Private Dropbox
Final Report
COSC480

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1 Abstract

Private decentralised dropbox. Node to node replication, unison.

Contents

2 Introduction

3 Project goal

The aim of this project is 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:

- Be decentralised. It will not necessarily need to be run in "the cloud" there should be no centralised server, just many cooperating client nodes. However it should be possible to configure the system to be centralised 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. Clients may be running different operating systems. Clients may run on different networks, with different costs of access, including being disconnected from the Internet at times.
- Allow for fine-grained user control for the majority of the program's functions, *e.g.*, how often, and what, to replicate within different sets of files. 'What' could be file name, file type, file size, *etc.*
- 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.
- Operate automatically, without the user having to initiate a file synchronisation themselves. The user should be able to set when and where they would like synchronisation to occur.

4 Background

There are already many services available that synchronize your files. Dropbox, Google Drive, Microsoft SkyDrive, Apple iCloud all offer cloud based solutions for automatically synchronizing your files. 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 also cannot guarantee that you will always be able to access your data, if the company who owns 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.com a file hosting service has recently been shut down by the United States Department of Justice for alleged copyright infringement. According to the founder, 100 million users lost access to 12 billion unique files[1].

The are other possible approaches to replicating files across multiple computers. For example you could use version control systems like Subversion, Mercurial, 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 but they create a bottleneck at the server. Cloud based solutions are also often centralised. Another problem is that even if they are decentralised like git, they won't automatically push updates to other working sets.

Example use case

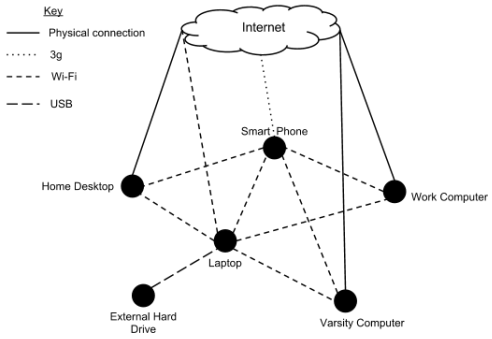
Here is how I would use such a tool as an example use case.

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 around ≈5MB and I like to have a relatively current backup of this collection. My 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 a couple of DVDs. 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.

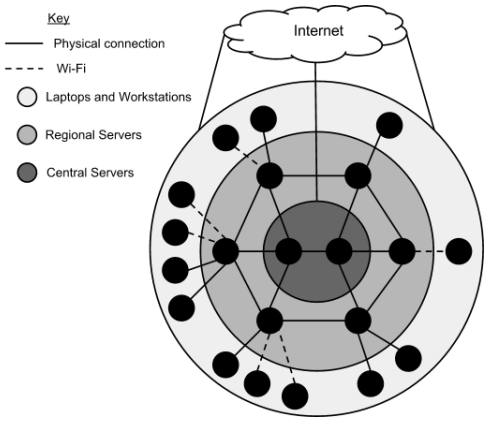
Some of the files that I move around are of a sensitive or personal nature and I would prefer not to store them with a third party vendor. I also have different synchronisation requirements for different types of data. For example my collection of large video files does not change that often and will 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.

An effective file synchronisation tool would be of great use to me personally. Dropbox does not do enough for me. It does not give me 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 Dropbox closes down or my internet connection dies.

The personal graph has been described above, the corporate graph 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 private dropbox will.



(a) Personal Network



(b) Corporate Network

5 Work Done

So far I have written a program in python which reads user settings from a file. Synchronises the appropriate files to the appropriate machines when they have been modified. Using an efficient two way file synchronising tool called unison. I will discuss what I have done and how I have tested it in this section.

5.1 Virtual Machines, Node networks

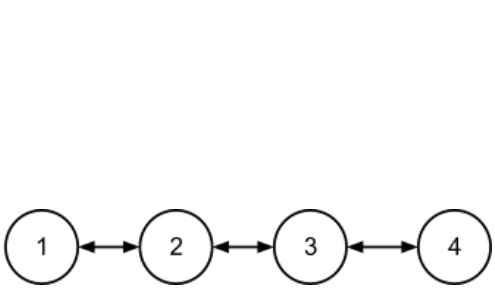
For testing my program I needed to have a network of computers that can be linked together in different arrangements easily. I decided to use virtual machines for this job since it means I do not need to have a large number of physical machines. I can create new machines very easily, and manipulate the links between them.

I have used Oracle's VirtualBox software. I chose VirtualBox because of its easy to use command line interface. I have several scripts that call the `vbmoxmange` command to set up the internal network connections between machines and then start up the machine itself. This makes switching between network configurations very easy as I can just run a different script depending on which network topology I would like to test.

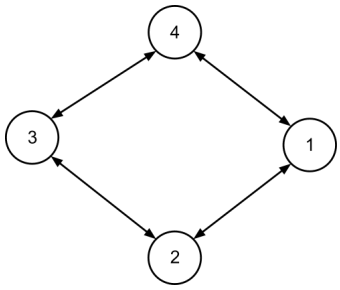
I have decided to start testing my program with some simple topologies to see if I can gain any insight into how best to replicate data around a network with many nodes. The next step will be to use those principles and start running more complicated networks to see how the program performs.

Snippet from one of my network scripts:

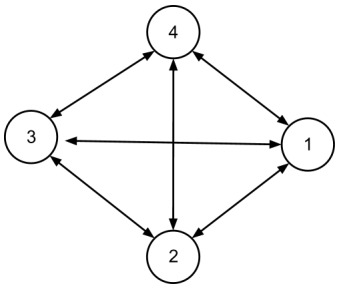
```
VBoxManage modifyvm "Ubuntu-Test" --nic2 intnet
VBoxManage modifyvm "Ubuntu-Test" --intnet2 "intnet"
VBoxManage startvm "Ubuntu-Test"
```



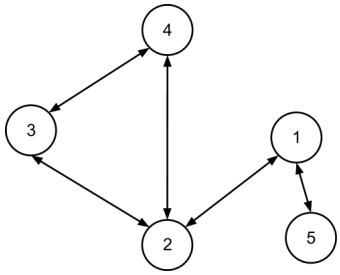
(c) Line topology



(d) Circle topology



(e) Connected mesh topology



(f) Other topology

Figure 1: Simple network topologies

5.2 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 (hopefully) encounter fewer compatibility problems when running my program across different operating systems in the future.

5.3 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 use directories as my granularity for replication as opposed to files because keeping track of a large list of files may become unwieldy, and because I replicate directories recursively, I can replicate large amounts of data without a cluttered configuration file.

5.4 Monitoring Directories

The application needs to monitor directories for changes 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 and my application is designed to be as

efficient as possible. 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. Instead I have looked into ways of being notified of a change in the file system below the watched directory.

- Inotify
  - Inotify is a linux 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 which provided the same function. 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 uses SIGIO. Inotify only uses one file descriptor and returns events to the listener as they occur[2]. It works well and does what I need it to do. There is a Python module called pyinotify that provides a Python interface to inotify, which I have used and tested in my program.
- FSEvents
  - FSEvents is an API in MacOS X[3]. It is similar to inotify in that it provides a notifaction 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, as well.

    I also looked at using the `kqueue`[4] system call that is supported by OS 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 the application's needs.

5.5 Point-to-Point synchronisation

After some preliminary analysis of the available file synchronisation tools I have found a tool called Unison 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 machines (or the same machine).

I decided to run some tests using unison and the network I had set up to determine whether this would make a good base for my program or not.

I looked at three methods of file synchronisation across different networks. Naive copying; using rsync, an application for efficiently copying files in one direction by looking at the differences in the files; and unison described above.

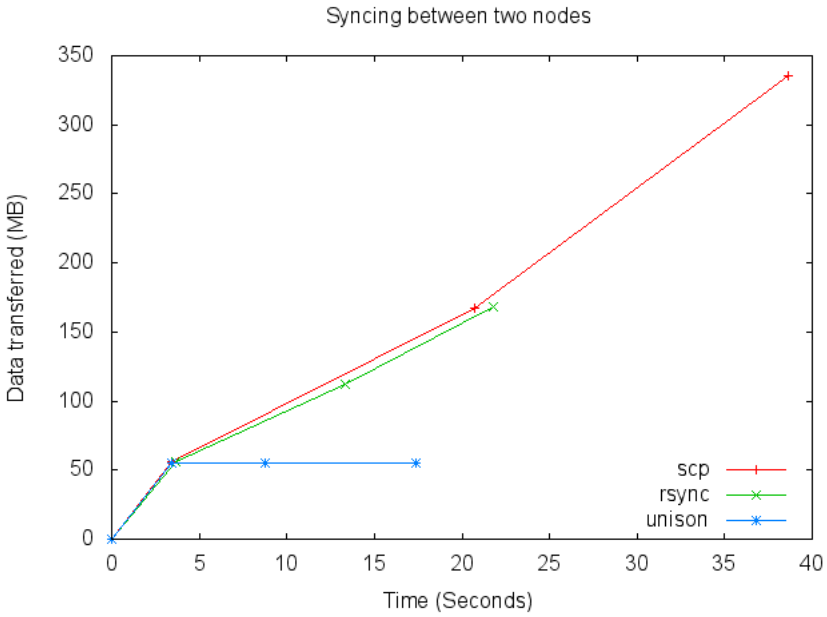


Figure 2: Comparison of scp,rsync,unison

Rsync and unison performed significantly better than the naive copy method (as expected). After the initial file transfer subsequent edits to the file meant much less data had to be transmitted over the network, which meant the node graph became up to date much more quickly.

Figure 2 illustrates another advantage of unison over rysnc. The graph shows three zero filled binary files being copied from one node to another one after the other. Unison recognised that even though the files were named differently they were the same file. Another advantage of unison is that it handles replication in two directions without clobbering the files on the other side.

6 When to stop copying

After testing my program on some simple topologies one problem became clear. Each node would notice changes had occurred to a folder it was watching and would then try to copy these changes to other nodes that it was connected to. The problem was that if the changes came from one of its neighbour nodes this would cause an infinite loop of two nodes trying to copy changes to each other. This was particularly a problem when using scp to copy. When using Unison this was not as much of a problem because it could detect that no changes had occur between the nodes and would stop syncing after one check (which had minimal overhead).

I used a configuration file to get around this problem. Each time a node synchronised with another node it would write out a configuration file telling the other node what files had been copied, who sent them and what the modification time of the files were.

In this way a node could check if it was about to synchronise a file back to the node it received the file from or if it had local changes that were newer than a received file it could continue with its sync.

7 Sub-nodes

I chose to classify directories as 'sub nodes' of a graph. The reason i choose directories is because they are easy to manage a configuration file of directories to keep in sync (from the users point of view). If we wanted to only synchronize certain files in a directory we could write a unison configuration file with exclusions/inclusions in it. The other reason directories are a good choice is because I can have different directories in different places on different file systems by using symbolic links. I wanted to see how the freshness of different sub-nodes varied between nodes when the program was running.

8 How often to sync

I noticed Vim would create temporary files (4913), move files, etc. So how often should I sync once I noticed a change.

9 Future work

9.1 Full node graph replication

I am going to be looking into the most efficient way to replicate data between many nodes in a graph, where nodes are machines running the program and edges in the graph are connections between machines such as over Wi-Fi, USB, or through the internet, *etc.* Each connection may have different properties associated with it, for example each link may have a different cost associated. The two costs that I am most interested in are data throughput and latency. There may be data caps to worry about (for 3G especially) or costs associated with usage (this could be money charged per megabyte used or the time cost of sending a lot of data over an (potentially) already busy/important channel). The link may be down temporarily or may rarely be up. The task here will be to find algorithms that give as near to optimal as possible, given certain conditions and preferences, to shift data between all the necessary nodes efficiently and with minimal cost. Cost will most likely involve keeping the number of bytes passed over the network(s) to a minimum. Efficiency will depend on personal preference and the situation, ideally one would not want to have to be waiting on replication to occur but this should not come at the expense of extreme cost, however. There will be an infinite number of use cases for this project which means an infinite number of graphs, however I will attempt to look at common use cases and as many different types of graph as possible.

9.2 Sub-Nodes

The other aspect of the "multiple nodes in the graph" problem is that each node will most likely be made up of many smaller nodes. Each user will be unlikely to select the root directory of the file system to synchronise, which means they may select a few different directories on the file system. This gives us sub nodes that the main node is still the machine as above. The sub nodes are an individual directory or set of directories that are set to be replicated. The reason this is interesting is because each of these sub nodes may have different synchronisation settings (see fine-grained controls). This leaves us with the possibility of machines being fully up to date, partially up to date, or completely out of date with all other nodes in the graph.

An example of this potential situation is shown below. This sort of graph ties in with the statistics/feedback side of the project. How out of date is the graph at any given time? If the graph contains out of date data, do we ever expect it to get back to being completely up to date? How long do we expect this to take? How do these facts reflect on the synchronisation settings we chose? Can we improve on the performance by tweaking the settings?

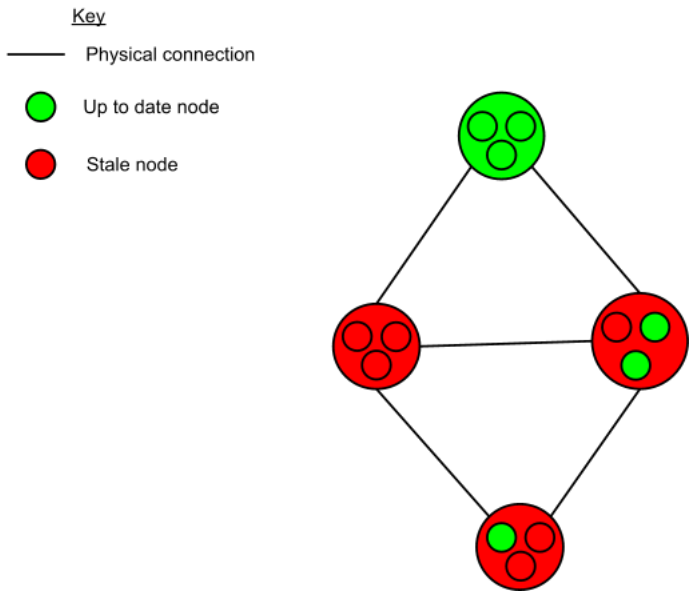


Figure 3: Graph of sub nodes within nodes

9.3 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 will be interesting to see how mobile nodes affect how up to date the nodes in the graph are. We might expect that nodes that are not available for very long periods lag behind others that are. We might also expect that if a mobile node is a link between two parts of the network that these two parts fall out of synchronisation. I want to look at how nodes in the graph may get smarter about how they use unreliable edges. I will do this by having the edges up or down at different points in time and taking snapshots of the graph as it is at that time.

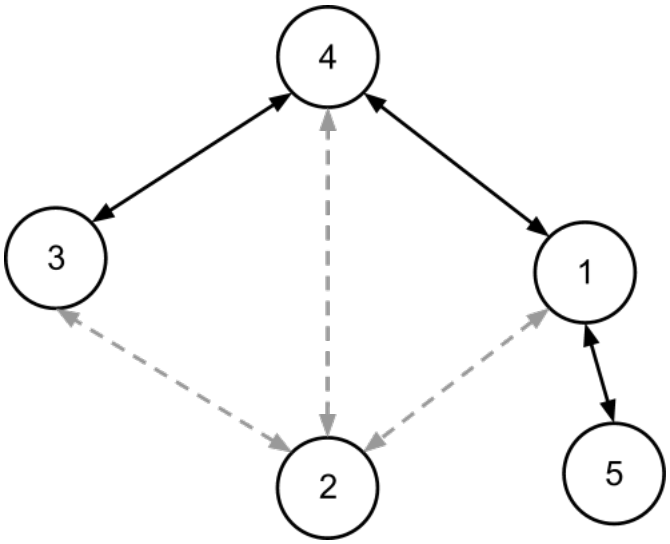


Figure 4: Node two moves within the graph

In figure 4 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.

9.4 More user control

Due to the highly unpredictable nature of the graph the user should be able to greatly affect how the program runs. A user should be able to set how often replication occurs and under what conditions it should occur *e.g.* only when connected to a certain network.

For example replicate my documents `/Users/Calum/Documents` on my laptop every hour to work but only when connected to the work Wi-Fi network. There should be some intelligent indication of how certain options may affect performance which relates to the next section. This may be able to be estimated by looking at previous running settings and seeing what effect they had on the network. This ties in with the next section.

9.5 Feedback

Private dropbox should keep logs of what is happening with the system at the current point in time. It should log:

- what the current user settings are.
- how much data is being transferred between the nodes.
- which links between nodes are being used the most.
- how up to date each part of the graph is.

I will then look at presenting this information in a meaningful way to the user. One way to do this would be when the user changes the settings. Private dropbox could then estimate whether that change will speed up or slow down overall synchronisation of the graph and pass that (potentially) useful information to the user.

10 Results

11 Conclusion

References

[1] Foreman, Michael "Kim Dotcom v United States of America". Computerworld. 3 February 2012.

[2] www.kernel.org/pub/linux/kernel/people/rml/inotify/README, 22 September 2004.

[3] Apple Inc. https://developer.apple.com/library/mac/#documentation/Darwin/Conceptual/FSEvents_ProgGuide/Introduction/Introduction.html, 11 October 2011.

[4] Apple Inc. http://developer.apple.com/library/mac/#documentation/Darwin/Reference/ManPages/man2/kqueue.2.html

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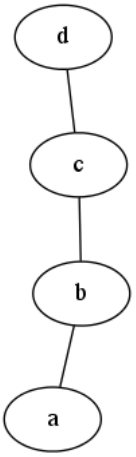

Figure 5: Line topology

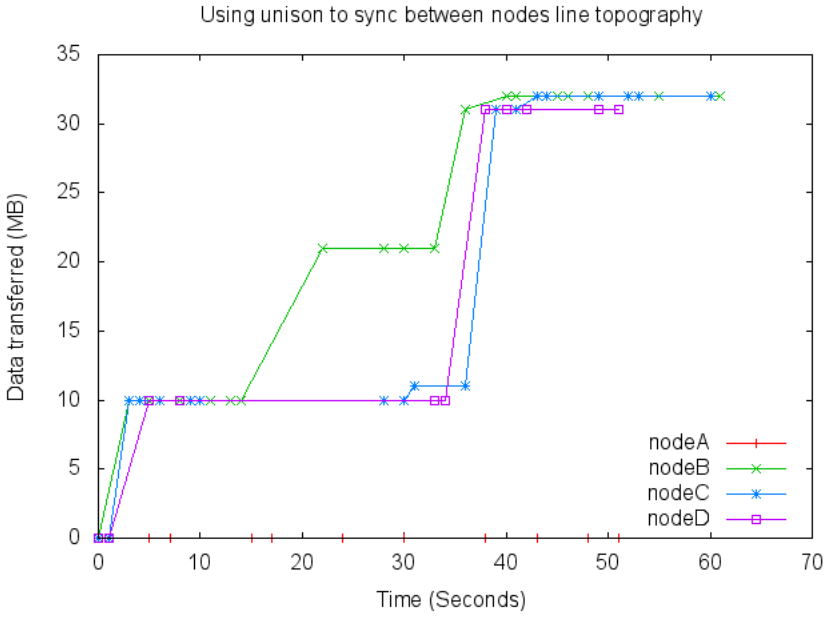

Figure 6: 10mb random files, 10 seconds, unison

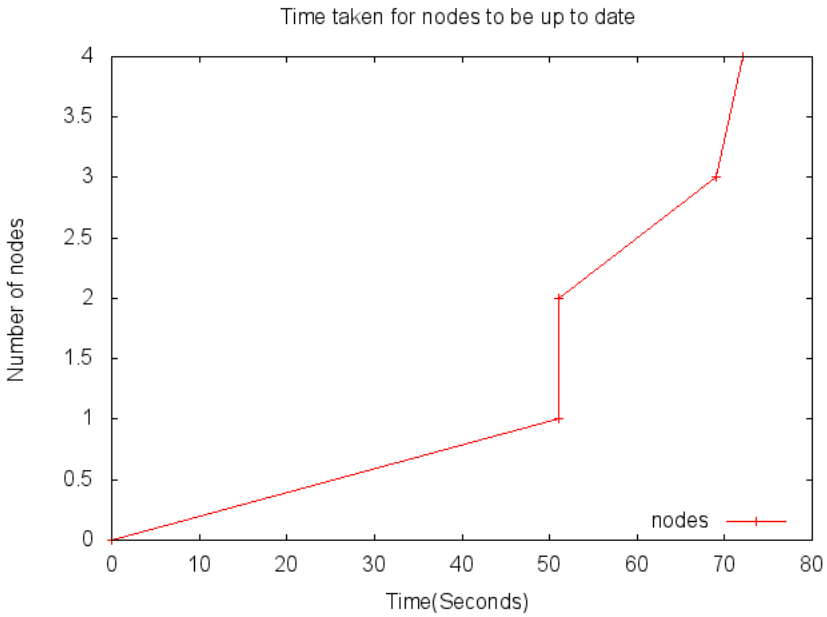

Figure 7: Unison, line, finishing times

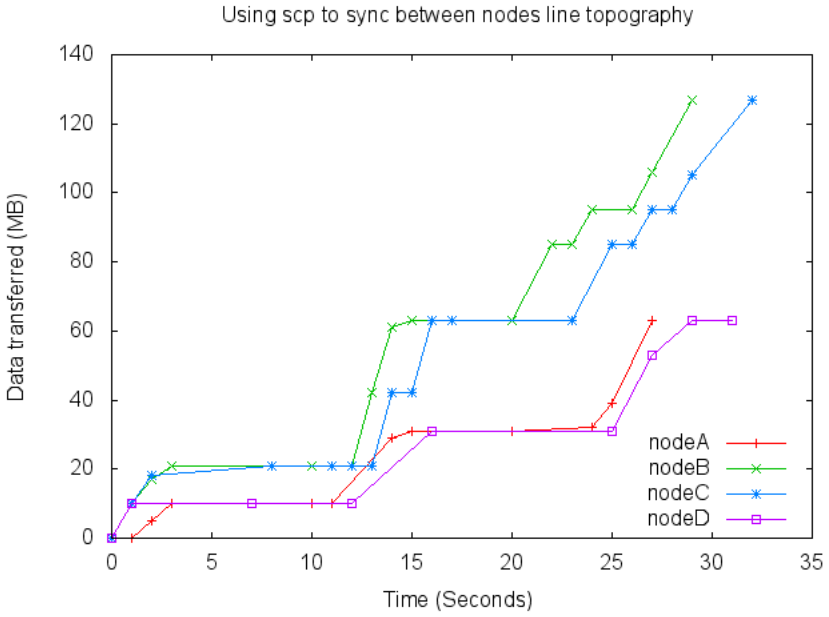

Figure 8: Line, scp, back and forth

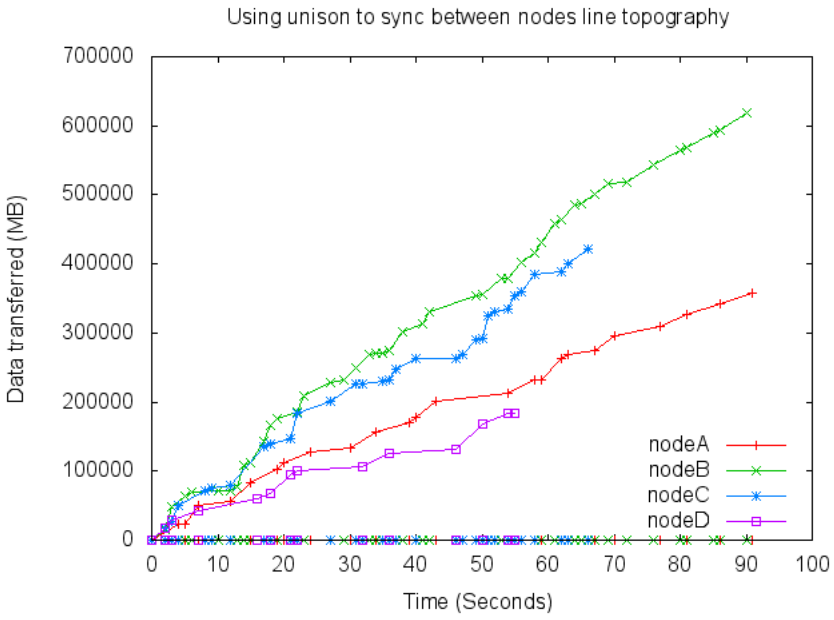

Figure 9: 2 seconds sleep text file

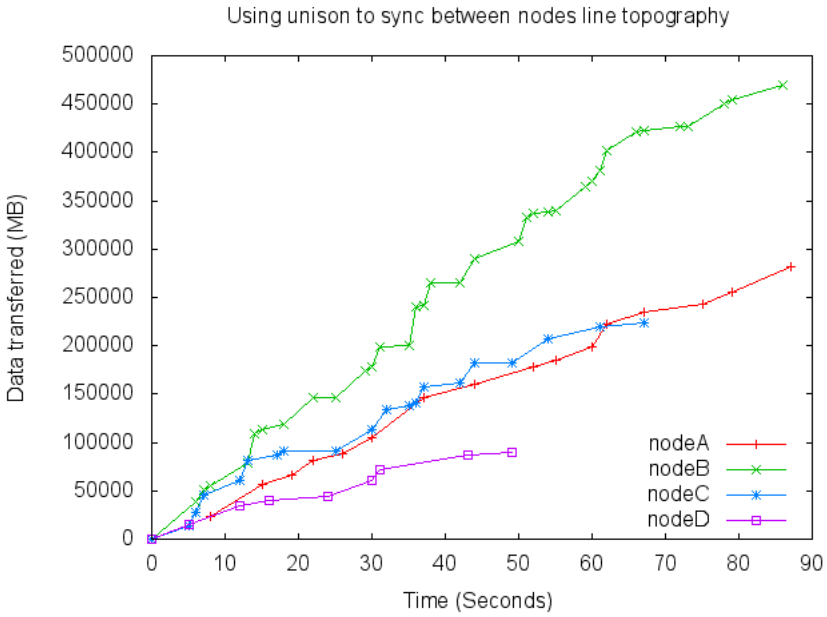

Figure 10: 5 seconds sleep text file