Master Thesis

Samba Client/Server for A2

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Abstract

The goal of this master thesis is to simplify data access between A2, an operating system developed at ETH Zurich, and other operating systems, in particular Windows. Windows and many Linux versions use Samba for this purpose. Samba is a client-server based protocol used to provide access to files, printers, serial ports and interprocess communication over the network. The implementation of a Samba client and a Samba server for A2 helps to increase the interoperability between A2 and other operating systems.

Contents

Chapter 1

Introduction

The Native Systems Group of the ETH Zurich has developed an operating system called A2. The kernel of A2 offers multi-processor support, preemptive multi-tasking, automatic memory management and dynamically loadable modules. The language used in A2 is the Active Oberon Language, which is strongly typed, object-oriented and has integrated concurrency support.

At the moment, A2 has not the functionality to access files on remote shares. The goal of this master thesis is to increase the interoperability between A2 and other operating systems by implementing a client and a server for the Server Message Block (SMB) protocol. SMB is a client-server based protocol used to provide access to files, printers, serial ports and interprocess communication over the network. Originally SMB was developed by Microsoft, IBM, Intel and 3Com for DOS, but Microsoft integrated SMB also in Windows versions. Through the dominance of Microsoft in the desktop world, SMB became the de facto standard for file and printer access in Local Area Networks. Roughly on every major release or update of Windows, Microsoft has introduced new dialects which added extensions to the core SMB protocol. The currently most diffused dialect, also in the Unix world, is NT LM 0.12, which was introduced with Windows NT 4.0. The A2 implementations of client and server support only NT LM 0.12, since Microsoft guarantees backward compatibility.

SMB allows a client to manipulate files (read, write, create, delete and

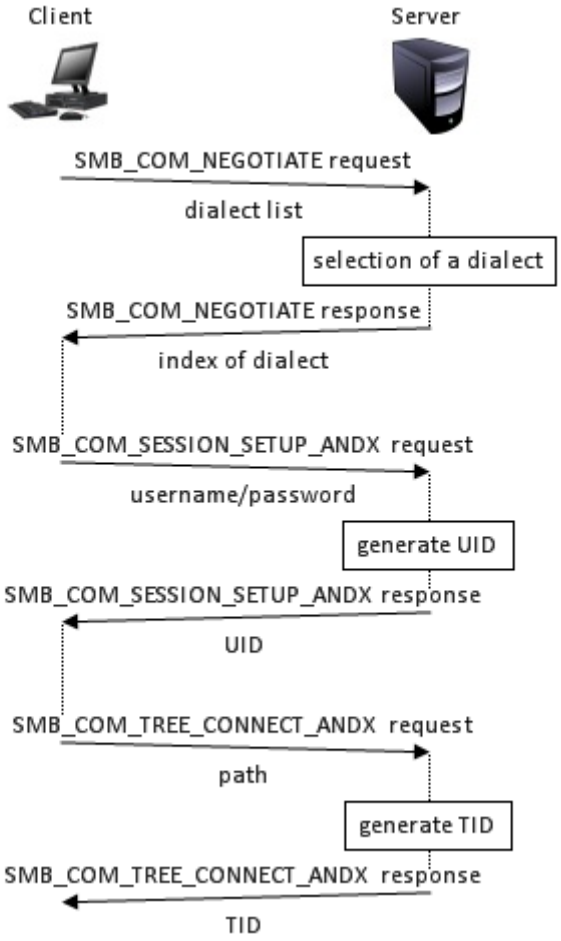
rename), as if they were available on the local computer, but in fact the files are stored on a remote server. Therefore, the client has to send commands to the server. Client and server communicate over the network using packets. In the OSI model, the SMB protocol is classified in the Application/Presentation level. The transport, which has to be absolutely reliable in SMB, is realized through the well-known Transmission Control Protocol (TCP).

7	Application Layer
6	Presentation Layer
5	Session Layer
4	Transport Layer
3	Network Layer
2	Data Link Layer
1	Physical Layer

The OSI model.

The client has to map all functions related to the file system to SMB packets. A SMB packet contains all necessary information to perform a manipulation to a file. Not all operations are executable with one SMB request. Certain operations need multiple different requests. The first of the two following figures shows, which packets are sent to log in on a SMB server and the second figure shows the packets sent to read a file from a share:

Login

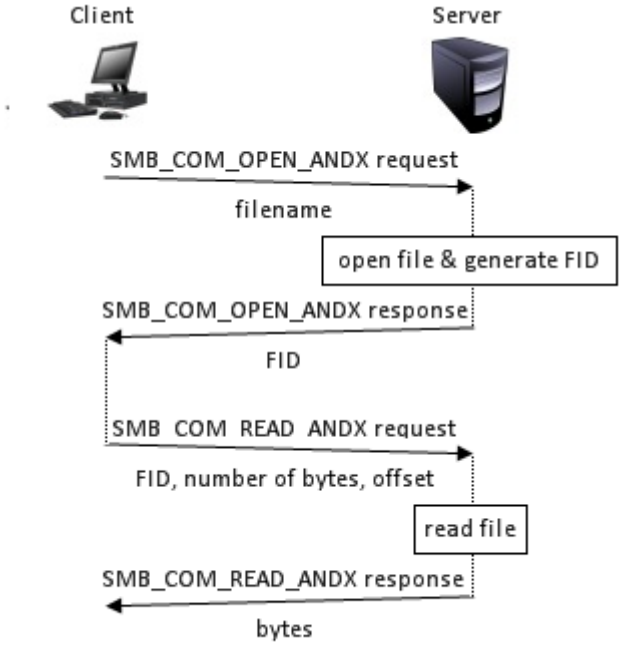


Typical message flow to perform a login.

The first packet is sent by the client and contains a list of dialects, that the client understands. The server can choose one dialect of the list, that the server also understands, and sends the response to the client containing the index of the chosen dialect in the list. At this point, client and server have agreed on one dialect (often NT LM 0.12). The second step to perform a login is the validation of the username/password combination. The client sends its second packet to the server containing the username and the password. If the server accepts the username/password combination or grants guest accounts, it generates a User ID (UID) and sends the response to the client containing the generated UID. The last step of the login is the

access to the desired path. The client sends its third packet to the server containing the path name in UNC format (i.e. \\SERVER\SHARE). The server generates a Tree ID (TID) and grants access to the path, if the user has the appropriate rights. The user is now logged in and can continue with other operations like listing all files in the share or directly accessing a file.

File access



Typical message flow to read a file.

Before the client can read or write a file, it has first to open the file. Therefore, the client sends a packet containing the filename. The server opens the file and generates a File ID (FID) used for further operations based on the opened file. The second packet of the client contains the FID, specifying the opened file, the number of bytes to read and the offset from where starting to read. The server sends a response containing the desired bytes.

Chapter 2

Implementation

The implementation is subdivided in two modules. One module implements the client, the other module implements the server. The modules are independent from each other and can work simultaneously at the same machine.

2.1 The Client Implementation

In A2 every file system has to implement two interfaces. The first interface is the FileSystem interface, which handles operations on files, e.g. rename and delete. The second interface is the File interface, which handles operations on the content of files, e.g. read and write bytes. As shown in the figure below, applications operate directly on the two interfaces. While a classical file system like FAT operates on disks, a SMB file system operates through the network.

<table>
<tr><td colspan="4">Applications</td></tr>
<tr><td>File</td><td>FileSystem</td><td>File</td><td>FileSystem</td></tr>
<tr><td>SambaFile</td><td>SambaFileSystem</td><td>FATFile</td><td>FATFileSystem</td></tr>
<tr><td colspan="2">TCP/IP</td><td colspan="2">Disk</td></tr>
</table>

The architecture of the Samba file system compared to the FAT file system.

2.1.1 The File System Interface

The traditional Windows SMB client has one very important characteristic: it offers transparency. A user can manipulate files on a remote share,

as if they were locally available. To improve transparency it is even possible to mount a remote share as a local file system. The A2 client implementation copies this characteristic by implementing the FileSystem interface offered by the operating system. The interface contains 9 procedures: `New0`, `Old0`, `Delete0`, `Rename0`, `Enumerate0`, `FileKey`, `CreateDirectory0`, `RemoveDirectory0` and `Finalize`.

`New0` **Creates a new file.**

To create a file on the server, the client first has to create a file object locally. The newly created file is associated to the SMB file system. Now, the client can proceed with the remote operations. Therefore the client sends a request to the server containing the command to create a new file. As response, the client receives a file ID (FID), which is used as local ID, too. This unique ID ensures that the client as well as the server are operating on the correct file.

Packets needed: `SMB_COM_OPEN_ANDX`

`Old0` **Opens an existing file.**

To open a remote file, the client has to follow a similar procedure to `New0` and create a file object locally. Then the client sends an open request and receives a FID, which is needed for further operations on the file.

Packets needed: `SMB_COM_OPEN_ANDX`

`Delete0` **Deletes a file.**

If the client wants to delete a remote file, the file has to be closed. To delete the file, the client sends a delete request for the given filename. If no other clients have this file opened, i.e. have a lock on this file, the server can successfully delete the file.

This command cannot be executed always successfully, because A2 cannot explicitly close files. In general, the client opens a file at least once

without closing it. A solution would maintain a list of open files and close the relative file before it is deleted. All applications having a reference to an open file would not be considered when closing the file. These references would become invalid. Client and server were in an inconsistent state.

Packets needed: SMB_COM_DELETE, (SMB_COM_CLOSE)

Rename0	**Renames a file.**

As in Delete0, if the client wants to rename a remote file, the file has to be closed. To rename the file, the client sends a rename request containing the old filename and the new filename. If no other clients have this file opened, i.e. have a lock on this file, the server can successfully rename the file.

This command cannot be executed always successfully, because A2 cannot explicitly close files. The problem is the same, as described in Delete0.

Packets needed: SMB_COM_RENAME, (SMB_COM_CLOSE)

Enumerate0	**Lists all files in a share.**

The client typically calls this procedure, if it needs to list the files on the share or a subdirectory of it in the File Manager. This procedure works with filename masks, which differ from the masks used in SMB. The client sends a listing request containing the appropriate mask, previously transformed by a simple helper procedure. If the list is too big for a packet, the list is divided in multiple packets. The client continues sending other requests containing the last entry and the ID of the search, until the list is complete.

Packets needed: TRANS2_FIND_FIRST2, TRANS2_FIND_NEXT2

FileKey	**Returns the unique non-zero key of the file.**

The FileKey procedure returns the unique non-zero key of a file. The key is generated by the server, when a file is opened (see Old0). If a file does not exist, the result is 0.

Packets needed: SMB_COM_OPEN_ANDX

`CreateDirectory0` **Creates a directory.**

A new directory is created by sending a create directory request with a pathname to the server. Unlike file creation, it is not necessary to create a directory locally first.

This command cannot be executed always successfully, because the AOS file system used in A2 does not support directories. A solution would be the integration of diretories in AOS file systems or the use of a FAT file system.

Packets needed: `SMB_COM_CREATE_DIRECTORY`

`RemoveDirectory0` **Deletes a directory.**

A directory can be deleted by sending a delete directory request to the server. The directory can only be deleted, if it does not contain files.

This command cannot be executed always successfully, because the AOS file system used in A2 does not support directories. The problem is the same, as described in `CreateDirectory0`.

Packets needed: `SMB_COM_DELETE_DIRECTORY`

`Finalize` **Finalizes the file system.**

This procedure closes the network connection before unmounting the file system.

Packets needed: -

2.1.2 The File Interface

The File Interface handles operations on the content of files. It is different from the File System Interface, which does not modify the content, but the properties of files. The interface contains 12 procedures: `Set`, `Pos`, `Read`, `ReadBytes`, `Write`, `WriteBytes`, `Length`, `GetDate`, `SetDate`, `GetName`, `Register0`, `Update`. The most important procedures, also largest in code size, are `ReadBytes` and `WriteBytes`.

`ReadBytes` **Reads a sequence of bytes.**

The client can read bytes of a file, if it was already opened. The request sent by the client must contain the file ID, the offset from where to start reading and the desired number of bytes. The response contains the requested bytes, which are buffered locally. The client also has to adjust the offset of the Rider. The Rider holds the position in a certain file. Reading or writing the file always starts from this position. On every modification of the content of a file the Rider has to be adjusted. Too large requests (more than 65'535 bytes) are splitted up in multiple requests.

Packets needed: `SMB_COM_READ_ANDX`

`WriteBytes` **Writes a sequence of bytes.**

As in `ReadBytes`, the file has to be open and the request must contain file ID, offset and length. The difference is, that the request also contains the bytes to be written remotely.

Packets needed: `SMB_COM_WRITE_ANDX`

For the sake of completeness the other procedures are just mentioned:

Set	Positions the Rider at a certain offset in a file.
Pos	Returns the offset of a Rider positioned on a file.
Read	Reads one byte.
Write	Writes one byte.
Length	Returns the current length of a file.
GetDate	Returns date and time of the last modification.
SetDate	Sets the modification date and time.
GetName	Returns the canonical name of a file.
Register0	Registers a file created with New0 in the directory.
Update	Flushes the changes made to a file from its buffers.

All procedures (except ReadBytes and WriteBytes) contained in the File Interface.

2.1.3 Connection

The client has to establish a reliable connection to the server. As seen in the introduction, the connection is based on TCP. This is realized by an object called TCPSender, which establishes a connection to a specified IP address and port and opens streams to read and write. Packets are created and sent directly in the SMB implementation of the File System and File interface. Helper procedures preprocess incoming packets and in case of error take the appropriate steps.

2.1.4 Mounting

To access the files on a server, the client has to mount the share. The client establishes a connection to the server and tries to log in. The log in step is the same as described in the introduction. At this point, the client is running and files can be accessed, if no error has occured so far.

To unmount the file system, the client has first to log off on the remote machine and close the connection.

2.1.5 Implemented SMB Packets

The SMB protocol offers approximately 75 different commands, not including subcommands. Not all are necessary to implement the client. The list of needed commands can be determined by the functions required by the client, i.e. the equivalent commands to the procedures of the File System and File interfaces. A command of special interest is `SMB_COM_TRANSACTION2`, which carries one of potentially 17 different subcommands. The client can send only 2 of them needed for the directory listing.

Command	Description
0x00	SMB_COM_CREATE_DIRECTORY
0x01	SMB_COM_DELETE_DIRECTORY
0x04	SMB_COM_CLOSE
0x06	SMB_COM_DELETE
0x07	SMB_COM_RENAME
0x08	SMB_COM_QUERY_INFORMATION
0x2D	SMB_COM_OPEN_ANDX
0x2E	SMB_COM_READ_ANDX
0x2F	SMB_COM_WRITE_ANDX
0x32	SMB_COM_TRANSACTION2
0x72	SMB_COM_NEGOTIATE
0x73	SMB_COM_SESSION_SETUP_ANDX
0x75	SMB_COM_TREE_CONNECT_ANDX

All commands implemented by the client.

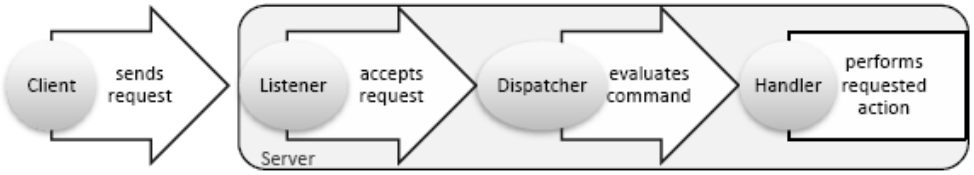
2.2 The Server Implementation

The server works in a different way as the client. While the client can send requests if required, the server can only send responses when it receives a request. An efficient server therefore has to understand all requests a client might send. The list of commands to implement was determined through a network protocol analyzer using a Windows XP client and the client provided by Ubuntu 8.10.

2.2.1 Request Handling

The running server listens on port 445 (defined port for raw SMB) for incoming connections. The port listener is implemented using an Agent of module TCPServices. If a client tries to connect to the server, the listener accepts the connection, reads the recieved packet and passes it to the dispatcher. The dispatcher interprets the command and passes the packet to the appropriate handler, which starts to evaluate the information contained in the packet and performs the requested operation. Then the handler gen-

erates a response for the client. Since the server is in an endless loop, it can accept the next packet and the cycle restarts.



The server steps.

2.2.2 Implemented SMB Packets

0x00	SMB_COM_CREATE_DIRECTORY

The create directory message is sent to create a new directory. The additional pathname is passed. The directory must not exist for it to be created.

This command cannot be executed always successfully, because the AOS file system used in A2 does not support directories.

0x01	SMB_COM_DELETE_DIRECTORY

The delete directory message is sent to delete an empty directory. The additional pathname is passed. The directory has to be empty for it to be deleted.

This command cannot be executed always successfully, because the AOS file system used in A2 does not support directories.

0x02	SMB_COM_OPEN

This message is sent to obtain a file handle for a data file. It is the predecessor of the SMB_COM_OPEN_ANDX packet.

This command was implemented to handle pipe requests, but became obsolete since Windows clients prefer the newer SMB_COM_OPEN_ANDX packet.

0x04	SMB_COM_CLOSE

The close message is sent to invalidate a file handle for the requesting client. All locks held by the client on the file should be released by the server. The client can no longer use the FID for further file access.

This command has no effect, because files cannot be closed in A2.

0x05	SMB_COM_FLUSH

The flush message is sent to ensure all data for the corresponding file has been written to stable storage.

This command has no effect, because all bytes received by previous write commands are directly written to disk.

0x06	SMB_COM_DELETE

The delete message is sent to delete a file. The additional filename is passed.

Deleting multiple files using wildcards and SearchAttributes are not supported by the server and are ignored.

0x07	SMB_COM_RENAME

The rename message is sent to change the name of a file. The old and new filenames are passed.

Renaming multiple files using wildcards and SearchAttributes are not supported by the server and are ignored.

0x08	SMB_COM_QUERY_INFORMATION

The query information message is sent to obtain the properties of a file, e.g. last write time and file size. Attributes are not implemented and therefore ignored.

0x09	SMB_COM_SET_INFORMATION

The set information message is sent to change the properties of a file, e.g. last write time and file size. The support of attributes is optional, therefore not implemented and ignored.

0x0B	SMB_COM_WRITE

The write message is sent to write bytes to a file. The additional file ID, the offset specifying form where to start, the number of bytes and the data itself are passed. If the length is zero and no data is passed, the server must truncate the file to the length specified in the offset field.

0x0F	SMB_COM_CREATE_NEW

The create new message is sent to create a new non-existing file or to truncate an existing file to zero. Truncating is implemented as deleting the file and creating a new one with same properties.

0x22	SMB_COM_SET_INFORMATION2

This set information message is similar to SMB_COM_SET_INFORMATION. The main difference is, that the file is defined by its FID (previously opened) and not by its filename.

0x23	SMB_COM_QUERY_INFORMATION2

This query information message is similar to SMB_COM_QUERY_INFORMATION. The main difference is, that the file is defined by its FID (previously opened) and not by its filename.

0x25	SMB_COM_TRANSACTION

The transaction message is sent to pass pipe or LANMAN information. The server accepts this packets, but does not perform any operation. If the server would not accept this command, a client running on Windows would probably not establish a connection.

0x2B	SMB_COM_ECHO

The echo message is sent to test the connection to the server and to check that the server works. The server echoes the data received in the request.

0x2D	SMB_COM_OPEN_ANDX

The open andx message is sent to open an existing file or to create a new non-existing file. The action depends on a field. The additional filename is passed. A file can be opened in two access modes: for reading or for writing. Both modes are mutually exclusive. The server ignores the access mode, because A2 does not distinguish between the two modes.

0x2E	SMB_COM_READ_ANDX

The read andx message is sent to read bytes of a file. The additional file ID, the offset specifying form where to start and the number of bytes are passed.

0x2F	SMB_COM_WRITE_ANDX

The write andx message is similar to SMB_COM_WRITE, except for the truncation, which is not supported here.

0x32	SMB_COM_TRANSACTION2

The transaction message is sent to obtain information. This packet can carry 17 different subcommands, but only 5 are implemented.

- FIND_FIRST2 used to start a search (file listing).
- FIND_NEXT2 used to continue a search.
- QUERY_FS_INFORMATION used to get information of the remote file system.
- QUERY_PATH_INFORMATION used to get information of a directory.
- QUERY_FILE_INFORMATION used to get information of a file.

0x34	SMB_COM_FIND_CLOSE2

The find close message is sent to close a search started by a TRANS2_FIND_FIRST2 request. The additional search ID is passed.

0x71	SMB_COM_TREE_DISCONNECT

The tree disconnect message is sent to invalidate a share handle for the requesting client. The client can no longer use the TID for further access.

0x72	SMB_COM_NEGOTIATE

The negotiate message is sent to agree on a dialect. This is the first packet sent by the client to establish a connection. This message contains a list of dialects, that the client understands. The response contains information about the server, e.g. server time, server name.

0x73	SMB_COM_SESSION_SETUP_ANDX

The session setup message is sent to log in. This is the second packet sent by the client. This message contains username and password. If the server accepts the combination of username and password or accepts guest login, the client is logged in.

0x75	SMB_COM_TREE_CONNECT_ANDX

The tree connect message is sent to connect to a share. The additional pathname following the UNC style syntax (e.g. \\SERVER\SHARE) is passed.

The new Samba documentation released by Microsoft reveals two important fields: MaximalShareAccessRights and GuestMaximalShareAccessRights specify the respective rights on a share. These fields were probably unknown in the old server implementation for Bluebottle and therefore Windows clients refused the connection.

0xA0	SMB_COM_NT_TRANSACT

The transact message is sent to transfer file system control functions. The server accepts this packets, but does not perform any operation. If the server would not accept this command, a client running on Windows would probably not establish a connection.

2.3 Time in Samba

In Samba time values can be encoded in three different modes. A2 does not use any of these modes. But, the server as well as the client provide specific conversion procedures.

- SMB_TIME & SMB_DATE
  Time base: 01-01-1980, 00:00:00
  Size: 4 bytes
  Composition:

DOS TIME			DOS DATE		
Hour (5)	Minute (6)	TwoSecond (5)	Year (7)	Month (4)	Day (5)
0-23	0-59	0-29	0-119	1-12	1-31

Composition of DOS Time and DOS Date with number of used bits in brackets and range value below.

- `TIME`

  Time base: 01-01-1601, 00:00:00

  Size: 8 bytes

  Composition: Time passed in 100ns since time base.

- `UTIME`

  Time base: 01-01-1970, 00:00:00

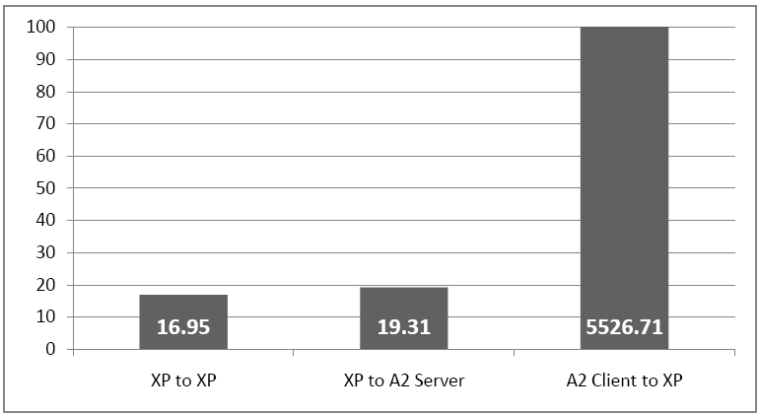
  Size: 4 bytes

  Composition: Time passed in seconds since time base.

Chapter 3

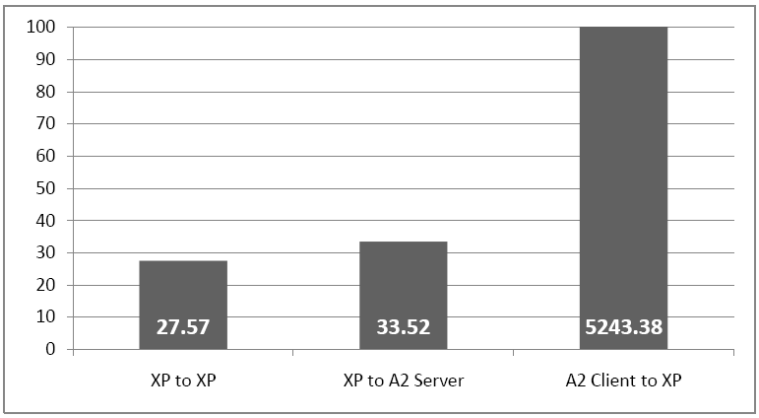
Evaluation

3.1 Benchmark



Seconds elapsed to transfer 1x 100MB-file.

The time for the transfer of one 100MB file from a Windows XP machine to another Windows XP machine is taken as a reference point. The transfer from a Windows XP client to the A2 server needed 19.31s, which is close to the Windows reference value. The most surprising value is the transfer from the A2 client to a Windows XP server. This mode is definitely the slowest. The main reason for this weak performance is unclear. One point is, that the Windows XP client sends 32kB data per packet, but the A2 client only sends 4kB data per packet.



Seconds elapsed to transfer 1000x 100kB-files.

Also for this benchmark the Windows XP to Windows XP value is taken as a reference point. The Windows XP client to the A2 server transfer of 1000 100kB files performs well compared to the reference value. As with one file, the A2 client to Windows XP server is again the slowest mode. The reasons may be the same as with one file, but no anomalities were detected in both cases.

Chapter 4

Conclusion & Future Work

4.1 Conclusion

This master thesis provides a client and server implementation of Samba, the de facto standard for file access in Local Area Networks, for A2. The goal, to simplify data access and to increase the interoperability between A2 and other operating systems, especially Windows, is reached. With the A2 client implementation it is possible to mount a share on a Windows or Unix server as a file system. The A2 server implementation allows Windows and Unix clients to access an A2 share.

The procedures-to-packets mapping of the client is complete. All procedures are implemented equivalently in Samba packets. The server definitely does not implement all existing commands, but understands all encountered by sniffing the network using Windows and Linux clients.

4.1.1 Problems

A yet unsolved problem was caused by `SMB_COM_CLOSE` (closes a file). A2 does not provide a `File.Close`. Therefore, files are kept open, as long as the client is running. This impedes the client to rename or delete already opened files. Various solutions like keeping a list of open files or immediatly closing the file failed. A solution would be the implementation of a close procedure in A2.

4.2 Future Work

- **Challenge/Response Authentication**
  The current implementation of the login only provides plaintext passwords and guest access. This solution might be enough in a secure environment, but is risky otherwise. Implementing the challenge/response authentication improves the security.

- **Printer access**
  The printer access is part of Samba and allows a client to print on a connected server. The implementation requires DCE/RPC, but also uses packets for file access like `SMB_COM_WRITE_ANDX`.

- **SMB2**
  This protocol was introduced with Windows Vista. The implementation of SMB2 is less important than the two points before, but offers the possibility to perform multiple actions with a single request. The increased buffer sizes allow the transport of more data in a packet. These are two important improvments when operating with large files.

Appendix A

Samba in Detail

A.1 Header

0 . . . 7	8 . . . 15	16 . . . 23	24 . . . 31
0xFF	'S'	'M'	'B'
COMMAND	STATUS. . .		
. . . STATUS	FLAGS	FLAGS2	
EXTRA			
TID		PID	
UID		MID	

0xFF SMB The first 4 bytes are the protocol identifier string, which are always the same: 0xFF and the ASCII representation of the letters 'S', 'M' and 'B'.

Command The one-byte command field tells the type of the SMB.

Status Two versions of error reporting exist: 16-bit DOS error code and 32-bit NT status code. The DOS error code is grouped in two classes *Error-Class* (1 byte) and *ErrorCode* (2 bytes) separated by a 8-bit reserved block. The NT status code, introduced with Windows NT, uses the entire field to contain the *NT Status* (4 bytes). The error reporting version is determined

at beginning by a Flags2 bit. Regardless of the version, if the fields are zero, they indicate success.

Flags The Flags field contains 8 different flags numbered here from least significant to most significant bit.

Bit	Description
0	Lock & Read and Write & Unlock
1	Recieve Buffer Posted
2	Reserved
3	Case Sensitivity
4	Canonicalized Pathnames
5	Oplocks
6	Notify
7	Request/Response

The implementation takes only bits 3,4 and 7 into consideration. The other bits are simply ignored, which does not cause any side-effect. Flags which are not used must be 0 and flags which are not set must be ignored.

Flags2 The Flags2 field contains 9 different flags numbered here form least significant to most significant bit.

Bit	Description
0	Long Names Allowed
1	Extended Attributes
2	Security Signatures
6	Long Names Used
11	Extended Security Negotiation
12	DFS Resolution
13	Execute-only Reads
14	Error Code Type
15	Unicode Strings

All bits which are not listed in the table above must be 0 and therefore ignored. The implementation takes only bit 0 into consideration. The other bits are simply ignored as in Flags, which does not cause any side-effect.

Extra The Extra field is splitted in three fields: Process ID High (2 bytes), Signature (8 bytes) and Reserved (2 bytes). The Process ID High field can be used to support 32-bit process IDs. The implementation uses only 16-bit process IDs which is enough. The field is 0 and can be ignored. The Signature field can be used to sign the SMB but is not used by the implementation. The Reserved field must be 0 and is therefore useless.

TID The Tree ID identifies the client connection to a specific share. The server returns a TID to the client when the client successfully connects to a server ressource. For any subsequent requests the client uses the TID.

PID The Process ID identifies the client process and is mainly used to control concurrency. The PID is initially set by the client. The server should not change the value.

UID The User ID identifies a successfully authenticated user (username/ password). The UID is assigned by the server. For any subsequent requests the client uses the UID. The UID is only valid for the given session.

MID The Multiplex ID identifies multiple outstanding requests. The server must not answer in a specific order but a response must contain the same MID and PID as in the corresponding request.

A.2 Case in Point: NEGOTIATE PROTOCOL

The first packet a client sends to a server to establish a connection is a Negotiate Protocol Request.

```
NEGOTIATE_PROTOCOL_REQUEST
  {
  SMB_HEADER
    {
    PROTOCOL  = 0xFF SMB
    COMMAND   = SMB_COM_NEGOTIATE (0x72)
    STATUS
```

```
    {
    ErrorClass = 0x00   (Success)
    ErrorCode  = 0x0000 (No Error)
    }
  FLAGS     = 0x18   (Canonicalized and case-sensitive path names)
  FLAGS2    = 0x0001 (Long file names allowed)
  EXTRA
    {
    PidHigh   = 0x0000
    Signature = 0 (8 bytes)
    }
  TID       = 0    (still unknown)
  PID       = 9876 (defined by client)
  UID       = 0    (still unknown)
  MID       = 0    (no pending responses)
  }
SMB_PARAMETERS
  {
  WordCount = 0
  Words     = (empty)
  }
SMB_DATA
  {
  ByteCount = 12
  Bytes
    {
    BufferFormat = 0x02         (Dialect)
    Name         = "NT LM 0.12" (0x00 terminated)
    }
  }
}
```

A.3 File System Interface

```
(** Create a new file with the specified name. *)
PROCEDURE New0*(name: ARRAY OF CHAR): File;

(** Open an existing file. The same file descriptor is returned
    if a file is opened multiple times. *)
PROCEDURE Old0*(name: ARRAY OF CHAR): File;

(** Delete a file. res = 0 indicates success. *)
PROCEDURE Delete0*(name: ARRAY OF CHAR; VAR key, res: LONGINT);

(** Rename a file. res = 0 indicates success. *)
PROCEDURE Rename0*
    (old, new: ARRAY OF CHAR; f: File; VAR res: LONGINT);

(** Enumerate canonical file names. mask may contain * wildcards.
    For internal use only. *)
PROCEDURE Enumerate0*
    (mask: ARRAY OF CHAR; flags: SET; enum: Enumerator);

(** Return the unique non-zero key of the named file, if it
    exists. *)
PROCEDURE FileKey*(name: ARRAY OF CHAR): LONGINT;

(** Create a new directory structure. May not be supported by
    the actual implementation. *)
PROCEDURE CreateDirectory0*(name: ARRAY OF CHAR; VAR res: LONGINT);

(** Remove a directory. If force=TRUE, any subdirectories and
    files should be automatically deleted. *)
PROCEDURE RemoveDirectory0*
    (name: ARRAY OF CHAR; force: BOOLEAN; VAR key, res: LONGINT);
```

```
(** Finalize the file system. *)
PROCEDURE Finalize*;
```

A.4 File Interface

```
(** Position a Rider at a certain position in a file. Multiple
    Riders can be positioned at different locations in a file.
    A Rider cannot be positioned beyond the end of a file. *)
PROCEDURE Set*(VAR r: Rider; pos: LONGINT);

(** Return the offset of a Rider positioned on a file. *)
PROCEDURE Pos*(VAR r: Rider): LONGINT;

(** Read a byte from a file, advancing the Rider one byte
    further.  R.eof indicates if the end of the file has been
    passed. *)
PROCEDURE Read*(VAR r: Rider; VAR x: CHAR);

(** Read a sequence of len bytes into the buffer x at offset
    ofs, advancing the Rider. Less bytes will be read when
    reading over the end of the file. r.res indicates the
    number of unread bytes. x must be big enough to hold all
    the bytes. *)
PROCEDURE ReadBytes*
    (VAR r: Rider; VAR x: ARRAY OF CHAR; ofs, len: LONGINT);

(** Write a byte into the file at the Rider position,
    advancing the Rider by one. *)
PROCEDURE Write*(VAR r: Rider; x: CHAR);

(** Write the buffer x containing len bytes (starting at
    offset ofs) into a file at the Rider position. *)
PROCEDURE WriteBytes*
    (VAR r: Rider; CONST x: ARRAY OF CHAR; ofs, len: LONGINT);
```

```
(** Return the current length of a file. *)
PROCEDURE Length*(): LONGINT;

(** Return the time (t) and date (d) when a file was last
    modified. *)
PROCEDURE GetDate*(VAR t, d: LONGINT);

(** Set the modification time (t) and date (d) of a file. *)
PROCEDURE SetDate*(t, d: LONGINT);

(** Return the canonical name of a file. *)
PROCEDURE GetName*(VAR name: ARRAY OF CHAR);

(** Register a file created with New in the directory,
    replacing the previous file in the directory with the
    same name. The file is automatically updated. *)
PROCEDURE Register0*(VAR res: LONGINT);

(** Flush the changes made to a file from its buffers.
    Register0 will automatically update a file. *)
PROCEDURE Update*;
```

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