A Secure and Distributed Architectural Model for File Sharing

- Secure Distributed File Sharing

DAVID JOHN BROWN

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Authorship Declaration

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Abstract

There has been a huge growth in the use of file sharing software over the last year, making file sharing one of the top uses of the Internet. Napster was the first technology that empowered users with the ability to share files amongst themselves. The demise of Napster led to the development of numerous file sharing technologies, most of which are based on the Gnutella protocol. The problem with all current file sharing technologies is that none of them can guarantee the security of the shared file.

This report describes the design, development and evaluation of a file sharing system that proposes a novel solution to the shared file security problem. The system will allow users to share files in a secure manner and comprises of client and server applications. The client allows users to connect to a server and shares their files amongst all other system users. The client also gives users the ability to search for files shared by the other system users, and when a file is found it could be transferred from the other user securely, as the file would be encrypted. The server allows valid users to connect, records their shared file list and enables connected users to search this list. The server authenticates connected users by performing a test that only a valid user can respond to in the correct manner.

The report outlines research in the area of networking, including technological backgrounds such as distributed file system architectures, cryptographic techniques and network programming methods.

The novel feature of the system is the method used to address the security problem inherent to all current file sharing technologies. The system developed uses cryptographic techniques to implement a framework in which to model system security, including authentication of system users and the files that they share. The report defines the strength of the encryption, and makes recommendations for enhancements.

A major objective of the system is to provide a model that can be easily scaled with a number of clients. The tests performed show that the response time of the system remains fairly linear to the number of concurrent clients. Additional tests have also shown that MySQL is vastly superior to Access XP, especially with 10 clients logging on simultaneously. In this case, MySQL is almost five times faster than Access XP.

The report concludes with recommendations for future work, such as an addition to the client application requirements, improvements to the encryption speed and strength, further performance tests and a test to investigate network traffic generated by clients.

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1 Introduction

1.1 Scope and aims of the project

The main aim of this project was to create a system that allows files to be distributed over a wide area and to be shared in a secure manner. The system should allow clients to search for other clients that have required files and provide them with a mechanism to share those files securely. It involves research in the following subjects:

- Distributed File System Architectures.
- Security Techniques.
- File Transfer Protocols.
- Network Programming Methods.
- Database Technologies.

This research will be applied in the creation of a final working system, which will be tested and evaluated.

1.2 Background

Most applications on the Internet currently use a client-server model, where a client actively connects to a server, which then provides it with a given resource. This resource could be access to files, print services, and so on. A client-to-client (or peer-to-peer) model provides an enhancement to this in that it allows clients to actively seek other clients, without using a server as an intermediate device. There are though many issues involved in this, especially related to the amount of network traffic generated by peer-to-peer communications, and security. This project will try and analyse a model for peer-to-peer communications for file sharing, and look at models for enhancing the security of such as system.

Distributed, peer-to-peer, file sharing is one of the fastest growing and controversial applications of the Internet. In its most basic form, file sharing can occur between two computers connected via the Internet or another form of network connection. Napster was one of the first applications to use peer-to-peer communications, and Oram (2001) stated that:

> ... The first application that gave the Internet community the ability to share files freely was Napster, which consisted of a centralised directory server that stored shared file and addressability information of connected clients.

After Napster, a large number of file sharing applications became widely available. Forte (2001) observed that there was a rapid appearance of these new applications and stated that the majority of them were based on the peer-to-peer model. Waters (2001) then showed that the use of this model in file sharing applications is increasing rapidly, which is mainly due to the general availability of the Internet. Many

researchers believe that peer-to-peer applications have a great potential, one such researcher is Doherty (2002), who states 'peer-to-peer shows great promise for file sharing and collaboration'.

Peer-to-peer uses a different approach from Napster to sharing files. Gerwig (2002) and Vrana (2001) define this approach as a decentralised network where client computers communicate with each other directly, without the help of centralised servers. So rather than using a central server to store file and client information, each client uses an application that connects directly to other clients. According to Gerwig (2002), out of the available peer-to-peer technologies, the most popular is Gnutella.

1.2.1 Napster

Oram (2001) and Kant, Iyler and Tewair (2002) describe the architecture of Napster as a mixture of centralisation and decentralisation, consisting of centralised directory servers that built and maintained a file list, adding and removing entries as individual clients connected and disconnected. Yang and Garcia-Molina (2001) brand Napster as a 'hybrid' peer-to-peer system, with their research concentrating on the issues and trade-offs in the design of a scalable peer-to-peer system.

Oram (2001) also provided information on the popularity of Napster (before it was closed, of course), where the directory servers kept track of thousands of clients, holding millions of files, which amounted to over several terabytes of data[1].

Napster gave Internet users a new and exciting way of sharing files; previously users would have to upload their files onto a central web server in order for them to become accessible to everyone. An overview of Napster's architecture is defined in the research papers written by Kant, *et al.* (2002) and Ratnasamy, *et al.* (2001). From the papers it was discovered that Napster dispensed with the task of uploading, leaving the files on the client's PCs, simply brokering file requests from one PC to another, so only the file addressability information would have to be stored on the central Napster servers, not the file itself.

1.2.2 Gnutella

Aberer and Hauswirth (2001) state that Gnutella was the first fully decentralised peer-to-peer system running on the Internet. Rather than using a central server that clients use to find files, each client runs an application that connects directly to other clients. File search requests are then passed from client-to-client until one acknowledges that it has the requested file. A connected client in the Gnutella network is both a client and an ad-hoc server, as they both get and/or send files.

A horizon in Gnutella defines the boundary up to which a client can see other client. Horizons are defined to reduce the network communications to within a range of clients. When a client connects to the network there can be any number of other clients connected at the same time, but the client can only see clients within a given domain. The horizon is defined using the Time-to-live (TTL) field in an IP datagram, which defines the approximate distance that a packet can travel before it is discarded. Oram (2001), states that the Gnutella horizon is set to seven decrements, which effectively sets the maximum number of clients in a horizon to 10,000.

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[1] A terabyte is 1,024 GB's, which is 1,099,511,627,776 Bytes.

As Gnutella uses a horizon, each connected client sees a limited distance that radiates out from the client. As each client is situated differently in the network, every client will therefore see a different network. When clients connect and disconnect over time, the network viewpoint changes and the connected clients see different clients as the network changes around them.

Lv, *et al.* (2002) view the Gnutella architecture as the most attractive method for sharing files, as there is no requirement for centralised storage and no need to control the topology of the network, in relation to where the files are located.

The main issues involved in peer-to-peer communications are:

- **Bandwidth usage**. As the network traffic is likely to increase as the network size increases.
- **Security**. As resources can be freely shared over a network, and there is no form of authentication, thus it is not possible to refine security privileges.
- **Scalability**. As there are limitations on the viewpoint that nodes have over the network. Gnutella suffers in this area, as it does not scale well, as the network traffic increases exponentially with the number of connected clients.

This report will focus on design issues for both security and scalability. Network bandwidth will be discussed, but it is not an aim of this report to analyse this factor. The report splits into seven main sections, these are:

- **Introduction**. This chapter, and outlines the basic aims of the project, and its context.
- **Theory**. This chapter outlines the theory related to the technical background of the project, such as Window's sockets, the principles of encryption, file sharing architecture, and so on.
- **Requirements Analysis**. This chapter defines the high-level abstraction of the system, and it basic functionality and the main system properties.
- **Design**. This chapter outlines the full design process to match the requirements analysis.
- **Implementation**. This chapter outlines the main highlights for the coding. These identify the key elements of the overall system, such as registering a user, and encrypting a file.
- **Testing**. This analyses the key functional tests for the system, such as encryption speed, encryption strength, database comparisons, and so on.
- **Conclusions**. This defines whether the main aims have been met, and how they have been met. It also discusses future work.

2 Theory

2.1 Introduction

Before the design of a secure file sharing application begins, there are five main areas to be considered:

1. **Distributed File System Architectures.** It is important to consider the available system structures to discover which is the most suitable.
2. **Security.** Cryptography is a technique used to maintain consistency and secrecy of data, which has many different methods that deserve consideration.
3. **File Transfer Protocols.** The application requires the transfer of data between two devices, so the format of the data transfer must be researched.
4. **Network Programming.** As the application will communicate over a network, available network programming techniques must be considered, along with techniques for improving performance.
5. **Database Technologies.** The application will require storage to a database, so the available database technologies must be researched, to discover the most suitable. Technologies for communicating with a database are also considered.

2.2 Distributed File System Architectures

2.2.1 Client-Server Architecture

A distributed file system allows a file structure to be stored over one or more file servers. Kantet, *et. al.* (2002) revealed that the client-server architecture is the most widely used for this purpose. Figure 1 illustrates this model, which is based on a central server that is responsible for providing a remote file service to clients. On receipt of a valid client request, the server executes the appropriate operation and sends a reply back to the client. This type of interaction is known as request/response or interrogation.

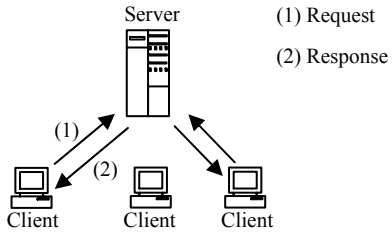


Figure 1 – Client-Server Architecture

2.2.2 Napster Architecture

The Napster web page (2002) provided information on the Napster architecture, which is based on a central directory server that contains addressability information on the connected clients and information on the files they are sharing. This architecture is illustrated in Figure 2. The central server offers connected clients the facility to search

for a required file and assists in the identification of the most suitable location from which to download that file.

Kant, *et. al.* (2002) stated that the centralisation of the directory server allows file searches to be performed relatively fast, with the IP address of clients that host the required file passed to the requesting client. The file download can then take place between the requesting client and the client who hosts the file via TCP/IP.

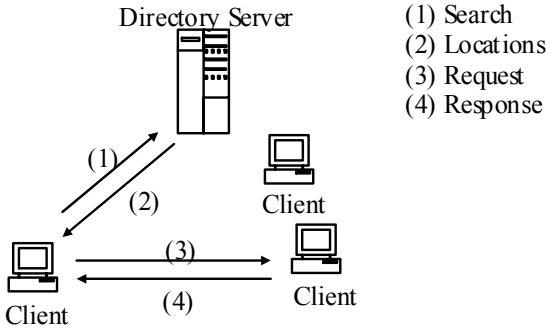


Figure 2 – Napster Architecture

2.2.3 Gnutella Architecture

Kant, *et. al.* (2002) provide information on the Gnutella architecture, which is based on a fully distributed approach where clients connect to each other directly through a software interface that forms a high-level network. This architecture is illustrated in Figure 3. When a client connects to the Gnutella network, all the sharable files are made public to all other clients through a set of local folders that the client specifies as shared.

The Gnutella client software, which is freely available from the Gnutella home page (2002), is essentially a file serving system and search engine in one. Portmann, *et. al.* (2001) provide function information on the underlying Gnutella protocol. They outline that the discovery of peers and searching for files are the main elements of this protocol, and are both implemented by sending messages to all connected clients within the network horizon.

When a connected client submits a search to the Gnutella Network, the search parameters are flooded throughout the network horizon, which returns any search matches. The file download takes place between the requesting client and the client who hosts the file. Technical information on this transfer was obtained from the Gnutella development WWW page (2001), which revealed that the transfer is based on an HTTP-like connection.

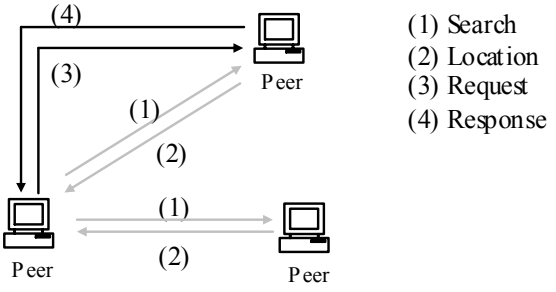


Figure 3 – Gnutella Architecture

Unfortunately, Gnutella has problems in terms of scalability and ineffective use of bandwidth. Both of which are common problems with peer-to-peer architectures. Krishna, *et. al.* (2002) and Ripeanu (2002) propose that the problems are caused by the way the Gnutella peer-to-peer networks are formed. Krishna, *et. al.* (2002) propose a solution to improve the overall performance of the Gnutella network, by creating small clusters of peers with similar file sharing interests. These clusters further distribute the system and should generally reduce network traffic, as fewer broadcasts are likely to be required for the smaller clusters.

2.3 Security Techniques

Peer-to-peer communications obviously have weaknesses in authentication, as there is no intermediate server which can authenticate the client to the other client. In order for us to under the problems that may be causes and their solution we must analyse key areas of security, especially in data encryption, which is the best way to secure both the data, and any transactions. Tanenbaum (1996) states that whenever a computer system is a potential target for a malicious or mischievous attack, security measures must be incorporated into these systems to prevent such actions. This is especially relevant for systems that contain classified, confidential or financial information, where integrity and secrecy is of paramount importance.

Whenever information is transmitted across a network, it is vulnerable to tampering and eavesdropping. Coulouris, *et. al.* (2001), state that cryptography is used to maintain the integrity and secrecy of information when it is exposed to such attacks.

2.3.1 Cryptography

Singh (2001) provides a definition of cryptography, which is derived from the Greek word *kryptos*, meaning 'hidden' and its aim is to hide the meaning of a message. Encryption typically uses a standard well-published algorithm, and varies the electronic cryptographic key. A cryptographic key is a mathematical parameter used in an encryption algorithm so the encryption process cannot be reversed without the key. As much as possible the encryption algorithm should be robust, so that it does not have any weaknesses that can be exploited.

The process of encryption involves transforming plaintext into ciphertext, with the reversal of this process called decryption. Figure 4 illustrates that both the encryption and decryption is controlled by the cryptographic key.

There are two main types of encryption algorithm in use today. The first uses a secret encryption key and the second uses public/private key pairs.

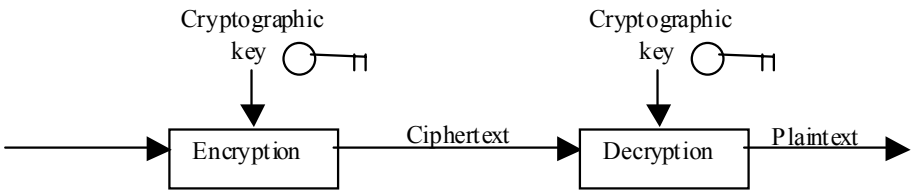


Figure 4 – Encryption/Decryption process

2.3.2 Secret-key

In secret-key cryptosystems, a single key is used for both encryption and decryption. The encryption key cannot be revealed to anyone other than the sender and recipient. Buchanan (2000) states the two most popular secret-key techniques that are in use today are DES (Data Encryption Standard) and IDEA (International Data Encryption Algorithm).

2.3.3 Public-key

In public-key cryptosystems, each user has two related keys, a public-key and a private key. The private key is only known by the user and is used to decrypt messages encrypted by that user's public-key, which is freely available to anyone.

Public and private keys are symmetrical, so code encrypted by one key can be decrypted by the other. This means that knowing the public-key does not allow a user to deduce the corresponding private key. Singh (2001) outlines that anyone can encrypt a message with a user's public-key and the only person that can decrypt it is the intended recipient, as no one else has access to the required private key.

Buchanan (2000) describes how authentication can be performed with public-key cryptosystems. This is achieved by encrypting a message with the sender's private key, effectively creating a digital signature of the message, which the recipient can check by using the sender's public-key to decrypt it. This proves that the sender was the true originator of the message, and it has not been altered by a third party. The most popular public-key technique is RSA, named after its creators Rivest, Shamir and Adleman.

2.3.4 Pretty Good Privacy (PGP)

Both secret-key and public-key cryptosystems are used in secure distributed systems, but both have disadvantages. In secret-key, both the sender and receiver must posses the same key to encrypt and decrypt the data. Unfortunately, the key would have to be passed from sender to recipient through a secret channel, but there is no guarantee the channel is actually secure.

The main disadvantage of public-key cryptosystems is the encryption algorithms require 100 to 1,000 times more processing power than their secret-key counterparts do. This disadvantage is highlighted by Singh (2001). To overcome this Zimmermann (1995) outlined a new technique, named PGP, which simplified the public-key encryption process, and significantly reduced processing times. It operates by using a random session key, which encipher the plaintext file conventionally. It thus combines the RSA public-key cryptosystem with the speed of conventional encryption. This session key is enciphered by the recipient's public-key and sent along with the enciphered text to the recipient. The recipient then uses their private key to decrypt the session key, and uses the recovered session key to decipher the ciphertext message.

2.4 Network Protocols

An important factor in both peer-to-peer and client-server architecture is the protocol used for the nodes to talk to each other. Typically, this is achieved using a layered approach. At the lowest level, communication over a network involves the transfer of bits from one machine to another. Mackenzie (1998) points out that to create an

application to communicate in this manner would be an awkward task, as it would take a large number of 0's and 1's to create a simple message. Instead, a high-level interface for applications to communicate is provided by software running on the networked computers, usually in the operating system itself.

All communicating entities on a network must agree on a set of rules and conventions to be used when sending information over the network medium. These rules are called a network protocol, which sets the format of messages and the appropriate actions required for each message and specifies how the data is packaged into messages. The network protocol can also determine the following:

- Error checking to be used.
- Data compression method.
- How the sending device indicates a message is sent.
- How the receiving device indicates a message is received.

2.4.1 Protocol Layered Model

Instead of having one large protocol to specify the rules for any possible form of communication, the problem was divided into subsections, with a protocol required for each subsection. To ensure that the protocols cooperate, they are developed in complete sets called suites, where each protocol in the suite tackles one part of the communication process. As a protocol is required for each subsection in a suite, it increases the overall flexibility as new protocols can be created and used as required.

The most important factor in protocol design is the layered model, which describes how the communication process can divide into subsections called layers. A protocol suite is designed by specifying a protocol that corresponds to each layer. Comer (1997) provides information on the most commonly used layered model, which is the Open Systems Interconnection (OSI) developed by the International Standards Organization (ISO) and is illustrated in Figure 5.

The OSI model provides a straightforward explanation of the associations between the hardware and protocol components of the network. In the OSI model, the lowest layer corresponds to the physical hardware and the following layers correspond to the software. Stallings (2000) describes the purpose of each of the layers, which are as follows:

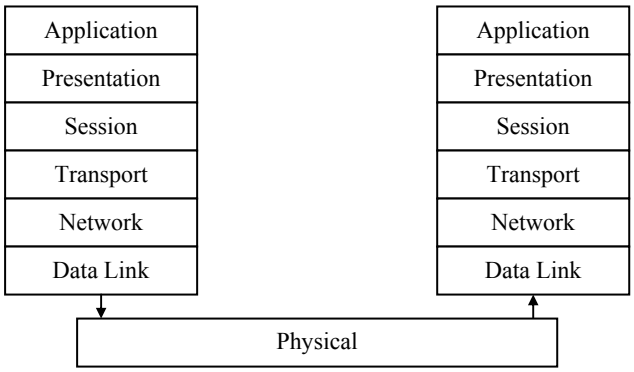


Figure 5 – The OSI Layered Model

1. **Physical**. Corresponds to the network hardware, such as the characteristics of the voltage of transmitted signals, or the intensity of the light pulses.
2. **Data Link**. Specifies how transmitted data is received in a reliable way, and involves adding extra bits for error detection, and so on. A typical example of this layer is Ethernet IEEE 802.3.
3. **Network**. Determines how network addresses are specified and the routing of data through interconnected networks. A typical example of this layer is IP (Internet Protocol).
4. **Transport**. Specifies reliable transport details and the support of multiple streams from a single computer. A typical example of this layer is TCP (Transport Control Protocol).
5. **Session**. Specifies the establishment, maintenance and closing of a communication. A typical example of this layer is HTTP (Hypertext Transfer Protocol).
6. **Presentation**. Specifies how the data is represented, as systems may use different data representation standards. A typical example of this layer is HTML (Hypertext Markup Language).
7. **Application**. Provides network services to an application and specifies how the application uses the network. A typical example of this layer is a WWW Browser.

When a protocol is designed using the OSI model, the protocol software is divided into distinct modules which correspond directly to a layer. Layering also determines how the modules interact, as each module communicates with the layer directly above or below, so outgoing data will pass down through the layers and incoming data will pass up through the layers.

The most widely known and used protocols are those relating to the Internet and TCP and IP. Out of these protocols, the most relevant to this project is the File Transfer Protocol (FTP).

2.4.2 File Transfer Protocol

FTP is one of the oldest Internet protocols, and is used to transfer files between two computers on a TCP/IP network. FTP is based on the client/server architecture where an FTP client is an application running on a computer that connects to a remote computer running an FTP server application. When the connection between the client and server is established, the client can then choose to send or receive files.

Tulloch (1996) provides information on FTP, which uses the Transmission Control Protocol (TCP) to establish a connection-oriented session before initialising the data transfer. TCP is used as it ensures reliable network communication, guaranteeing that data will be delivered intact to the destination. The FTP server listens on TCP port number 21 for connection attempts from an FTP client, this port is also used as for the communication control port, allowing the client to send FTP commands to the server, and to send the response from the server.

2.5 Network Programming

Applications that communicate over a network use an interface to interact with the communication protocols, which is typically known as an Application Programming Interface (API). The API defines the operations that the application can call and the number of arguments that the operation requires. For example, the API would contain an operation used to establish a connection to a remote computer. Tulloch (1996) states that out of the available APIs, the socket API is the de-facto standard.

2.5.1 Windows Sockets (WinSock)

WinSock provides connection-oriented, reliable two-way communication or unreliable connectionless communication between applications on two computers. WinSock is the Microsoft implementation of the Berkeley Sockets Application Programming Interface (API), with the addition of Windows-specific extensions to support the message-driven nature of the Windows operating system and is implemented as a dynamic-link library (DLL). Examples of Windows applications that are implemented using WinSock include Internet Explorer, Telnet and FTP.

2.5.2 Sockets

A socket is the logical endpoint between two communicating hosts on a network. Two sockets form a bi-directional communications path between applications on two different host computers. A socket is comprised of an IP address and a port number. Some port numbers are reserved for well-known services (such as port 21 for FTP) and others are for use by applications. Sockets can be configured to provide either a connection-oriented reliable service or a connectionless, unreliable service.

Davis (1995) describes the function of the reliable service, which is based on TCP and requires that a connection is established between the two processes before data can be sent or received. The data is in a stream of bytes, which has no record delimiters in the data stream, so if a process sends a 200-byte packet of data, the recipient process may receive the data as a single 200-byte packet, or four packets of 50 bytes. If an application were to depend on records of a fixed size being sent, the application must be written to provide application-level headers in the data stream, as the packet size will not be preserved on the receiving end.

Dumas (1995) points out that the reliable service is suited to client-server architectures. Typically, the server will create a socket, give the socket a name, and wait for clients to connect to the socket. The client creates a socket and connects to the server's named socket. When the server detects the connection, it creates a new socket and uses the new socket to communicate with the client. The server's named socket continues to listen for connections from other clients. This process is illustrated in Figure 6.

2.5.3 Microsoft WinSock Guidelines

WinSock was developed by Microsoft to enable Windows applications to take full advantage of the available network bandwidth, allowing them to achieve outstanding performance, reliability and throughput. This is illustrated by the following facts, which were obtained from the Microsoft sockets development page (2002):

- Over 200,000 simultaneous TCP connections can be serviced by Windows.

- A data transmission record of over 750 Mbps was set by Windows.

Windows serviced over 25,000 requests per second running Internet Information Server in a test performed by SPECWeb96.

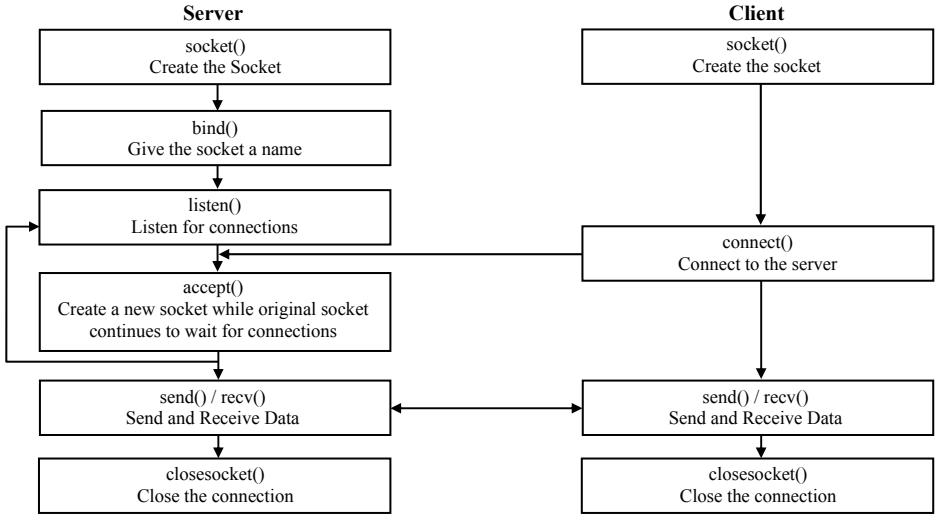


Figure 6 – WinSock Client-Server

However, many applications are developed so they do not take advantage of the performance capabilities of WinSock, as they unintentionally implement techniques that hinder performance.

The most common mistake resulting in reduced application performance involves the TCP/IP protocol, mainly the overhead required for establishing and terminating a connection. For example, if an application uses the TCP/IP protocol on an Ethernet network, it must send four 60-byte packets to establish a connection and the same amount to terminate the connection. An application that regularly establishes and terminates connections incurs this overhead on each occurrence.

Another common programming mistake involves the communication stream between the applications. The most efficient way is to use a small number of large transactions rather than a large number of small transactions, as large transactions are more efficiently streamed. This may involve grouping smaller transactions together and sending as one large transaction.

It also important to consider application behaviour when developing networked applications, as some behaviours will work well on a local machine, but can cause performance problems if run over a network. One such behaviour to avoid is a 'chatty' application, which involves the application sending a large number of small transactions over the network. This is not an efficient method, as there is a large network overhead for each transaction, in the same way as establishing a connection.

2.6 Database Technologies

A database is essentially a repository of data, which allows information to be stored and retrieved quickly. Databases come in two main types:

- **Relational Database Management System (RDBMS).** This is where data is logically grouped into tables, with each table consisting of columns and rows. Begg, *et. al.* (1998) state that RDBMS's are the dominant database technologies in use today, with estimated sales between $8-$10 billion per year, and growing at a rate of 25% per year.
- **Object Oriented Database Management System (OODBMS).** This is where data is stored in the form of objects, where each object has its own properties. According to Begg, *et. al.* (1998), OODBMS's only have a 3% share in the database market.

2.6.1 Common Databases

It is entirely possible to use either of these two types of database, although relational databases are favoured due to their speed, stability and maturity. The three most commonly used relational databases in use today are as follows:

- **Microsoft Access.** Is a RDBMS that can be run on any Windows platform, but does not have any of the advanced capabilities of the other two database systems. The performance of Access is poor compared to the other database system, but is commonly accepted in industry due to its ability to integrate with other Microsoft technologies and its simplicity to set up.
- **Microsoft SQL Server.** Is a RDBMS that runs only on the Server versions of Windows and is used for high-volume transaction-processing environments. It consists of a server that runs the database software that processes requests submitted by the database client software.
- **MySQL.** Is a RDBMS that can be run on any Windows platform, which has the advantage of being an open source product, so its advanced capabilities and performance can be used without incurring any costs.

2.6.2 Open Database Connectivity (ODBC)

Tulloch (1996) describes the function of Microsoft ODBC, which provides an interface that allows Windows applications to access databases over a network through an appropriate ODBC driver. ODBC provides applications with an API, allowing them to be completely independent of the host DBMS that manages the data.

There are two main components used in ODBC:

1. **API**. Function calls that can be called from the application which define how the data in a DBMS is accessed.
2. **Database Drivers**. Translates the API calls into ODBC function calls so the exact DBMS used can respond.

ODBC provides complete interoperability as it allows an application to access any SQL database using common code. A developer using ODBC can build a client-server application without having to specify what DBMS will be used, as it can simply be linked up at a later stage. ODBC has database drivers for over fifty of the most popular DBMS's including Microsoft Access, MySQL and SQL Server.

2.6.3 Database Access Technologies

Currently, there are three Microsoft database access technologies that may be used through applications: Data Access Objects (DAO), Remote Data Objects (RDO) and ActiveX Data Objects (ADO).

DAO was the first technology to provide an object-oriented interface that allowed developers to connect directly to database tables using ODBC, although it was not able to utilise the entire functionality of ODBC.

RDO provides the same style of object-oriented interface to ODBC as DAO, but practically all functionality of ODBC can be utilised. Unfortunately, RDO cannot access databases created with Microsoft Access.

ADO is the successor to DAO and RDO and provides the same interface to ODBC, although the object model in ADO contains more methods and properties. ADO is the only database access technology with a future as it is slowly replacing DAO and RDO. Tulloch (1996) states that using ADO means that an application will be completely interoperable with other database technologies through an ODBC driver.

A developer using ADO and ODBC can write an application that can connect to a range of different data sources using the same programming. This means that the application will be completely interoperable with other database technologies as long as an ODBC driver exists for that data source.

2.7 Conclusions

This chapter has covered the key areas involved in the design and creation of a distributed file sharing application that will utilise cryptographic techniques to enforce security. It covered important system design areas such as current distributed system architectures, available cryptographic techniques and communication protocols, especially in relation to the application-level. It also discussed areas that will be considered during the implementation phase of the application such as network programming techniques and available database technologies, including methods to access these databases through applications.

3 Requirements Analysis & Design

3.1 Introduction

The planning and design stage of any software project can be a difficult process. This chapter highlights the actual specification of the proposed application, what are its goals, how it will function to achieve these goals and what improvements the application could bring to current existing file sharing technologies.

This chapter also highlights the available software process models. According to Sommerville (2001), "A software process is a set of activities and associated results that lead to the production of a software product". Each of the software process models illustrates a different approach to developing a software product. Each model will be reviewed and the most appropriate method will be used to plan and develop the project.

3.2 Software Engineering Methods

In any serious software project, a software process model is used. This allows the management of all aspects involved in the production of the software, from the first stage of specifying the proposed system through to final stage of maintaining the system when it is complete and in use.

Three of most commonly used software process models illustrated by Sommerville (2001) will be evaluated, with the most appropriate model selected for this project. The three models are Spiral development, Evolutionary development and Waterfall. Although these are different process models, each has common stages:

1. **Specification**. Defines the functionality and operation of the software, set by customers and potential users.
2. **Design and Implementation**. The software is developed so it functions as defined in the initial specification.
3. **Evaluation**. The finished software is evaluated so it meets the functionality and operation defined in the specification.
4. **Evolution**. The software must be able to evolve to meet changes in technology and user requirements.

3.2.1 Spiral Development

The spiral model is shown in Figure 7 and represents the software development process as a spiral, instead of a sequence of activities. The spiral starts at the centre, with each loop representing a phase of the development. In each phase of the spiral, objectives are identified, followed by risk analysis, development and evaluation.

The main advantage of the spiral model is there are no fixed phases such as specification or design, which allows the software to be adapted according to additional requirements.

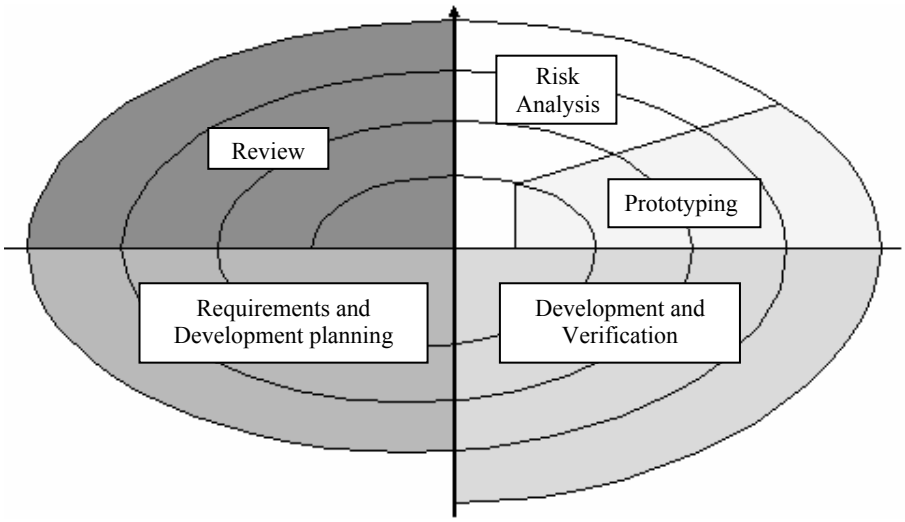


Figure 7 – Spiral Model

3.2.2 Evolutionary Development

This model involves creating an initial version of the software and then allowing the target user to change the specification, advancing the software through multiple versions until the final version is developed. In this model the specification, development and validation stages are conducted concurrently. This model is illustrated in Figure 8.

The advantage of this model is that the software can be produced in incremental stages, with each stage having a revised specification from the target user. However, this model suffers from two main disadvantages:

- The produced software systems are often structured poorly. This is a result of the continual changes to the software, whose structure is often corrupted.
- The software development process is not visible. As the software is developed quickly, documentation for each version is not produced and the target users receive no deliverables to measure the development process.

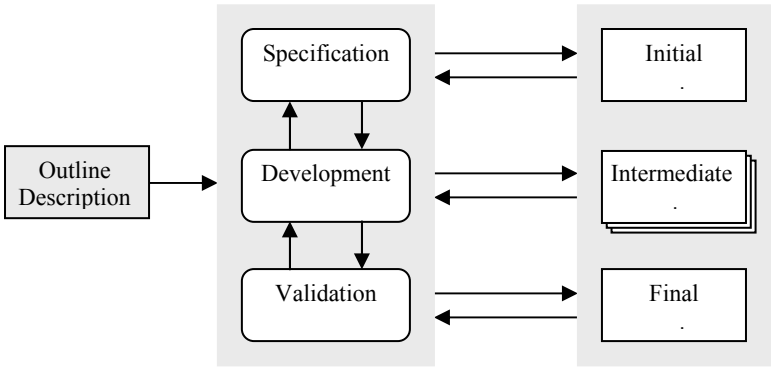


Figure 8 – Evolutionary Development Model

3.2.3 Waterfall Model

The Waterfall model consists of five stages that map onto specific development activities that flow from one to another when an activity is completed and is shown in Figure 9. The model can evolve if additional requirements are discovered at a later stage in the project, which may involve repeating earlier stages. For example, during the implementation stage problems may be discovered which will require a change to the design of the software.

The main advantage of this model is it reflects normal engineering practice and therefore, is commonly used and understood. However, this model suffers from two main disadvantages:

- It should only be used when the requirements of the project are well understood, as it does not readily accommodate requirements changes.
- The software product will not usually be available for use until almost the final stages of the project.

The waterfall model will be selected over the other models as it suits the needs of this project, as the requirements of the project are well understood and the software product is not required until the later stages.

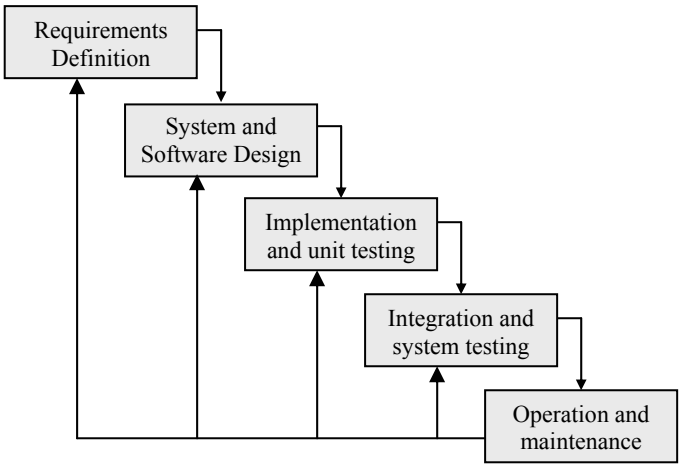


Figure 9 – Waterfall Model

3.3 System Requirements

Many existing technologies allow clients to share files amongst themselves. The main improvement this system offers over the other available technologies is that the files will be shared securely. The security aspects will involve encryption of the file before it is sent and subsequent decryption by the recipient of the file. This means only the intended recipient will be able to read the contents of the file, so if the data transmission were intercepted by a third party, it would be undecipherable.

Another security measure of the system should allow it to detect invalid users. Therefore, if a hacker were able to break into a communication stream, the system would be able to validate the authenticity of the user and then take appropriate action.

The system must also provide users with a file search facility, or they would be unable to share them. This facility should allow users to search for files via a file name or the name of the user, which will return the entire list of files shared by that user.

3.4 Design

The original thinking behind this system was it could be deployed in a commercial environment, where a group of users who require the need to share files amongst themselves in a secure manner could subscribe to the service, and guarantee their authenticity. Therefore, if it were to be deployed in a business environment, only authorised users would be able to gain access share files with each other.

File sharing can already be achieved with a standard network operating system, as access permissions can be set to directories, giving access only to authorised users. However, this is not the safest or most efficient method of sharing files as passwords can be obtained and transmitting files over a wide area using a network can be slow.

3.4.1 File System Architecture

The research conducted into distributed file system architectures outlined that the Client-Server and Gnutella architectures are completely unsuitable for this type of application, as both architectures do not meet the system requirements.

In the Client-Server architecture, files would have to be placed on the central server by the clients in order to be shared. This does not meet the system requirements, as only the client should host the file and should only release it when they want to. If the file was to reside on a server, it could be viewed by any user with enough access rights.

In the Gnutella architecture, there is no central server to store user information as clients connect directly to one another. This does not meet the system requirements either, as there would be no method to validate the authenticity of a client.

The remaining Napster architecture will be used for the system model. This architecture meets the requirements of the system, as the central server can store user information to validate client authenticity. In addition, files are shared between the clients, as the central server offers connected clients the facility to search for a file and provides the address of the client hosting that file.

3.4.2 System Model

The Napster architecture was used as a basis for system design, out of which, three system model candidates were developed:

1) **Single Server**. This model consists of one server and when a client successfully connects, their session details and files they are sharing are recorded in the database. When connected, the client is free to interrogate the server for any required files, with the connection details of clients that hold those files returned.

   Unfortunately, this model suffers from a serious problem, as there is a central point of failure for the system. So if the central server was to become unavailable, so would the entire system. This could be the result of a hacker launching a denial of service attack. This bombards the server with requests that slows it down to the point where no one can gain access.

2) **Multiple Server**. This model consists of three servers and when a client successfully connects to either of them, their session details and files they are sharing are recorded in the server database. This information is then replicated to the other two servers, so each server maintains a global list of connected clients and shared files. This gives a client connected to Server one the ability to search and commence download of a file hosted by a client connected to Server 2 or Server 3.

   Unfortunately, this model suffers from a problem that may lead to database inconsistencies. This would occur if one of the servers were to become unavailable, as the databases in the functional servers would indicate that clients are still connected to the unavailable server and that their files are still available.

3) **Multiple Server with Controlling Server**. This model consists of four servers, with one used exclusively for administering replication between the three remaining servers. This solves the database inconsistency problem in the multiple server model, as functional servers are updated immediately when the controlling server detects that a server is unavailable. In this model, when a client connects to any server, their session details and files shared are recorded in the local server database, which is replicated to the controlling server and finally replicated to the remaining two servers.

   Unfortunately, the multiple server model suffers from the same problem as the single server, as there is a central point of failure for the system, although if the controlling server was to become unavailable, the three remaining servers would be able to provide a partial service to their locally connected clients.

Out of these three possible system models, the model that will be used to implement the system is the Multiple Server model, which is illustrated in Figure 10. The reason behind this decision is there is no central point of failure for the system, which the other two models suffer from. The database inconsistency problem that this model suffers from can be resolved using WinSock programming, as each server will maintain a socket connection to the other two servers, and will immediately be able to detect if a server disconnects, due to the connection-oriented nature of sockets.

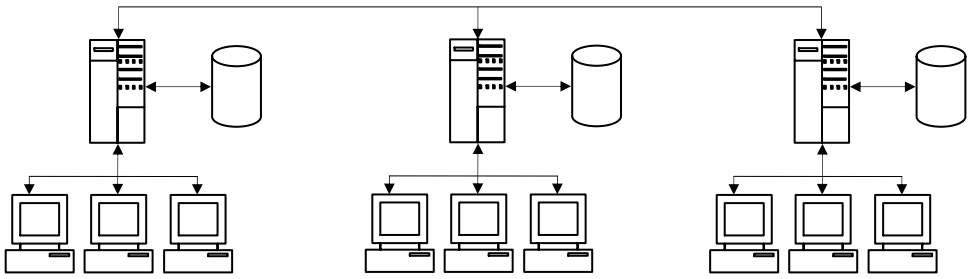


Figure 10 – Multiple Server System Model

3.4.3 System Security

The Theory chapter of this report outlined the three main cryptographic techniques used for the encryption of files. This section discusses the suitability of these three techniques in context of the system.

In secret-key cryptography, the sender and receiver must have the same key to encrypt and decrypt the file. This cryptographic technique is not suitable for the system as the key would have to be sent from sender to recipient with every file transfer, or every system user would have to have the same key. In either case, the security of the key is not guaranteed.

In public-key cryptography, each user has two related keys, a public-key and a private key. The private key is only known by owner of the key and is used to decrypt messages encrypted by the corresponding public-key, which is available to anyone. This cryptographic technique is not suitable for the system either, as public-key encryption algorithms are up to 1000 times slower than secret-key encryption algorithms.

The remaining cryptographic technique, Pretty Good Privacy (PGP) combines both private and public-key cryptography, by using a random session key to encrypt the file conventionally and then encrypting the session key with the recipient's public-key. This cryptographic technique will be used in the system, as it meets the security aspects set in the system requirements.

Additionally, the use of PGP allows the server to detect invalid users, as authentication can be achieved with public-key cryptography. The server can test the validity of a connected user at any time by enciphering a small plaintext message using their public-key. The ciphertext is then sent to the user, where they will use their private key to recover the plaintext and send it back to the server for validation. If the received value does not match the original value, then the user is disconnected from the server.

3.4.4 Client Design

This section identifies the operations and functionality of the client application, illustrating how the client application interacts with the user and the server application. The Client design is illustrated in Appendix 1.

- **Register User Details**. When the client application is run for the first time, it will check if the user has previously registered, possibly using the windows registry. If no previous user details have been detected, the application will prompt the user to register their details (username, password, public-key and modulus key).

  Once the details are entered, the application randomly selects one of the servers, connects and informs the server that a new user is registering their details. It then sends the user details to the server. The Server then validates these details and informs the user if they have been accepted or rejected, if they are rejected, the server informs the user of the reason for rejection. The user may be rejected if the username or the public/modulus keys are already in use, in either case, the user can choose a new username or regenerate the public/private key combination.

- **Logging In/Out**. When a registered user attempts to login, the client application selects one of the servers at random and connects. The server authenticates their details, either granting or denying them system access. If they are denied access,

the server informs the user of the reason for rejection, which may be an invalid username or password. If they are granted access, the list of files the user is sharing is sent to the server and made available to all system users. When the user logs out, the server deletes the shared file entries for that user from the database.

- **Account Maintenance**. When logged on, a user will have the ability to change their password or their public/private key combination. In both cases, the user will submit the new details to the server for validation. The server will then inform the user if the change was successful or not.
- **File Searching/Transferring/Updating**. When logged on, a user can submit search queries by filename or username to the server, which will return any matches. The user can select any of these files and commence file transfer by establishing a connection to the user who hosts the file. The file is encrypted by the user hosting the file using a randomly generated session key, which is encrypted itself using the public-key of the requesting user. Finally, both the encrypted file and the encrypted session key are then sent.

  At any time, a connected user can update their list of files they are sharing, which happens automatically when the user first logs on to the server. If the user is already logged on, the server deletes the shared file entries for that user from the database and writes the new entries submitted by the user.

3.4.5 Server Design

This section identifies the operations and functionality of the server application, illustrating how the server application interacts with the client and the other servers. The server design is illustrated in Appendix 2, and has the following parts:

- **Registering Client Information**. When a new user connects to the server, they will supply their username, encrypted password and public/modulus keys. To ensure the username and public/modulus keys are unique, the server checks them against the existing entries in the database, and notifies the client if they have been registered successfully or not. If the registration was successful, the new user details are written to the database and immediately replicated to the other server databases.
- **Validating Clients**. When an existing client connects, they supply their username, encrypted password and their current IP address. The server looks up the username from the database and retrieves the password and public-key associated with that username. The received password is decrypted, compared against the password from the database and the user is informed of the result. If the logon attempt was successful, the username and current IP address of the user is written to the server database, so the other system users can connect directly via the IP address.
- **Recording Shared Files**. When a user logs on to a server, they automatically send the server a list of files they are sharing. The server writes this file list into the database, making the files available to all other system users. While connected, a user can update their shared file list with the server any time.
- **Searching for Files**. When a connected user submits a file search to the server, it first queries its own local database for any files matching the search criteria. If there are any active connections to the other servers, the search query is then sent

to their databases via the ODBC connection. Finally, any results from the file search are sent to the user.

- **Updating Client Passwords**. When a connected user requests to change their password, they send their username, encrypted old password and encrypted new password. The server looks up the username from the database and retrieves the password and public/modulus keys associated with that username. The received old password is decrypted, compared against the password from the database and if they match, the database is updated with the new password.
- **Updating Client Keys**. When a connected user requests to change their keys, they send their username, encrypted password and new public/modulus keys. The received password is decrypted using the old key values from the database and compared against the password from the database. If they match, the server checks the database for the new public/modulus key combination, in order to determine if they are currently in use. If they are not in use, the new keys are written to the database.
- **Challenging Client Sessions**. In a process invisible process to the clients, the server randomly selects a connected user from the database and obtains their current socket number and public/modulus keys. The server then generates a random value, encrypts it with the public/modulus keys of the selected client and sends the encrypted value to the client. The client will decrypt the value using their private key and send the decrypted value back to the server for comparison. If the decrypted value received from the client does not match the original, the user is disconnected from the system.
- **Other Server Connections**. When a server is started, the administrator can attempt to connect to the other servers manually, or allow the server to attempt to connect automatically. If the automatic connection is chosen, the server will attempt to establish a socket connection to the other servers every five seconds. When a socket is not attempting to connect to a server, it will listen for a connection. This way if all servers in the system are set connect automatically, they will all do so within a relatively small amount of time.

  When a socket connection is established from one server to another, an ODBC connection is also created. Now every file search submitted by clients connected to either of these servers is queried first in the local database of the server, followed by the other server's remote database.

  If a server were to become unavailable, the servers connected to it would detect this using their socket connections. The servers would then close their ODBC connections to the unavailable server and only submit file searches to their local databases and the remote databases of the remaining connected servers.

3.4.6 System Protocols Design

Now that the client and server operations of the system have been identified, the application level protocols can now be designed. Using the client and server operations, the following system protocols have been identified:

Register User Protocol

This protocol is used when a new user is attempting to register their details with a server. This process is illustrated in Figure 11.

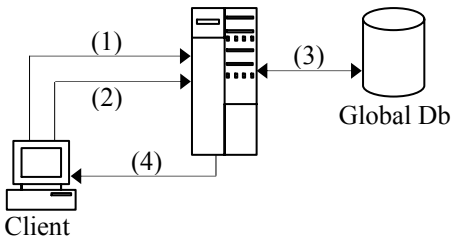


Figure 11 – Register User Protocol

1) Client connects to a server and sends the message **NEW_USER**.
2) Client sends username, encrypted password and public/modulus keys.
3) Server decrypts the password and validates the keys/username.
4) Server sends either **NEW_USER_ACK** or **NEW_USER_NAK,** depending on the result of the validation of the details. If **NEW_USER_NAK** were sent, the server would then send a message to the client, identifying the reason for the rejection. There are two possible messages: **USER_EXIST** (username in use) or **PUB_EXIST** (public-key in use).

Logon Protocol

This protocol is used when an existing user is attempting to logon to a server. This process is illustrated in Figure 12.

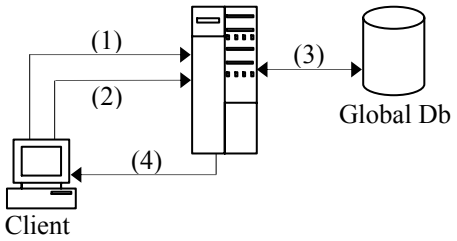


Figure 12 – Logon Protocol

1) Client connects to a server and sends the message **EXIST_USER.**
2) Client sends username, encrypted password and current IP address.
3) Server looks up the username from the database and retrieves the password and public/modulus keys associated with that username. The received password is decrypted and compared against the password from the global database.
4) Server sends either **LOGON_ACK** or **LOGON_NAK**, depending on the result of the comparison of the received password against the global database password.

   If **LOGON_ACK** were sent to the client, they would then start to send their list of shared files to the server using the Shared File List Protocol. If **LOGON_NAK** were sent, the server would then send a message to the client, identifying the reason for the rejection. There are two possible messages: **LOGON_PASSWD** (invalid password) or **LOGON_USER** (Invalid username).

Shared File List Protocol

This protocol is used when an existing user has just logged onto a server or if they are already connected and they wish to update their list of shared files. This process is illustrated in Figure 13.

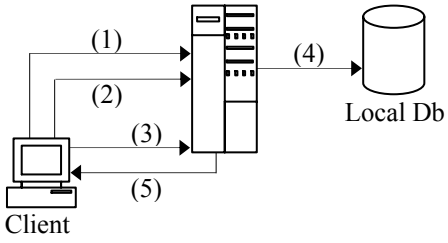


Figure 13 – Shared File List Protocol

1) Client sends the message **SHARED_START** to the server.
2) Client sends the filename and the file size (repeated until all the files in the shared directory are processed).
3) Client sends **SHARED_END** to indicate the end of the file list.
4) Server attempts to write the shared file list to the local database.
5) Server sends either **SHARED_ACK** or **SHARED_NAK**, depending if the shared file list was successfully written to the database or not.

Change Password Protocol

This protocol is used when an existing user is connected to a server and they request to change their password. This process is illustrated in Figure 14.

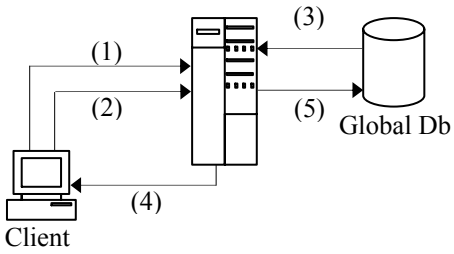


Figure 14 – Change Password Protocol

1) Client sends the message **PASSWD_CHNG** to the server.
2) Client sends username, encrypted old password and encrypted new password.
3) Server looks up the username from the database and retrieves old password, public and modulus keys associated with that username from the global database.
4) The received old password is decrypted and compared against the password from the database. Server sends either **PASSWD_ACK** or **PASSWD_NAK**, depending on the result of the comparison of the received old password against the global database password.

   If **PASSWD_ACK** were sent to the client, their new password would then be written to the global database (5). If **PASSWD_NAK** is sent, there is only one

possible reason for the rejection, so the server sends **LOGON_PASSWD** to inform the client that the incorrect password was supplied.

Change Keys Protocol

This protocol is used when an existing user is connected to a server and they request to change their public/modulus keys. This process is illustrated in Figure 15.

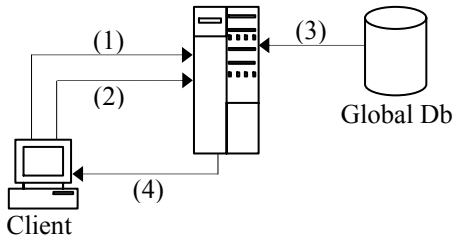


Figure 15 – Change Keys Protocol

1) Client sends the message **KEY_CHNG** to the server.
2) Client sends username, encrypted password and new public/modulus keys.
3) Server looks up the username from the global database and retrieves the password and the old public/modulus keys.
4) The received password is decrypted using the old key values and compared against the password from the global database. Server sends either **KEY_ACK** or **KEY_NAK**, depending on the result of the comparison of the received password against the global database password.

   If **KEY_ACK** were sent to the client, their new public/modulus keys would then be written to the global database (5). If **KEY _NAK** were sent, the server would then send a message to the client, identifying the reason for the rejection. There are two possible messages: **LOGON_PASSWD** (invalid password) or **PUB_EXIST** (public-key already in use).

File Search Protocol

This protocol is used when an existing user is connected to a server and they submit a file search to the server. This process is illustrated in Figure 16.

1) Client sends the message **FILE_SEARCH** to the server.
2) Depending on the search type chosen, the client sends either **FILE_NAME** (followed by the filename) or **USER_NAME** (followed by the username).
3) Server searches its local database and the local databases of the other servers.
4) Server sends **FILE_START** to indicate the file search results are being sent.
5) Server sends the Filename, File size, Username and User IP Address (repeated until all results from the search are sent).
6) Server sends **FILE_END** to indicate the end of the file search results.

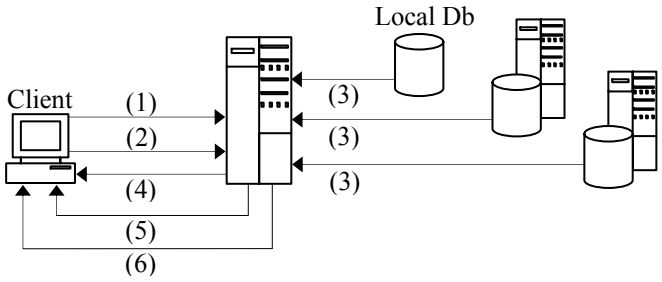


Figure 16 – File Search Protocol

File Transfer Protocol

This protocol is used when a client wishes to download a file from another client. This process is illustrated in Figure 17.

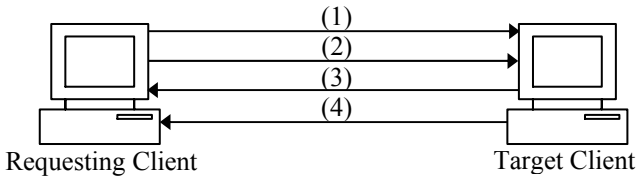


Figure 17 – File Transfer Protocol

1) Requesting client sends the message **FILE_TRANSFER** to the target client.
2) Requesting clients sends the filename, public/modulus keys and username.
3) Requesting client can then receive one of two responses: **TRANSFER_ACK** (Filename exists), or **TRANSFER_NAK** (Filename does not exist). If the target client sends **TRANSFER_ACK**, it generates a random session key, encrypts the file with it and encrypts the session key with the requesting client's public-key.
4) Target client sends **TRANSFER_START** to indicate the start of the transfer, followed by the encrypted session key and the encrypted file.

Client Validity Challenge Protocol

This protocol is used when the server wishes to test the validity of a connected client. This process is illustrated in Figure 18.

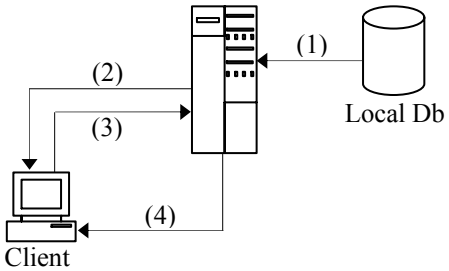


Figure 18 – Change Keys Protocol

1) Server randomly selects a connected client from the local database and reads their current socket connection number and public/modulus key values.

2) Server generates a random value, encrypts it using the public/modulus keys and sends the message **SESS_CHALL** to the client followed by the encrypted value.
3) Client then decrypts the value and sends the message **CHALL_REPLY** followed by the decrypted value.
4) Server compares the received decrypted value with the original value and sends either **SESS_ACK** or **SESS_NAK**, depending on the result of the comparison. If the server sends **SESS_NAK**, the client is disconnected from the server.

3.4.7 Database Design

There were two candidates for the database management system: relational or object-oriented. The relational database was selected for use, as they are fast, stable and widely available. Additionally, the data that will be stored in the database is not complex. MySQL was chosen for the database management system, the justification of this decision can be found in the Technology Choices section later in this chapter.

From the identification of the server operations, it is clear that each server in the system would require two databases: a local database and a global database.

- The global database will store the details of all registered system users, such as username, password and public/modulus keys. When a user registers at a server, their details are written to this database and immediately replicated to the other server's global database. This will maintain consistency throughout the system, as a user may register with one server and attempt to logon to another server at a later stage. If this were to happen without replication, the other server would have no record of this user and deny them access.

  The global database will contain one table called SystemUsers, which has the following fields: Username, Password, PublicKey and ModulusKey.

- The local database will store details of the users currently logged on to the server and the list of files they are sharing. When a user logs in, their socket number, username and IP address are written to this database. This is followed by the names and sizes of any files they are sharing. Instead of this information being replicated to the other server's databases, the servers in the system connect to each other's local databases via an ODBC connection to submit file search queries, which removes a large replication overhead from the system.

  The local database will have two tables: ConnectedUsers and SharedFiles. The ConnectedUsers has the following fields: SocketNumber, Username and IPAddress. The SharedFiles table has the following fields: Username, Filename and Filesize.

The database tables and their replication associations are illustrated in Figure 19.

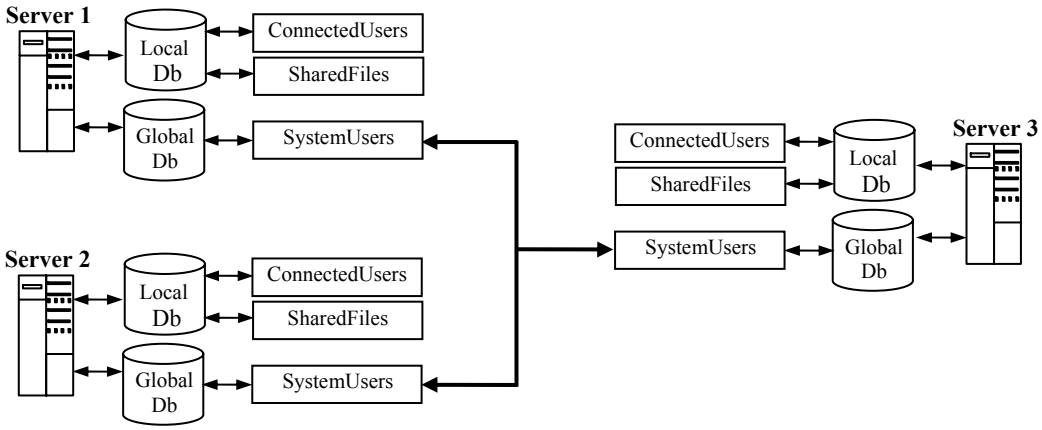


Figure 19 – Database Tables and Replication

3.4.8 User Interface Design

The design of the User Interface (UI) began after the client and server operations of the system were identified, as these operations describe how a user would interact with the client application and how an administrator would interact with the server application.

Instead of sketching out possible client and server application UI's on paper, non-functional prototypes were developed using the Rapid Application Development (RAD) capabilities of Visual Basic. This made the creation of the required amount of forms for each application simplistic, with each form given a number of relevant controls, such as list boxes, command buttons, etc. The RAD capabilities also allowed the layout of the controls on each form to be easily arranged, so the controls are laid out in a visually pleasing manner.

It was very important to consider the potential user for each application, in order to determine the level of complexity. The client application could conceivably be used by someone with very little computing experience, so the UI must be straightforward and give the user access to the client functions easily. The server application however, would be used by a system administrator, who would have a great deal of experience with configuring systems and would require detailed information on the performance of the server and access to complex configuration options.

Creating non-functional prototypes of the client and server applications allowed experimentation with each UI in order to find the right balance of simplicity with functionality for each application. Additionally, the creation of prototypes decreased the overall implementation time for each application, as the functionality of the controls on each form were added during the development phase of the project.

3.4.9 Technology Choices

The technologies used to develop a software project may have a negative impact on the progress of the project, so must be selected carefully. The main decisions on the technologies used during this project relate to the design and implementation stages.

There were two possible candidates for the programming language to develop the applications, which were Visual Basic (VB) and Java. VB is considered the best application for Rapid Application Development (RAD), while Java is platform independent and has a large number of networking libraries available. VB6 was used

instead of VB.NET, as VB.NET is radically different as it fully supports objects and multithreading, but no longer supports WinSock as a means for communicating over a network. These issues combined with the availability of the language meant that VB.NET would not be a viable option for this project.

InstallShield for Windows is an independent package that was used to create the installation program for both Client and Server applications. It allows entries to be made to the Windows registry regarding the installation directory of the application and allows required application DLLs to be registered in the Windows system directory.

As the server application is designed for use with an additional two servers, a DBMS with replication capabilities was required. Replication in Microsoft Access XP is limited, as it requires the use of an additional application called Replication Manager that can only replicate tables after a time interval, with the lowest interval being fifteen minutes. Information on the replication capabilities of MySQL was obtained from the MySQL web page (2002), which justified the selection of MySQL as transaction-based replication is fully supported.

There were three possible technologies for database access: DAO, RDO and ADO, which are both Microsoft technologies. Since ADO is the successor to DAO and RDO, the other two technologies, it is the only one that has a future. Another benefit of using ADO is the application will be completely interoperable with other database technologies through an ODBC driver via SQL statements.

3.5 Conclusions

This chapter has covered the main decisions that were made during the analysis and design phase of the project. These decisions, such as using the waterfall software process model, using the multiple server architecture and using PGP for system security, had a fundamental effect on the implementation of the system, which is covered in the next chapter.

4 Implementation

4.1 Introduction

This chapter highlights the implementation of the system corresponding to the design specification outlined in the previous chapter, concentrating on the client and server applications. A high-level view of these applications is adopted, which illustrates the integration of the system protocols. This chapter also highlights a solution to the problem when sending data using a socket connection.

4.2 WinSock Programming

In the theory chapter of this report, Davis (1995) highlighted that when data is sent using sockets, it is sent in a stream of bytes, which has no record delimiters in the data stream. This meant that if an application were to depend on records of a fixed size being sent, the application must be written to provide application-level headers in the data stream, as the packet size will not be preserved on the receiving end.

The main WinSock connection in the client application (ServerConn) is used to create a connection to the server and allows the client to issue commands to the server. In order to understand responses from the server, each received string is stripped down into its component parts.

This is performed by obtaining the length of the received string, removing one character from the string at a time and storing each character in a variable until a control code is found. When one is found, any remaining characters in the string are stored and the relevant procedure is executed using the variable holding the received string. This process is shown in the following code example:

```
'Read incoming data into the str variable, strip the server command off it
'and strip the other pieces of data off the string
ServerConn.GetData recString

'get the length of the received string
stringLen = Len(recString)

For count = 1 To stringLen
    'get the character
    workstring = Mid(recString, count, 1)

     'check to see if this is a returncode (signifies end of string)
     If workstring = vbCr Then
        'The server has a protocol command code so strip the code off
        'the received string and execute the relevant procedure
        recString = Right(recString, stringLen - count)

        Select Case serverCommand

               Case "NEW_USER_ACK" 'new user registration accepted
           Case "NEW_USER_NAK" 'new user registration rejected

          End Select
     End If
     'append this to the server command variable
     serverCommand = serverCommand & workstring
Next Count
```

In addition to the ServerConn WinSock control, the client application has two more WinSock controls:

- **ClientSend** – Creates a connection to a remote client to send a file. This WinSock control supports multiple connections.
- **ClientRecieve** - Creates a connection to a remote client to receive a file. This WinSock control supports multiple connections.

The server application has three WinSock controls in total:

- **TcpServer** – Creates a connection to the server and allows the client to issue commands to the server. This WinSock control supports multiple connections.
- **Server1** & **Server2**– Each control creates a connection to a remote server, for the purpose of creating and maintaining an ODBC connection to the remote server's database. The connection-oriented nature of sockets allows the local server to detect if the remote server becomes inactive and to close the ODBC connection. These WinSock controls allow only one connection.

4.3 Client Implementation

Figure 20 illustrates a high-level view of the client application, with each important section individually numbered. This number corresponds directly to a sub-section in this chapter, where the functionality and corresponding code is explained in detail.

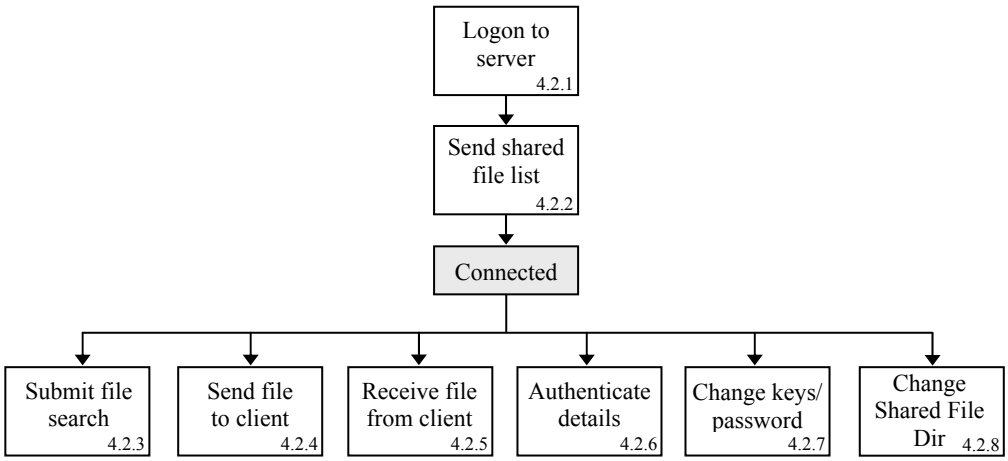


Figure 20 – Client Application High Level View

4.3.1 Logon to Server

There are two functions within this area: registering new user details and existing user logon. When the client application is started, a splash screen is displayed that secretly reads an entry from the Windows registry. This is shown in the following code:

```
userName = GetSetting("SFDS_Client", "Startup", "Username", "")
'check is the username value has an entry
If userName = "" Then
```

```
    strCont = MsgBox("SDFS Client has detected that you are not registered, do
you want to register now?", vbInformation + vbYesNo)
    If strCont = vbNo Then
        End
    Else
        frmRegister.Show
    End If
Else
    Unload frmRegister
    frmMain.Show
End If
```

If the required entry is not found, then it is clear that the user is unregistered, so the form shown in Figure 21 is displayed to prompt the user to enter their details.

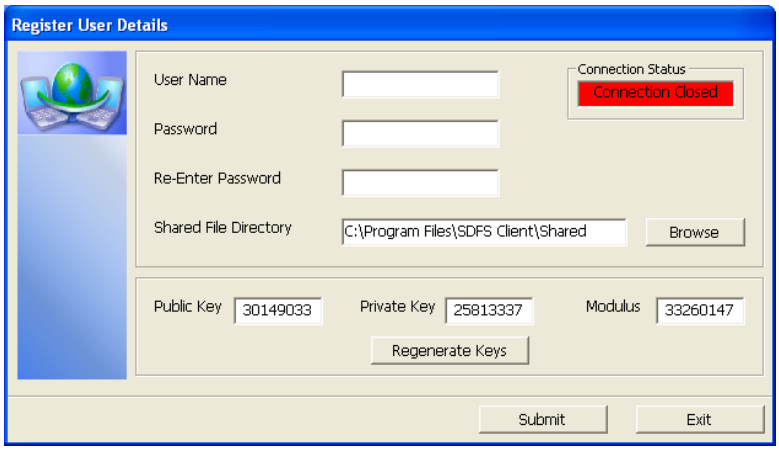


Figure 21 – Register User Details Form

This form sets the shared file directory to the installation directory of the client application and generates a public/private key set, which the user can regenerate if required. These keys are generated using the 'CreateKeys' procedure of the RSA module, which is modified from the code supplied by Griffths (2000) and attached in Appendix 3.

Once successfully registered with the server, the form shown in Figure 22 is presented to the user. This same form is displayed if the entry is found in the Windows registry when the client application is started.

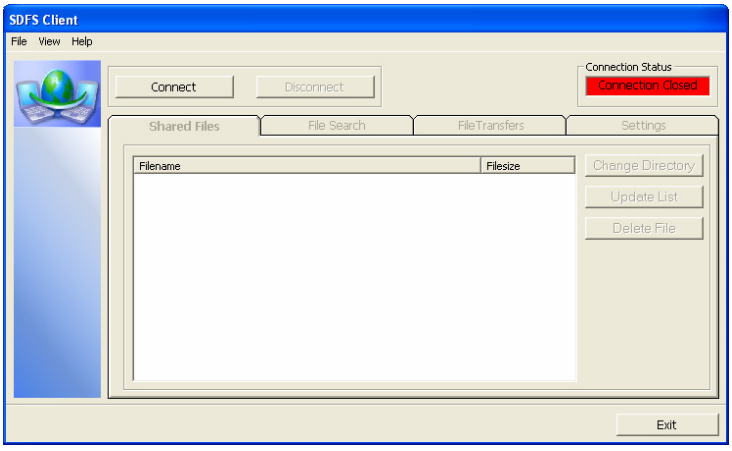


Figure 22 –Main Client Form

When the user clicks the ‘connect’ button on the main form, the client application randomly selects a server, which is achieved using the following code:

```
serverFile = FreeFile
Open (stName & "\Server.dat") For Input As #serverFile

'now read in the values and store them in a dynamic array - as it may be
possible
'that the service is expanded to include more than three servers in the future
Do Until EOF(1)
    Line Input #serverFile, stLine
    'preserve the contents in the array
    ReDim Preserve dynArray(count)
    dynArray(count) = stLine
    count = count + 1
Loop

'close the file
Close #serverFile

'get a random number from the number of server IP addresses read from file
randVal = Int(Rnd * count)

'use that value to get the IP address out of the array and set the Winsock
control RemoteHost variable
frmMain.ServerConn.RemoteHost = dynArray(randVal)
frmMain.ServerConn.RemotePort = 1001
```

After a server has been selected, the client then attempts to connect to it. If there is no response from the server after 20 seconds, the connection attempt is abandoned and the user is informed. If the server responds within this time, the connection status control in the client window is updated and the client application continues to the next task. This process is achieved with the following code:

```
'attempt to connect to the server
frmMain.ServerConn.Connect

'set the status of the connection
Call connectionStatus

startTime = Timer

Do While frmMain.ServerConn.State <> 7 And Timer - startTime < 20
    DoEvents
Loop

'if the Timer exceeds 20 Seconds, the program times out
If Timer - startTime > 20 Then
    GoTo Timeout
Else
    'connection established - set connection status so user sees a result
    Call connectionStatus
End If
Exit Sub

Timeout:
    'notify user connection has timed out
    Call MsgBox("Connection timed out.", vbExclamation, "SDFS Client")
```

As soon as the client successfully connects to the server, the client sends the user details to the server. This process begins with the encryption of the user password using the ‘enc’ method of the RSA module, which is attached in appendix 3. The client then obtains its current IP address and sends this information, along with the username to the server. This is achieved with the following code:

```
encryptPasswd = RSAv1.enc(txtPasswd.Text, txtPrivate.Text, txtModulus.Text)

'get the IP address
ipAddressVal = ServerConn.LocalIP

'inform server existing user is logging in by sending 'EXIST_USER'
If ServerConn.State <> sckConnected Then 'Connection failed
    Call cmdDisconnect_Click
Else
    frmMain.ServerConn.SendData "EXIST_USER" & vbCr

    'send details to the server (username, password and current IP address)
    frmMain.ServerConn.SendData txtUser.Text & vbCr 'username
    frmMain.ServerConn.SendData encryptPasswd & vbCr 'enc password
    frmMain.ServerConn.SendData ipAddressVal & vbCr 'ip address
End If
```

If the logon attempt is successful, the client then sends the shared file list to the server, which is discussed in the next section.

4.3.2 Send Shared File List

The client application automatically sends the list of shared files to the server immediately after a successful logon attempt. The user can also trigger this process at any time, while logged on to the server. This process uses an ADO record set to store the file list and comprises of two stages: reading and sending.

The read process begins by clearing the ADO record set, each file in the shared file directory is added to the record set, with the exception of files that contain an apostrophe, which are ignored as these characters cause an SQL error. After the last file in the directory is processed, the send process begins. The read process is performed using the following code:

```
'first clear any records in the recordset
If rs.RecordCount > 0 Then
    rs.MoveFirst
    Do While rs.EOF = False
        rs.Delete
        rs.MoveNext
    Loop
End If

'Loop through the shared directory and populate the Recordset
strPath = txtDirList.Text & "\"
strName = Dir(strPath)

Do While strName <> ""
    If strName <> "." And strName <> ".." Then

        'Make sure the filename does not have a ' character in it - SQL Error
        If InStr(strName, "'") = 0 Then
            FileSize = FileLen(strPath & strName)

            'Convert filelength into the best possible value (Mb, Kb or bytes)
            strFinal = modClient.getFileSize(FileSize)

            With rs
                .AddNew
                .Fields.Item("Filename") = strName
                .Fields.Item("Filesize") = strFinal
                .Update
            End With
        End If
    End If
    strName = Dir
Loop
```

The send process begins with the transmission of the protocol code 'SHARED_START' to the server, which informs the server that a shared file list is about to be sent. Each entry from the ADO record set is then sent to the server, with a control code added to the end that acts as a record delimiter, which is discussed earlier in this chapter. After the last entry has been sent, the server is informed of this with the transmission the protocol code 'SHARED_END'. The send process is performed using the following code:

```
frmMain.ServerConn.SendData "SHARED_START" & vbCr

'use the recordset to send the files - first check there are files in it
If rs.RecordCount > 0 Then
    rs.MoveFirst
    Do While rs.EOF = False
        frmMain.ServerConn.SendData (rs.Fields.Item("Filename") & vbCr)
        frmMain.ServerConn.SendData (rs.Fields.Item("Filesize") & vbCr)
        rs.MoveNext
    Loop
End If

'now that all files are sent, inform the server
frmMain.ServerConn.SendData "SHARED_END" & vbCr
```

4.3.3 Submit File Search

While logged on to the server, a user is free to submit file search queries either by the name of the file or by the username of the user hosting the files. This process comprises of two stages: sending the search query and receiving the search results.

The send query process begins with the transmission of the protocol code 'FILE_SEARCH' to the server, followed by a file name or username, depending on the search type submitted by the user. The process of receiving the results from a file search begins with the client receiving the protocol code 'FILE_START' to indicate the start of the search results. The received string is then stripped down into its component parts and a count is maintained on the number of strings gathered, as four are required per search result.

As soon as four string values are obtained, the result is written into an ADO record set to store the search results. When the protocol code 'FILE_END' is processed, the entries in the ADO record set are then used to populate the list on the client application form. This process is performed using the following code:

```
'check to see if this is a returncode (signifies end of string)
If workstring = vbCr Then
    retCount = retCount + 1

    'check if this is the end of the list - "FILE_END"
    If searchString = "FILE_END" Then
        'update the search file listview box
        Call populateFileSearch
        Exit Sub
    End If

     'retcount used to count the strings received as there are four for each
result
    Select Case retCount

    Case 1 'filename
        recFile = searchString
        searchString = ""
                workstring = ""
```

```
    Case 2 'filesize
        recSize = searchString
        searchString = ""
        workstring = ""

    Case 3 'Username
        recUser = searchString
        searchString = ""
        workstring = ""

    Case 4 'User ip address
        recIP = searchString
        searchString = ""
        workstring = ""

    'Add this received search into the recordset
    With rs2
        .AddNew
        .Fields.Item("Filename") = recFile
        .Fields.Item("Filesize") = recSize
        .Fields.Item("Username") = recUser
        .Fields.Item("IP") = recIP
        .Update
    End With
```

4.3.4 Send File to Client

This process begins with the requesting client sending a connection request to the target client's ClientSend WinSock control. When this is detected, the target client creates a new instance of the socket and accepts the connection from the remote client. The remote client then sends the protocol code 'FILE_TRANSFER', the name of the required file, their public/modulus keys and username.

The target client then checks if the requested file exists in the shared file directory. If not, the protocol code 'TRANSFER_NAK' is sent, to inform the requesting client that the file no longer exists. If the file does exist, the target client then generates a random 32-bit key using the following code:

```
Dim keyVal As String
Dim randVal As Integer
Dim i As Integer

'Loop 32 times and generate a random 0 or 1
For i = 1 To 32
    randVal = Rnd(1)
    'Add the random number to the key string
    keyVal = keyVal & randVal
Next i

getEncryptionKey = keyVal
```

The file is then encrypted with the session key using modified code supplied from Lai (2002), which is attached in Appendix 4. Once the file has been successfully encrypted, the session key is encrypted using the public and modulus keys of the requesting client using the 'enc' method of the RSA module, which is attached in Appendix 3. The target client then sends the protocol code 'TRANSFER_ACK', followed by the encrypted session key.

The target client begins the process of sending the encrypted file by setting the size of the data packet. This packet is filled with data from the encrypted file and sent to the requesting client, which is repeated until the entire file has been sent. After the file has been successfully sent, the encrypted file is deleted.

During the send process, a count is kept on the amount of bytes sent which is used to update the upload list on the client application form. The send process is performed using the following code:

```
'Set the packetsize to send
packetsize = 256
'Used to make the sent file the same size as the original file
lastdata = False
Temp = ""

'Loop until End Of File.
Do Until EOF(OpenedFileNbr)

    'If the last packet of data has been sent - exit the loop
    If lastdata = True Then
        Exit Do
    End If

    'Adjust the packetsize for the last packet, so too much data isn't sent
    If FileLength - Loc(OpenedFileNbr) <= packetsize Then
        packetsize = FileLength - Loc(OpenedFileNbr)
        lastdata = True
    End If

    'Make the temp variable equal to the size of the packet
    Temp = Space$(packetsize)

    'Load the data into the empty Temp string
    Get OpenedFileNbr, , Temp

    If ClientSend(Index).State <> sckConnected Then
    ' The connection has failed so close the file, delete it and update the
    ' listview
        Close OpenedFileNbr
        Kill strEncFilePath
        itemNumber = modClient.getUploadListItem(Index)
        lvwUpload.ListItems(itemNumber).SubItems(4) = "Failed"
        Unload ClientSend(Index)
        Exit Sub
    End If

    'This is used to keep track of how much data is sent
    doneBytes = doneBytes + Len(Temp)

    'Get the best format for the amount of data sent
    FileSize = modClient.getFileSize(doneBytes)

    'Find the position in the listview of this upload item and update the
    'amount sent
    itemNumber = modClient.getUploadListItem(Index)

    'Update the amount sent for this item - acts as a send progress for the
    'user
    lvwUpload.ListItems(itemNumber).SubItems(4) = FileSize

    'Send the data to the remote client(if still connected)
    If ClientSend(Index).State = sckConnected Then
        ClientSend(Index).SendData (Temp)
    Else
        'The connection has failed so close the file, delete it and update the
        ' listview
        Close OpenedFileNbr
        Kill strEncFilePath
        itemNumber = modClient.getUploadListItem(Index)
        lvwUpload.ListItems(itemNumber).SubItems(4) = "Failed"
        Exit Sub
    End If

DoEvents
Loop

'Close the file now that the last packet has been sent
Close OpenedFileNbr
```

4.3.5 Receive File from Client

In order to request a file download, the user must first select a file from the list of file search results, which is illustrated in Figure 23. When the user clicks the 'download' button, an entry is made in the download list and the client then waits for a response from the remote client.

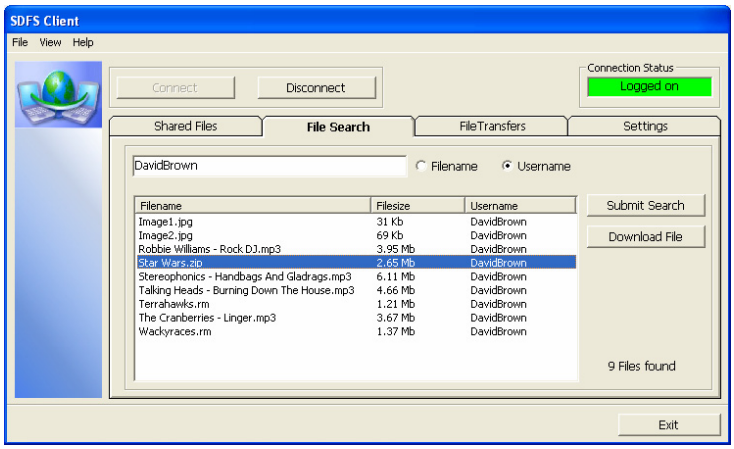


Figure 23 –File Search Results

The remote client will immediately respond with the protocol code 'TRANSFER_NAK' if the file is not available. If the file is available, the remote client will begin to encrypt the file and as soon as the file is encrypted, the remote client sends the protocol code 'TRANSFER_ACK', the encrypted session key and then the file itself. The session key is stored in a variable for later use and the file is built-up from the received packets. The following code illustrates this process:

```
'put the session key in the global array for later retrieval
sessionKey(Index) = strSess

'Get the filename off the download listview
'Find the entry in the listview by using the function in modClient
itemNumber = modClient.getDownloadListItem(Index)
'Set the filename to this
strFileName = lvwDownload.ListItems(itemNumber).SubItems(1)

'Get the path of the SDFS Client App
strPath = modServer.getProgramLocation()

'Open the file for writing and give it an identifier
DownloadingFile(Index) = FreeFile

Open strPath & "\Temp\" & strFileName For Binary Access Write As
#DownloadingFile(Index)

'Trim the session key off the the received string
strData = Right(strData, stringLen - count)

'Get the new length of the string and store it in the byte array
stringLen = Len(strData)

'Reset the array value - as this may have been used by a previous connection
downloadBytes(Index) = 0
downloadBytes(Index) = downloadBytes(Index) + stringLen

'Write the remaining part of the received string to this file
Put #DownloadingFile(Index), , strData
```

When the file transmission is complete, the socket connection between the remote and local clients is closed. The old socket number is used to obtain the file entry from the

download list, and the size of the downloaded file is compared against the original size of the file from the list. If both sizes are identical, the file was downloaded successfully, so the session key is decrypted and used to decrypt the file. If the file sizes do not match, then the downloaded file is deleted. The following code illustrates this process:

```
'Find the entry in the listview by using the function in modClient
itemNumber = modClient.getDownloadListItem(Index)

'Set the filename to this
strFileName = lvwDownload.ListItems(itemNumber).SubItems(1)

'Now test to see if this download completed - if not exit
'If Download completed successfully, filesize and received filesize should be
'the same
If lvwDownload.ListItems(itemNumber).SubItems(2) <>
lvwDownload.ListItems(itemNumber).SubItems(4) Then

    'Delete and reset the temporary file
    Close DownloadingFile(Index)
    DownloadingFile(Index) = 0
    Kill strPath & "\Temp\" & strFileName

resumeError:
    'Update the status of the download item in the ListView
    'so the user can clear it at a later stage
    itemNumber = modClient.getDownloadListItem(Index)
    lvwDownload.ListItems(itemNumber).SubItems(4) = "Failed"
    Exit Sub

End If

'The file was successfully downloaded so now close and reset the file
'that was written to by the winsock object
Close DownloadingFile(Index)
DownloadingFile(Index) = 0

'We now have the filepath and encrypted session key
'first recover the encrypted key
decryptSess = RSAv1.dec(sessionKey(Index), txtPrivate.Text, txtModulus.Text)

'Before decrypting the file - inform the user of this by updating
'the status in the listview (as decryption can take some time on big files)
lvwDownload.ListItems(itemNumber).SubItems(4) = "Decrypting"

'Now decrypt the received file using this information
Call modBinaryEncrypt.DecryptFile((strPath & "\Temp\" & strFileName), (strPath
& "\Shared\" & strFileName), decryptSess)

'Update the download listview for this item
lvwDownload.ListItems(itemNumber).SubItems(4) = "Completed"

'Delete the old File from the temp directory
Kill (strPath & "\Temp\" & strFileName)
```

4.3.6 Authenticate Details

This process begins when the protocol code ‘SESS_CHALL’ is received from the server. The client decrypts the received value using the private and modulus keys and sends the server the protocol code ‘CHALL_REPLY’, followed by the decrypted value. This process is performed using the following code:

```
'We now have a received encrypted value from the SDFS Server
'unencrypt it using the private key
challVal = RSAv1.dec(challString, txtPrivate.Text, txtModulus.Text)

'Inform the server that the response is being sent
'and send the decrypted value to the server
ServerConn.SendData "CHALL_REPLY" & vbCr
```

```
ServerConn.SendData challVal & vbCr
```

4.3.7 Change Password/Public-key

While logged on to the server, a user can change their password or their public/private keys at any time. After selecting a new password, the client application encrypts it along with the old password. The protocol code 'PASSWD_CHNG' is sent to the server, followed by the username and the old & new passwords. This is achieved using the following code:

```
'encrypt the old password with the users private key
encryptOldPasswd = RSAv1.enc(txtPasswd.Text, txtPrivate.Text, txtModulus.Text)

'encrypt the new password with the users private key
encryptNewPasswd = RSAv1.enc(txtPasswd.Text, txtPrivate.Text, txtModulus.Text)

'inform the server that a password change is being sent
'achieved by sending the code 'PASSWD_CHNG'
If ServerConn.State <> sckConnected Then 'Connection failed
    ServerConn.Close
Else
    ServerConn.SendData "PASSWD_CHNG" & vbCr
    ServerConn.SendData txtUser.Text & vbCr 'contents of username text box
    ServerConn.SendData encryptOldPasswd & vbCr 'encrypted old password
    ServerConn.SendData encryptNewPasswd & vbCr 'encrypted new password
End If
```

A new public/private key set can be automatically generated if required by the user. After a new key set is generated, the client application encrypts the user's password and informs the server that a key change is being sent, by sending the protocol code 'KEY_CHNG', followed by the username, password and new public/modulus keys. This is achieved using the following code:

```
'encrypt the password with the users OLD private key
encryptPasswd = RSAv1.enc(txtPasswd.Text,txtPrivate.Text,txtModulus.Text)

'first inform the server that a key change is being sent
'achieved by sending the code 'KEY_CHNG'
If ServerConn.State <> sckConnected Then 'Connection failed
    ServerConn.Close
Else
    ServerConn.SendData "KEY_CHNG" & vbCr
    ServerConn.SendData frmMain.txtUser.Text & vbCr 'contents of username text
box
    ServerConn.SendData encryptPasswd & vbCr 'encrypted password
    ServerConn.SendData txtPublic.Text & vbCr 'new public-key
    ServerConn.SendData txtModulus.Text & vbCr 'new modulus key
End If
```

4.3.8 Change Shared File Directory

While logged on to the server, a user can change their shared file directory at any time. After selecting a new directory, the client application checks if the new directory is different from the previous one. If it is, the Windows registry is updated and the new list of shared files is sent to the server.

4.4 Server Implementation

Figure 24 illustrates a high-level view of the server application, with each important section individually numbered. This number corresponds directly to a sub-section in this chapter, where the functionality and corresponding code is explained in detail.

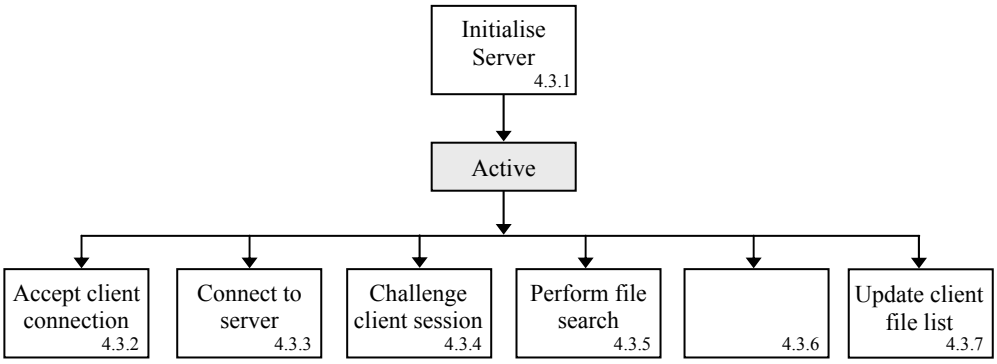


Figure 24 – Server Application High Level View

4.4.1 Initialise Server

When the server is started, it first creates connections to its local and global databases and erases any entries from the two tables in the local database. The server then begins to listen for any client connections.

4.4.2 Accept Client Connection

When a client connects to the server, a new socket connection is created. In order to reuse the socket numbers, a global array is used, which is searched for the first zero value, indicating a free number. The socket is created using the position in the array and as this number is now in use, the array value is set to one.

Finally, the global variable used to keep a count of the number of users connected is incremented and updated on the main server form. The following code illustrates this process:

```
'In order to reuse connections, the clientConn array is used
'If the value in the array is 0, it's position is used to create a winsock
'object
'If the value in the array is 1, it is in use, so try another one
For i = 1 To 2000000
    If clientConn(i) = 0 Then 'Found an empty value
        Load tcpServer(i)
        tcpServer(i).Accept requestID
        clientConn(i) = 1
        Exit For 'Found one, so break from the loop
    End If
Next i

'Get a count of all active client connections
connCount = connCount + 1

'Update the client connection label
lblConnClient.Caption = connCount
```

Once the connection is created, the client will attempt to either register or logon. If the client is registering, the protocol code ‘NEW_USER’ is received followed by the username, encrypted password and public/modulus keys. The server then validates the username and keys by checking if they are already in use. If they are in use, the relevant protocol code is sent to the server to inform the client that they will need to change their details. If not in use, the client information is written to the global database and the client is informed. The following code illustrates this process:

```
'Use the db connection and validate this info
```

```
Set rs1 = New ADODB.Recordset
rs1.Open "select username from systemusers where username ='" & userName & "'",
GlobalDb, adOpenStatic, adLockReadOnly

If rs1.EOF = False Then 'there is a record match in the table (username in use)
    'Inform the connected client
    tcpServer(Index).SendData "NEW_USER_NAK" & vbCr
    tcpServer(Index).SendData "USER_EXIST" & vbCr
    rs1.Close
    Exit Sub
End If

'Check if the pub/mod key combo is in use
Set rs2 = New ADODB.Recordset
rs2.Open "SELECT modkey FROM systemusers Where pubkey = '" & pubKey & "'",
GlobalDb, adOpenStatic, adLockReadOnly

If rs2.EOF = False Then 'there is a record match in the table (keys in use)
    'Inform the connected client
    tcpServer(Index).SendData "NEW_USER_NAK" & vbCr
    tcpServer(Index).SendData "PUB_EXIST" & vbCr
    rs2.Close
    Exit Sub
End If

'Now decrypt the password using the pub & mod keys
decPasswd = RSAv1.dec(encPasswd, pubKey, modKey)

'If username & pub/pri keys not in the Db, add
Set rs3 = New ADODB.Recordset
rs3.Open "insert into systemusers values ('" & userName & "','" & decPasswd &
"','"                 & pubKey & "','" & modKey & "')", GlobalDb, adOpenStatic,
adLockReadOnly

'Now notify the client
tcpServer(Index).SendData "NEW_USER_ACK" & vbCr
```

If the client is logging on, the protocol code ‘EXIST_USER’ is received followed by the username, encrypted password and the local IP address of the client. The server then obtains the public/modulus keys for the client, decrypts the received password and validates it against the password stored in the database. The client is then granted or denied access, based on the result of the password validation. The following code illustrates this process:

```
'Now we have the data, use the db connection and validate the password
'against the one in the Global database SystemUsers table
Set rs1 = New ADODB.Recordset
rs1.Open "SELECT Password, Pubkey, Modkey FROM SystemUsers Where Username = '"
& userName & "'", GlobalDb, adOpenStatic, adLockReadOnly

pubKey = rs1("Pubkey")
modKey = rs1("Modkey")

'Decrypt the password using the pub and mod keys
decPasswd = RSAv1.dec(encPasswd, pubKey, modKey)

If decPasswd = rs1("Password") Then 'password valid
    'This user is now validated so write their socket number,
    'username and IP address to the connectedUsers table
    Set rs2 = New ADODB.Recordset

    rs2.Open "insert into ConnectedUsers values ('" & Index & "','" & userName
              & "','" & localIP & "')", LocalDb, adOpenStatic, adLockReadOnly

    'Send the protocol command code to the client
    tcpServer(Index).SendData "LOGON_ACK" & vbCr
Else 'password invalid
    tcpServer(Index).SendData "LOGON_NAK" & vbCr
    rs1.Close
End If
```

4.4.3 Connect to Server

There are two methods to connect to another server: creating a connection, or listening for a connection. If the server creates a connection, it can be done manually, or set to connect automatically. If the automatic connection is chosen, the server will attempt to establish a socket connection to the other servers every five seconds.

Using either method, if a connection is established, an ODBC connection is established to the remote server's local database, which is used for client file searches. This is achieved using the following code:

```
'check that the server is connected
If Server1.State = sckConnected Then

Call modFunction.server1ConnStatus
timerServ1Uptime.Enabled = True

'Now open the database connection to this server
servConn = connectionString & txtServ1Db.Text

'Open Server 1's local database using the connection string
With Server1Db
    .connectionString = servConn
    .ConnectionTimeout = 10
    .Open
End With
```

4.4.4 Challenge Client Session

The client session challenge is triggered by a timer that is running on the main server form that has a 60-second delay. The server first checks if there are any clients connected, as there would be no point continuing if there are no clients to validate. If there are connected clients, the server picks one randomly from the local database and obtains their current socket number and username, which is used to obtain the public/modulus keys from the global database.

The server then generates a random number and stores it in a global variable. This random number is then encrypted using the public/modulus keys and the server then sends the protocol code 'SESS_CHALL', followed by the encrypted number. This is achieved using the following code:

```
'Check how many users are connected - if none, there is no point continuing
If lblConnClient.Caption = "0" Then
    Exit Sub
End If

'Now randomly select a connected client from the local database
Set rs1 = New ADODB.Recordset
rs1.Open "SELECT * FROM ConnectedUsers", LocalDb, adOpenStatic, adLockReadOnly

'Get a count of the records in the recordset
clientRec = rs1.RecordCount

'Ensure that the number zero is never generated
Do While clientRand = 0
    'Get a random number from the recordset
    clientRand = Int(Rnd * clientRec + 1)
Loop

rs1.MoveFirst
rs1.MovePrevious
rs1.Move (clientRand)

connIndex = rs1("SocketNumber")
strUserName = rs1("Username")
```

```
If rs1.EOF = False Then
    connIndex = rs1("SocketNumber")
    strUserName = rs1("Username")
Else
    rs1.Close
    Exit Sub
End If

rs1.Close

'Open the global databse and retrieve this client's public and modulus keys
Set rs2 = New ADODB.Recordset
rs2.Open "SELECT * FROM SystemUsers Where Username = '" & strUserName & "'",
GlobalDb, adOpenStatic, adLockReadOnly
dblPubKey = rs2("Pubkey")
dblModKey = rs2("Modkey")
rs2.Close

'The randval variable is used to generate a random session key
'set it to the maximum value that a long integer can hold
'Then generate a random number from this value
randVal = 2147483647
challValue = (Rnd * randVal)

'Convert this value into a string, and encrypt it
strRandNum = Str(challValue)

encryptChall = RSAv1.enc(strRandNum, dblPubKey, dblModKey)

'Send the encrypted value to the selected client (if client is still connected)
If tcpServer(connIndex).State = sckConnected Then
    tcpServer(connIndex).SendData "SESS_CHALL" & vbCr
    tcpServer(connIndex).SendData encryptChall & vbCr
End If
```

When the client replies to the challenge, the value they send back is compared against the original random value that is stored in the global variable, and if they do not match, the server sends the protocol code ‘SESS_NAK’ to disconnect the client.

4.4.5 Perform File Search

The file search process is instigated by a connected client, who transmits the protocol code ‘FILE_SEARCH’ followed by the search type and the search parameter. The server obtains the username of the requesting client, so to omit any files shared by this client in the search.

The server then constructs the SQL statement based on the search type specified by the client, by either file name or username. The server informs the client that the file search results are about to be sent and then conducts the file search, first on its own local database and the local databases of any other connected servers. When all the results from the file search have been sent, the server sends the protocol code ‘FILE_END’ to the client. The following code shows an example of this process:

```
'The index of the tcpServer winsock is used to find this client
Set rs1 = New ADODB.Recordset
rs1.Open "SELECT Username FROM ConnectedUsers Where SocketNumber = " & Index &
"", LocalDb, adOpenStatic, adLockReadOnly

'if the recordset contains no records a major failure has occured
If rs1.EOF = True Then
    'Send the protocol command code to disconnect this client
    tcpServer(Index).SendData "SESS_NAK" & vbCr
    rs1.Close
    Exit Sub
End If

'Store the username of this client
```

```
userName = rs1("Username")
rs1.Close

'Constuct the SQL statement according to the search type
If searchType = "FILE_NAME" Then
   searchSQL = "SELECT Filename, Filesize, ConnectedUsers.Username,
   IPAddress FROM SharedFiles, ConnectedUsers Where
   ConnectedUsers.Username = SharedFiles.Username AND Filename like
   '%" & searchParam & "%' AND SharedFiles.Username <> '" & userName & "'"
Else
    searchSQL = "SELECT Filename, Filesize, ConnectedUsers.Username,
    IPAddress FROM SharedFiles, ConnectedUsers Where
    ConnectedUsers.Username = SharedFiles.Username AND
    SharedFiles.Username = '" & searchParam & "' AND
    SharedFiles.Username <> '" & userName & "'"
End If

'Let the client know search results are on their way
tcpServer(Index).SendData "FILE_START" & vbCr

'Now conduct searches using the parameters supplied by the client
'First on the local server
If LocalDb.State = 1 Then
    'Perform search
    rs1.Open searchSQL, LocalDb, adOpenStatic, adLockReadOnly
    'rs1.Close
    If rs1.EOF = False Then
        'Send the results to the client
        rs1.MoveFirst
        Do While rs1.EOF = False
            'Send the results
            tcpServer(Index).SendData (rs1("filename")) & vbCr
            tcpServer(Index).SendData (rs1("filesize")) & vbCr
            tcpServer(Index).SendData (rs1("Username")) & vbCr
            tcpServer(Index).SendData (rs1("IPAddress")) & vbCr
            rs1.MoveNext
        Loop
        rs1.Close
    End If
End If

'Now on Server 1 Local Db connection
If Server1Db.State = 1 Then
    'Perform search
    rs2.Open searchSQL, Server1Db, adOpenStatic, adLockReadOnly

    If rs2.EOF = False Then
        'Send the results to the client
        rs2.MoveFirst
        Do While rs2.EOF = False
            'Send the results
            tcpServer(Index).SendData (rs2("filename")) & vbCr
            tcpServer(Index).SendData (rs2("filesize")) & vbCr
            tcpServer(Index).SendData (rs2("Username")) & vbCr
            tcpServer(Index).SendData (rs2("IPAddress")) & vbCr
            rs2.MoveNext
        Loop
        rs2.Close
    End If
End If

'Finally inform the client that there is no more search results
tcpServer(Index).SendData "FILE_END" & vbCr
```

4.4.6 Client Password/Key Change

The change password process begins when the protocol code ‘PASSWD_CHNG’ is received from a connected client, which is followed by the username, encrypted old password and encrypted new password.

The server then obtains the public/modulus keys for the client from the global database, decrypts the received old password and validates it against the password stored in the database. If the decrypted password matches the password from the

database, the new password is written to the database. The following code illustrates this process:

```
'Now we have the data, use the db connection and validate the OLD password
'against the one in the Global database SystemUsers table
Set rs1 = New ADODB.Recordset
Set rs2 = New ADODB.Recordset
rs1.Open "SELECT Password, Pubkey, Modkey FROM SystemUsers Where Username = '"
& userName & "'", GlobalDb, adOpenDynamic, adLockPessimistic

pubKey = rs1("Pubkey")
modKey = rs1("Modkey")

'Decrypt the password using the pub and mod keys
decOldPasswd = RSAv1.dec(encOldPasswd, pubKey, modKey)

If decOldPasswd = rs1("Password") Then 'password valid
    'Decrypt the new password first
    decNewPasswd = RSAv1.dec(encNewPasswd, pubKey, modKey)

    'Update the password
    rs2.Open "Update SystemUsers set Password = '" & decNewPasswd & "' Where
    Username = '" & userName & "'", GlobalDb, adOpenDynamic, adLockPessimistic

    'Send the protocol command code to the client
    tcpServer(Index).SendData "PASSWD_ACK" & vbCr
Else 'password invalid
    tcpServer(Index).SendData "PASSWD_NAK" & vbCr
    tcpServer(Index).SendData "LOGON_PASSWD" & vbCr
End If
```

The change public/modulus keys process begins when the protocol code ‘KEY_CHNG’ is received from a connected client, followed by the username, encrypted password and the new public/modulus keys.

The server then obtains the old public/modulus keys for the client, decrypts the received old password and validates it against the password stored in the database. If the decrypted password matches the password from the database, the keys are then validated to test if they are already in use. If they are not, the new public/modulus keys are written to the database. If the keys are in use, the client is informed with the relevant protocol code. The following code illustrates this process:

```
'Now we have the data, use the db connection and validate the Password
'against the one in the Global database SystemUsers table
Set rs1 = New ADODB.Recordset
Set rs2 = New ADODB.Recordset
Set rs3 = New ADODB.Recordset
rs1.Open "SELECT Password, Pubkey, Modkey FROM SystemUsers Where Username = '"
& userName & "'", GlobalDb, adOpenForwardOnly, adLockOptimistic

pubKey = rs1("Pubkey")
modKey = rs1("Modkey")

'Decrypt the password using the pub and mod keys
decPasswd = RSAv1.dec(encPasswd, pubKey, modKey)

If decPasswd = rs1("Password") Then 'password valid
'This user is now validated so check if their keys are already in use
rs2.Open "SELECT Pubkey FROM SystemUsers Where Pubkey = '" & newPubKey & "'",
GlobalDb, adOpenStatic, adLockReadOnly

'Check if this recordset contains any records
If rs2.EOF = False Then
    'Send the protocol command code to indicate that the keys are in use
    tcpServer(Index).SendData "KEY_NAK" & vbCr
    tcpServer(Index).SendData "PUB_EXIST" & vbCr
    rs1.Close
    rs2.Close
```

```
    'Update the fields with the new values
    rs3.Open "Update SystemUsers set pubkey = '" & newPubKey & "',
    modkey ='" & newModKey & "' Where Username = '" & userName & "'",
    GlobalDb, adOpenDynamic, adLockPessimistic

    'Send the protocol command code to the client
    'to indicate a successful key change
    tcpServer(Index).SendData "KEY_ACK" & vbCr
Else 'password invalid
    'Send the protocol command code to the client
    tcpServer(Index).SendData "PASSWD_NAK" & vbCr
    tcpServer(Index).SendData "LOGON_PASSWD" & vbCr
    rs1.Close
    Exit Sub
End If
```

4.4.7 Update Client Shared File List

This process begins when the protocol code ‘SHARED_START’ is received from a connected client. This process is automatically performed when a client first logs in and can be performed again any number of times, at the client’s request. The server then obtains the username of the client and deletes the current shared file list from the database.

The client then sends the names and sizes of their shared files, which the server stores in the database until the client sends the protocol code ‘SHARED_END’, which indicates the end of the list. To inform the client that the shared file list has been successfully received, the protocol code ‘SHARED_ACK’ is sent to the client. This is performed using the following code:

```
'First get the client's username from the connected users table
'The index of the tcpServer winsock is used to find this client
Set rs1 = New ADODB.Recordset
rs1.Open "SELECT Username FROM ConnectedUsers Where SocketNumber = " & Index &
"", LocalDb, adOpenStatic, adLockReadOnly

'if the recordset contains no records a major failure has occured
If rs1.EOF = True Then
    'Send the protocol command code to disconnect this client
    tcpServer(Index).SendData "SESS_NAK" & vbCr
    rs1.Close
    Exit Sub
End If

'Store the username of this client
userName = rs1("Username")
rs1.Close

'delete any files shared by this client from  the table
Set rs2 = New ADODB.Recordset
rs2.Open "SELECT Filename FROM SharedFiles Where Username = '" & userName &
"'", LocalDb, adOpenStatic, adLockPessimistic

If rs2.EOF = False Then
    rs2.MoveFirst
    Do While Not rs2.EOF
        rs2.Delete
        rs2.MoveNext
    Loop
End If

rs2.Close

'The user will send filenames and filesizes, ending with 'SHARED_END'
'First get the new length of the recieved string (minus protocol code)
stringLen = Len(recString)

For count2 = 1 To stringLen
    'get the character
```

```
    workString = Mid(recString, count2, 1)

    'Check to see if this is a returncode (signifies end of string)
    If workString = vbCr Then
        'Check if this string is the protocol code that indicates end of list
        If searchString = "SHARED_END" Then
            tcpServer(Index).SendData "SHARED_ACK" & vbCr
            Exit Sub
        End If

        retCount = retCount + 1
        'The retcount variable is used to count the number of strings recieved
        ' as there are two strings - filename and filesize
        If retCount = 1 Then
            recFile = searchString
            searchString = ""
            workString = ""
         Else
            recSize = searchString
            'Write the username, filename and filesize to the table
        rs2.Open "insert into SharedFiles values ('" & userName & "','" &
        recFile & "','" & recSize & "')", LocalDb, adOpenStatic,
        adLockOptimistic
                    searchString = ""
                    workString = ""
                    retCount = 0
        End If
    End If

    'append this to the session key variable
    searchString = searchString & workString
Next count2
```

4.5 Conclusions

This chapter has covered the implementation of the system, which began with a solution to the problem of transmitting data via a socket connection. Detailing the implementation of the system was achieved by adopting a high-level view of the client and server applications. This allowed the implementation of each important section of the application to be fully explained and illustrated with a code example.

5 Testing and Analysis

5.1 Introduction

It is important to consider the levels and methods of software testing, from the initial stage of unit testing through to the final stage of validation testing. Rakitin (1997) provided a great deal of information on these levels, which form a hierarchy. The base of the hierarchy is unit testing, which is intended to locate bugs in the logic and algorithms in the individual modules. Following unit testing is integration testing, the objective of which is to find bugs in the interfaces between modules. The final stage is validation testing, which determines if the software actually meets all the requirements set at the beginning of the software development phase. These testing levels are explained further in this chapter.

5.2 Unit Testing

The purpose of unit testing is to locate bugs in separate modules and is generally integrated with the coding of the module. During unit testing, the separate modules in both applications were tested separately, as they were being developed. The tests that were performed adopted a 'white box' approach, which meant that the tests were developed using knowledge of the internal design. The tests that were performed included:

- **Logic and algorithms**. Must be unambiguous and have a clear resolution.
- **Interfaces**. Data supplied from a calling module matches what the module receives and vice versa.
- **Execution paths**. All independent paths through the module are ran through.
- **Error trapping and handling**. Any routine in the module that may cause a failure due to an error is identified.

The amount of bugs caught by these four tests varied for each module, although the greatest number discovered concerned the error trapping tests.

5.3 Integration testing

The purpose of integration testing is to locate bugs when integrating the individual components of each application, consisting of modules and forms. Although each individual module and form is unit tested, there is still a need to perform integration tests, as it may be possible that one module could affect other modules, even though that module was successfully unit tested.

Integration testing begins with the testing of a small amount of combined modules and progresses to the testing of the complete application. The bugs introduced by integration can be difficult to locate, as the bug could theoretically exist in any of the combined components. For this reason, the integration process of the system was performed in small sections, so any new bugs found could easily be traced to the newly introduced component.

5.3.1 User Interface Testing

The User Interface (UI) was tested during the integration-testing phase, as the entire UI for both applications had been developed earlier during the design phase in the form of two non-functional prototypes. Each prototype contained all the forms, menus and controls required for each application. The main test performed on each UI was a functionality test, to ensure that every control performed its relevant task and that error messages were displayed when required. The other tests performed were cosmetic, in ensuring that the UI followed Microsoft Windows standards and that there was no spelling mistakes.

5.4 Requirements Testing

The objective of requirements testing is to ensure that the software performs its functions as specified in the original system requirements and design documentation. The documentation is reviewed and all the objectives stated in these documents are verified against the software, to determine if they have been implemented in the software successfully.

Testing of the applications involves the creation of functional test cases, which are developed from the perspective of the end-user rather than from system requirements documentation, as errors in the documentation would not be found. Creating test cases from the perspective of a user allows the detection of documentation errors and allows the overall quality of the software to be measured, by how well the software meets the user requirements.

5.5 Performance Testing

After unit, integration and requirements tests were performed on the system, and the bugs found by these processes repaired, the system was then subjected to a number of performance tests. Several researchers have outlined tests for performance testing with peer-to-peer protocols, such as Scarlata, Levine & Shields (2001), who compared the performance of peer-to-peer protocols against the client-server type protocol. They found that transfer times were doubled due to an increase in traffic between peers. This will not be an issue in this system, as the only traffic occurring between peers other than three protocol codes is actual file data.

The objectives of the performance tests are to indicate the scalability, robustness and security of the system through detailed analysis of the test results. In total, there were four tests devised for the system:

- Database Tests.
- Client Speed Tests.
- Encryption Speed Tests.
- Encryption Strength Tests.

In order to measure the performance of the database and the client, versions of the client and server applications were developed specifically for testing. These versions

included code modified from Daniel (2000) that enabled the application to time certain events using a microsecond timer, measuring them by millionths of a second.

The server application was given a timer to assess the length of time for the details of a connected client to be written to the local database. The client application was given three timers, to assess the time to logon to the server, the time to update list of shared files and the time taken to receive the results from a file search.

Additionally, the database tests required a number of clients to simultaneously logon to the server and the and client speed tests required that a number of clients were to simultaneously login, update their shared files and submit a file search. In order to achieve this, an automated test application was developed, which is discussed in the next section.

5.5.1 Automation Test Application

This application used code modified from Cornelisse (2000) to access an atomic clock web page, so the clock used to time the tests running on each computer would be synchronised. The automation application was able to access the client application controls, by using the Application Programming Interface (API) of Windows, which enables an application to locate controls situated on a window. This is achieved by obtaining the handle of the parent window, then accessing the relevant control as they are all children of the parent window and stored in a collection of controls.

The user coordinating the testing would obtain the handle of the client application window by using the 'Grab Window' feature. They would then specify the same start time for all clients in the test, specify if the test is to be repeated and finally, set the actual test that is to be performed. When the start time is reached, all the clients participating in a test would perform the required actions. A screenshot of this application is shown in Figure 25.

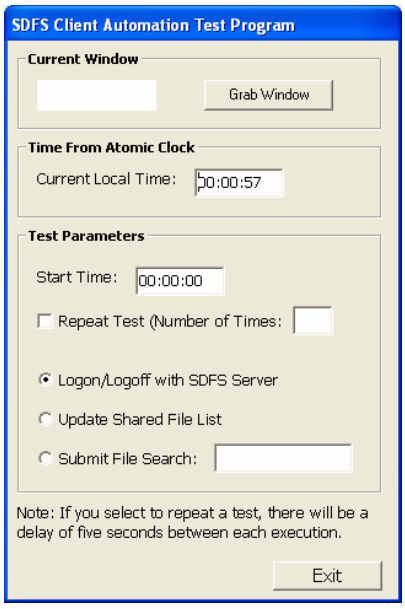


Figure 25 – Automated Test Program

5.5.2 Database Tests

The purpose of the database testing is to discover the amount of time it takes for the details of a user to be written to the database when they first logon. The tests began

with one client and were scaled to ten clients logging onto the server simultaneously. This gave an indication of how scalable the system is, as it would be entirely possible that there could be a far greater number of users attempting to connect simultaneously at any given time.

Even though Microsoft Access XP was not selected as the system database, it was tested along with MySQL mainly out of curiosity, in order to discover which of the two databases were faster.

In each test, the client logged on ten times, with a delay of five seconds per logon, to obtain an average time. Each test was repeated twice in order to acquire an average for the entire test. Table 1 shows the average times to write the user details for both databases, which are combined in the chart featured in Figure 26.

The results of these tests illustrated the fact that MySQL is vastly superior to Access XP. The largest variance of the results between the two databases was when ten clients were logging on simultaneously, as the MySQL time was 468% faster than the time of Access XP.

Number of clients	Access XP time (µs)	MySQL time (µs)
1	0.33	0.00
2	0.17	0.00
3	0.11	0.00
4	0.17	0.00
5	0.27	0.13
6	2.01	0.72
7	2.48	1.10
8	2.58	1.05
9	2.78	0.71
10	3.00	0.64

Table 1 – Access XP and MySQL Test Results

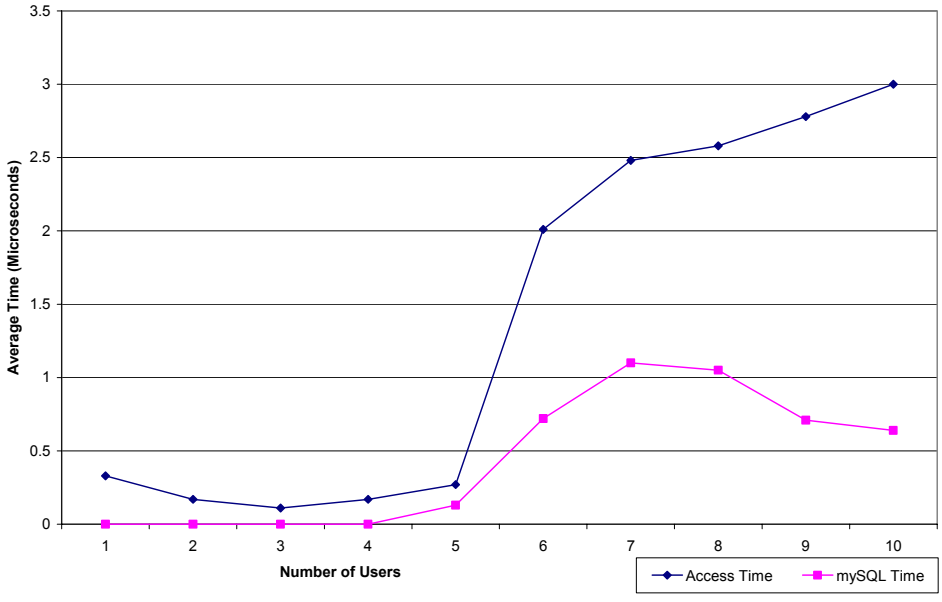


Figure 26 – Access XP and MySQL Times Graph

5.5.3 Client Speed Tests

The purpose of the client speed testing is to discover the amount of time it takes for three client functions to be performed. The functions are logging onto the server, updating the shared file list and performing a file search. Using the same technique as the database tests, these tests began with one client and scaled up to ten clients, all performing the same tests simultaneously. Again, this gave an indication of how scalable the system would be in a working environment, as it would be possible that the final system would have a large amount of users performing various actions at the same time.

In each test, the client performed each test ten times, with a delay of five seconds per logon, to obtain an average time. Each test was repeated twice in order to acquire an average for the entire test. Table 2 shows the average times to write the user details for both databases, which are combined in the chart featured in Figure 27.

The results of these tests illustrated the fact that the system proved to be scalable and robust, as the system continued to function within acceptable parameters, even with 10 connected clients concurrently performing operations.

Number Of Clients	Average Logon Time (µs)	Average File Update Time (µs)	Average File Search Time (µs)
1	53.33	30.00	10.00
2	51.67	30.00	20.00
3	54.44	30.00	20.00
4	55.83	35.00	25.83
5	56.67	38.00	28.00
6	57.78	41.72	33.39
7	54.76	44.33	37.14
8	54.58	46.29	42.13
9	57.04	50.04	45.59
10	62.67	53.37	50.20

Table 2 – Client Test Results

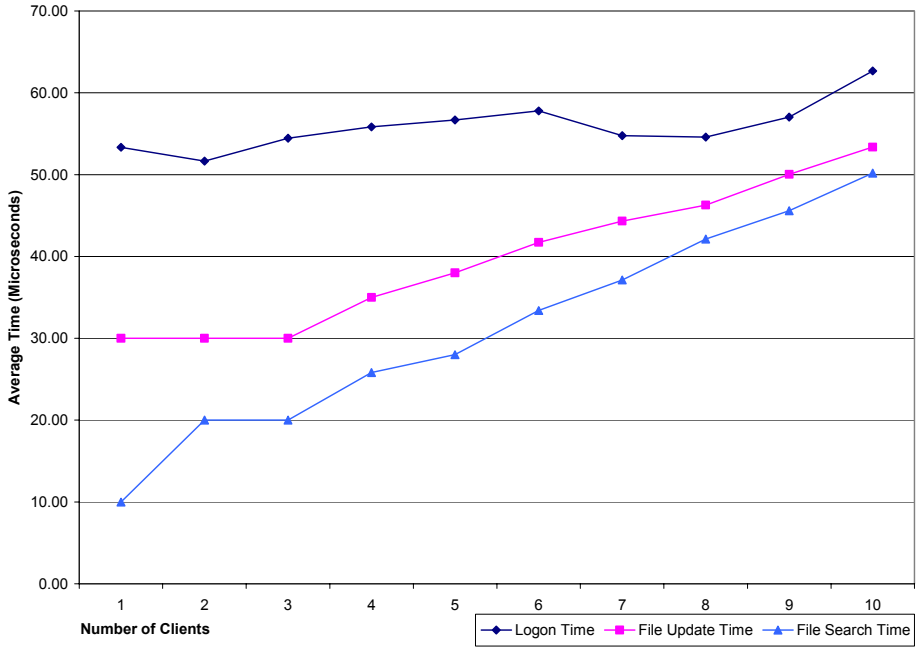


Figure 27 – Client Test Results Graph

5.5.4 Encryption Speed Tests

The purpose of the encryption speed tests was simply to discover the length if time it would take to encrypt a file of a given size. The testing process began with a one Megabyte file, which was scaled up to a ten Megabyte file, this would give an indication if the time taken to encrypt a file was directly related to the size of the file and therefore, it would possible to project the encryption time for any file size.

Five computers of differing specifications were used during this test, in order to gain a varied number of results. Each file size was encrypted five times and an average time was calculated from the five results. Table 3 shows the average encryption time for each computer specification, which are combined in the chart featured in Figure 28.

The results of these tests showed that there was a linear increase in the encryption time of a file relating directly to its size. This would make it possible to project the encryption time of any file, based on its size.

File Size	P4 1.7	P4 1.4	P3 500	P3 800	P3 1000
1Mb	0.45	0.58	1.68	0.99	0.77
2Mb	0.92	1.16	3.36	1.87	1.57
3Mb	1.40	1.75	4.99	2.75	2.37
4Mb	1.86	2.34	6.83	3.74	3.15
5Mb	2.28	2.93	8.63	4.67	3.96
6Mb	2.74	3.51	10.48	5.57	4.73
7Mb	3.20	4.14	12.07	6.46	5.50
8Mb	3.76	4.75	13.84	7.49	6.32
9Mb	4.14	5.27	15.36	8.44	7.12
10Mb	4.69	5.88	17.20	9.50	7.89

Table 3 – Encryption Speed Test Results

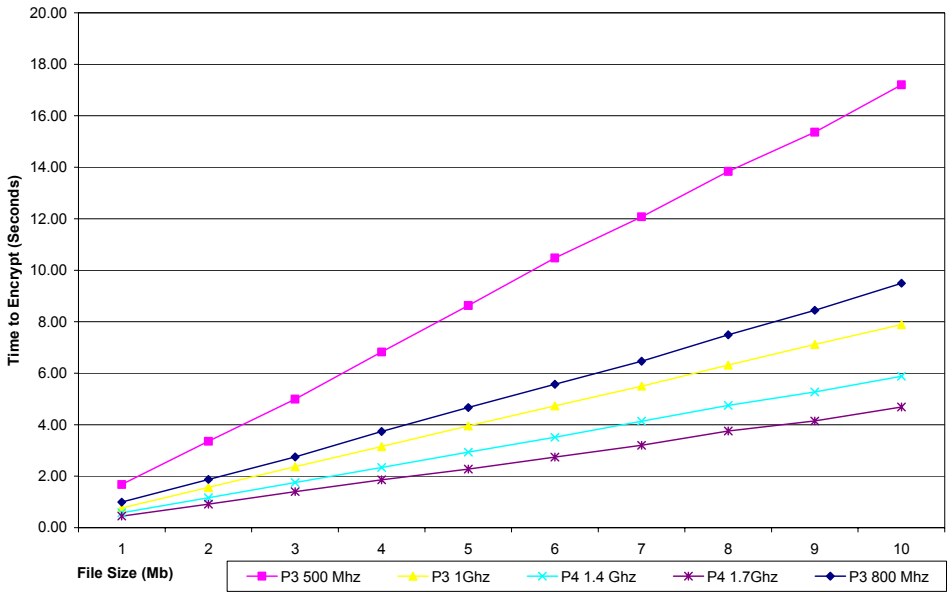


Figure 28 – Graph of Encryption Speed Tests

5.5.5 Encryption Strength Tests

Any encryption code is theoretically breakable, the measurement of how strong the encryption code is the amount of time it would take to break the code by an unauthorised user.

In normal circumstances, the user attempting to break the code would obtain the encryption algorithm by analysing the ciphertext. They would then try every possible permutation of the code key until a match is found. To find a match, they would decrypt a portion of the ciphertext with each key permutation and look for any commonly occurring English words in the decrypted text such as 'the', 'to', and so on.

According to Buchanan (2000), the main factor in the security of an encryption code is its length, as this length determines the maximum number of possible code permutations. The research of Bahie-Eldin & Omar (1998) outlined that the strength of an encryption code can be evaluated by a complexity measure, which involves the randomness of the code via the maximum amount of possible combinations from the code. A single 1-bit code can only have a maximum combination of two keys; a 2-bit code has a maximum of four keys and so on. Table 4 shows some examples of the number of key permutations for a given code size.

Code Size	Total Number of Keys
1	2
2	4
4	16
8	256
16	65,536
20	1,048,576
24	16,777,216
26	67,108,864
28	268,435,456
32	4,294,967,296

Table 4 – Key Permutations

In the client application, the file encryption is based on a 32-bit key, which has over four billion different combinations (4,294,967,296). In order to discover the amount of time it would take for an unauthorised user to break a code of this size, if they discovered the encryption algorithm, a code breaking application was developed.

This application uses a 20-bit key, giving over a million possible key combinations and contains the ciphertext of the plaintext 'Hello'. This ciphertext is encrypted with the value 1,048,576, which is the maximum value of a 20-bit key. The application starts at the number 1 and continues to 1,048,576, using each key permutation to decrypt the ciphertext and comparing the decrypted string against the known plaintext.

The reason a 20-bit key was used rather than a 32-bit key was it would not take a great amount of time to crack the code and it would then be possible to calculate the amount of time it would take to break the 32-bit code, through simple multiplication. As a 32-bit key has 4,294,967,296 combinations and a 20-bit key has 1,048,576 combinations, the 32-bit key contains (4,294,967,296 / 1,048,576 = 4096) more combinations than the 20-bit key. Therefore, the length of time it takes to break a 20-bit key can then be multiplied by 4096 to obtain the time to break a 32-bit key.

On a Pentium 4 1.7 GHz processor, it takes 24 minutes to break a 20-bit key. Therefore, it would take 98,304 minutes (24 x 4096) to break a 32-bit key on this machine, which is 1638 hours (68 days).

Using information from Buchanan (2000), computer-processing power increases on a regular basis. If a computer with an average specification were to take 68 days to break this code, it would be safe to assume that the processing power would be at least doubled in one year; therefore, it would only take 34 days to break the code in the next year. Not only is the increase in processing power a factor in reducing the time it takes to break the code, but also the use of more than one processor working in parallel. Each processor could then be allocated a number of keys to check against the encrypted message. Each processor would then work independently on their key allocation.

Table 5 illustrates the time it would take to decrypt the code in minutes using parallel processors and an increase in computing power. The table shows that with eight processors it would take only six years before the code is decrypted within 12 minutes. Even without an increase in processing power, it would take eight processors 768 minutes, just over 12 hours to decrypt the code.

The results of these tests showed that the encryption employed in the system is not as strong as previously thought, as it would only take 12 hours to decrypt a code using eight average specification computers. If it were the government or the military attempting to break the code, they would be able to do it in minutes, as they would have access to unlimited computing resources.

Processors	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
1	98304	49152	24576	12288	6144	3072	1536
2	49152	24576	12288	6144	3072	1536	768
3	24576	12288	6144	3072	1536	768	384
4	12288	6144	3072	1536	768	384	192
5	6144	3072	1536	768	384	192	96
6	3072	1536	768	384	192	96	48
7	1536	768	384	192	96	48	24
8	768	384	192	96	48	24	12

Table 5 – Decryption Times

5.6 Conclusions

The testing process was performed throughout this project, from the initial unit testing stage through to the final system requirements testing stage. Because of this, the process of catching and repairing bugs was a relatively simple task to perform.

The performance tests proved that the system was scalable and robust, as the system functioned normally with a large number of clients performing concurrent operations. The strength of the encryption proved to be a point of concern, as it would not take a great deal of computing resources to break an encrypted message using the system.

6 Conclusions

6.1 Evaluation of Achievement

The aim of creating a fully functioning system that allows files to be distributed over a wide area and to be shared in a secure manner was completed successfully. All the features specified in the Requirements Analysis & Design chapter of this report were implemented in the final system.

The client application gives users the ability to connect to a server and allows them to send that server a list of their shared files, therefore making their files available to all other system users. Users are free to query the server for any files they may require and when a file is found, it can be downloaded from the other user securely, as the file is encrypted before transmission.

The server application allows users to connect and either logon or register. Once connected, the server records the shared file list of each user and allows connected users to query the list of files on the local server and any other active servers in the system. The server has the ability to authenticate connected users by performing a validation test, to which only a valid user can answer correctly.

A major objective of the system was to make it scaleable. It can be seen from Figure 27 that the relationship between the number of clients and the response time is almost linear. This shows that the system is scaleable within the test parameters. Unfortunately, due to time and resource constraints, it was not possible to test the system beyond 10 clients. This issue is addressed in section 6.2.4 of this chapter.

Tests performed have shown that MySQL is vastly superior to Access XP, especially with 10 clients were logging on simultaneously. In this case, it was shown that MySQL is nearly five times faster than Access XP. This is likely as MySQL is focused on multiple WWW-based transactions, whereas Access XP is based on single-user systems.

A weakness in current file sharing technologies, especially in relation to peer-to-peer systems, is the lack of security and authentication. In the system, cryptographic techniques have been used to implement this. A key factor is obviously the strength of the encryption used. The results of these tests show that the encryption employed in the system is not particularly strong, as it would only take 12 hours to decrypt a code using eight average specification computers.

6.2 Suggestions for Future Work

After requirements and performance testing was carried out on the final system, three points were raised that would require additional work if the system was ever to become available for public use. These points involve an addition to the requirements of the client application, improvements to the encryption speed and strength, further performance tests and a new test that would investigate traffic generated on the network by clients.

6.2.1 Client Application Modification

Even though the final client application met the original requirements specification, there is a need for an additional feature to the application. Currently, any files shared by a client are available to every other client connected to the system. Even though only authorised clients may use the system, a client may not wish to share their files amongst the entire population, but only to a select few.

For these reasons, the client application should be modified to include a feature that will enable a list of authorised clients to be created, so only clients on this list will be able to download files from the client.

6.2.2 Encryption Speed

The Research of Aoki, *et al* (2000), outlined a new encryption algorithm called Camellia, which has an encryption speed that is far superior to the current algorithm employed in the system.

On a Pentium III 500 MHz, an encryption rate of more than 276 Mbits per second was recorded using Camellia. During performance testing, a computer with the same specification was used to obtain the encryption rate of the current encryption algorithm. The test resulted in an encryption rate of just under five Mbits per second.

6.2.3 Encryption Strength

Brassard, *et al* (2000) and Singh (2000) provided information on Quantum cryptography, which is completely different from any other type of encryption in that it is completely unbreakable.

Quantum cryptography is based on Quantum theory, meaning that it is completely impossible for a third party to intercept the code key established between sender and receiver. Even if someone did attempt to intercept the code key, both legitimate communication parties would be warned about the eavesdropper.

Unfortunately, Quantum cryptography requires the use of specialised equipment and therefore, is not available outside laboratory conditions. Additionally, Quantum cryptography cannot currently be engineered to operate over extended distances. However, if these problems were to be resolved, a completely secure method of communicating would be available to everyone.

Because Quantum cryptography will be unavailable for many years, stronger encryption can be provided by another encryption algorithm. The Camellia algorithm highlighted earlier in this chapter as a possible solution to increase encryption speed, also offers a stronger encryption solution. Camellia supports a key size of up to 256-bits, giving a total number of 1.15×10^{77} key combinations, which is far greater than the four billion combinations from the 32-bit key currently used in the system.

6.2.4 Further System Performance Tests

Even though performance tests were carried out on the system, they did not produce the desired results because it was not possible to scale the tests up to the point where the system could no longer function adequately.

As scalability is a major objective of the system, additional performance tests should be performed. Instead of using 10 concurrent clients to test the system, the number of

clients should be scaled up to 10,000, as this will give a definite indication on how scalable the system is.

It would not be practical to use 10,000 computers to test the system as these resources are simply not available and it is not feasible to obtain these resources specifically for testing. A more viable solution would involve simulating the required number of clients using a smaller number of computers.

The ideal set of performance tests would stress the system to its breaking point, to reveal the maximum possible number of concurrent users. Upon discovering the maximum number, a constraint could be placed on the server application, which would limit the total amount of concurrent users per server and therefore, ensure that the system could never be overloaded and would always provide a service.

6.2.5 Network Traffic Tests

The purpose of network traffic testing would be to discover the volume of traffic occurring on the network from clients. The tests could also provide information on the maximum number of simultaneous file transfers that a client is capable of handling.

These tests would involve recording the transfer time of a file with a determined file size between increasing numbers of clients. Using the same testing method proposed by the further system performance tests, the tests could begin with two clients and be scaled up to 10,000 clients.

Again, it would not be practical to use 10,000 computers to test the system, so another method to perform the same test would be to use 500 computers, with each client simultaneously transmitting an increasing number of files. This would not only test the network traffic, but also the number of simultaneous file transfers that a client could handle. Upon discovering the maximum number of transfers, a constraint could be placed on the client application, which would limit the total amount of transfers, so the client could never be overloaded.

Before these tests are performed, it is obvious that the performance of the network will decrease as the number of client file transfers increases. The network traffic tests would be far more productive if they were conducted using several variations of the file transfer protocol, as this could lead to the discovery of the most efficient protocol.

References

Aberer, K. & Hauswirth, M. Peer-to-Peer information systems: concepts and models, state-of-the-art, and future systems. *Proceedings 8th European software engineering conference. ACM Press. 2001, pp326-7. New York, USA.*

Aoki, K., Ichikawa, T., Kanda, M., Matsui, M., Moriai, S., Nakajima, J. & Tokita, T. Camellia: a 128-bit block cipher suitable for multiple platforms - design and analysis. *Selected Areas in Cryptography. 7th Annual International Workshop, SAC 2000. Proceedings (Lecture Notes in Computer Science Vol.2012). Springer-Verlag. 2001, pp.39-56. Berlin, Germany.*

Bahie-Eldin, M.A. & Omar, A.A. Complexity measure of encryption keys used for securing computer networks. *Proceedings 14th Annual Computer Security Applications Conference (Cat. No.98EX217). IEEE Comput. Soc. 1998, pp.250-5. Los Alamitos, CA, USA.*

Begg, C., Connolly, T. & Strachan, A. 1998. Database Systems: A Practical Approach to Design, Implementation and Management. California: Addison-Wesley.

Brassard, G., Lutkenhaus, N., Tal, Mor. & Sanders, B.C. Security aspects of practical quantum cryptography. *Conference Digest. 2000 International Quantum Electronics Conference (Cat. No.00TH8504). IEEE. 2000, pp.1. Piscataway, NJ, USA.*

Buchanan, W. 2000. *Distributed Systems and Networks.* London: McGraw-Hill.

Comer, D. E. 1997. *Computer Networks and Internets.* New Jersey: Prentice-Hall.

Cornelisse, M. 2000. Atomic clock. URL: http://www.planetsourcecode.com/vb/scripts/showcode.asp?txtCodeId=11905&lngWId=1, [01 October 2002]

Coulouris, G., Dollimore, J. & Kindberg, T. 2001. Distributed Systems, Concepts and Design. San Francisco: Addison-Wesley.

Daniel, J. 2000. Accurate Visual Basic 6.0 timer. URL: http://www.planetsourcecode.com/vb/scripts/showcode.asp?txtCodeId=13557&lngWId=1, [01 October 2002]

Davis, R. 1995. *Windows NT Network Programming*. New Jersey: Prentice-Hall.

Doherty, S. P2P taps the enterprise. *Network Computing, vol.13, no.6, 18 March 2002, pp.94-7. CMP Media Inc, USA.*

Dumas, A. 1995. *Programming WinSock*. Indianapolis: Prentice-Hall.

Forte, D. Peer-to-peer file sharing is here to stay. *Network Security, Feb. 2001, pp.9-10. Elsevier, UK.*

Gerwig, K. V. Business: The 8th Layer: Computing power to the people. *Networker, vol.5, no.1, March 2002, pp.13-16. New York, USA.*

Gnutella development page. 2002. Protocol specification. URL: http://www.gnutelladev.com/protocol/gnutella-protocol.html [11 June 2002]

Gnutella home page. 2002. URL: http://welcome.to/gnutella. [11 June 2002]

Griffths, W. 2000. Fast 64bit RSA encryption algorithm. URL: http://www.planetsourcecode.com/vb/scripts/ShowCode.asp ?txtCodeId=6749&lngWId=1. [27 August 2002]

Kant, K., Iyer, R. & Tewari, V. A framework for classifying peer-to-peer technologies. *Proceedings CCGRID 2002. 2nd IEEE/ACM International Symposium on Cluster Computing and the Grid. IEEE Comput. Soc. 2002, pp.368-75. Piscataway, NJ, USA.*

Krishna Ramanathan, M., Kalogeraki, V. & Pruyne, J. Finding good peers in peer-to-peer networks. *Proceedings 16th International Parallel and Distributed Processing Symposium. IEEE Comput. Soc. 2002, pp.232-9. Los Alamitos, CA, USA.*

Lai, K. 2002. Binary encryption class. URL: http://www.planetsourcecode.com/vb/scripts/showcode.asp?txtCodeId=36457&lngWId=1, [3 September 2002]

Lv, Q., Cao, P., Cohen, E., Li, K. & Shenker, S. Search and replication in unstructured peer-to-peer networks. *Proceedings of the 2002 ACM SIGMETRICS international conference on Measurement and modeling of computer systems. ACM Press. 2002, pp.258-9. New York, USA.*

Mackenzie, L. 1998. *Communications and Networks.* London: McGraw-Hill.

Microsoft Corporation. 2002. WinSock development guide. URL: http://msdn.microsoft.com /library/default.asp?url=/library/en-us/winsock/winsock/ high_performance_windows_sockets_applications_2.asp [13 July 2002]

MySQL home page. 2002. Replication capabilities of MySQL. URL: http://www.mysql.com/doc/R/e/Replication.html [28 July 2002]

Napster home page. 2002. URL: http://opennap.sourceforge.net [11 June 2002]

Oram, A. 2001. *Peer-to-Peer: Harnessing the Benefits of Disruptive Technologies.* California: O'Reilly.

Portmann, M., Sookavatana, P., Ardon, S. & Seneviratne, A. The cost of peer discovery and searching in the Gnutella peer-to-peer file sharing protocol. *Proceedings Ninth IEEE International Conference on Networks. IEEE Comput. Soc. 2002, pp.263-8. Los Alamitos, CA, USA.*

Rakitin, S. 1997. *Software Verification and Validation.* Boston: Artech House.

Ratnasamy, S., Francis, P., Handley, M., Karp, R. & Shenker, S. A scalable content-addressable network. *ACM. Computer Communication Review, vol.31, no.4, Oct. 2001, pp.161-72. USA.*

Ripeanu, M. Peer-to-peer architecture case study: Gnutella network. *Proceedings First International Conference on Peer-to-Peer Computing. IEEE Comput. Soc. 2002, pp.99-100. Los Alamitos, CA, USA.*

Scarlata, V., Levine, B. & Shields, C. Responder anonymity and anonymous peer-to-peer file sharing. *Proceedings Ninth International Conference on Network Protocols. ICNP 2001. IEEE Comput. Soc. 2001, pp.272-80. Los Alamitos, CA, USA.*

Singh, S. 2000. *The Code Book*. London: Fourth Estate.

Sommerville, I. 2001. *Software Engineering.* New York: Addison-Wesley.

Stallings, W. 2000. *Data & Computer Communications.* New Jersey: Prentice-Hall.

Tanenbaum, A. S., Van Steen, M. 1996. Distributed Systems: Principles and Paradigms. New Jersey: Prentice-Hall.

Tulloch, M. 1996. *Microsoft Encyclopaedia of Networking.* Redmond: Microsoft Press.

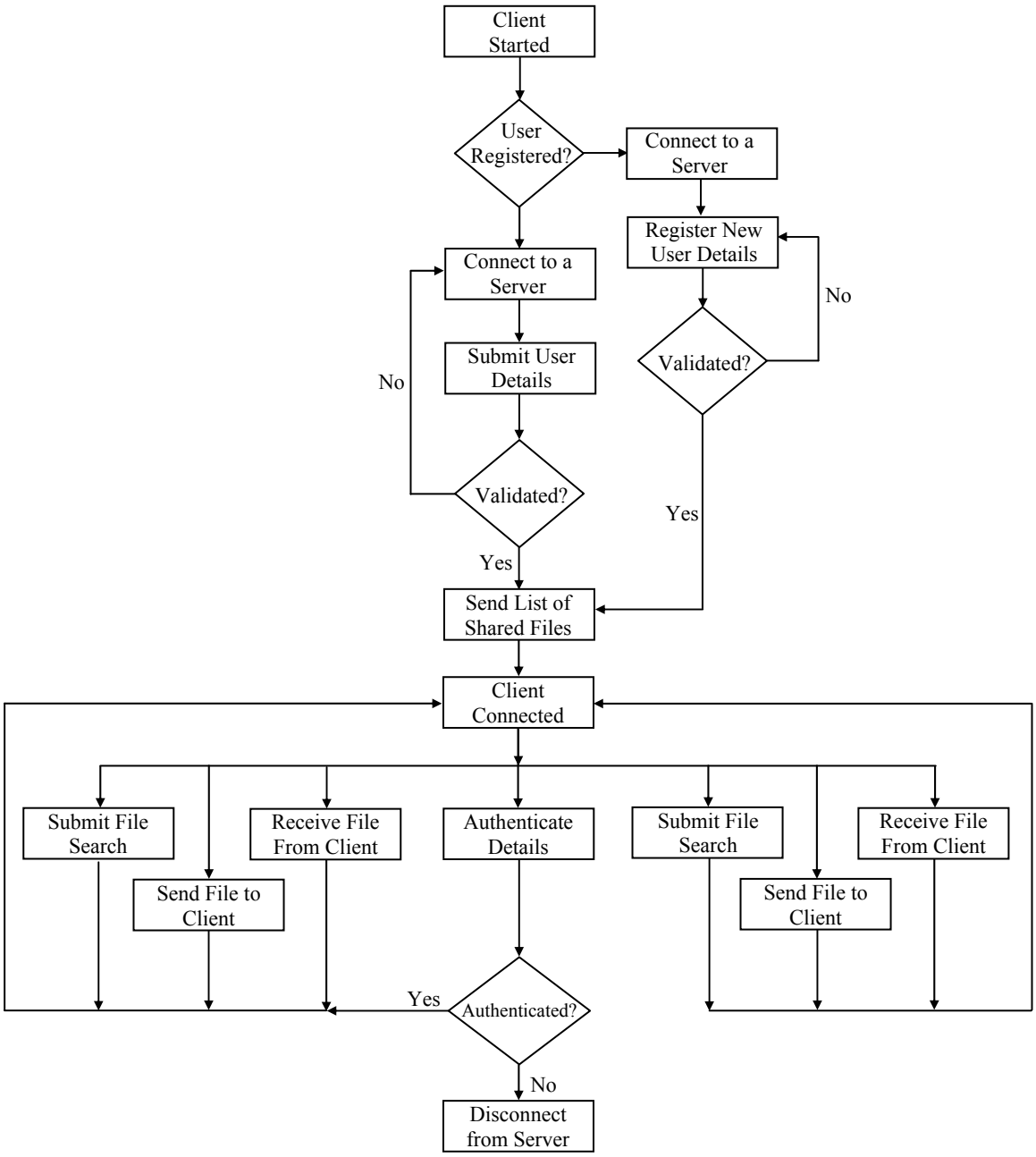
Vrana G. Peering through the peer-to-peer fog. *EDN, vol.46, no.16, 19 July 2001, pp.75-9. Cahners Publishing, USA.*

Waters JK. Peer-to-peer computing: the new old thing. *Application Development Trends, vol.8, no.1, Jan. 2001, pp.20-7.101communications LLC, USA.*

Yang B, Garcia-Molina H. Comparing hybrid peer-to-peer systems. *Proceedings of the 27th International Conference on Very Large Databases. Morgan Kaufmann Publishing. 2001, pp.561-70. Orlando, FL, USA.*

Zimmermann, P. R. 1995. *The Official PGP User's Guide.* Massachusetts: IT Press.

7 Appendix 1: Client Design



8 Appendix 2: Server Design

9 Appendix 3: RSA Encryption Module

```
'RSA Encryption module
'Modified from the original sourcecode created by W.G.Griffiths
'Available from PlanetSourceCode - Fast 64bit RSA Encryption Algorithm.zip
'http://www.planetsourcecode.com/vb/scripts/ShowCode.asp?txtCodeId=6749&lngWId=1

'First declare the public variables
Public primeNumA As Double
Public primeNumB As Double
Public valueN As Double
Public EncryptionKey As Double
Public DecryptionKey As Double
Public PHI As Double

Public Sub CreateKeys()

Const AB_UPPER As Integer = 9999 'set upper limit of random number
Const AB_LOWER As Integer = 3170 'set lower limit of random number
Const KEY_LOWER_LIMIT As Long = 10000000

'initialise the variables
primeNumA = 0
primeNumB = 0
valueN = 0
EncryptionKey = 0
DecryptionKey = 0
PHI = 0
Randomize

'Ensure that the keys are a 64bit minimum
Do Until DecryptionKey > KEY_LOWER_LIMIT
    'Ensure that A and B are prime numbers
    Do Until IsPrime(primeNumA) And IsPrime(primeNumB)

        primeNumA = Int((AB_UPPER - AB_LOWER + 1) * Rnd + AB_LOWER)
        primeNumB = Int((AB_UPPER - AB_LOWER + 1) * Rnd + AB_LOWER)
    Loop

    valueN = primeNumA * primeNumB
    PHI = (primeNumA - 1) * (primeNumB - 1)
    EncryptionKey = GCD(PHI)
    DecryptionKey = Euler(EncryptionKey, PHI)

Loop
End Sub

Private Function Euler(E3 As Double, PHI3 As Double) As Double

On Error Resume Next

Dim u1#, u2#, u3#, v1#, v2#, v3#, q#
Dim t1#, t2#, t3#, z#, uu#, vv#, inverse#

u1 = 1
u2 = 0
u3 = PHI3
v1 = 0
v2 = 1
v3 = E3

Do Until (v3 = 0)
     q = Int(u3 / v3)
     t1 = u1 - q * v1
     t2 = u2 - q * v2
     t3 = u3 - q * v3
     u1 = v1
     u2 = v2
     u3 = v3
     v1 = t1
     v2 = t2
     v3 = t3
     z = 1
```

```
Loop
uu = u1
vv = u2

If (vv < 0) Then
          inverse = vv + PHI3
Else
     inverse = vv
End If

Euler = inverse

End Function

Private Function GCD(nPHI As Double) As Double

On Error Resume Next

Dim nE#, y#
Const N_UP = 99999999 'set upper limit of random number for E
Const N_LW = 10000000 'set lower limit of random number for E

Randomize
nE = Int((N_UP - N_LW + 1) * Rnd + N_LW)

top:
    x = nPHI Mod nE
    y = x Mod nE
    If y <> 0 And IsPrime(nE) Then
        GCD = nE
        Exit Function
    Else
        nE = nE + 1
    End If

    GoTo top

End Function

Private Function IsPrime(lngNumber As Double) As Boolean

On Error Resume Next

Dim lngCount#
Dim lngSqr#
Dim x#
lngSqr = Int(Sqr(lngNumber)) ' Get the int square root

    If lngNumber < 2 Then
        IsPrime = False
        Exit Function
    End If
    lngCount = 2
    IsPrime = True

    If lngNumber Mod lngCount = 0 Then
        IsPrime = False
        Exit Function
    End If
    lngCount = 3

    For x = lngCount To lngSqr Step 2
        If lngNumber Mod x = 0 Then
            IsPrime = False
            Exit Function
        End If
    Next
End Function

Public Function Mult(ByVal x As Double, ByVal p As Double, ByVal m As Double) As
Double

On Error GoTo error1

y = 1
    Do While p > 0
```

```
        Do While (p / 2) = Int((p / 2))
            x = nMod((x * x), m)
            p = p / 2
        Loop
        y = nMod((x * y), m)
        p = p - 1
    Loop
    Mult = y
    Exit Function

error1:
y = 0
End Function

Private Function nMod(x As Double, y As Double) As Double

On Error Resume Next

Dim z#
z = x - (Int(x / y) * y)
nMod = z
End Function

Public Function enc(tip As String, eE As Double, eN As Double) As String

On Error Resume Next

Dim encSt As String
encSt = ""
e2st = ""
    If tip = "" Then Exit Function
    For i = 1 To Len(tip)
        encSt = encSt & Mult(CLng(Asc(Mid(tip, i, 1))), eE, eN) & "+"
    Next i
enc = encSt
End Function

Public Function dec(tip As String, dD As Double, dN As Double) As String

On Error Resume Next

Dim decSt As String
decSt = ""

For z = 1 To Len(tip)
    ptr = InStr(z, tip, "+")
    tok = Val(Mid(tip, z, ptr))
    decSt = decSt + Chr(Mult(tok, dD, dN))
    z = ptr
Next z

dec = decSt
End Function
```

10 Appendix 4: Binary Encryption Module

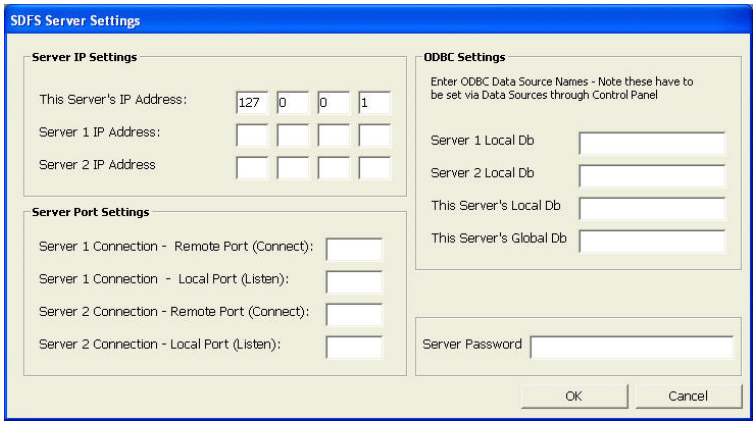
```
'Binary Encryption module
'Modified from the original sourcecode created by Kenny Lai
'Available from PlanetSourceCode - Extremely102235752002.zip
'http://www.planet-source-code.com/vb/scripts/showcode.asp?txtCodeId=36457&lngWId=1

Private Sub SaveBinaryArray(ByVal Filename As String, WriteData() As Byte)

    Dim t As Integer
    t = FreeFile
    Open Filename For Binary Access Write As #t
            Put #t, , WriteData()
    Close #t

End Sub

Function ReadBinaryArray(ByVal Source As String)

    Dim bytBuf() As Byte
    Dim intN As Long
    Dim t As Integer
    Dim n As Long
    t = FreeFile

    Open Source For Binary Access Read As #t

    ReDim bytBuf(1 To LOF(t)) As Byte
    Get #t, , bytBuf()
    ReadBinaryArray = bytBuf()
    Close #t

End Function

Public Sub EncryptFile(Source As String, Destination As String, Password As String)

    Dim ByteIn() As Byte, ByteOut() As Byte
    ByteIn() = ReadBinaryArray(Source)
    ReDim ByteOut(LBound(ByteIn) To UBound(ByteIn)) As Byte

    Dim i As Long, j As Long
    Dim PL As Integer
    PL = Len(Password)

    Dim ChrBNow As Integer
    Dim PosNow As Integer
    Dim TempByte As Integer

    'Decrypt
    Dim TempDByte As Integer, ByteFinal As Integer

    For i = LBound(ByteIn) To UBound(ByteIn)

        'If disconnected from the server - stop encrypting
        If frmMain.ServerConn.State = 0 Then
            Exit Sub
        End If

        PosNow = i Mod PL
        ChrBNow = AscB(Mid(Password, PosNow + 1, 1)) Xor 17
        TempByte = (ByteIn(i) + ChrBNow) Mod 256
        TempDByte = (TempByte - ChrBNow)

                If TempDByte < 0 Then
                    ByteFinal = 256 - Abs(TempDByte)
                Else
                    ByteFinal = TempDByte
                End If

        ByteOut(i) = TempByte

        If i Mod 500 = 0 Then
```

```
            DoEvents
        End If
    Next i

SaveBinaryArray Destination, ByteOut

End Sub

Public Sub DecryptFile(Source As String, Destination As String, Password As String)

    Dim ByteIn() As Byte, ByteOut() As Byte
    ByteIn() = ReadBinaryArray(Source)
    ReDim ByteOut(LBound(ByteIn) To UBound(ByteIn)) As Byte

    Dim i As Long, j As Long
    Dim PL As Integer
    PL = Len(Password)
    Dim ChrBNow As Integer
    Dim PosNow As Integer

    Dim TempDByte As Integer, ByteFinal As Integer

    For i = LBound(ByteIn) To UBound(ByteIn)
        PosNow = i Mod PL
        ChrBNow = AscB(Mid(Password, PosNow + 1, 1)) Xor 17
        TempDByte = (ByteIn(i) - ChrBNow)

                If TempDByte < 0 Then
                    ByteFinal = 256 - Abs(TempDByte)
                Else
                    ByteFinal = TempDByte
                End If

        ByteOut(i) = ByteFinal

        If i Mod 500 = 0 Then
        DoEvents
        End If
    Next i

SaveBinaryArray Destination, ByteOut

End Sub
```

11 Appendix 5: SDFS Server User Manual

11.1 Installation/Getting Started

Double-click the setup.exe to install SDFS Server and follow the prompts. When the installation process is finished, an icon for SDFS Server is placed on the desktop. When SDFS Server is launched for the first time, SDFS Server will detect this and prompt for system settings to be entered by presenting the window below:



This window contains three sections that require an entry from the user: Server IP Settings, Server Port Settings, ODBC Settings and Server Password.

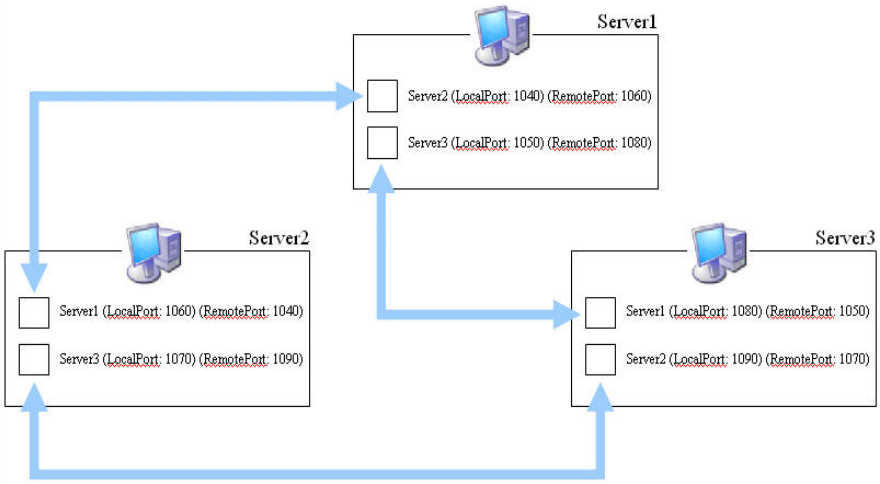
Server IP Settings

This section requires the IP addresses of the other two SDFS Servers in the system, if these addresses are currently unknown, any values may be entered as they can be changed later and the system will still function. SDFS Server automatically detects its own IP address.

Server Port Settings

This section requires the port numbers for the connections to Server 1 and Server 2. In the same way as entering the Server IP settings, if the port numbers are unknown, any values may be entered as they can be changed later and the system will still function.

The remote port is the port number on the remote Server that will be listening for a connection from this Server. The Local port is the port number on the local Server that listens for a connection to the remote Server. Now both servers can invoke a connection to each other, as both have the capability to listen and connect. The following diagram illustrates the process:



ODBC Settings

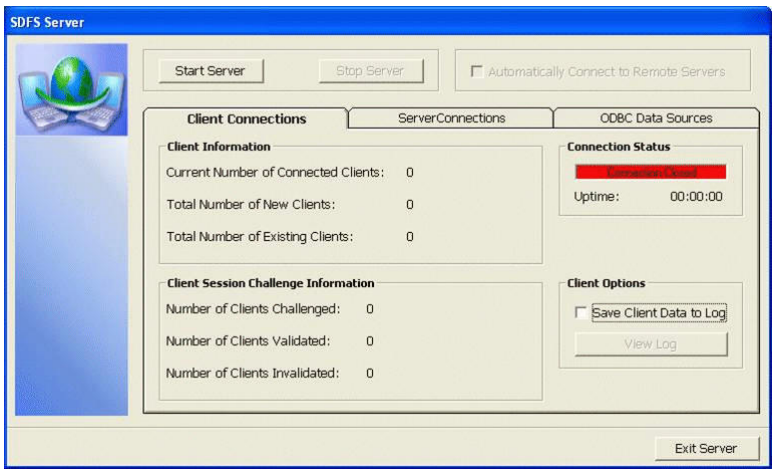
Before entering any information in this section, ODBC data sources must be created first. On Windows NT, 2000 & XP it is located in Control Panel/Administrative tools and on Windows 98 & ME, it is located in the Control Panel. When these data sources are created, the Data Source Names (DSNs) are entered for each server in this section.

Server Password

This section requires the password for the SDFS Server. This password will enable the administrator to change the Server settings at a later stage. Without this password, these settings cannot be changed, which prevents unauthorised tampering.

Running the Server

After the settings have been entered, the SDFS Server will launch and the following screen will be displayed:



There are three tabs on the SDFS Server window: Client Connections, Server Connections and ODBC Data Sources.

11.2 Client Connections

On this tab, there are four sections: Client Information, Client Session Challenge Information, Connection Status and Client Options.

Client Information

This section provides information on the number of clients currently connected to the server and the number of new and existing clients there have been since the server was started (which is shown by the uptime counter in the connection status section).

Client Session Challenge Information

Every 60 seconds, the server will randomly choose a connected client and challenge their session authenticity by generating a value and encrypting it with the selected client's public-key. This section provides information on these challenges, such as the number performed and results of each challenge.

Connection Status

This section simply displays the status of the server and how long the Server has been active.

Client Options

This section allows the server to write client data to a log file, and if this option is enabled, the user can view this log file. The server records the date and time clients perform certain functions, including: connecting, updating shared files, changing password and changing public/private keys.

11.3 Server Connections

This tab contains two sections, one for each of the other SDFS Servers in the system. Both these sections contain the same controls, which have the following functions:

- The IP address, remote port and local port of the remote server connection can be changed, but this can only be done when the connection is idle and the server password is supplied.
- Information about the remote server connection can be saved to a log file – information on connection attempts, lost connections etc.
- If the remote server connection is listening, connected or attempting to connect, this is shown in the remote server connection status.

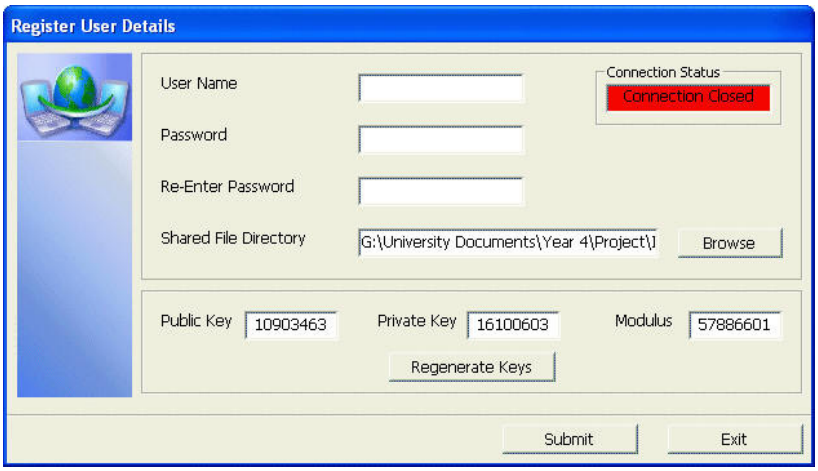
11.4 ODBC Data Sources

This tab shows the status on the ODBC connections to the two local database tables and the two database tables in the remote servers. The user has the ability to change the DSN of these ODBC data sources, but only when the SDFS server is inactive and a valid server password is entered.

12 Appendix 6: SDFS Client User Manual

12.1 Installation/Getting Started

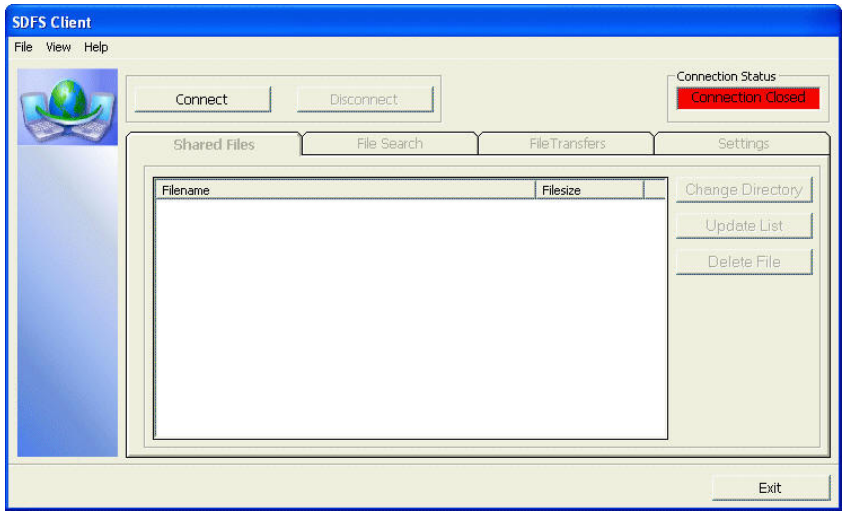
Double-click the setup.exe to install SDFS Client and follow the prompts. When the installation process has finished, an icon for SDFS Client is placed on the desktop. When SDFS Client is launched for the first time, SDFS Client will detect this and prompt for user details by presenting the window below:



In this window, the following details must be entered: Username, Password, Shared File Directory (Set by default to the installation directory) and Public/Private/Modulus Keys (A set is generated automatically).

12.2 Running the Client

After the settings have been entered, the SDFS Client will launch and you will be presented with the following screen:



This screen displays the status of the server connection and gives the user access to the control buttons to connect/disconnect with the SDFS Server. There are four tabs on the SDFS Client window: Shared Files, File Search, File Transfers and Settings, which are all disabled when disconnected from the SDFS Server.

12.3 Shared Files

This section displays information on the files currently shared, which are located in the shared file directory specified when registering user details. At the bottom right of this section, the current number of shared files is shown. There are three control buttons in this section:

- **Change Directory** - Allows the user to change their shared file directory to another directory.
- **Update List** - If the user was to add some files to their shared file directory, to submit these changes to the SDFS Server (to make them visible to other system users), they need to click this button.
- **Delete File -** Simply deletes the selected file and automatically updates the shared file list on the SDFS Server.

12.4 File Search

This section displays the results of file searches, which are performed by the name of the file or the name of the user holding the files. All results from a search are displayed in the list, by file name, file size and the username of the user who is holding the file. To download a file, the user can either click on the filename in the list and click 'Download File' or double-click the filename in the list.

12.5 File Transfers

This section shows the progress of file uploads and downloads. Each entry has a unique identifier, file name, file size, username and upload/download status. The status of an upload can be:

- **ENCRYPTING** - SDFS Client is encrypting the requested file. This is then followed by a send progress indication, as the amount of data sent is constantly updated and displayed.
- **COMPLETED** - SDFS Client has successfully sent the file.

If an error occurs during the upload process, such as the requesting client losing their connection, the status of the upload will change to **ERROR**.

The status of a download can be:

- **PROCESSING** - The target SDFS Client is encrypting the requested file. This is then followed by a send progress indication, as the amount of data sent is constantly updated and displayed.
- **DECRYPTING** - SDFS Client has recovered the random session key (with private key) and is decrypting the received file with it.
- **COMPLETED** - SDFS Client has successfully sent the file.

If an error occurs during the download process, such as the target client losing their connection, the status of the download will change to **ERROR**.

12.6 Settings

This section displays the current details of the user. From this screen, the user can change their password, shared file directory and their public/private & modulus keys.

13 Appendix 7: Project Gantt Chart