.* They system should allow for fine-grained user control for the majority of the program's functionality.

- Show statistics about which files are being replicated, efficiency (time taken for the files to become fully up to date), cost (bandwidth, disk space used). These statistics could also possibly lead to a heuristic for when to synchronise a given file. For example if a file is updated and a node has many neighbours to potentially send the file to then perhaps choosing the neighbour whose links has the lowest cost would be a good choice to send the data to first.

- Operate automatically, without the user having to initiate a file synchronisation themselves. The system's autonomous operation should be influenced by the users choices on how often to sync and what files should be synced, this relates to the fine-grained controls mentioned above.

1.2 Background

There are already many services available that can synchronize your files between different devices. Dropbox, Google Drive, Microsoft SkyDrive, Apple iCloud are all examples of cloud-based solutions for distributing your files across your devices. The problems with these services is privacy and availability. Storing your data with a third party gives them access to your documents. If you are a commercial organisation with sensitive information this might be concerning. You could of course choose to encrypt your files. Encrypting your files adds two slow extra steps, encrypting them before you upload and decrypting files before you can use them. This is less than ideal. You also cannot guarantee that you will always be able to access your data, if the company that hosts your data goes bankrupt or decides to shutdown their service you could lose all of your data with little or no warning. For example Megaupload, a file hosting service, has recently been shut down by the United States Department of Justice for alleged copyright infringement. According to its founder, 100 million users lost access to 12 billion unique files[1].

There are other possible approaches to replicating files across multiple computers. For example you could use version control systems like Subversion and CVS. One problem with these is that they are centralised (they rely on a central server); should that server fail the replication will break. Not only that, they create a bottleneck at the server which can slow replication down. Cloud-based solutions are often centralised. Another problem is that even if they are decentralised like Git or Mercurial, they will not automatically push updates to other working sets. This could be accomplished with some Cron scripts or a post-commit hook to get Git to propagate data onwards. Git might have made a promising base to build my application on top of; the only real problem was the version control overhead that comes with it. Old revisions would take up space on the hard disk and require more data to be transmitted across network links. I decided that as a file synchronisation program, revision history was out of scope and that my program would deal with just keeping files in sync. Using Git would be an interesting extension to my program and could easily be integrated into my current system.

1.3 Example use case

Here is an example use case demonstrating why I find my program useful.

I like to keep all of the data on my laptop backed up to an external hard drive. The data on my computer that I wish to back up falls into three main categories: documents, music, and movies. Documents are mostly scripts and programs that I am writing for University or work projects. Documents also include reports for assessment. These documents change very frequently and are very important to me. Often these are small files (but not always). My music collection changes relatively infrequently, files are ≈5MB and I like to have a relatively current backup of this collection. My

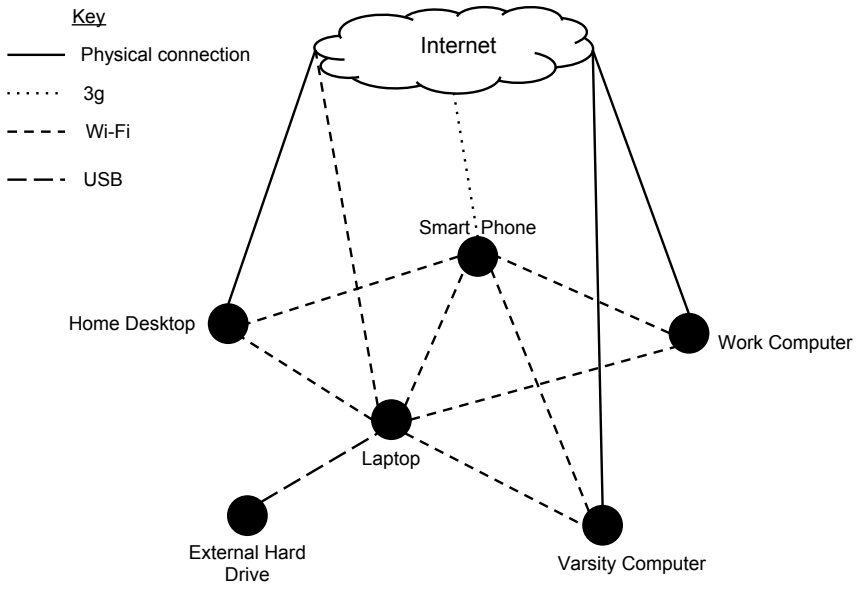
[1] http://computerworld.co.nz/news.nsf/news/kim-dotcom-wants-his-money-back

movie collection contains fairly large files but I do not need it to be backed up very often as it does not change very much and I do not care if I loose some of these movies. Files that I work on at University would be very useful to have on my laptop at home. Files that I work on at work mostly stay at work but occasionally I might want to bring something home to work on. The other device I always have with me and may be on one of any given (Wi-Fi or 3G) network at a certain time is my smart phone. I would like to have photos taken on this backed up to either (or both) my laptop and external hard drive.

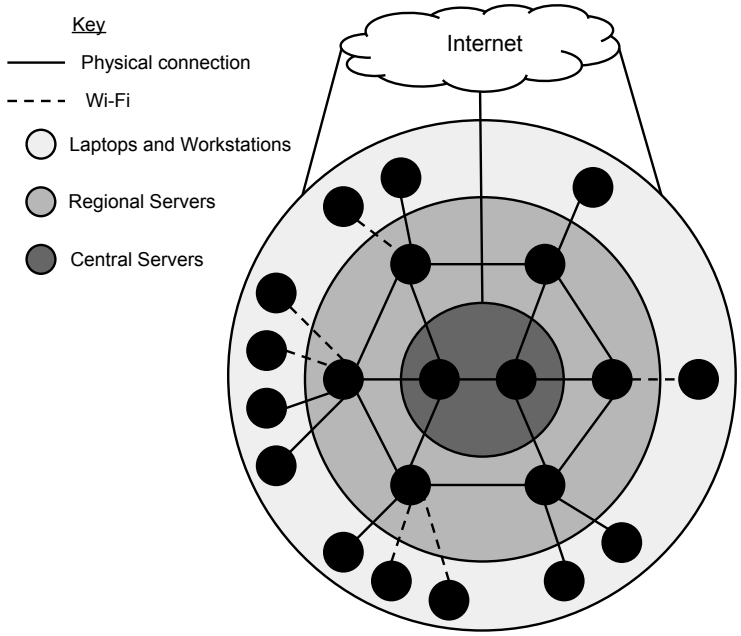
Some of the files that I move around are of a sensitive or personal nature and I would prefer not to store them with a third party vendor. I also have different synchronisation requirements for different types of data. For example my collection of large video files does not change that often and will chew up valuable network bandwidth whenever it has to transfer a new file. I like this to be replicated only occasionally as I do not use it that much. On the other hand my document collection which I use for work and coursework changes very often, is very important, and is fairly small. I would like this to be as up to date as possible.

Existing file synchronisation tools do not do enough for me. I do not have enough control over my data. I want to know which machines my files are going to and when. I want to feel confident that I will always be able to access my data even if the service closes down or my internet connection fails. My program is aimed at addressing these issues.

The personal network shown in Figure 1a is a graphical representation of my description above. Figure 1b shows a graph of a corporate network, this is another example use case. It will have many of the same basic needs as the personal graph. The coloured rings represent the need for different policies for different machines in a network. Something which Dropbox will not provide but my system does.



(a) Personal Network



(b) Corporate Network

Figure 1: Example use cases

2 Architecture and program development

Before I could begin developing my program, I needed to have a test environment to run it in. Given that my program is designed to run across a network of computers I needed to be able to change links between machines and add or remove machines automatically for testing purposes. Doing this manipulation of the network manually would be too time consuming in the long run. In this section I will discuss how I control a virtual network of virtual machines for testing, how I manage the links between them and how I monitor these links to gather performance statistics regarding the execution of my program.

2.1 Virtual machines and node networks

For testing my program I needed to have a network of computers that could easily be linked together in different arrangements. I think of a network of machines as a graph, where each machine is a node of the graph and the links between machines are edges in the graph. I decided to use virtual machines for my network since it means I do not need to have a large number of physical machines. I can create new machines very easily, and manipulate the links between them.

I have used Oracle's VirtualBox software. I chose VirtualBox because of its straight forward command line interface. My program should be able to run across any network of nodes. For this reason I wanted the potential to be able to test a given arrangement of nodes. I decided that I needed to be able change network topologies easily without having to re-write my scripts.

I built some Bash scripts to run on top of a program called Graphviz.[2] Graphviz is open source software for generating graphical representations of graphs. I used Graphviz to generate graphs of all the topologies I worked with. This made it easy to keep track of what a topology looks like which was useful for debugging. It was also useful to display results alongside an image of what the topology looks like. Building my program on top of Graphviz meant that I could couple the production of the topology graph and the configuration of the virtual machines. I never wanted one without the other so this was very useful.

Graphviz takes input from scripts written in DOT language.[3] DOT language is a simple graph description language. I have written a script to read in these DOT files and interpret the graph to set-up my virtual machines (see Appendix A.3 line 125 onwards). My script also calls a program called Neato (part of Graphviz) to generate graphical presentations of graphs. This means I only have to write one DOT file to get a graph of my network topology and set-up my virtual machines.

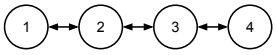
My Bash script enables the appropriate network adaptors on each virtual machine (see Appendix A.3 line 60). It does this by calling the `VboxManage`, command which

[2] www.graphviz.org

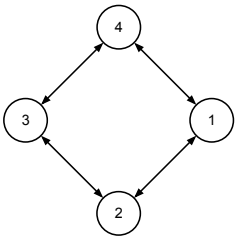
[3] http://www.graphviz.org/doc/info/lang.html

provides a command line interface to VirtualBox's functionality and allows me to configure the virtual machines to meet my needs. Then it creates an internal network and attaches these adaptors to use that network. I chose to use an internal network as the link between any given machines because this way I could guarantee my program was the only program using the interface. This helped me monitor the network traffic generated by my program (see Section 2.2). I sniffed network traffic using packet sniffing tool Wireshark[4] when my program was not running and also when my program was running to verify that no other programs were using the interfaces attached to internal networks.

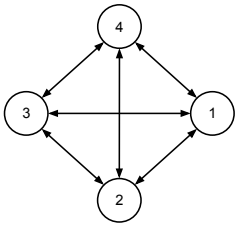
I started initial tests by writing some simple network topology DOT scripts. The reason I chose to use simple topologies when testing my programs was because it is easier to visualise how my program runs from the data if the topologies are simple. The other reason I chose to do this is because more complex topologies can be thought of as being made up of many simple topologies. In this way I might be able to generate a model of how more complicated topologies might behave by looking at how the program runs in simpler topologies.



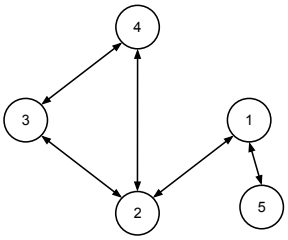
(a) Line topology



(b) Circle topology



(c) Connected mesh topology



(d) More complex topology

Figure 2: Simple network topologies

2.2 Reading network statistics

In order to gather network traffic statistics I chose to monitor the upload and download data collected by the interfaces over time. Given that my program was the only program using these interfaces I did not have to differentiate between different processes using the network. I looked at the possibility of gathering statistics on a network where

[4]http://www.wireshark.org/

other processes are using the network connection as you would expect in a real world application of my program. I found a tool called NetHogs[5]. NetHogs runs on Linux and monitors the amount of data sent over the network by any given process. An interesting challenge I faced when I was trying to log network usage was what interface to log data for. Initially I logged the traffic data of all of the interfaces on the machine (see appendix A.2 line 92). The flaws in this approach became apparent very quickly; machines with an internet connection sometimes used large amounts of data which interfered with the results. It also did not work with machines that were on more than one internal network as they might be sending/receiving data on both of the networks at the same time. I overcame this problem by using a built-in Linux command `ip`. I always had an IP address to send data to, so all I needed to do was run `ip route get {IP address}` and examine the route information to see which interface was being used for communication to that IP address (see appendix A.2 line 38). Once I had the interface name I would then record that data before and after a sync occurred for that given interface. I would also do this on the machine I was sending data to. This would give me timestamps of when a sync was initiated and when it finished. Knowing the network traffic statistics before and after a sync also allowed me to determine how much data each machine sent or received during a transfer or over any given time period. I also decided to include the folder's name being synchronised in the log files. This was useful for differentiating which sub-node (See Section 3.4 for further details on sub-nodes) was being synchronised. It would be trivial to add more detailed information to my logs, such as the IP data is being sent to or received from. This is a feature I would like to add in the future: I discuss this possibility further in section 5.2.

[5]http://nethogs.sourceforge.net/

3 Program design

In this section I discuss the design decisions I have made when building my program. This section details why I chose to use Unison, Python and Inotify to build a file synchronisation tool. Some of my design decisions came from running test cases of the program and reacting to the results I obtained.

3.1 Python

I have chosen to use Python to implement my program. Python appealed to me because it supports many different platforms (Windows, Linux, Mac OS X). This is useful because it means I will encounter fewer compatibility problems when running my program across different operating systems in the future.

3.2 User control

One of the main goals of my project is to allow the user to have a large amount of control over how the program behaves. I currently have the program reading from configuration files that allow the user to specify which directories they want to watch and where those directories should be synchronised to.

I chose to replicate directories rather than files because keeping track of a large list of files may become unwieldy. Because I replicate directories recursively, I can replicate large amounts of data without a cluttered configuration file. Another reason I chose directories as my granularity was because it may be handy to have a directory full of symlinks pointing to other directories.

3.3 Monitoring directories

The application needs to monitor directories for changes (see section 3.4) so that it knows when to perform a sync. The reason I have chosen to do this is because synchronising a directory that has not been changed is a waste of time. I do not however want to be continually polling the watched directories to see if there have been any changes made. This would be a significant waste of CPU time and the input/output time associated with checking the disk. Instead I have looked into ways of being notified of a change in the file system below the watched directory.

- Inotify
  - Inotify is a kernel feature that has been included in the Linux kernel since version 2.6. It is used to watch directories for changes and notify listeners when a change occurs. Inotify is inode based and replaced Dnotify, an older system that provided the same functionality. Dnotify however was inefficient, it opened up the file descriptors for each directory it was watching which

meant the backing device could not be unmounted. It also had a poor user-space interface which used SIGIO. Inotify only uses one file descriptor and returns events to the listener as they occur [6] There is a Python module called Pyinotify[7] that provides a Python interface to Inotify, which I have used in my program. Another reason I chose Inotify was because different kinds of changes triggered different Inotify events. So I can differentiate between a file being deleted, created or modified, *etc.*

- FSEvents
  - FSEvents is an API in MacOS X[8] It is similar to Inotify in that it provides a notification to other applications when a directory is changed however it does not inform you which file in the directory was changed. This does not matter for my application since Unison is smart enough not to copy unchanged files in a directory. There is a Python module for FSEvents called MacFSEvents[9]. I also looked at using the `kqueue` [10] system call that is supported by MacOS X and FreeBSD. It notifies the user when a kernel event occurs. I decided against using `kqueue` as the high level approach of FSEvents suits my application's needs.
- ReadDirectoryChangesW
  - Windows, like the other operating systems I have examined, provides a way of doing this too. There is a function called `ReadDirectoryChangesW`. There is a FileSystemWatcher Class in .NET version 4 and above. IronPython might prove to be a good choice for a Windows implementation as it is a version of Python integrated with the .NET framework. I have chosen only to implement my program on Linux because portability was not in the main scope of the project. I would have liked to look at it further but became too time consuming and not interesting from a research perspective.

3.4 Dealing with sub-nodes

I chose to classify directories as 'sub nodes' of a graph. The reason I choose directories was because I thought it would be easier for a user to maintain the configuration file. A configuration file listing every file to be synchronised could become very cluttered. If a user wanted to synchronize certain files in a directory they could write a Unison configuration file with exclusions/inclusions in it or use my program's built-in ignore list (see Section 3.5) I wanted to see how the freshness of different sub-nodes varied

[6] www.kernel.org/pub/linux/kernel/people/rml/inotify/README
[7] http://pyinotify.sourceforge.net/
[8] https://developer.apple.com/library/mac/#documentation/Darwin/Conceptual/FSEvents_ProgGuide/Introduction/
[9] http://pypi.python.org/pypi/MacFSEvents/0.2.1
[10] http://developer.apple.com/library/mac/#documentation/Darwin/Reference/ManPages/man2/kqueue.2.html

between nodes when the program was running so I tagged each sub-node when logging information about the programs run (see Section 2.2 for more details on logging). Figure 3 shows a network with two sub-nodes. I alternated between creating 10MB files in each sub-node. The data transferred for the second sub-node trails the first sub-node in time but a similar amount of data is transferred over time.

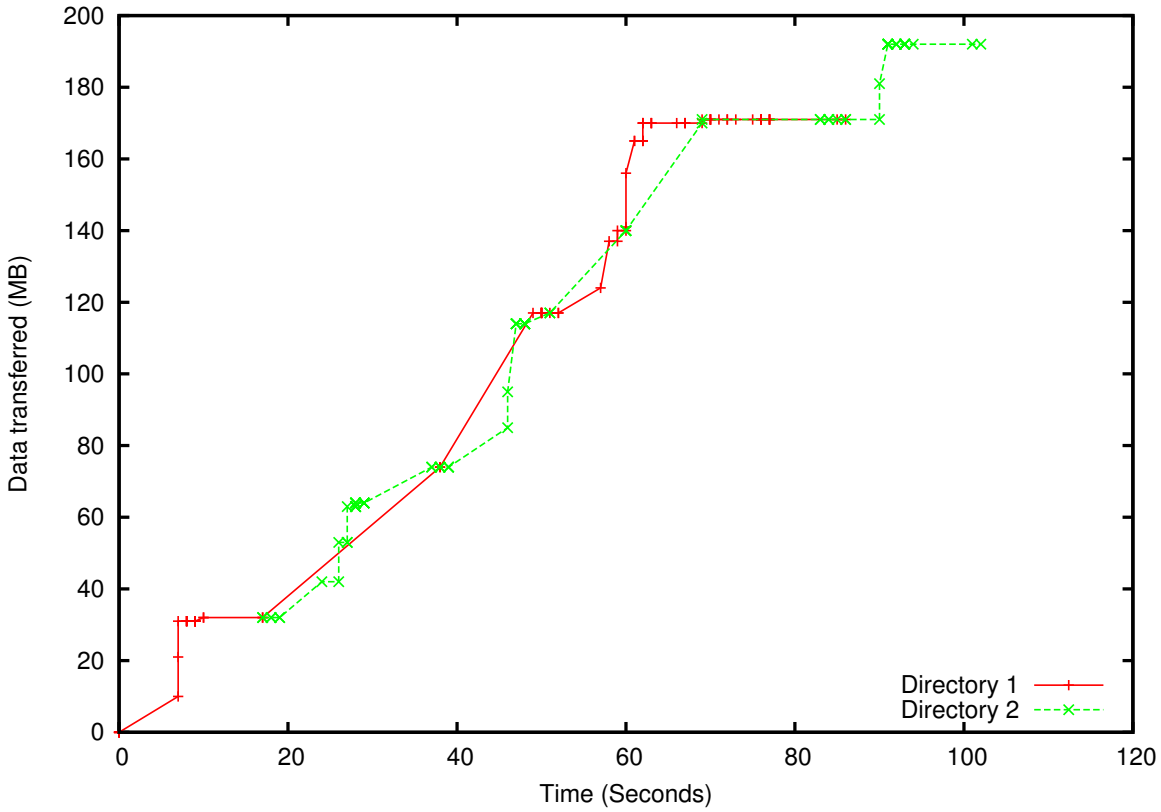


Figure 3: Line topology synchronisation using Unison. Two different directories are being synchronised with 10MB files are sent to each directory alternately every ten seconds.

3.5 Unison and temporary files

I noticed that when Unison ran it created temporary files in the directory and once these files had been fully copied it renamed them to their intended name. The problem with this was that my program was picking up these temporary files as they were created and trying to copy them to the next node, only to find that these files no longer existed. To get around this problem I decided to implement a filter on the files to be copied. The program filters out files that contain ".tmp" in the filename. Unison is not the only program that uses temporary files. I decided that this should be a user set preference given that users may want to filter out different files.

My program simply reads from a file with each file pattern to exclude listed on a new line. It is easy to add to/remove from. As I said above I added .tmp to the file as a default. This could easily be extended to allow a user to omit certain files from the replication by adding all files in my program's ignore file to Unison's ignore list, or conversely by maintaining a white list of files to sync. This would allow for greater granularity when syncing nodes.

4 Program evaluation

During the development of my program I ran tests after major changes so that I would know if the program was behaving the way I expected or not. When problems arose such as machines continuously polling each other for changes. I made adjustments to my program to address these problems. In this section I discuss the results from testing my program and how my results influenced my program.

4.1 Point-to-Point synchronisation

After looking for cross-platform, open source, file synchronisation tools, I have found a tool called Unison[11] to be a promising starting base for this project. Unison is an open source file synchronisation tool. It supports efficient (*i.e.,* it attempts to only send changes between file versions) file synchronisation between two directories (including sub-folders) between two "roots" that may or may not be on the same machine. Unison calls the directories it is synchronising, roots. I decided to run some tests using Unison and two machines running on the same network to determine whether Unison copies data efficiently.

I looked at three methods of file synchronisation across these two machines. Naïve copying using SCP; using Rsync, an application designed for efficiently copying files in one direction by looking at the differences in the files; and Unison described above.

Figure 4 shows how Rsync and Unison performed significantly better than SCP (as expected). After the initial file transfer, new files added to the directory resulted in much less data being transmitted over the network, which meant the node graph (see Section 2.1) became up to date much more quickly.

Figure 4 shows that SCP sent over 300MB of data to copy three 50MB files. This was because SCP is naïve; when it is told to copy a directory it will copy the entire directory without looking at the files inside. This means SCP copies the entire directory each time the directory is changed. Rsync and Unison were able to send less data because they work based on the differences between the files. SCP however will copy 50MB after file one is created, 100MB after the second file is added and finally 150MB when all three files are present for a total of 300MB.

Rsync copies the expected 150MB for three 50MB files. Figure 4 illustrates another advantage of Unison over Rsync. The graph shows three zero-filled binary files being copied from one node to the other, one file at a time. Unison recognised that even though the files were named differently they had the same content. Another advantage of Unison is that it handles replication in two directions without overwriting the files on one node when two nodes have conflicting changes.

Each of the three methods I trialled had some overhead associated with them. This overhead was due to the secure shell (SSH) tunnel between the machines that all three methods used. Unison and Rsync also incur some overhead when comparing the differences between the files in the directories. This is why the graph shows the three

[11] `http://www.cis.upenn.edu/~bcpierce/unison/`

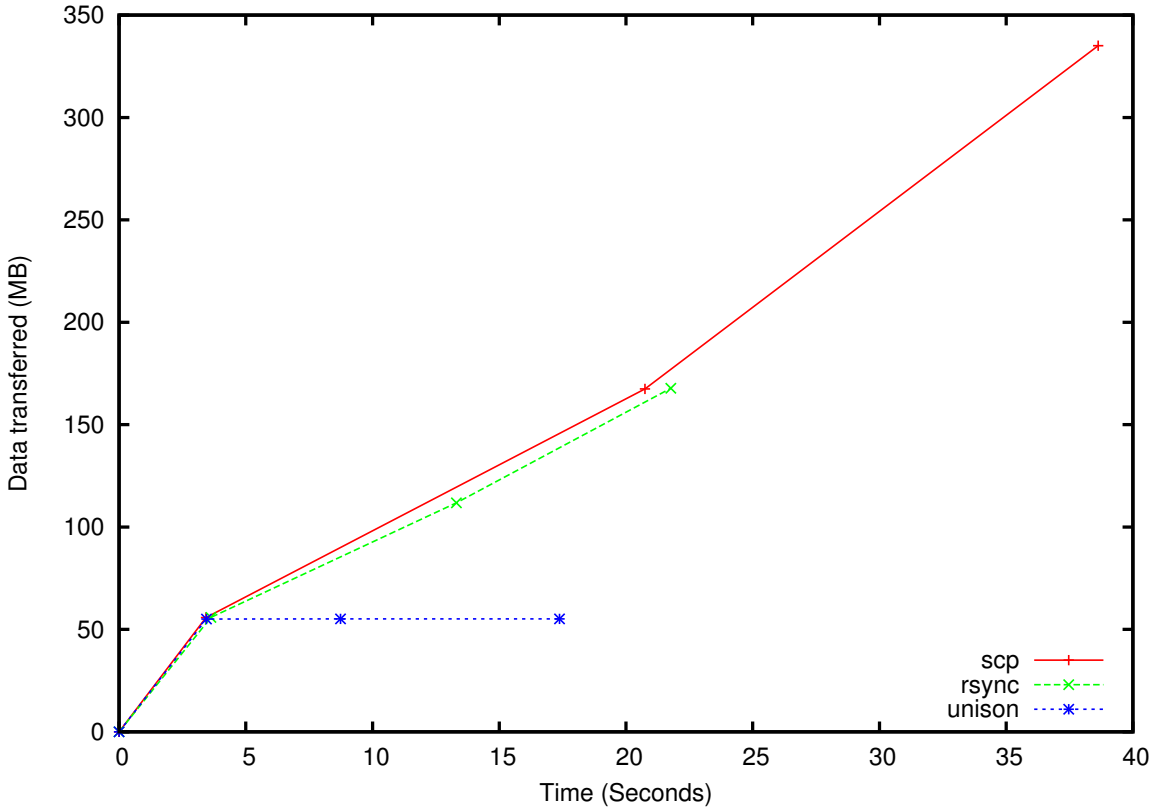


Figure 4: Comparison of SCP, Rsync, Unison. Three identical 50MB files with different names are being transfered between two nodes. Each point on the graph represents the start or end of a sync.

lines slightly above where you might expect them to be for the amount of data that was copied.

4.2 Full graph replication

I ran my program on a simple line topology (shown in Figure 5) of all three of my program's file synchronisation techniques. Figure 6 shows SCP performing poorly compared to Figure 7 (Rsync) and Figure 8 (Unison). Using Unison and Rsync each node only received ≈30MB, given that 30MB of data was sent to node A this is a pleasing result. SCP on the other hand sent much more data than necessary as I have explored in Section 4.1.

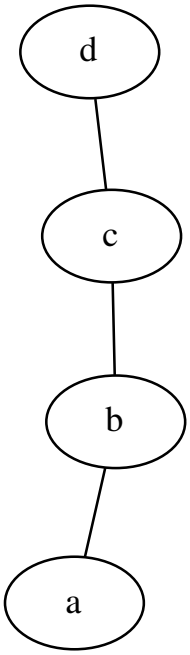


Figure 5: Generated graph of line topology

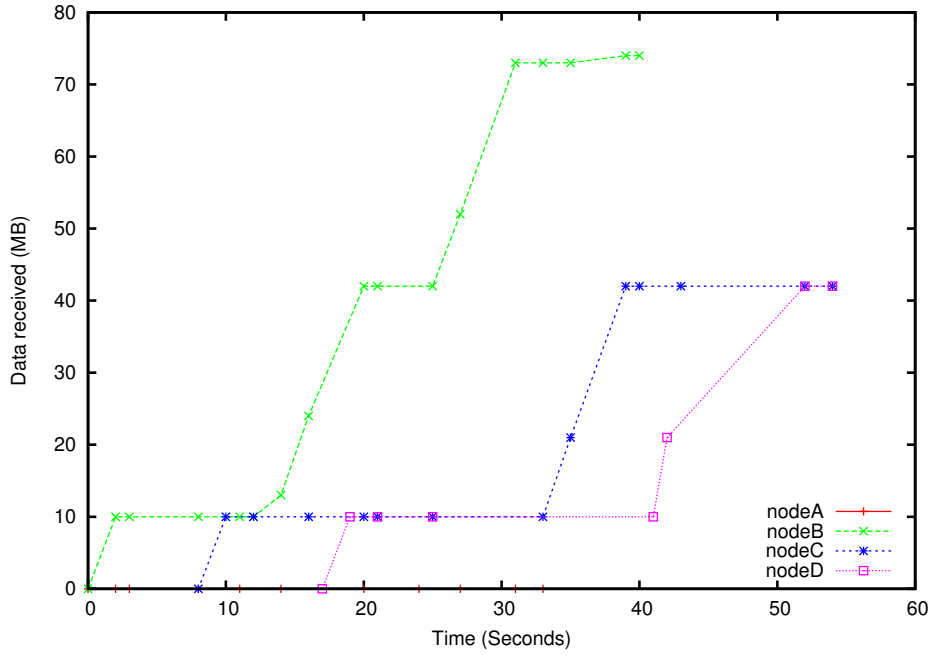


Figure 6: Program running using SCP. A 10MB file filled with random data is being sent every 10 seconds to node A for thirty seconds.

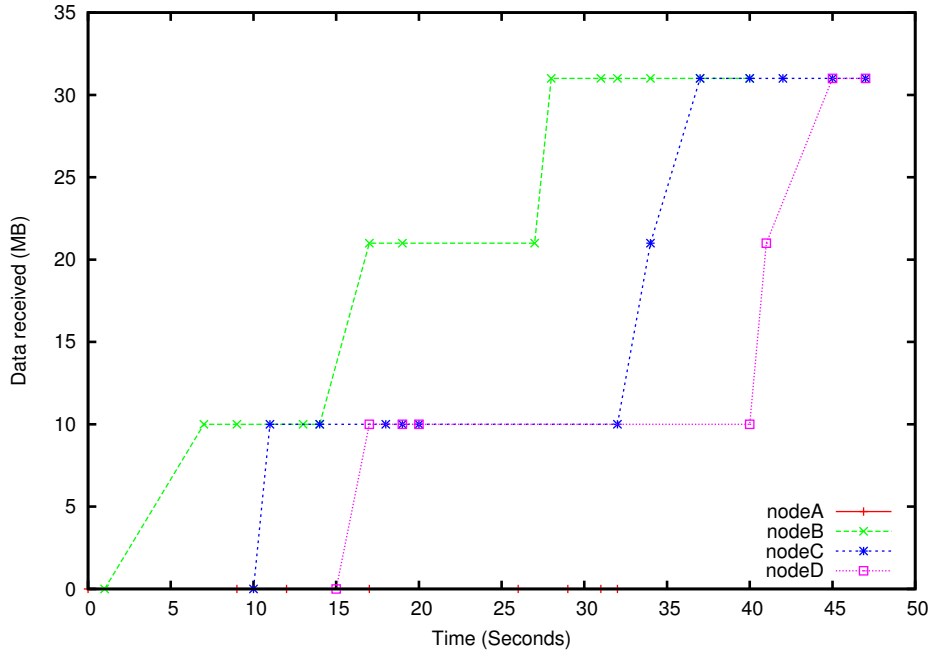


Figure 7: Program running using Rsync. A 10MB file filled with random data is being sent every 10 seconds to node A for thirty seconds.

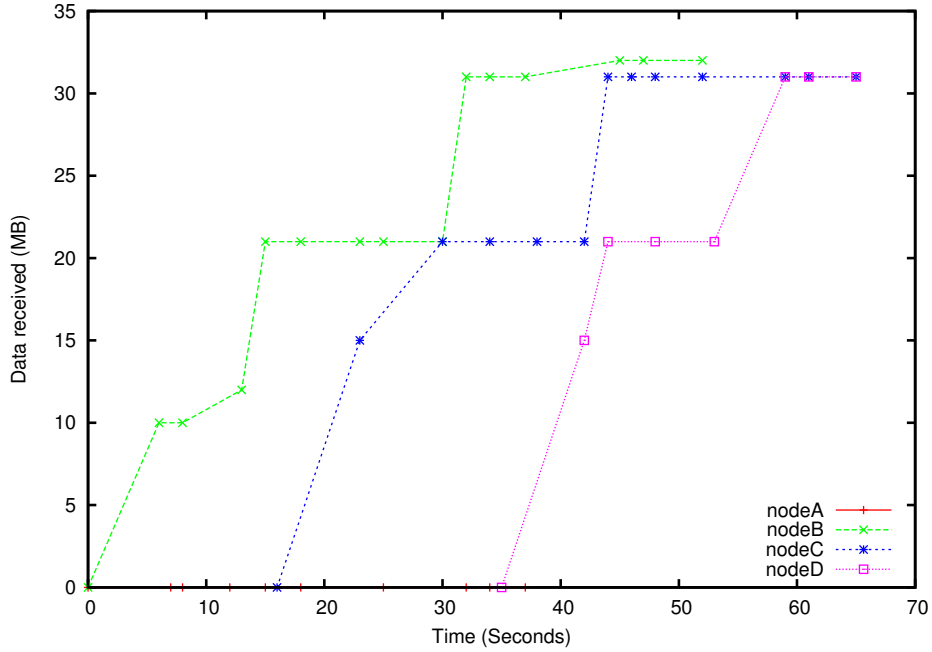
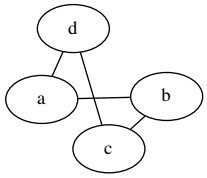
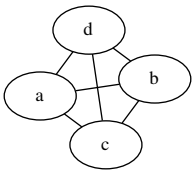


Figure 8: Program running using Unison. A 10MB file filled with random data is being sent every 10 seconds to node A for thirty seconds.

My program ran smoothly on a line topology so I set-up some new topologies as shown in Figure 9a and Figure 9b. These were the topology graphs generated by my set-up scripts (see Section 2.1) I designed them to be a circle (Figure 9a), although it does not look like a circle this is how Neato represented the topology, and a connected mesh (Figure 9b). My program ran as expected with the topologies that I tested it on. Figure 10 shows the results of the circle topology test case. Figure 11 contains the mesh topology results. These are both graphs of the program running using Unison. In both cases each node received ≈30MB of data which means each node received all of the changes created on node A and that my program successfully replicated data to all nodes in the network. You can see in Figure 11 that the changes propagated through the graph in a different order to Figure 10 this was to be expected given the more connected nature of the nodes in the mesh graph. With the completion of these tests I had achieved one of my main objectives; to have my program running over different network topologies.



(a) Generated graph of circle topology



(b) Generated graph of mesh topology

Figure 9: Topology graphs

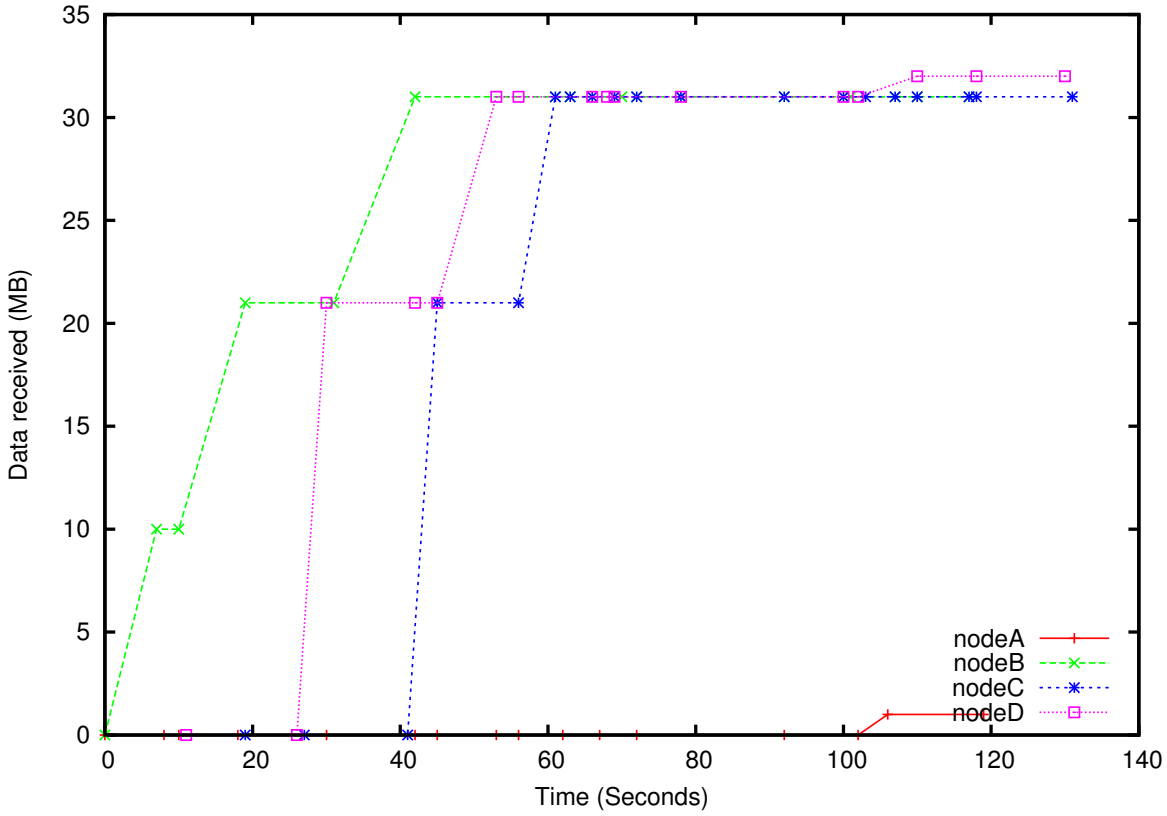


Figure 10: My program running using Unison on a circle topology. A 10MB file filled with random data is being sent every 10 seconds to node A for thirty seconds.

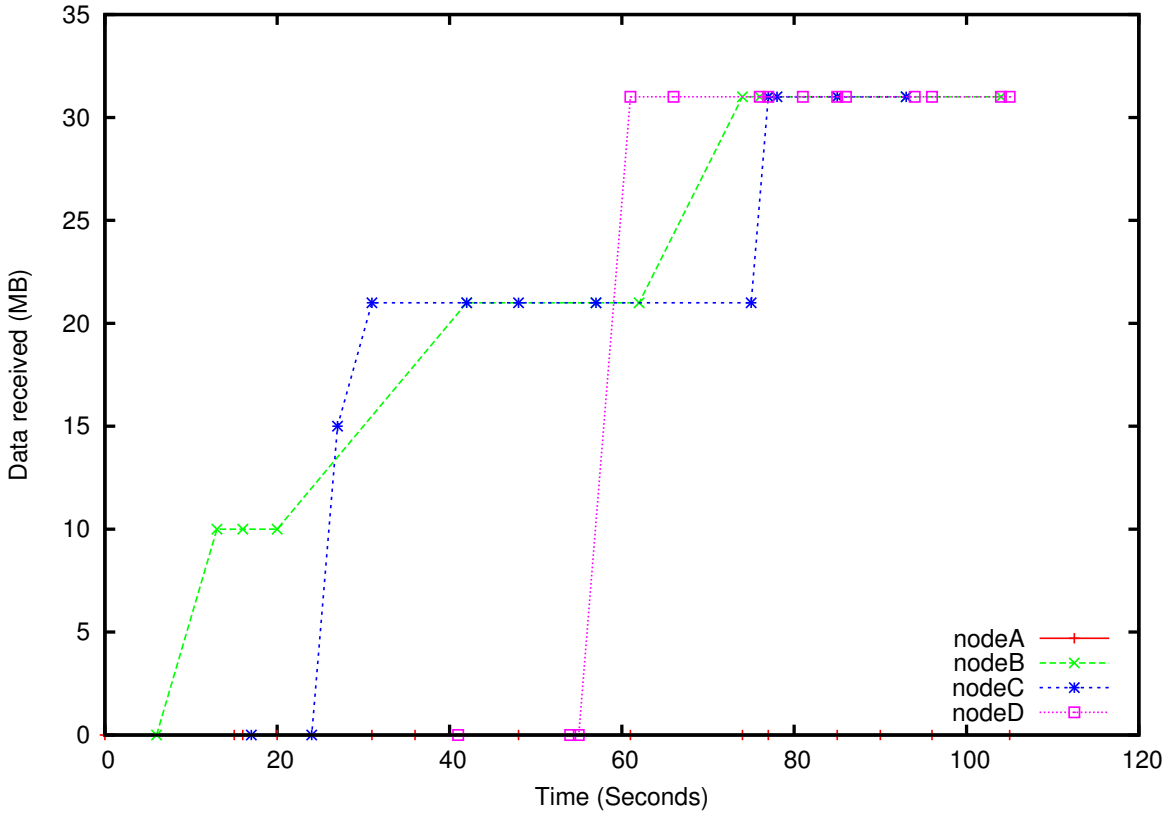


Figure 11: My program running using Unison on a mesh topology. A 10MB file filled with random data is being sent every 10 seconds to node A for thirty seconds.

4.3 When to stop copying

The way my program works is that each node notices when changes have occurred to a folder it is watching and when a change occurs, it copies these changes to other nodes specified in the configuration file. After testing my program on some simple topologies one problem became clear; if the changes came from one of its neighbour nodes the node would notice the change and send data back to its neighbour this would cause an infinite loop of two nodes trying to copy changes to each other. When using Unison this was not as much of a problem because Unison can detect that no changes had occurred between the nodes and would stop synchronising after one check (which had minimal overhead). However for SCP this was a big issue.

Figure 12 shows each node receives more data than it should. Node B and node C receive over 120MB worth of data even though there was only 30MB worth of changes and node A receives over 60MB even though it was the source of the file changes. My program would have run forever if I had not stopped it.

The data points in Figure 13 show that when using Unison, although no extra data was sent, Unison still had to make checks to see whether there were any changes or not.

To fix this problem I used a control file. Each time a node synchronised with another

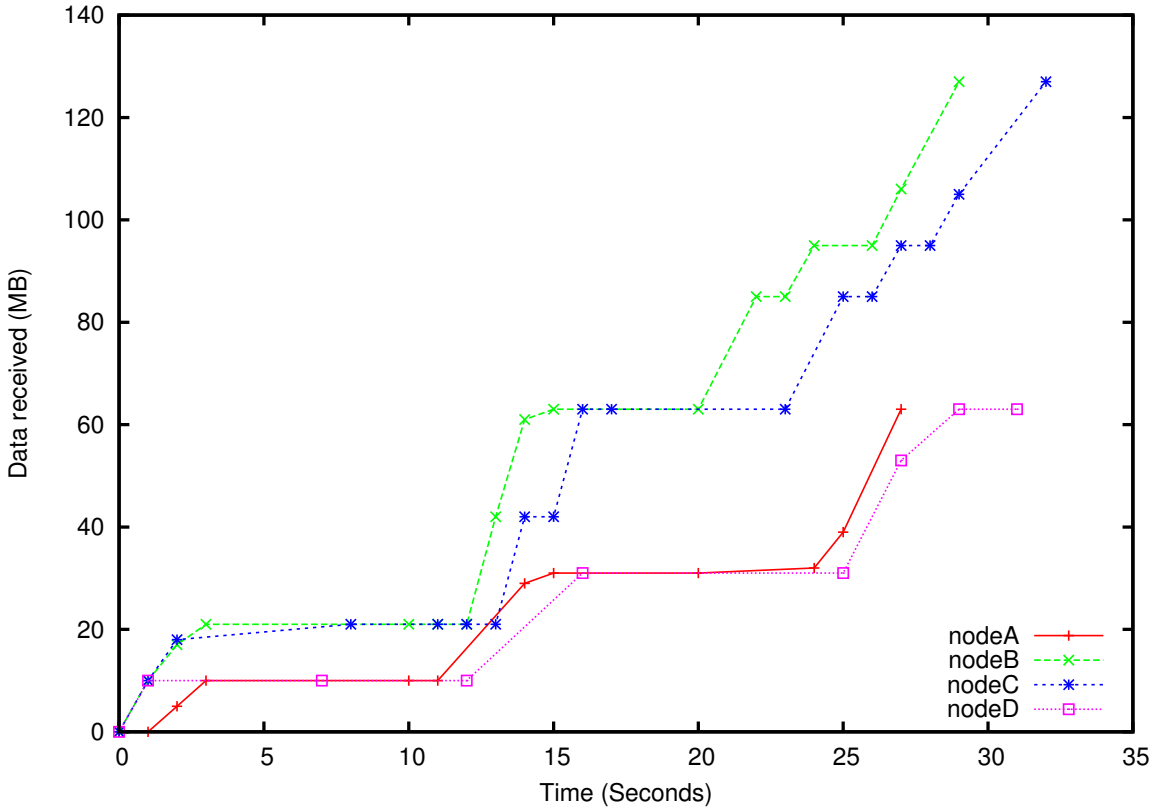


Figure 12: My program using SCP running on a line topology. 10MB files are being sent every ten seconds to node A. All of the nodes receive more data than they should because they are constantly propagating changes to their neighbours.

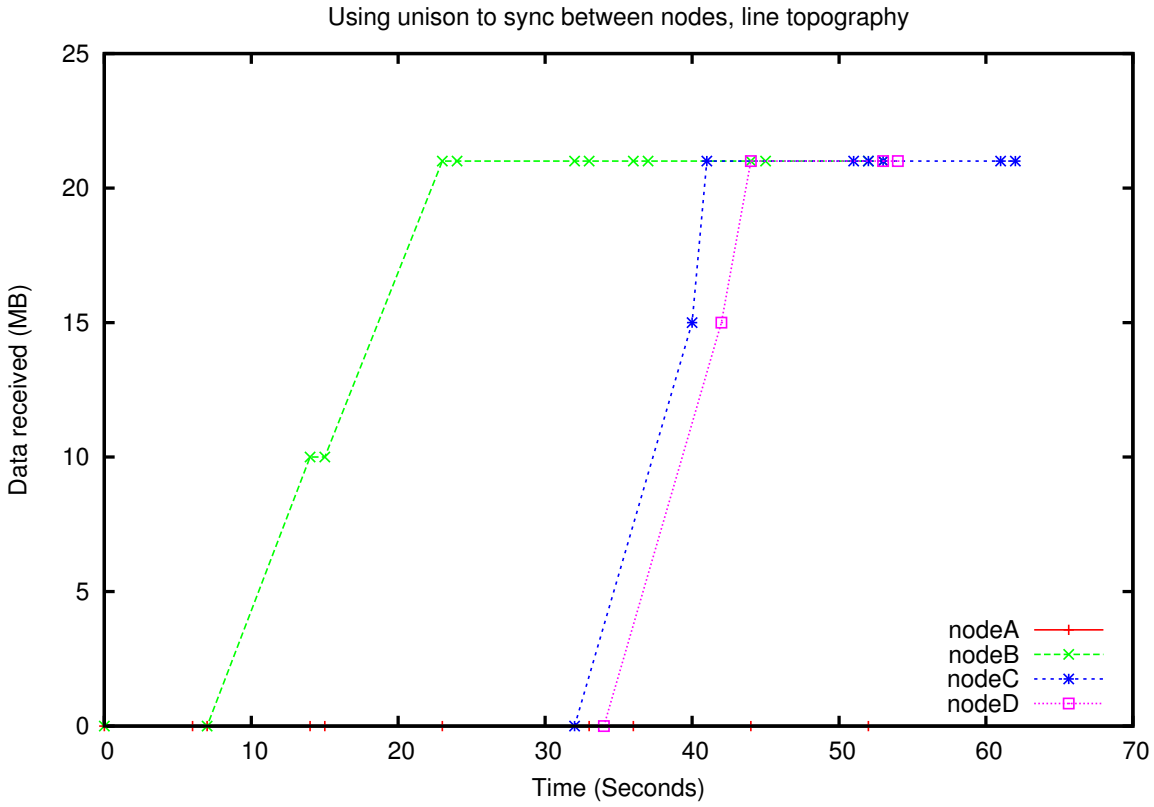


Figure 13: Line topology, using Unison, program continues to check for differences in files even after all nodes are the same. Each point represents an attempted sync.

node it would write out a control file telling the other node what files had been copied, who sent them and what the modification times of the files were. In this way a node could check if it was about to synchronise a file back to the node it had just received the file from, or if local changes really had occurred to that file that were newer than a received file it should continue with its sync.

4.4 How often to sync

So how often should I sync once I notice a change? If lots of small changes are occurring frequently it might be more efficient to perform a synchronisation after several changes have occurred. Given that there is overhead with each synchronisation, fewer copies means less data sent over the network.

Figures 14, 15, 16, and 17 show my program running using Unison to sync 10MB over a network arranged in a line topology. The files were moved into the watched directory in ten second intervals. You can see that there is not much difference between the graphs except Figure 14 where the time taken for all of the nodes to become up to date is shorter than the others. In the case of Unison it is best just to sync as often as possible because Unison only sends file differences. The only saving when sending multiple changes at a time is on the SSH overhead and the overhead associated with Unison comparing the files. This overhead is negligible when the files are of any meaningful size.

Figures 18, 19, 21, and 22 show the same 10MB files being transferred every 10 seconds over the same line topology as previously mentioned except I used the SCP option on my program for these tests. Figure 21 shows that (20 second delay) the time taken for all nodes to get the changes was less than in Figure 22 (30 second delay) You can also notice that when the delay was set to less than or equal to the time the files were being created (10 seconds) that my program behaved in an erratic fashion with some nodes receiving less data than others. This could indicate an error in my program or that the data simply takes an odd way through the graph as it is being replicated as soon as possible. The data is still replicated in full to each node in the graph however. You can see that in Figure 20 that the graph became more uniform as soon as I increased the delay to 11 seconds.

These results reinforced my idea that the delay should be set through a configuration file since the appropriate delay will vary based on how often the files change. This is currently the case with my program, users can set a different (or the same) delay for each folder that they are watching. I also allow the user to use the '*' wild card character to tell the program to sync as often as possible. Based on my findings I would recommend to any user that the delay time be greater than the average time between modification of the files but as short as possible as long delay times slow down replication proportional to the delay time. If the user is using Unison they should set the delay time to be '*' (sync as often as possible) unless they are trying to synchronise very small files.

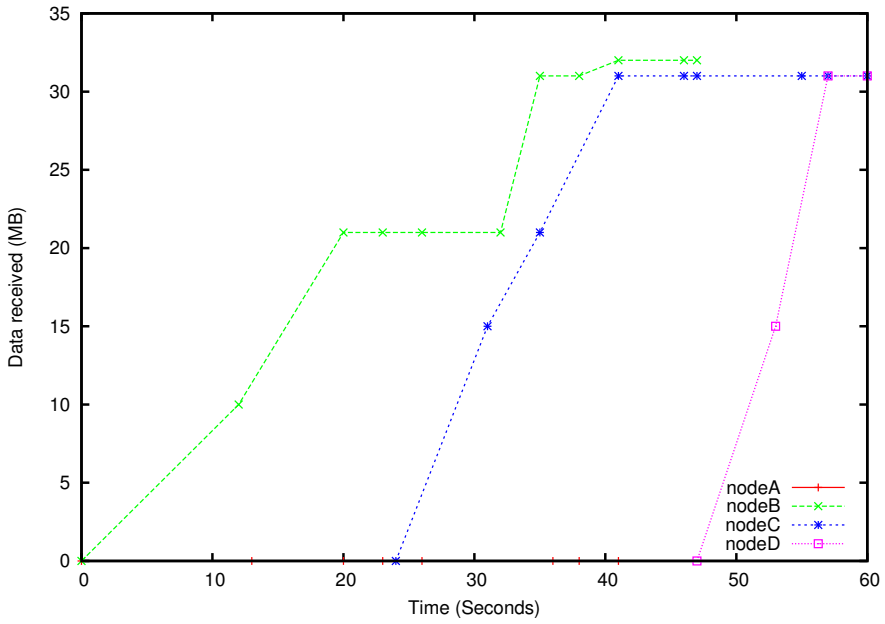


Figure 14: My program running on a line topology using Unison. The delay to synchronise time is set to five seconds. 10MB files are being sent every ten seconds to node A. The graph shows the amount of data received by each node.

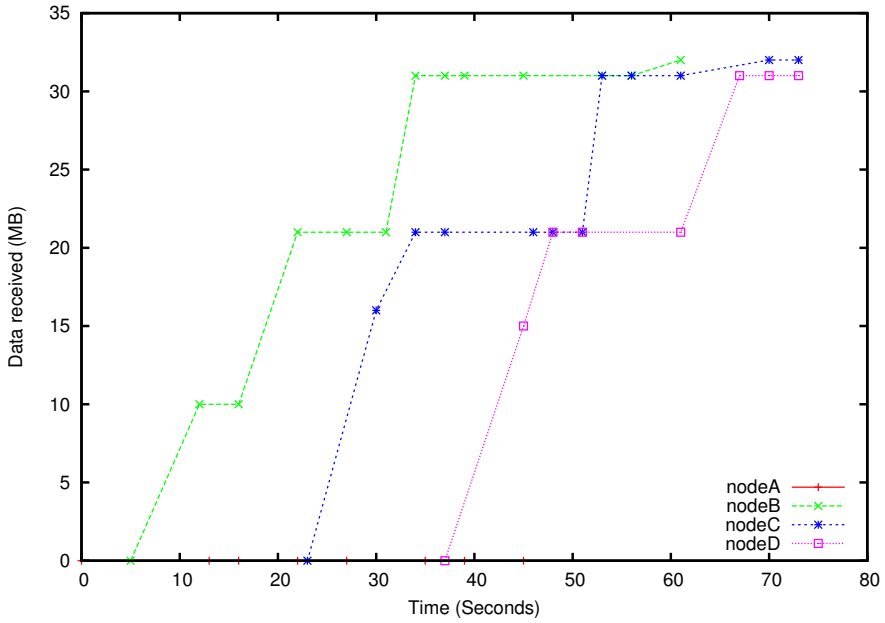


Figure 15: My program running on a line topology using Unison. The delay to synchronise time is set to ten seconds. 10MB files are being sent every ten seconds to node A. The graph shows the amount of data received by each node.

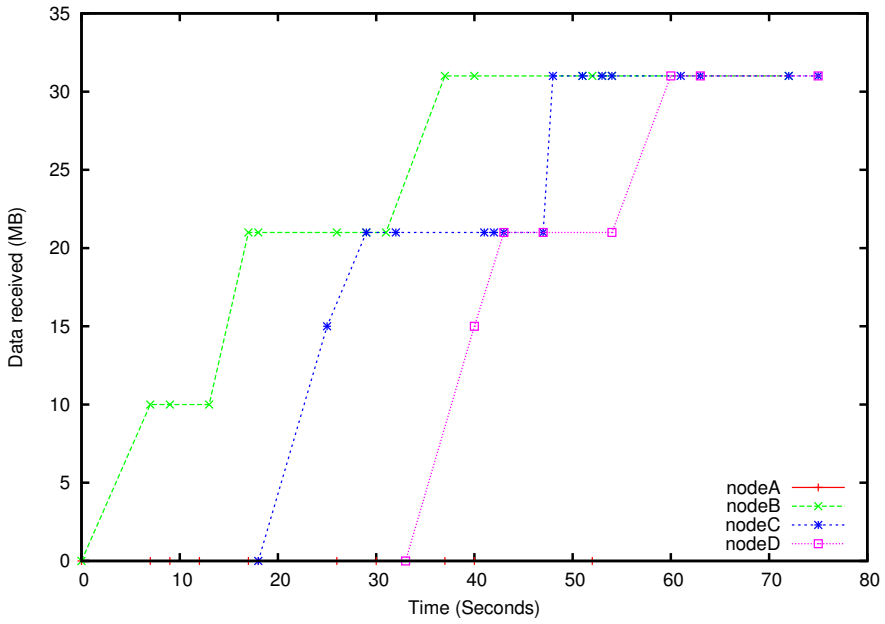


Figure 16: My program running on a line topology using Unison. The delay to synchronise time is set to twenty seconds. 10MB files are being sent every ten seconds to node A. The graph shows the amount of data received by each node.

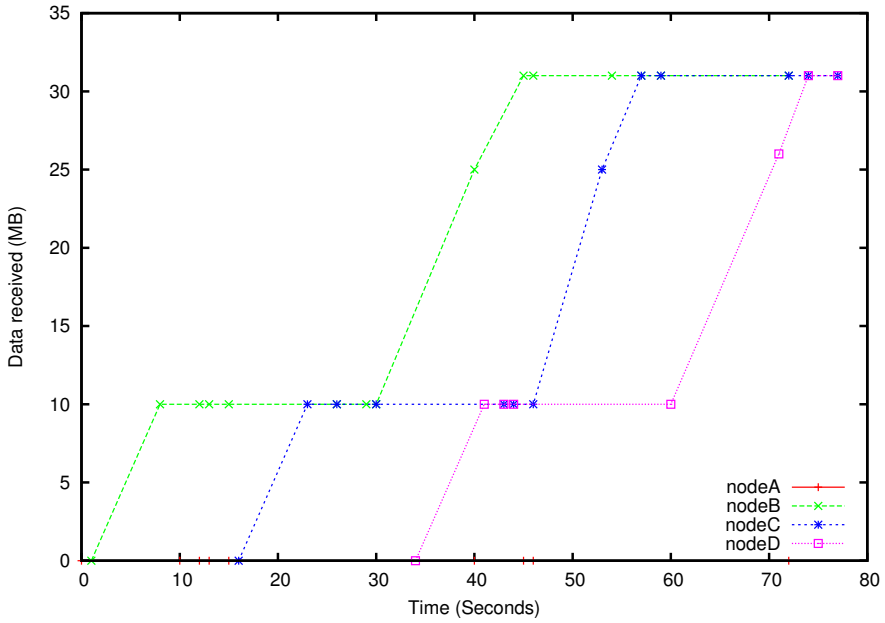


Figure 17: My program running on a line topology using Unison. The delay to synchronise time is set to thirty seconds. 10MB files are being sent every ten seconds to node A. The graph shows the amount of data received by each node.

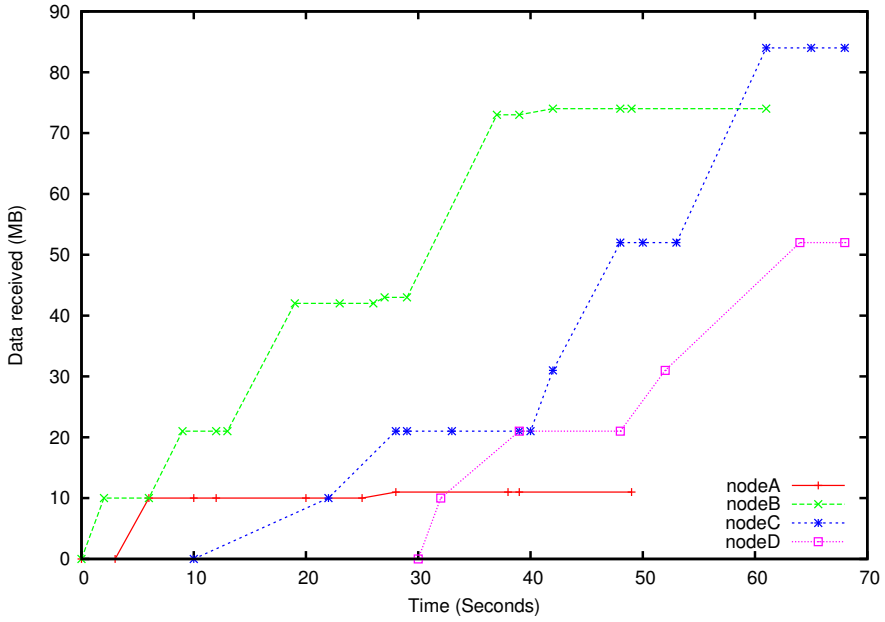


Figure 18: My program running on a line topology using SCP. The delay to synchronise time is set to five seconds. 10MB files are being sent every ten seconds to node A. The graph shows the amount of data received by each node.

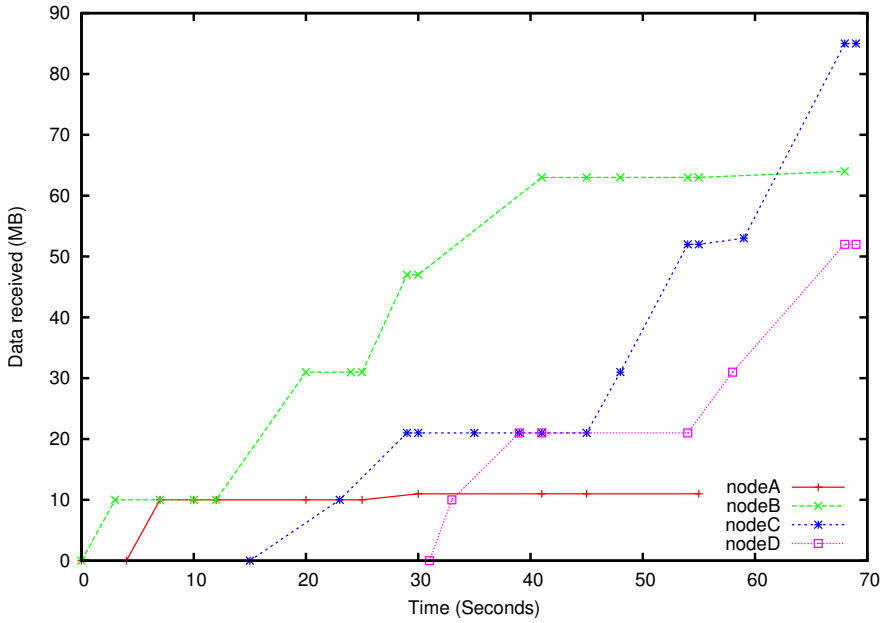


Figure 19: My program running on a line topology using SCP. The delay to synchronise time is set to ten seconds. 10MB files are being sent every ten seconds to node A. The graph shows the amount of data received by each node.

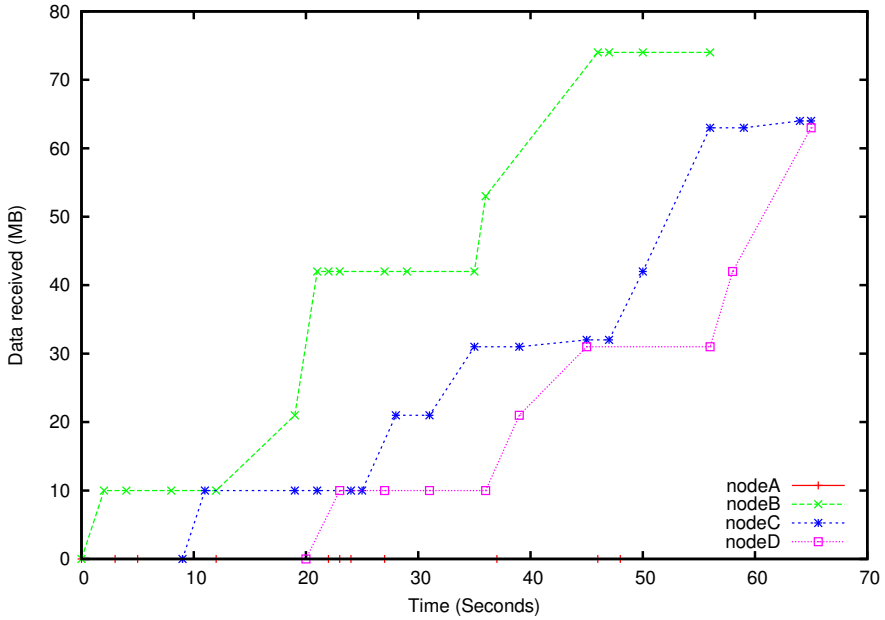


Figure 20: My program running on a line topology using SCP. The delay to synchronise time is set to eleven seconds. 10MB files are being sent every ten seconds to node A. The graph shows the amount of data received by each node.

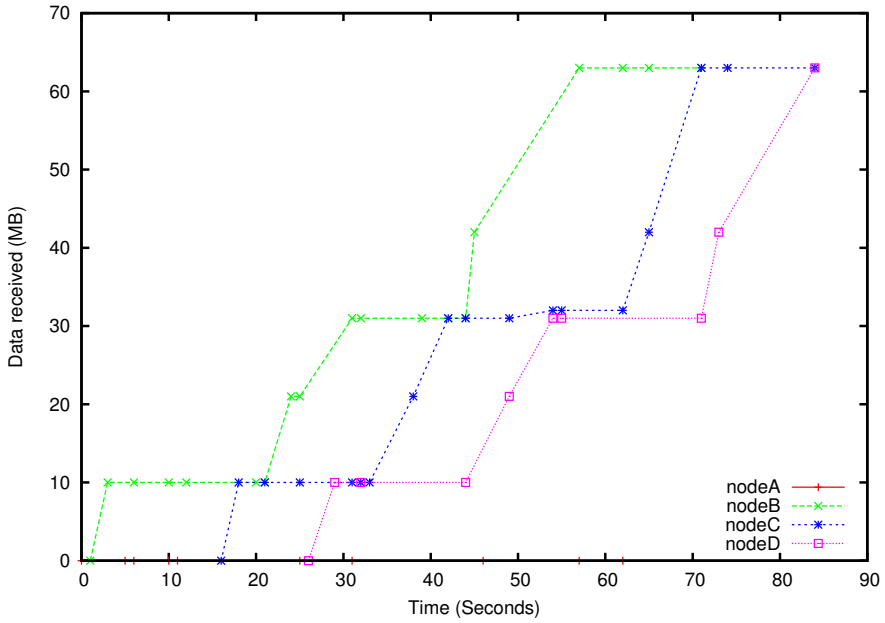


Figure 21: My program running on a line topology using SCP. The delay to synchronise time is set to twenty seconds. 10MB files are being sent every ten seconds to node A. The graph shows the amount of data received by each node.

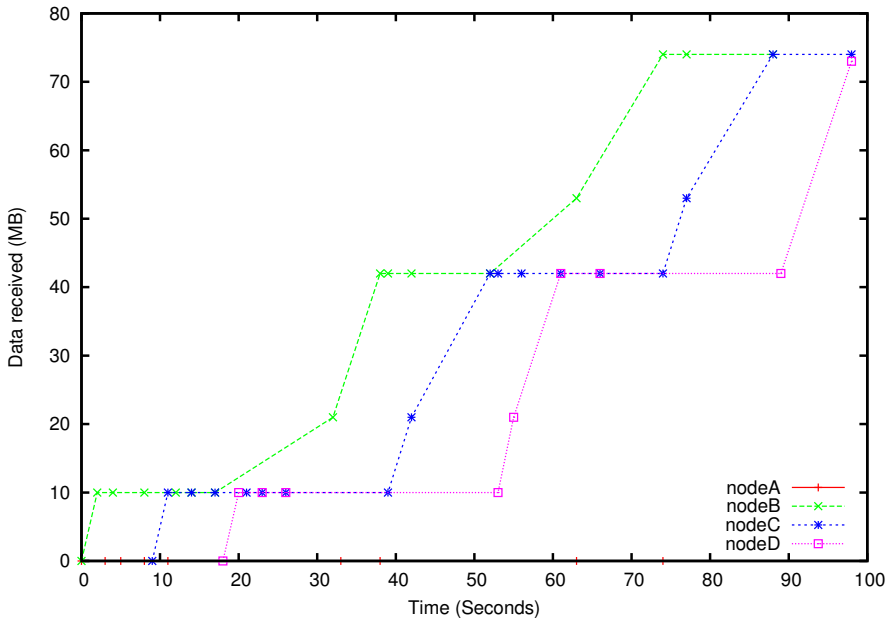


Figure 22: My program running on a line topology using SCP. The delay to synchronise time is set to thirty seconds. 10MB files are being sent every ten seconds to node A. The graph shows the amount of data received by each node.

4.5 Wi-Fi vs 3G

An important use case of my program was where one machine was connected by a link that a user would not want to use very often. For example a node might be connected by a 3G link which is slow and expensive to use. I wanted to make sure that my program could be set to prefer some links to others. For example to use Wi-Fi whenever possible and try not to use 3G. I designated the link between node A and node B as a 3G link in my circle topology (see Figure 9a in Section 4.2). Node A is linked directly to node B by a slow link and indirectly by fast links (Wi-Fi link to node D, node D links to node C and node C links to node B all designated as Wi-Fi links). Previously in Figure 10 (Section 4.2) node A sent data to node B and D which then propagated to node C. In Figure 23 node B receives data last only after nodes D and C have got the changes. This is because I set the delay time to 100 seconds between node A and node B as if it were a 3G link that we do not want to use very often. All the other nodes had delay times of 10 seconds on their links. My program spawns multiple threads for each link when a change has occurred in a watched directory. The thread for the 3G link then sleeps for 100 seconds and when it wakes looks at the control files of the remote machine to see that it already has the changes node A was going to send so it aborts. Node B has already got the files because they travelled through the graph in the other direction and reached node B before A was ready to send.

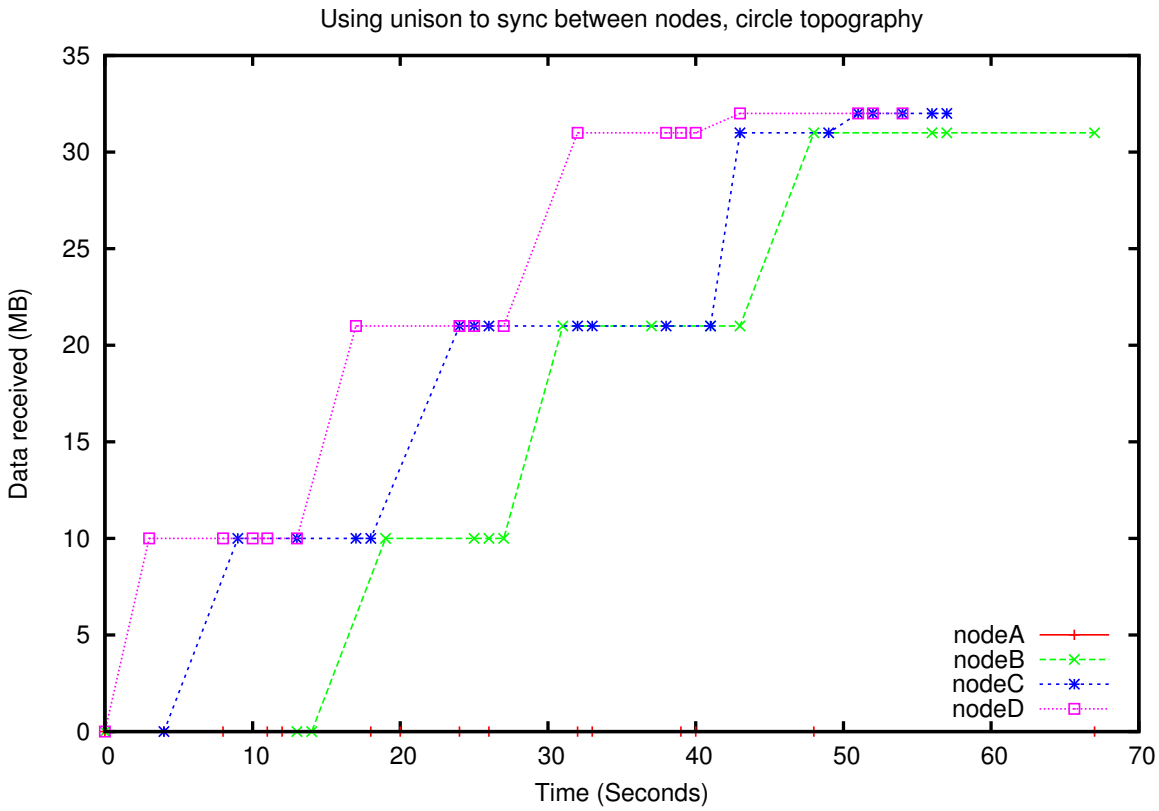


Figure 23: Node A is connected to node B by 3G, the other links are all Wi-Fi. Three 10MB files are sent to node A over ten second intervals. Node A has a longer delay on sending over 3G than Wi-Fi and node B is the last node to receive the changes.

5 Future Work

My project ended up requiring a lot of initial set-up time getting the testing infrastructure ready to produce different networks and graphs without requiring user input. As such this drew time away from other areas of research that I had originally planned to investigate. The main two areas that I would liked to have spent more time looking at were mobile nodes and user/system feedback of data. When nodes leave and join the graph *i.e.* when nodes leave a network and then join a new network, or rejoin the old one I call this a mobile node. I would also have been interested in seeing how I could have improved the performance of the program using the statistics the program gathers as it runs.

5.1 Mobile nodes

Connections between nodes in the graph (edges) may change over time. This could be because one of the nodes is a laptop and joins different networks at different times or because a network/machine is unreliable and is not up at a given point in time. I have represented edges that behave in this way as grey on the diagram below. I will refer to nodes with grey edges as 'mobile' nodes.

It would have been interesting to see how mobile nodes affect how up to date the nodes in the graph are. I predict that nodes that are not available for very long periods would lag behind others that are available. I wanted to see what would be the most effective way of getting these mobile nodes up to date quickly. Giving mobile nodes priority over normal nodes might be one solution. I expect that if a mobile node is a link between two parts of the network that these two parts will fall out of synchronisation when the node leaves the graph. I wanted to look at how nodes in the graph may rely less on unreliable edges. I would like my program to associate a cost with each edge and prioritise edges with lower costs when synchronising data. Another option would be to preference reliable edges and only fall back to using unreliable edges when necessary. Classifying edges could be done by cost or by how often an edge is available.

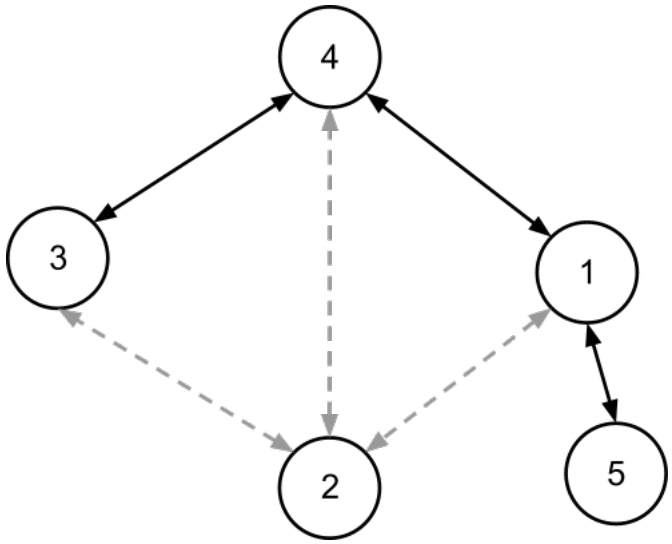


Figure 24: Node two intermittently has a connection to a subset of nodes 1, 3 and 4. The edges in grey are links that are not always present.

5.2 Feedback

My program currently keeps detailed logs of the system state. Logs are kept of the amount of data transferred between the machines; which files were updated and when; and the last time the data being watched was updated by another client (see Section 2.2 for more details on logging). I currently have scripts to generate graphs of the data used and the time taken for the graph to become up to date. I would have liked to integrate these scripts into my program to show an end user a graphical representation of the program running. Integrating my current graph scripts should be easy since these scripts are written in python and so is my main program. What would have been very interesting to look at would be to see if I could use data gathered from previous runs of the program to see if my program could estimate future performance based on changes made to the settings file (like how often to sync a given sub-node). I envisaged each of the clients sharing their data with each other to get a view of the network as a whole and then looking at nodes that were out of date as candidates for a shorter sync delay time *etc.* In hindsight I think that this would have been quite an undertaking, requiring significant time to develop and should not have been in the scope of this project.

6 Conclusion

In this dissertation I discussed the need for a private file synchronisation tool. I outlined the faults with current synchronisation tools such as Dropbox. My program aims to address these shortcomings. I detailed the implementation details of my program and the design decisions I made. I showed how I changed my design when I came across issues. I tested my program in as many different situations that I thought would be useful. I have shown that my program performs better than naïve copying, works in a variety of situations and behaves in general how I expect it too. I achieved my goals of creating a decentralised file synchronisation tool that will run across any network configuration. My program allows for fine-grained user control of settings such as which files should be replicated and how often they should be synchronised. My program generates logs of data transferred and the files being synchronised. This did not lead to detailed statistics about how the program behaved or heuristics on future behaviour as I intended. However I was able to generate graphs from my log files and this could be extended in a future implementation of my program. Once the user has written their configuration files the program operates autonomously as intended. My program has been a success and does its job of replicating files well.

A Program listings

A.1 WatchAndSync.py

```
1  import pyinotify, os, subprocess, argparse, socket, time, glob
       , datetime
2  import readnet
3
4  wm = pyinotify.WatchManager()
5  watchedfolders = {}
6  homepath = "/home/cal/Documents/Private-Sync/"
7  #homepath = "/Users/calum/Documents/Private-Sync/"
8
9  parser = argparse.ArgumentParser()
10 parser.add_argument("-c","--scp",action="store_true",help="
       Copy using scp")
11 parser.add_argument("-r","--rsync",action="store_true",help="
       Copy using rsync")
12 args = parser.parse_args()
13
14 class Tools():
15     def updateFolderInfo(self, wfolds):
16         f = open('./folders.dat','w')
17         for fold in wfolds:
18             f.write(fold + " ")
19             for i in range(0,len(wfolds[fold])-1):
20                 f.write(wfolds[fold][i] + " ")
21             f.write(wfolds[fold][len(wfolds[fold])-1] + "\n")
22         f.close()
23
24     def timeElapsed(self, dtstamp, diff):
25         if diff == "*":
26             print "Sync ASAP"
27             return
28         diff = int(diff)
29         FMT = '%Y-%m-%d %H:%M:%S.%f'
30         #FMT = '%Y-%m-%d %H:%M:%S'
31         tdelta = datetime.datetime.now() - datetime.datetime.
               strptime(dtstamp, FMT)
32         print  tdelta.total_seconds()
33         timeDiff = tdelta.total_seconds()
34         if (timeDiff >= diff):
35             print "Time period reached"
```

```
36          else:
37              print "Time not elapsed, sleeping for " + str(diff
                    - timeDiff + 1)
38              time.sleep(int(diff - timeDiff + 1))
39
40  class MyEventHandler(pyinotify.ProcessEvent):
41      def flipIP(self,ip):
42          octets = ip.split(".")
43          if(octets[3] == "1"):
44              octets[3] = "2"
45          elif(octets[3] == "2"):
46              octets[3] = "1"
47          else:
48              octets[3] = "1"
49          return ".".join(octets)
50
51      #Get the last modified time of a file
52      def getModTime(self,path):
53          try:
54              return time.ctime(os.path.getmtime(path))
55          except Exception, e:
56              return time.ctime(0)
57
58      #Deprecated - Check for IP not to copy too
59      def getStopInfo(self):
60          stopIP = ["",""]
61          try:
62              o = open("./stop",'r')
63              stopIP = o.read().split()
64              o.close()
65          except IOError, e:
66              pass
67          return stopIP
68
69      def inStopFile(self,ip,path):
70          stopIPs = {}
71          stop = False
72          modTime = self.getModTime(path)
73          while True:
74              tmpcount = 0
75              print "Files found: " + str(glob.glob("Stop-*"))
76              for files in glob.glob("Stop-*"):
77                  #print "File: " + str(files)
```

```
78                  if ".tmp" in files:
79                      tmpcount += 1
80                      time.sleep(5)
81                      break
82                  f = open(files,"r");
83                  for line in f:
84                      l = line.split()
85                      if self.exclusions(l[1]):
86                          print str(l[1]) + " was in ignore file
                               skipping"
87                      else:
88                          print "local " + str(path) + " modtime
                               : " + modTime
89                          print "Stop " + l[1] + " modtime: " +
                               str(l[2:])
90                          ts1 = time.strptime(modTime,"%a %b %d
                               %H:%M:%S %Y")
91                          ts2 = time.strptime(" ".join(l[2:]),"%
                               a %b %d %H:%M:%S %Y")
92                          print "local <= stop: " + str(ts1 <=
                               ts2)
93                          #if l[0] == ip and l[1] == path and
                               ts1 <= ts2:
94                          #If IP sending to has sent data more
                               recently don't send back
95                          if l[0] == ip and ts1 <= ts2:
96                              print "Stop = True, file: " + l[0]
97                              stop = True
98                          else:
99                              stopIPs[l[0]] = [l[1]," ".join(l
                                   [2:])]
100
101                 if stop:
102                     f.close()
103                     #f = open(files,"w")
104                     #for k in stopIPs.keys():
105                     #    f.write(k + " " + stopIPs[k][0] + " "
                            + stopIPs[k][1] + "\n")
106                     #f.close()
107                     #stopIPs.clear()
108                     return True
109
110                 f.close()
```

```
111                 #stopIPs.clear()
112             if tmpcount == 0:
113                 break
114
115         return False
116
117     #Set flag on other server telling it not to immediately
        try and copy data here
118     def setStopFileUniq(self,ip,myIP,path,folder):
119         nodename = self.getNodeName()
120         #print "ssh",ip,"echo " + myIP + " " + path + " " +
            self.getModTime(path) + " >> " + homepath + "Stop-"
            + nodename + ".tmp;"
121         #subprocess.call(["ssh",ip,"echo " + myIP + " " + path
            + " " + self.getModTime(path) + " >> " + homepath +
            "Stop-" + nodename + ".tmp;"])
122         subprocess.call(["ssh",ip,"rm " + homepath + "Stop-" +
            nodename + ".tmp;"])
123         for cpFile in glob.glob(folder + "/*"):
124             subprocess.call(["ssh",ip,"echo " + myIP + " " +
                cpFile + " " + self.getModTime(cpFile) + " >> "
                + homepath + "Stop-" + nodename + ".tmp;"])
125
126     #Sets the config files on the remote node
127     def beginCopy(self, ip):
128         nodename = self.getNodeName()
129         print "ssh",ip,"touch " + homepath + "Stop-" +
            nodename + ".tmp; mv " + homepath + "Stop-" +
            nodename + " " + homepath + "Stop-" + nodename + ".
            tmp;"
130         subprocess.call(["ssh",ip,"touch " + homepath + "Stop-
            " + nodename + ".tmp; mv " + homepath + "Stop-" +
            nodename + " " + homepath + "Stop-" + nodename + ".
            tmp;"])
131
132     #Moves the Stop files back into place
133     def endCopy(self, ip):
134         nodename = self.getNodeName()
135         print "ssh",ip,"mv " + homepath + "Stop-" + nodename +
            ".tmp " + homepath + "Stop-" + nodename
136         subprocess.call(["ssh",ip,"mv " + homepath + "Stop-" +
            nodename + ".tmp " + homepath + "Stop-" + nodename
            ])
```

```
137
138     def setLastSync(self):
139         #print "echo \"" + str(datetime.datetime.now())+ "\" >
                " + homepath + "lastSync"
140         #subprocess.call(["echo", str(datetime.datetime.now())
                + " > " + homepath + "lastSync"])
141         f = open(homepath + "lastSync","w")
142         f.write(str(datetime.datetime.now()))
143         f.close()
144
145     def getLastSync(self):
146         f = open(homepath + "lastSync","r")
147         time = f.read()
148         f.close()
149         return time.rstrip()
150
151     def newerThanLast(self, fileName):
152         stop = False
153         print "Last sync time: " + str(self.getLastSync())
154         FMT = '%Y-%m-%d %H:%M:%S.%f'
155         #datetime.datetime.strptime(dtstamp, FMT)
156         ts2 = time.strptime(self.getLastSync(),FMT)
157         modTime = self.getModTime(fileName)
158         print "local " + str(fileName) + " modtime: " +
              modTime
159         ts1 = time.strptime(modTime,"%a %b %d %H:%M:%S %Y")
160         print "local <= stop: " + str(ts1 <= ts2)
161         if ts1 > ts2:
162             print "Newer file than last sync!"
163             stop = True
164         return stop
165
166
167     #Get node name from whoami file
168     def getNodeName(self):
169         w = open(homepath + "whoami","r")
170         nodename = w.read()
171         nodename = nodename[0].upper()
172         w.close()
173         return nodename
174
175     #Deprecated stop file
176     def setStopFile(self,ip,myIP,path):
```

```
177         subprocess.call(["ssh",ip,"echo " + myIP + " " + path
                + ">" + homepath + "stop"])
178         print "ssh",ip,"echo " + myIP + ">" + homepath + "
                stop"
179
180     def rmTree(self,path):
181         subprocess.call(["ssh",ip,"rm -r '" + path + "'"])
182         print "ssh",ip,"rm -r '" + path + "'"
183
184     #Exclude files matching patterns in the ignore file
185     def exclusions(self, path):
186         try:
187             f = open("./ignore",'r')
188             for line in f:
189                 if line.rstrip() in path:
190                     #print "Ignoring: " + path
191                     return True
192             f.close()
193         except error, e:
194             print e
195         return False
196
197     def initFileSync(self,event):
198         if self.exclusions(event.pathname):
199             #print "Excluded returning"
200             return
201         pathparts = event.pathname.split("/")
202         foldName = "/".join(pathparts[0:len(pathparts)-1])
203
204         print "Removing watch on: " + foldName
205         wm.rm_watch(wm.get_wd(foldName), rec=True)
206
207         self.setLastSync()
208         self.fileSync(event.pathname)
209
210         print "Putting watch back on: " + foldName
211         wm.add_watch(foldName.rstrip(),pyinotify.ALL_EVENTS,
                rec=True, auto_add=True)
212
213         for i in range(0, len(watchedfolders[foldName]),4):
214         #     ip = watchedfolders[foldName][i]
215         #     myIP = readnet.getMyIP(ip)
216             for f in glob.glob(foldName + "/*"):
```

```
217                 if self.newerThanLast(f):
218                     print "init: CONTINUE"
219                     self.setLastSync()
220                     self.fileSync(f)
221                 else:
222                     print "init: STOP"
223 
224     #Sync the files
225     def fileSync(self,pathname):
226         t = Tools()
227         if os.path.isdir(pathname):
228             print "Watching: ",pathname
229         for folder in watchedfolders.keys():
230             print "For each folder: " + str(folder) + " in
                    watchedfolder keys"
231             if folder in pathname:
232                 for i in range(0, len(watchedfolders[folder])
                        ,4):
233                     ip = watchedfolders[folder][i]
234                     path = watchedfolders[folder][i+1]
235                     waitTime = watchedfolders[folder][i+2]
236                     lastTime = watchedfolders[folder][i+3]
237                     print "Wait: " + str(waitTime) + " Last: "
                            + str(lastTime)
238                     print "Current ip and path: " + ip + " " +
                            path
239                     readnet.logIPtraffic(ip, pathname)
240                     myIP = readnet.getMyIP(ip)
241                     subprocess.call(["ssh",ip,"/usr/bin/python
                        " + homepath + "readnet.py -i " + myIP
                        + " -f " + pathname])
242                     print "ssh",ip,"'/usr/bin/python " +
                        homepath + "readnet.py -i " + myIP + " -
                        f " + pathname + "'"
243                     fparts = folder.split("/")
244                     fname = fparts[len(fparts)-1]
245                     #stopIP = self.getStopInfo()
246                     #print "STOP: " + stopIP[0] + " " + stopIP
                            [1]
247                     #if stopIP[0] == ip and stopIP[1] ==
                            pathname:
248                     if self.inStopFile(ip,pathname):
249                         print "STOPPED to " + ip + " " + path
```

```
250                         #os.remove("./stop");
251                     else:
252                         print "CONTINUE"
253                         t.timeElapsed(lastTime, waitTime)
254                         watchedfolders[folder][i+3] = str(
                                datetime.datetime.now())
255                         t.updateFolderInfo(watchedfolders)
256                         self.beginCopy(ip)
257                         self.beginCopy(myIP)
258                         if args.scp:
259                             #print "SCP: For cpFile in " +
                                    folder
260                             for cpFile in glob.glob(folder + "
                                    /*"):
261                                 #print "SCP GLOB:" + cpFile
262                                 print "scp","-rp",cpFile,ip +
                                        ":" + cpFile + ".tmp"
263                                 subprocess.call(["scp","-rp",
                                        cpFile,ip + ":" + cpFile + "
                                        .tmp"])
264                                 #subprocess.call(["ssh",ip,"
                                        yes y | find /tmp/" + fname
                                        + " -type f -exec cp -p {} "
                                         + path + fname + "/ \; rm /
                                        tmp/" + fname])
265                                 print "ssh",ip,"mv " + cpFile
                                        + ".tmp " + cpFile
266                                 subprocess.call(["ssh",ip,"mv "
                                        + cpFile + ".tmp " +
                                        cpFile])
267                                 print "END SCP GLOB"
268                         elif args.rsync:
269                             print "rsync","-rt",folder,ip + ":
                                    " + path
270                             subprocess.call(["rsync","-rt",
                                    folder,ip + ":" + path])
271                         else:
272                             time.sleep(5)
273                             print "unison","-batch","-
                                    confirmbigdel=false","-times",
                                    folder,"ssh://" + ip + "/" +
                                    path + fname
```

```
274                                 subprocess.call(["unison","-batch"
                                        ,"-confirmbigdel=false","-times"
                                        ,folder,"ssh://" + ip + "/" +
                                        path + fname])
275                             print "Set stop files uniq: " +
                                    pathname
276                             #Set stop file on foreign host
277                             self.setStopFileUniq(ip,myIP,pathname,
                                    folder)
278                             #Set stop file for myself to look at
279                             self.setStopFileUniq(myIP,myIP,
                                    pathname,folder)
280                             self.endCopy(ip)
281                             self.endCopy(myIP)
282                         subprocess.call(["ssh",ip,"/usr/bin/python
                                " + homepath + "readnet.py -i " + myIP
                                + " -f " + pathname])
283                         readnet.logIPtraffic(ip, pathname)
284
285     #Sync files - DEPRECATED
286     def oldfileSync(self,event):
287         t = Tools()
288         if os.path.isdir(event.pathname):
289             print "Watching: ",event.pathname
290         for folder in watchedfolders.keys():
291             print "For each folder: " + str(folder) + " in
                        watchedfolder keys"
292             if folder in event.pathname:
293                 for i in range(0, len(watchedfolders[folder])
                            ,4):
294                     ip = watchedfolders[folder][i]
295                     path = watchedfolders[folder][i+1]
296                     waitTime = watchedfolders[folder][i+2]
297                     lastTime = watchedfolders[folder][i+3]
298                     print "Wait: " + str(waitTime) + " Last: "
                            + str(lastTime)
299                     print "Current ip and path: " + ip + " " +
                            path
300                     readnet.logIPtraffic(ip, event.pathname)
301                     myIP = readnet.getMyIP(ip)
302                     subprocess.call(["ssh",ip,"/usr/bin/python
                            " + homepath + "readnet.py -i " + myIP
                            + " -f " + event.pathname])
```

```
303                     print "ssh",ip,"'/usr/bin/python " +
                            homepath + "readnet.py -i " + myIP + " -
                            f " + event.pathname + "'"
304                     fparts = folder.split("/")
305                     fname = fparts[len(fparts)-1]
306                     #stopIP = self.getStopInfo()
307                     #print "STOP: " + stopIP[0] + " " + stopIP
                            [1]
308                     #if stopIP[0] == ip and stopIP[1] == event
                            .pathname:
309                     if self.inStopFile(ip,event.pathname):
310                         print "STOPPED to " + ip + " " + path
311                         #os.remove("./stop");
312                     else:
313                         print "CONTINUE"
314                         t.timeElapsed(lastTime, waitTime)
315                         watchedfolders[folder][i+3] = str(
                                datetime.datetime.now())
316                         t.updateFolderInfo(watchedfolders)
317                         self.beginCopy(ip)
318                         if args.scp:
319                             #print "SCP: For cpFile in " +
                                    folder
320                             for cpFile in glob.glob(folder + "
                                    /*"):
321                                 #print "SCP GLOB:" + cpFile
322                                 print "scp","-rp",cpFile,ip +
                                        ":" + cpFile + ".tmp"
323                                 subprocess.call(["scp","-rp",
                                        cpFile,ip + ":" + cpFile + "
                                        .tmp"])
324                                 #subprocess.call(["ssh",ip,"
                                        yes y | find /tmp/" + fname
                                        + " -type f -exec cp -p {} "
                                         + path + fname + "/ \; rm /
                                        tmp/" + fname])
325                                 print "ssh",ip,"mv " + cpFile
                                        + ".tmp " + cpFile
326                                 subprocess.call(["ssh",ip,"mv "
                                        + cpFile + ".tmp " +
                                        cpFile])
327                                 print "END SCP GLOB"
328                         elif args.rsync:
```

```
329                                 print "rsync","-rt",folder,ip + ":
                                        " + path
330                                 subprocess.call(["rsync","-rt",
                                        folder,ip + ":" + path])
331                             else:
332                                 time.sleep(5)
333                                 print "unison","-batch","-
                                        confirmbigdel=false","-times",
                                        folder,"ssh://" + ip + "/" +
                                        path + fname
334                                 subprocess.call(["unison","-batch"
                                        ,"-confirmbigdel=false","-times"
                                        ,folder,"ssh://" + ip + "/" +
                                        path + fname])
335                             print "Set stop files uniq: " + event.
                                    pathname
336                             #Set stop file on foreign host
337                             self.setStopFileUniq(ip,myIP,event.
                                    pathname,folder)
338                             #Set stop file for myself to look at
339                             self.setStopFileUniq(myIP,myIP,event.
                                    pathname,folder)
340                             self.endCopy(ip)
341                         subprocess.call(["ssh",ip,"/usr/bin/python
                                " + homepath + "readnet.py -i " + myIP
                                + " -f " + event.pathname])
342                         readnet.logIPtraffic(ip, event.pathname)
343
344     #def process_IN_CREATE(self, event):
345     #    print "Create:",event.pathname
346     def process_IN_DELETE(self, event):
347         print "Delete: ",event.pathname
348         #self.initFileSync(event)
349     def process_IN_CREATE(self, event):
350         print "CREATE: ",event.pathname
351         self.initFileSync(event)
352     def process_IN_MOVED_FROM(self, event):
353         print "Move from: ",event.pathname
354     #    self.initFileSync(event)
355     def process_IN_MODIFY(self, event):
356         #print "Modify: ",event.pathname
357         self.initFileSync(event)
358     def process_IN_MOVED_TO(self, event):
```

```
359             print "Move to: ",event.pathname
360             self.initFileSync(event)
361
362
363     def main():
364         t = Tools()
365         f = open('./folderstowatch','r')
366
367         for folder in f:
368             if(folder[0] == '#'):
369                 pass
370             else:
371                 info = folder.split()
372                 wm.add_watch(info[0].rstrip(),pyinotify.ALL_EVENTS
                        , rec=True, auto_add=True)
373                 print "Watching: ", info[0].rstrip()
374                 if info[0] not in watchedfolders.keys():
375                     watchedfolders[info[0].rstrip()] = []
376                 watchedfolders[info[0].rstrip()].append(info[1])
377                 watchedfolders[info[0].rstrip()].append(info[2])
378                 watchedfolders[info[0].rstrip()].append(info[3])
379                 watchedfolders[info[0].rstrip()].append(str(
                        datetime.datetime.now()))
380         f.close()
381
382         try:
383             f = open('./folders.dat','r')
384             for folder in f:
385                 if(folder[0] == '#'):
386                     pass
387                 else:
388                     info = folder.split()
389                     if info[0] in watchedfolders.keys():
390                         del watchedfolders[info[0].rstrip()]
391                         #wm.add_watch(info[0].rstrip(),pyinotify.
                                ALL_EVENTS, rec=True, auto_add=True)
392                         #print "Watching: ", info[0].rstrip()
393                         if info[0] not in watchedfolders.keys():
394                             watchedfolders[info[0].rstrip()] = []
395                         watchedfolders[info[0].rstrip()].append(
                                info[1])
396                         watchedfolders[info[0].rstrip()].append(
                                info[2])
```

```
397                         watchedfolders[info[0].rstrip()].append(
                                info[3])
398                         watchedfolders[info[0].rstrip()].append(
                                str(datetime.datetime.now()))
399                     else:
400                         print "Removing: " + info[0]
401             f.close()
402         except IOError, e:
403             print "Folders.dat does not exist, skipping"
404 
405         t.updateFolderInfo(watchedfolders)
406 
407         #print watchedfolders
408         eh = MyEventHandler()
409 
410         notifier = pyinotify.Notifier(wm, eh)
411         notifier.loop()
412 
413 if __name__ == '__main__':
414     main()
```

A.2 ReadNet.py

```
 1 import subprocess, datetime, socket, argparse
 2 
 3 homepath = "/home/cal/Documents/Private-Sync/"
 4 #homepath = "/Users/calum/Documents/Private-Sync/"
 5 
 6 parser = argparse.ArgumentParser()
 7 parser.add_argument('-i',action="store",dest='ip',help='IP 
       address to record for')
 8 parser.add_argument('-f',action="store",dest='fold',help='
       Folder to record for')
 9 
10 interfacenames = []
11 
12 w = open(homepath + "whoami","r")
13 nodename = w.read()
14 nodename = nodename[0]
15 w.close()
16 
17 #Get my ip corresponding to the interface with ipaddr
18 def getMyIP(ipaddr):
```

```
19      route = subprocess.check_output("ip route get " + ipaddr,
            shell=True)
20      words = route.split()
21      interface = ""
22      for word in words:
23          if word.startswith("eth"):
24              interface = word
25              #print interface
26              break
27      ifconf = subprocess.check_output("ifconfig " + interface,
            shell=True)
28      words = ifconf.split()
29      now = False
30      for word in words:
31          if word == "inet":
32              now = True
33          elif now:
34              word = word.split(":")
35              #print word[1]
36              return word[1]
37
38  #Log interface coresponding to ipaddr
39  def logIPtraffic(ipaddr, folder):
40      route = subprocess.check_output("ip route get " + ipaddr,
            shell=True)
41      words = route.split()
42      interface = ""
43      for word in words:
44          if word.startswith("eth"):
45              interface = word
46              #print interface
47              break
48      writeIface(interface, folder)
49
50  #Write the upload/download data for a given interface and
        folder
51  def writeIface(iface, folder):
52      ifs = subprocess.check_output("ifconfig -s",shell=True)
53      ilines = ifs.split("\n")
54      for i in range(1,len(ilines)-1):
55          interfacenames.append(ilines[i].split()[0])
56      output = subprocess.check_output("ifconfig",shell=True)
57      splitput = output.split()
```

```
58      interface = False
59      interfacename = ""
60      nex = ""
61      count = 0
62      upload = 0
63      download = 0
64      for split in splitput:
65          if split in interfacenames:
66              interface = True
67              interfacename = split
68              #print interfacename
69          if(nex != ""):
70              sp = split.split(":")
71              if(sp[0] == "bytes"):
72                  if(nex == "RX"):
73                      download = int(sp[1])
74                  else:
75                      upload = int(sp[1])
76                  nex = ""
77                  count += 1
78                  if(count == 2):
79                      interface = False
80                      if interfacename == iface:
81                          f = open(homepath + "log/" \
82                          + "node" + nodename.upper() + "-" \
83                          + iface + ".log",'a')
84                          f.write("#D " + folder + "\n")
85                          f.write(str(datetime.datetime.now()) +
                                " " + interfacename + " download: "
                                + str(download) + " upload: " + str
                               (upload) + "\n")
86                          f.close()
87                      count = 0
88          elif(interface):
89              if(split == "RX" or split == "TX"):
90                  nex = split
91
92  #Log all interfaces
93  def main():
94      ifs = subprocess.check_output("ifconfig -s",shell=True)
95      ilines = ifs.split("\n")
96      for i in range(1,len(ilines)-1):
97          interfacenames.append(ilines[i].split()[0])
```

```
 98      output = subprocess.check_output("ifconfig",shell=True)
 99      splitput = output.split()
100      interface = False
101      interfacename = ""
102      nex = ""
103      count = 0
104      upload = 0
105      download = 0
106      for split in splitput:
107          if split in interfacenames:
108              interface = True
109              interfacename = split
110              #print interfacename
111          if(nex != ""):
112              sp = split.split(":")
113              if(sp[0] == "bytes"):
114                  if(nex == "RX"):
115                      download = int(sp[1])
116                  else:
117                      upload = int(sp[1])
118                  nex = ""
119                  count += 1
120                  if(count == 2):
121                      interface = False
122                      f = open(homepath + "log/" \
123                      + str(socket.gethostname()) + "-" \
124                      + interfacename + ".log",'a')
125                      f.write(str(datetime.datetime.now()) + "␣"
                             + interfacename + "␣download:␣" + str(
                            download) + "␣upload:␣" + str(upload) +
                            "\n")
126                      f.close()
127                      count = 0
128          elif(interface):
129              if(split == "RX" or split == "TX"):
130                  nex = split
131
132  if __name__ == "__main__":
133      args = parser.parse_args()
134      if args.ip != None:
135          logIPtraffic(args.ip, args.fold)
136          #getMyIP(args.ip)
137      else:
```

```
138             pass
139             main()
```

A.3 onTheFly.sh

```
1  vm_name_arr=("Ubuntu-Pool" "Ubuntu-Silence" "Ubuntu-Black" "
       Ubuntu-Spheros" "Ubuntu-Wild")
2  vm_addr_arr=("192.168.0.28" "192.168.0.27" "192.168.0.30" "
       192.168.0.14")
3  #Wild = 19
4  intnetarr=("lion" "tiger" "cat" "dog" "fish" "kiwi" "swish" "
       boom" "roar")
5  #These should all be in one big dictionary apart from inet
       names
6  letterarr=("a" "b" "c" "d" "e" "f" "g" "h" "i" "j")
7  ifcountarr=(2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2)
8  ethcountarr=(1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1)
9  incount=1
10 bigncount=2
11 littlencount=1
12 folderpath="/home/cal/Documents/t18"
13 folderpath2="/home/cal/Documents/t02"
14 homepath="/home/cal/Documents/Private-Sync/"
15 waitTime=5
16
17 function clear_ifaces() {
18     i=0
19     while [ "$i" -lt "${#vm_name_arr[@]}" ]; do
20         VBoxManage modifyvm ${vm_name_arr[$i]} --nic2 none
21         echo "VBoxManage modifyvm ${vm_name_arr[$i]} --nic2
               none"
22         VBoxManage modifyvm ${vm_name_arr[$i]} --nic3 none
23         echo "VBoxManage modifyvm ${vm_name_arr[$i]} --nic3
               none"
24         VBoxManage modifyvm ${vm_name_arr[$i]} --nic4 none
25         echo "VBoxManage modifyvm ${vm_name_arr[$i]} --nic4
               none"
26         let "i++"
27     done
28 }
29
30 function clear_watched_folders() {
31     i=0
```

```
32      while [ "$i" -lt "${#vm_addr_arr[@]}" ]; do
33          ssh cal@${vm_addr_arr[$i]} "echo \"#Local folder path
               to watch, host to copy to, remote dir to copy to,
               min time between syncs\" > /home/cal/Documents/
               Private-Sync/folderstowatch; echo ${letterarr[$i]} >
                /home/cal/Documents/Private-Sync/whoami"
34          let "i++"
35      done
36  }
37
38  function git_pull() {
39      i=0
40      while [ "$i" -lt "${#vm_addr_arr[@]}" ]; do
41          echo "ssh cal@${vm_addr_arr[$i]} \"cd /home/cal/
               Documents/Private-Sync; git pull origin master\""
42          ssh cal@${vm_addr_arr[$i]} "cd /home/cal/Documents/
               Private-Sync; git pull origin master"
43          let "i++"
44      done
45  }
46
47  function search_letters() {
48      index=0
49      while [ "$index" -lt "${#letterarr[@]}" ]; do
50          if [ "${letterarr[$index]}" = "$1" ]; then
51              echo $index
52              return
53          fi
54          let "index++"
55      done
56      echo "None"
57  }
58
59  function vbmMOD {
60      #Set the NIC to intnet on the VM and attach it to the
           given network
61      echo "VBoxManage modifyvm $1 --nic$3 intnet"
62      VBoxManage modifyvm $1 --nic$3 intnet
63      echo "VBoxManage modifyvm $1 --intnet$3 $2"
64      VBoxManage modifyvm $1 --intnet$3 $2
65  }
66
67  function gatherLogs {
```

```
68      index=0
69      while [ "$index" -lt "${#vm_addr_arr[@]}" ]; do
70          echo "scp cal@${vm_addr_arr[$index]}:/home/cal/
               Documents/Private-Sync/log/* ../logs/"
71          scp cal@${vm_addr_arr[$index]}:/home/cal/Documents/
               Private-Sync/log/* ../logs/
72          let "index++"
73      done
74  }
75
76  function clean {
77      index=0
78      while [ "$index" -lt "${#vm_addr_arr[@]}" ]; do
79          echo "ssh cal@${vm_addr_arr[$index]} \"rm ${homepath}
               log/*; rm ${homepath}Stop-*; rm ${homepath}folders.
               dat\""
80          ssh cal@${vm_addr_arr[$index]} "rm ${homepath}log/*;
              rm ${homepath}Stop-*; rm ${homepath}folders.dat"
81          let "index++"
82      done
83  }
84
85  function cleanFold {
86      index=0
87      while [ "$index" -lt "${#vm_addr_arr[@]}" ]; do
88          echo "ssh cal@${vm_addr_arr[$index]} \"rm -rf ${
               folderpath}/*;\""
89          ssh cal@${vm_addr_arr[$index]} "rm -rf ${folderpath
               }/*;"
90          let "index++"
91      done
92  }
93
94  function sendKeys {
95      index=0
96      while [ "$index" -lt "${#vm_addr_arr[@]}" ]; do
97          #ssh cal@${vm_addr_arr[$index]} "rm /home/cal/.ssh/
               authorized_keys"
98          for file in /Users/calum/.ssh/*.pub; do
99              #echo "$file"
100             echo "cat $file | ssh cal@${vm_addr_arr[$index]} \
                    "cat >> /home/cal/.ssh/authorized_keys\""
```

```
101             cat $file | ssh cal@${vm_addr_arr[$index]} "cat >>
                    /home/cal/.ssh/authorized_keys"
102         done
103         let "index++"
104     done
105     #for file in /Users/calum/.ssh/*.pub; do
106     #    echo "$file"
107     #    cat $file | ssh cal@192.168.0.17 "cat >> /home/cal/.
            ssh/testfile"
108     #    echo "cat $file | ssh cal@192.168.0.17 \"cat >> /home
            /cal/.ssh/testfile\""
109     #done
110 }
111
112 function ifconf {
113     echo "ssh cal@$1 'sudo /sbin/ifconfig eth$2 192.168.$3.$4
            netmask 255.255.255.0 up; echo \"$folderpath 192.168.$3.
            $5 /home/cal/Documents/ $waitTime\" >> /home/cal/
            Documents/Private-Sync/folderstowatch '"
114     ssh cal@$1 "sudo /sbin/ifconfig eth$2 192.168.$3.$4
            netmask 255.255.255.0 up; echo \"$folderpath 192.168.$3.
            $5 /home/cal/Documents/ $waitTime\" >> /home/cal/
            Documents/Private-Sync/folderstowatch" < /dev/null
115 }
116
117 function ifconf2 {
118     echo "ssh cal@$1 \"sudo /sbin/ifconfig eth$2 192.168.$3.$4
             netmask 255.255.255.0 up; echo \"$folderpath 192.168.$3
            .$5 /home/cal/Documents/ *\" >> /home/cal/Documents/
            Private-Sync/folderstowatch; echo \"$folderpath2
            192.168.$3.$5 /home/cal/Documents/ *\" >> /home/cal/
            Documents/Private-Sync/folderstowatch\" < /dev/null"
119     ssh cal@$1 "sudo /sbin/ifconfig eth$2 192.168.$3.$4
            netmask 255.255.255.0 up; echo \"$folderpath 192.168.$3.
            $5 /home/cal/Documents/ *\" >> /home/cal/Documents/
            Private-Sync/folderstowatch; echo \"$folderpath2
            192.168.$3.$5 /home/cal/Documents/ *\" >> /home/cal/
            Documents/Private-Sync/folderstowatch" < /dev/null
120 }
121
122 if [ $2 == "vm" ]; then
123     clear_ifaces
124
```

```
125     #Read in the DOT script
126     while read line
127     do
128         first=$(echo "$line" | awk '{print $1}')
129         last=$(echo "$line" | awk '{print $(NF)}' | sed 's
                /[;]//g')
130         #echo "$first and $last"
131         index=$(search_letters $first)
132         if [ "$index" = "None" ]; then
133             #echo "None"
134             :
135         else
136             vbmMOD ${vm_name_arr[$index]} ${intnetarr[$incount
                    ]} ${ifcountarr[$index]}
137             #echo "in: $index"
138             (( ifcountarr[$index]++ ))
139             index=$(search_letters $last)
140             vbmMOD ${vm_name_arr[$index]} ${intnetarr[$incount
                    ]} ${ifcountarr[$index]}
141             #echo "in: $index"
142             (( ifcountarr[$index]++ ))
143             incount=$incount+1
144         fi
145     done <graphs/$1
146 elif [ $2 == "if" ]; then
147     clear_watched_folders
148
149     while read line
150     do
151         first=$(echo "$line" | awk '{print $1}')
152         last=$(echo "$line" | awk '{print $(NF)}' | sed 's
                /[;]//g')
153         echo "$first and $last"
154         index=$(search_letters $first)
155         if [ "$index" = "None" ]; then
156             #echo "None"
157             :
158         else
159             ifconf ${vm_addr_arr[$index]} ${ethcountarr[$index
                    ]} $bigncount $littlencount $(( $littlencount+1
                    ))
160             #echo "in: $index"
161             (( ethcountarr[$index]++ ))
```

```
162             (( littlencount++ ))
163             index=$(search_letters $last)
164             ifconf ${vm_addr_arr[$index]} ${ethcountarr[$index
                    ]} $bigncount $littlencount $(( $littlencount-1
                    ))
165             #echo "in: $index"
166             (( ethcountarr[$index]++ ))
167             incount=$incount+1
168             (( bigncount++ ))
169             (( littlencount-- ))
170         fi
171     done <graphs/$1
172 elif [ $2 == "if2" ]; then
173     clear_watched_folders
174
175     while read line
176     do
177         first=$(echo "$line" | awk '{print $1}')
178         last=$(echo "$line" | awk '{print $(NF)}' | sed 's
                /[;]//g')
179         echo "$first and $last"
180         index=$(search_letters $first)
181         if [ "$index" = "None" ]; then
182             #echo "None"
183             :
184         else
185             ifconf2 ${vm_addr_arr[$index]} ${ethcountarr[
                    $index]} $bigncount $littlencount $((
                    $littlencount+1 ))
186             #echo "in: $index"
187             (( ethcountarr[$index]++ ))
188             (( littlencount++ ))
189             index=$(search_letters $last)
190             ifconf2 ${vm_addr_arr[$index]} ${ethcountarr[
                    $index]} $bigncount $littlencount $((
                    $littlencount-1 ))
191             #echo "in: $index"
192             (( ethcountarr[$index]++ ))
193             incount=$incount+1
194             (( bigncount++ ))
195             (( littlencount-- ))
196         fi
197     done <graphs/$1
```

```
198 elif [ $2 == "key" ]; then
199     sendKeys
200 elif [ $2 == "gather" ]; then
201     gatherLogs
202 elif [ $2 == "clean" ]; then
203     clean
204 elif [ $2 == "pull" ]; then
205     git_pull
206 elif [ $2 == "clean-fold" ]; then
207     cleanFold
208 elif [ $2 == "help" ]; then
209     echo "vm__________-_setup_vm_networking"
210     echo "if__________-_setup_network_addresses_etc_for_each_
        vm"
211     echo "if2_________-_setup_network_addresses_etc_for_each_
        vm_for_two_folders"
212     echo "gather______-_gather_the_logs_in"
213     echo "clean_______-_clean_out_the_logs/config_files"
214     echo "clean-fold__-_clean_out_the_files_folder"
215     echo "pull________-_pull_the_latest_code_from_the_
        repository_to_each_vm"
216     echo "help________-_display_this_help_message"
217 else
218     echo "Oops_try_again"
219 fi
220
221 neato -Teps graphs/$1 > graphs/$1-graph.eps
```