Tape Server's Handbook

CAStor development team

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CAStor Tape Server Documentation

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Contents

Preface

The Tape server project is targeted at replacing the CAStor tape server with a new drop-in reimplementation. The reimplementation will replace a legacy implementation that is written in C.

The reimplementation will be done using the latest tools available to us in the current Scientific Linux distribution. The language will be C++, to group concept and variables in self-contained (and unit testable) objects.

The interface to the mounting deamons might still change with repect to CAStor 2.1.14 as the mounting daemons are being reviewed in parallel.

This documentation itself currently references the older tape server this project is intending to replace. The references will have to be removed as they become unnecessary. Likewise, the layout of the document will be adapted.

The tape drive primitives have now been developed, and the rest of the project's plan is being laid out.

Chapter 1

Developer's manual

1.1 Requirements

1.1.1 Targeted environment

CERN SLC5 and SLC6, 64bits. Although it should compile in theory, the 32 bits version is not tested. The unit test purposely returns an error when run on non-64 bits architecture.

1.1.2 Pre-existing requirements

The new tape server (software) will have to replace the software running on a tape server (computer). A previous analysis describes the current software stack of the tape servers [1]. This new tape server will retain the same external interfaces as the old tape server, replacing the stack of daemons from the tape bridge down to the tape drive hardware.

The tape server will interface with the Volume and Drive Queue Manager daemon (vdqmd), the Volume manager daemon (vmgrd), the Castor User Privilege Validation daemon (cupvd) and tape gateway daemon (tapegatewayd) for data transfer management and access control.

It will connect to the CAStor disk servers to transfer the data itself, using one of the supported protocols (current candidates are rfio, xroot and ceph) and it will use the services of the Remote Media Changer daemon (rmcd) to mount and unmount tapes.

1.1.2.1 Tape session triggering

The tape server acts as a server only on one occasion, when it receives a client info request from the VDQM. This call triggers a tape session, recall or migrate. The information received at that point is only client system information and drive information (request ID, host, port, DGN, tape drive name and user information (user id, etc...)).

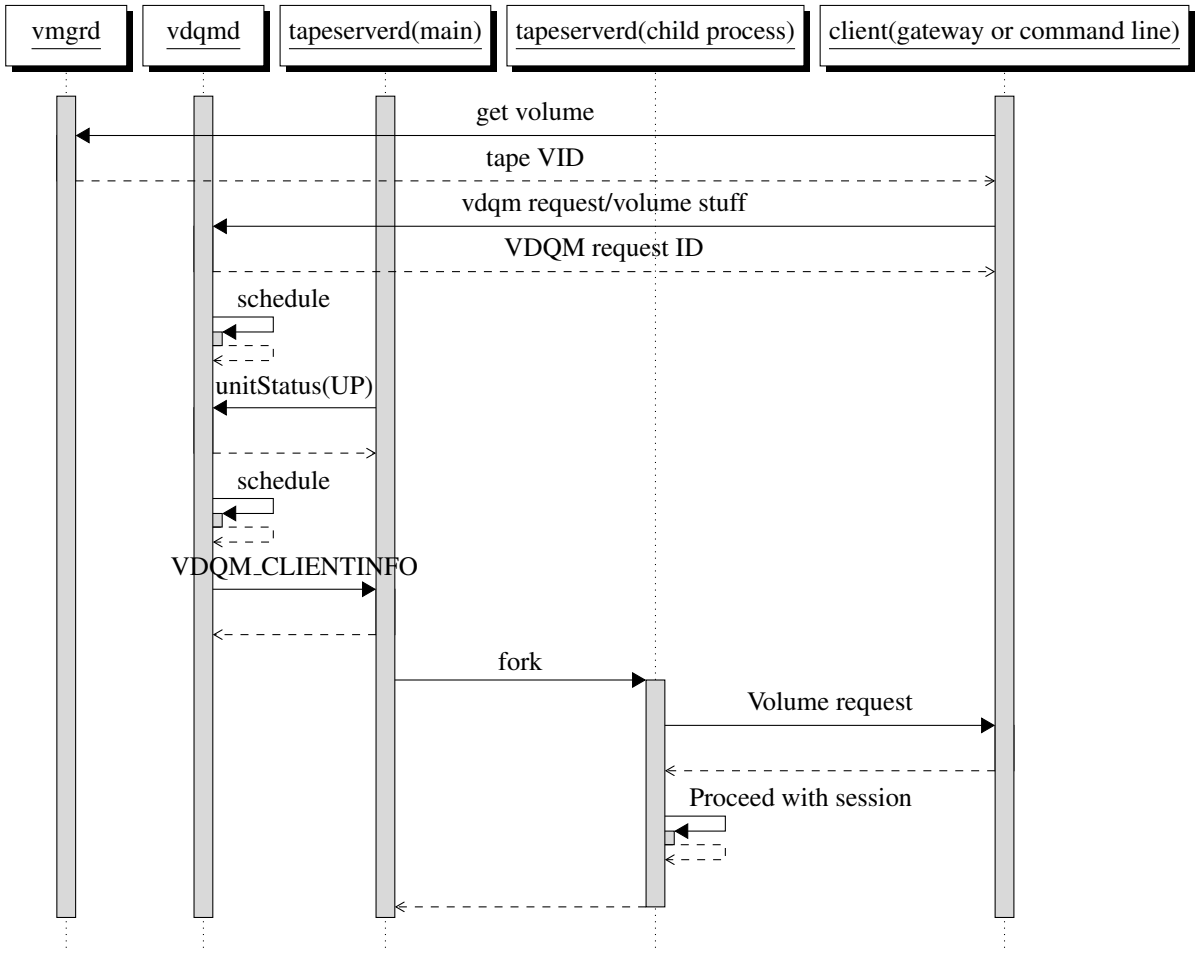
The main thread of the tape server will then just forks (and maybe exec, to be decided (TODO)) a new process, which will handle the session and quit.

A new session starts with the tape server connecting with the client (it could be the tape gateway, or one of the command line commands of castor (currently packages in castor-tapebridge-client: readtp, writetp, dumptp). In the case of the tape gateway, it can be either a read or a write session.

The collaboration diagrams of the previous version of the tape server (with all its sub components) can be found in dot format [2].

[1] http://svn.cern.ch/guest/CASTOR/CASTOR2/trunk/castor/tape/doc/TapeBridge.pdf
[2] http://svn.cern.ch/guest/CASTOR/CASTOR2/trunk/castor/tape/doc/collaboration_diagrams/

The new sequencing of a session start, simplified from the internal component communication is shown here:



At that point, already two client libraries are in use in the tape server: the tape gateway protocol client library and the vdqm client library, and a simple server, answering only one type or requests:

- The client library for the tape gateway is implemented using the UML/umbrello based serialisation system. It is contained in the `castor::tape::tapebridge::ClientProxy` class in CAStor.
- The direct C client API in CAStor's `h/vdqm_api.h`.
- The VDQM request handler is implemented in `castor::tape::tapebridge::VdqmRequestHandler`.

1.1.2.2 Tape session startup

Upon reception of the session request, the tape server checks that it can continue with the session.

Check with VMGR the volume status and block size. A disabled volume can only be mounted by a TP_OPER.

In case of a write session, queries pool info to know the owner.

If user is not the owner or ADMIN, refuse the mount.

Then reports are sent:

- Reports to VDQM that the drive is assigned. (VDQM_UNITSTATUS).
- Requests work to be done from the client to prevent useless mounts (and start caching data in case of migration.
- Mounts the tape, rewinds and validates the volume label.
- Reports to VMGR that the volume is mounted (`VMGR_TPMOUNTED`).
- Reports to the VDQM that the tape is mounted (VDQM_UNITSTATUS).

1.1.2.3 Work loop

TODO: VDQM status reporting sequencing

TODO: Mount time checks

TODO: GW protocol

1.1.2.4 Release tape

1.1.3 Extra requirements

Additional requirements, arising from the current practices of operators are:

- The tape server's session should gracefully handle an unclean situation where the tape is left in the drive by a previously crashed session. The protocol is to clean anything left over before proceeding to the new session.
- A tape sessions should be preemptable by the operator. This is currently achieved by killing the tape process. Closing the session on a kill (-1) could be a solution.
- The operator should be able to specify values in different SCSI code pages in order to setup the tape drive. This setting will be defined differently for each tape drive type.

1.2 Tape server architecture

To fulfil the requirement for an ability to kill a session, the main tape server daemon will be simple, and just report its status to the VDQM and wait for requests from it on an open port.

When a session should start, the process will fork a child process, which will reserve the memory and instantiate the session machinery.

The layout of the main thread is show in figure **??**. The layout of the child process, which contains all the complexity is shown in figure **??**.

The data path will go to/from tape drive, through the generic SCSI interface of st driver (CAStor uses a mixture of both in the Tape::Drive class), then through the File structure support class, as controlled by the tape thread. The tape thread will communicate the data to (or get from) the disk thread via the data FIFO class. This class will in turn allocate the memory from a preallocated, pool of fixed sized blocks. The size of the pool will be controlled by the operators.

Some libraries already exist in CAStor, and will be reused, either by copying or linking from pre-compiled packages. The main parts of the sessions spawner will be taken from the VDQM as well.

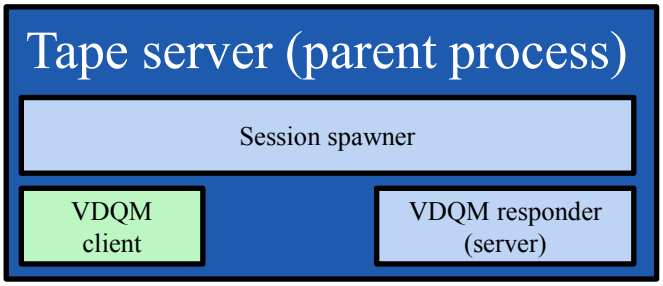


Figure 1.1: Tape server parent process: libraries used (purpose built libraries in blue, system libraries in beige, already existing CAStor libraries in green)

1.3 Reference documentations

1.3.1 SCSI specifications

The SCSI commands can be found in the SCSI section of Hackipedia.org [3] [4]. The most significant documents for tape server development are the SCSI stream commands (SSC-3 [5]) and the SCSI primary commands (SPC-4 [6]).

1.3.1.1 Manufacturer's specificities

The SCSI specification allows for some flexibility for the manufacturers of tape drives, and each of them has differences. The details can be found in the following documentations:

- StorageTek^{TM}T10000 Tape Drive [7]
- Sun StorageTek^{TM}T10000 Tape Drive Fibre Channel Interface Reference Manual [8]
- IBM System Storage TS1120 and TS1130 Tape Drives and TS1120 ControllerOperator Guide3592 Models J1A, E05, E06, EU6, J70 and C06 [9]
- IBM System Storage Tape Drive 3592 SCSI Reference [10]
- IBM TotalStorage LTO Ultrium Tape Drive SCSI Reference (LTO-5 through LTO-6) [11]

1.3.2 SCSI support in Linux

On the Linux side, the main references are the Linux 2.4 SCSI subsystem HOWTO [12], especially for its section 9.3 on the st driver, and the Linux SCSI Generic (sg) HOWTO [13].

[3] http://hackipedia.org/Hardware/SCSI/
[4] The official site for SCSI standard is http://T10.org. All specifications can be found there in their approved version, but behind a paywall. Nevertheless all previous drafts were public and can conveniently be found on the web. Hackipedia hold a very nice collection of such documentations.
[5] http://hackipedia.org/Hardware/SCSI/Stream%20Commands/SCSI%20Stream%20Commands%20-%203.pdf
[6] http://hackipedia.org/Hardware/SCSI/Primary%20Commands/SCSI%20Primary%20Commands%20-%204.pdf
[7] http://docs.oracle.com/cd/E19957-01/96174E/96174E.pdf
[8] http://docs.oracle.com/cd/E19772-01/MT9259L/MT9259L.pdf
[9] ftp://ftp.software.ibm.com/storage/TS1130/a86opg02.pdf
[10] http://www-01.ibm.com/support/docview.wss?uid=ssg1S7003248&aid=1
[11] http://www-01.ibm.com/support/docview.wss?uid=ssg1S7003556&aid=1
[12] http://mirrors.kernel.org/LDP/HOWTO/pdf/SCSI-2.4-HOWTO.pdf
[13] http://mirrors.kernel.org/LDP/HOWTO/pdf/SCSI-Generic-HOWTO.pdf

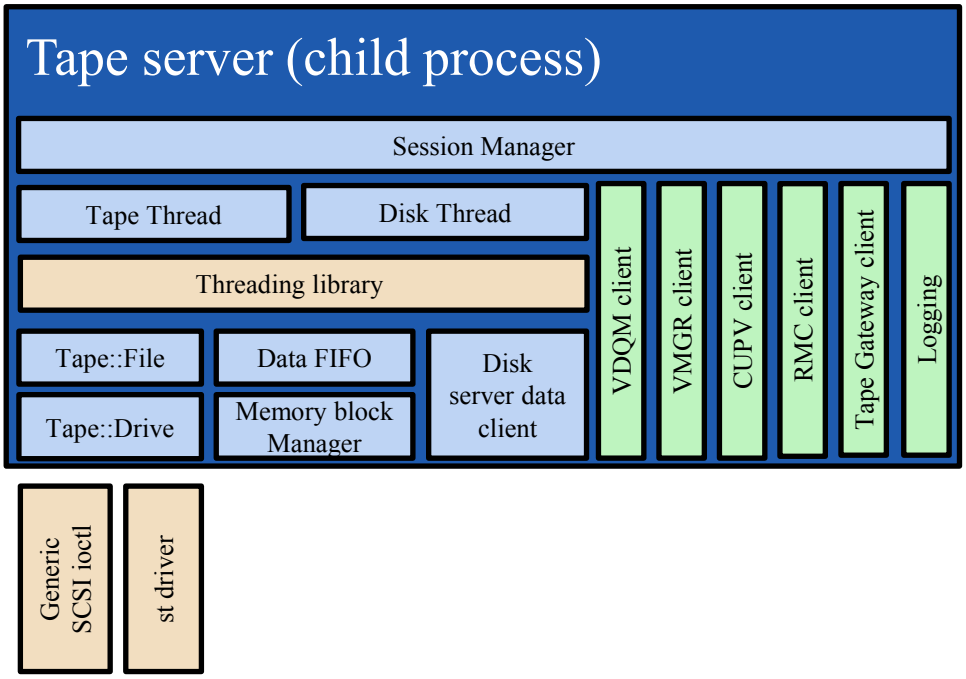


Figure 1.2: Tape server child process: libraries used (purpose built libraries in blue, system libraries in beige, already existing CAStor libraries in green)

More details regarding the Generic SCSI driver can be found on the SCSI subsystem maintainer's web site [14].

The section on the SG_IO ioctl, [15] details the usage of the simplest ioctl for the generic SCSI driver, which allows the invocation of a SCSI command and the collection of the result in a single system call.

This ioctl is provided in the middle layer of the SCSI subsystem of Linux. All SCSI drivers, st included, fall back to the middle layer when encountering an unknown ioctl. This means there is no need to open the matching generic SCSI, unless we want to control command queueing with separate sending of commands and result collection, which requires the use of read and write calls from the generic SCSI (sg) driver.

1.3.3 Unsorted CAStor docs

A collection of links to various documentations written in the past is available on one of CAStor's web pages [16].

1.3.4 SCSI tape support in Linux (st driver)

Generic SCSI allows detailed control of the operations, but the bulk of them (including reading and writing) can be managed by the higher level SCSI tape (or st) driver provided by the Linux kernel. More information on the st driver can be found in the man page "st" and in `Documentation/scsi/st.txt` in the sources of the kernel.

[14] http://sg.danny.cz/sg/
[15] http://sg.danny.cz/sg/sg_io.html
[16] http://castorwww.web.cern.ch/castorwww/links.htm

1.4 Tools used during development

1.4.1 Required tools for build

- GCC/G++ (Basic SLC version)
- CMake (Basic SLC version)
- rpmbuild (Basic SLC version)
- Google Mock/Google test (GTest is provided in EPEL repository for SLC. GMock requires recompilation. The source RPMs can be found for newer versions of RPM based distributions, for example from rpmfind [17]. For convenience, they are also available on AFS as a temporary solution [18].
- Valgrind (Basic SLC version)
- LaTeX(Basic SLC version) to compile this document
- Doxygen for code documentation (Basic SLC version)

1.4.2 Tools used during development

- mhvtl [19] for developing against virtual drives and libraries (to enable mhvtl kernel debug output to dmesg opts=3 have to be used for kernel module options, i.e. `modprobe mhvtl opts=3`).
- TeamCity for continuous integration
- NetBeans as an IDE, including for remote development

1.4.3 Code coverage using lcov

Although the code coverage is not integrated in the build process, it is straightforward to run on the code. The following recipe will deliver a set of web pages indicating which parts of the code are covered or not in the unit tests. The lcov package is required. It is only available on SLC6, and can be installed via yum.

- Change the main CMakeFiles.txt as in this diff:

```
Index: CMakeLists.txt
===================================================================
--- CMakeLists.txt      (revision 76)
+++ CMakeLists.txt      (working copy)
@@ -45,7 +45,8 @@
 ############################################################################
 # compiler options
 ############################################################################
-set (CMAKE_CXX_FLAGS "-g3 -Wall -Werror -pedantic -O2")
+set (CMAKE_CXX_FLAGS "-g3 -Wall -Werror -pedantic -O2 --coverage")
+set (CMAKE_LD_FLAGS "--coverage")

 ############################################################################
 # dependancies
```

- Re-run cmake, recompile as usual and run the unit test.
- Capture the result:

```
lcov --capture --directory 00build/ --output-file 00build/coverage.info.
```

[17] http://rpmfind.net/linux/rpm2html/search.php?query=gmock
[18] /afs/cern.ch/user/c/canoc3/public/GoogleTest-Mock
[19] https://sites.google.com/site/linuxvtl2/

- Generate the resulting html pages:

  `genhtml 00build/coverage.info --output-directory 00build/coverage.`

1.5 Software layout

1.5.1 SCSI structures, constants and endianness

In order to make the code readable, and to avoid heavy mask-and-shift usage (which one would tend to code using litterals in order to avoid many constants definitions), we use bit field structures. The unused fields can be left anonymous. The definition is shown in listing **??**, and usage in listing **??**. As there could be endianness issues, we limit this usage to within bytes. Fortunately, the SCSI standard nicely adheres to this rule.

```
1  namespace SCSI {
2    namespace Structures {
3
4      /*
5       * Inquiry data as described in SPC-4.
6       */
7      typedef struct {
8        unsigned char perifDevType : 5;
9        unsigned char perifQualifyer : 3;
10
11       unsigned char : 7;
12       unsigned char RMB : 1;
13
14       unsigned char version : 8;
15
16       unsigned char respDataFmt : 4;
17       unsigned char HiSup : 1;
18       unsigned char normACA : 1;
19       unsigned char : 2;
20 [...]
21     } inquiryData_t;
22   }
23 }
```

Listing 1.1: SCSI::Structures example

The unit test resorts to shift and mask, once and only once, to validate the bit fields in another way. There is an example for this validation in `SCSI/StructureTest.cc` an excerpt is in listing **??**.

Other common types in the SCSI specification are multi-bytes number, which are represented by `unsigned char[2/* (or 4)*/]` and handled by helper functions `toU16()` and `toU32()`. The helper functions conveniently use `ntoh{l|s}`, as SCSI and network orders are the same. The reverse is covered by `setU16()` and `setU32()`. Another helper function takes care of string extraction from fixed sized char arrays. See listing **??**.

Those arrays are space-padded, and may not be 0 terminated. It is seen in listing **??**. The helper function extracts the string, dealing with potential zeros at the end, and the fixed length. They keep the space-padding at the end of the extracted string.

To avoid literals in the code, which forces anyone reading it to do tedious lookups, the SCSI constants are also defined as constants in the code. See listing **??**.

Finally all structures have a constructor, which at least zeroes all the data. Some structures (typically the CDBs, where the first byte is the operation's code) automatically set the value of fields which can only have one value. Helper functions are created as needed, where accessing/setting the data in the structure

```
1       SCSI::Structures::inquiryData_t & inq = *((SCSI::Structures::
            inquiryData_t *) dataBuff);
2       std::stringstream inqDump;
3       inqDump << std::hex << std::showbase << std::nouppercase
4               << "inq.perifDevType=" << (int) inq.perifDevType << std::endl
5               << "inq.perifQualifyer=" << (int) inq.perifQualifyer << std::
                    endl
6   [...]
7               << "inq.T10Vendor="      << SCSI::Structures::toString(inq.
                    T10Vendor) << std::endl
8               << "inq.prodId="         << SCSI::Structures::toString(inq.
                    prodId) << std::endl
9               << "inq.prodRevLv="      << SCSI::Structures::toString(inq.
                    prodRevLvl) << std::endl
10              << "inq.vendorSpecific1="<< SCSI::Structures::toString(inq.
                    vendorSpecific1)<< std::endl
```

Listing 1.2: SCSI::Structures usage example

requires non-trivial processing (and when the case is not covered by the common tools handling strings that endianness).

1.5.2 Exceptions hierarchy and error handling strategy

There is a small class hierarchy for exceptions: `Tape::Exception` inherits from `std::exception`, and `Tape::Exceptions::Errnum` inherits from the latter. `Tape::Exceptions::Errnum` manages the errnos. It collects the errno value and turns it into a string automatically at construction time.

`Tape::Exception` and all its heirs automatically generate a stack trace at creation time. This allows easy tracing of unhandled exceptions, as the stack trace is embedded in the content of the `what()` method. For the cases where the exception is indeed handled, a shorter version called `shortWhat()` allows the logging of the problem without bloating the logs with long stack traces.

Another exception class, `SCSI::Exception`, turns the SCSI status and sense buffer into a user readable string. In addition, a helper exception thrower function avoids code repetitions (`ExceptionLauncher()`).

Throughout the project, the error handling strategy is to throw an exception when any error condition occurs. This ensures that any returned value is valid, and prevents the calling function from testing for error conditions. The default exception throwing is coming from a narrow set of exceptions types. This gives a crude exception handling capacity to the user of the functions. When finer grained exceptions will turn out to be required, we will add them on an as needed basis.

1.5.3 Non-fatal warnings strategy

We want to deliver an interface, preferably common, to most object where the non-fatal problems are recorded (with time of occurrence) and stored for further retrieval by upstream caller. This allow developers to deal with the logging interface only in the top "application" class which glues all the bricks of the project together.

A lower level failure (exception) could also be turned into a warning by a higher level retry.

TODO: define API.

```
namespace UnitTests {
  TEST(SCSI_Structures, inquiryData_t_multi_byte_numbers_strings) {
    /* Validate the bit field behavior of the struct inquiryData_t,
     which represents the standard INQUIRY data format as defined in
     SPC-4. This test also validates the handling of multi-bytes numbers,
     as SCSI structures are big endian (and main development target is
     little endian.  */
    unsigned char inqBuff [100];
    memset(inqBuff, 0, sizeof(inqBuff));
    SCSI::Structures::inquiryData_t & inq = *((SCSI::Structures::inquiryData_t
        *) inqBuff);
    /* Peripheral device type */
    ASSERT_EQ(0, inq.perifDevType);
    inqBuff[0] |= (0x1A & 0x1F) << 0;
    ASSERT_EQ(0x1A, inq.perifDevType);

    /* Peripheral qualifier */
    ASSERT_EQ(0, inq.perifQualifyer);
    inqBuff[0] |= (0x5 & 0x7) << 5;
    ASSERT_EQ(0x5, inq.perifQualifyer);
[...]
  }
}
```

Listing 1.3: SCSI::Structures usage example

```
SCSI::Structures::uint32_t toU32(const char(& t)[4]);
SCSI::Structures::uint32_t toU32(const char(& t)[4]);

template <size_t n>
std::string toString(const char(& t)[n]);
```

Listing 1.4: SCSI::Structures helper functions

```
namespace SCSI {
  class Commands {
  public:
    enum {
      /*
       *      SCSI opcodes, taken from linux kernel sources
       *      Linux kernel's is more complete than system's
       *      includes.
       */
      TEST_UNIT_READY                         = 0x00,
      REZERO_UNIT                             = 0x01,
      REQUEST_SENSE                           = 0x03,
[...]
```

Listing 1.5: SCSI::Constants

1.5.4 The Tape::Drive object

This first deliverable is a tape drive object. This tape drive object abstracts all SCSI and technical details and provides a high level interface, to be used by the file structure layer.

It will provide as much data safety as possible by blocking writes in situations where they are not safe (to be defined in details, but the most obvious is right after positioning, as the file layer is expected to check the position by reading the trailer of the previous file before writing.

The SCSI commands and st driver's functions used in previous software (CAStor's taped/rtcpd) are:

- Individual SCSI commands sent using generic SCSI:
  - Read status (inquiry SCSI command used by posovl)
  - Read serial number (inquiry SCSI command, asking for vital product data page 0x80)
  - Locate (locate(10) SCSI command: 32 bits logical object identifiers) [20]
  - Read position (read position SCSI command – short form): get the current logical object location (a.k.a. block ID).
  - Log select (for clearing compression stats page. The function clear_compression_stats actually does a blanket reset of all statistics. It sets the PCR/SP/PC combination to 1/0/3. The basic SCSI specification states that the value pf PC is not important, but for the T10000 drives, the documentation recommends PC=11b, which we have for all drives.
  - Log sense, to read the compression pages. This is device dependant. The code covers 5 blocks of device types: DAT, DLT-SDLT-LTO, IBM(3490, 3590, 3592), StorageTek RedWood(SD3), StorageTek(9840, 9940, T10000).
  - Log sense for page 0x2E (tape alert, as defined in SSC-3) on all modern tape drives to detect tape alerts.
  - Mode sense and Mode select was used in setdens called itself by mounttape. They get the drive parameters and set density and compression parameters based on the drive type and the density requested by the caller. On all modern tape drives, the compression page is 0x10. This will be replaced by the function `Tape::Drive::setCompressionAndDensity()`.
- st driver's commands, leading to internal variables setting or SCSI actions:
  - Get internal driver state via the MTIOCGET ioctl (for drive ready, write protection, get some error condition, when MTIOSENSE failed, to get the EOD, BOT bits (readlbl)). This functionality is covered by `Drive::getDriveStatus`.
  - Try and get the sense data for the last-ish command with MTIOSENSE. This relies on a CERN-made patch. As the patch is not available in SLC6, MTIOSENSE will not be used in this project. This is also covered `Drive::getDriveStatus`.
  - Setup the driver's parameters (MTIOCTOP/MTSETDRVBUFFER) for (un)buffered writes and asynchronous writes (in confdrive, a child process of taped). This option is currently not set in production environments.
  - Jump to end of media (before rewinding, as a mean to rebuild the MIR) (MTIOCTOP/MTEOM, with some MTIOCTOP/MTSETDRVBUFFER before, in repairbadmir). The setting of the driver buffer is used to set the boolean flag MT_ST_FAST_MTEOM to 0. If not, the mt driver uses a nasty trick asks the device to skip 0x7fffff files forward. The comment in the CAStor code claims it's 32k files, but $2^{23}-1$ is indeed 8M files. Anyway, after turning off the option, the st driver reverts to telling the SCSI device to space to end of data. This behavior is documented in the IBM's operator manual mentioned in **??**, on page 53 for tape alert 18 (Tape directory corrupted on load).

    It is not mentioned for other tape server's documentations. Specifically, StorageTek only lists operator-initiated methods for MIR rebuild.

[20] There is also a locate(16) command allowing 64 bis addresses. This might become necessary as tapes grow. Discounting the per-file overhead, with 256kB block, it still takes 1PB to get 2^{32} blocks.

Nevertheless, we will still issue this operation in all drives as it is not known if it works in practice for StorageTek drives (or others).

- Rewind (MTIOCTOP/MTREW, in rwndtape).
- Skip to end of data (MTIOCTOP/MTEOM, in skip2eod, without the trick of repairbadmir).
- Skip n file marks backwards (MTIOCTOP/MTBSF, in skiptpfb).
- Skip n file marks forward (MTIOCTOP/MTFSF, in skiptpff).
- Skip n file marks forward (MTIOCTOP/MTFSF, in skiptpfff). skiptpfff and skiptpff differ only by error reporting. Both functions exists since CAStor has been put in SVN (20/07/1999)
- Skip n blocks backwards (MTIOCTOP/MTBSR, in skiptprb).
- Skip n blocks forward (MTIOCTOP/MTFSR, in skiptprf).
- Unload the tape (MTIOCTOP/MTOFFL, in unldtape).
- Write synchronous file mark(s) (tape marks in CAStor jargon) (MTIOCTOP/MTWEOF, in wrttpmrk).
- Write immediate (asynchronous file marks (MTIOCTOP/MTWEOFI, also in wrttpmrk).
- Clear the EOT condition by calling MTIOCGET. This is done in wrttrllbl, 3 times. In MTIOCGET, indeed, a member of the scsi_tape structure called recover_reg is reset to 0. This clearing is used to properly report errors in label writing functions. The usefulness of this function is dubious and it is not included in the current API.
- Write is used in 2 places only : twrite and writelbl (which is a specialized function to write 80 bytes blocks). twrite is not checking the size of blocks, which is determined in the calling functions.
- Read is used in tread, which is used in a single place of TapeToMemory. It is also used in readlbl. The latter uses a trick to detect that a tape is blank. This could be turned into a specialized function.

The interface is shown in listing **??**.

TODO: define end of tape behavior for write (create an exception, and throw it).

TODO: define how detect a blank tape.

1.5.5 The Tape::File class

1.5.5.1 CAStor file format

Over time, CAStor used several file formats, but as of 2013, only one file format is used, called AUL. This format is described an old CERN web site [21], and the general description of the ANSI fields can be found in IBM's z/OS documentation [22].

The AUL format consists of volume label, header blocks and trailer blocks. All those descriptors are contained in tape blocks of 80 bytes. All data is in ASCII nowadays and empty bytes are spaces.

Table 1.1: AUL label format

VOL1	HDR1	HDR2	UHL1	TM	DATA	TM	EOF1	EOF2	UTL1	TM
	one data file									

[21] http://it-dep-fio-ds.web.cern.ch/it-dep-fio-ds/Documentation/tapedrive/labels.html
[22] http://publib.boulder.ibm.com/infocenter/zos/v1r12/index.jsp?topic=%2Fcom.ibm.zos.r12.idam300%2Flabdef.htm

```
namespace Tape {
  class Drive {
  public:
    Drive(SCSI::DeviceInfo di, System::virtualWrapper & sw);
    /* Direct SCSI operations */
    virtual compressionStats getCompression() throw (Exception);
    virtual void clearCompressionStats() throw (Exception);
    virtual deviceInfo getDeviceInfo() throw (Exception);
    virtual std::string getSerialNumber() throw (Exception);
    virtual void positionToLogicalObject(uint32_t blockId) throw (Exception);
    virtual positionInfo getPositionInfo() throw (Exception);
    virtual std::vector<std::string> getTapeAlerts() throw (Exception);
    virtual void setDensityAndCompression(unsigned char densityCode = 0,
            bool compression = true) throw (Exception);
    virtual driveStatus getDriveStatus() throw (Exception);
    virtual tapeError getTapeError() throw (Exception);
    /* ST driver based operations */
    virtual void setSTBufferWrite(bool bufWrite) throw (Exception);
    virtual void fastSpaceToEOM(void) throw (Exception);
    virtual void rewind(void) throw (Exception);
    virtual void spaceToEOM(void) throw (Exception);
    virtual void spaceFileMarksBackwards(size_t count) throw (Exception);
    virtual void spaceFileMarksForward(size_t count) throw (Exception);
    virtual void spaceBlocksBackwards(size_t count) throw (Exception);
    virtual void spaceBlocksForward(size_t count) throw (Exception);
    virtual void unloadTape(void) throw (Exception);
    virtual void sync(void) throw (Exception);
    virtual void writeSyncFileMarks(size_t count) throw (Exception);
    virtual void writeImmediateFileMarks(size_t count) throw (Exception);
    virtual void writeBlock(const unsigned char * data, size_t count) throw (
        Exception);
    virtual void readBlock(unsigned char * data, size_t count) throw (
        Exception);
    virtual ~Drive()
  };
} // namespace Tape
```

Listing 1.6: Tape::Drive interface

Table 1.2: AUL prelabeled tape with one HDR1

VOL1	HDR1(PRELABEL)	TM

Table 1.3: The structure of the volume label

VOL1			
Bytes	Length	Offset	Content
0-3	4	0x00	Volume label indicator: the caracters "VOL1"
4-9	6	0x04	Volume serial number (VSN) (ex: "AB1234")
10	1	0x0A	Accessibility (In CAStor, left as space)
11-23	13	0x0B	Reserved for future (spaces)
24-36	13	0x18	Implementation identifier (left as spaces by CAStor)
37-50	14	0x25	Owner identifier (in CAStor, the string "CASTOR" or STAGESUPERUSER name padded with spaces)
51-78	28	0x33	Reserved (spaces)
79	1	0x4F	Label standard level (1,3 and 4 are listed as valid in IBM's documentation. CAStor uses ASCII '3')

CAStor example for the beginning of the tape:

```
00000000  56 4f 4c 31 56 35 32 30  30 31 20 20 20 20 20 20  |VOL1V52001      |
00000010  20 20 20 20 20 20 20 20  20 20 20 20 20 20 20 20  |                |
00000020  20 20 20 20 20 43 41 53  54 4f 52 20 20 20 20 20  |     CASTOR     |
00000030  20 20 20 20 20 20 20 20  20 20 20 20 20 20 20 20  |                |
00000040  20 20 20 20 20 20 20 20  20 20 20 20 20 20 20 33  |               3|
```

Table 1.4: The structure of the HDR1, EOF1 labels

HDR1, EOF1			
Bytes	Length	Offset	Content
0-3	4	0x00	Header label: the caracters "HDR1 or EOF1"
4-20	17	0x04	File identifier: hexadecimal CAStor NS file ID. nsgetpath -x can be used to find the CASTOR full path name. Aligned to left. In case of prelabeled tape 'PRELABEL' is used instead of file ID.
21-26	6	0x15	The volume serial number of the tape.
27-30	4	0x1B	File section number: a number (0001 to 9999) that indicates the order of the volume within the multivolume aggregate. This number is always 0001 for a single volume data set.
31-34	4	0x1F	File sequence number: a number that indicates the relative position of the data set within a multiple data set group (aggregate). CAStor uses modulus for fseq by 10000
35-38	4	0x23	Generation number: '0001' in CAStor.
39-40	2	0x27	Version number of generation: '00' in CAStor.
41-46	6	0x29	Creation date: Date when allocation begins for creating the data set. The date format is cyyddd, where: c = century (blank=19; 0=20; 1=21; etc.) yy = year (00-99) ddd = day (001-366)
47-52	6	0x2F	Expiration date: year and day of the year when the data set may be scratched or overwritten. The data is shown in the format cyyddd. It is always advisable to set the expiration date when a volume is being initialised ('prelabelled') to be a date before the current date, so that writing to the tape is immediately possible.
53	1	0x35	Accessibility: a code indicating the security status of the data set and 'space' means no data set access protection.
54-60	6	0x36	Block count: This field in the trailer label shows the number of data blocks in the data set on the current volume. This field in the header label is always '000000'.
60-72	13	0x3C	System code of creating system: a unique code that identifies the system. CASTOR with CASTOR BASEVERSION number string.
73-79	7	0x49	Reserved

CAStor example for the second file on the tape:

```
00000000  48 44 52 31 31 32 41 31  36 30 43 33 38 20 20 20  |HDR112A160C38   |
00000010  20 20 20 20 20 56 35 32  30 30 31 30 30 30 31 30  |     V5200100010|
00000020  30 30 32 30 30 30 31 30  30 30 31 32 30 34 31 30  |0020001000120410|
00000030  31 32 30 34 31 20 30 30  30 30 30 30 43 41 53 54  |12041 000000CAST|
00000040  4f 52 20 32 2e 31 2e 31  32 20 20 20 20 20 20 20  |OR 2.1.12       |
```

CAStor example for the empty tape with PRELABEL and one HDR1 is used:

```
00000000  56 4f 4c 31 56 35 32 30  30 31 20 20 20 20 20 20  |VOL1V52001      |
00000010  20 20 20 20 20 20 20 20  20 20 20 20 20 20 20 20  |                |
00000020  20 20 20 20 20 72 6f 6f  74 20 20 20 20 20 20 20  |     root       |
00000030  20 20 20 20 20 20 20 20  20 20 20 20 20 20 20 20  |                |
00000040  20 20 20 20 20 20 20 20  20 20 20 20 20 20 20 33  |               3|
00000050  48 44 52 31 50 52 45 4c  41 42 45 4c 20 20 20 20  |HDR1PRELABEL    |
00000060  20 20 20 20 20 56 35 32  30 30 31 30 30 30 31 30  |     V5200100010|
00000070  30 30 31 30 30 30 31 30  30 30 31 33 32 33 34 30  |0010001000132340|
00000080  31 33 32 33 34 20 30 30  30 30 30 30 43 41 53 54  |13234 000000CAST|
00000090  4f 52 20 32 2e 31 2e 31  33 20 20 20 20 20 20 20  |OR 2.1.13       |
```

Table 1.5: The structure of the HDR2, EOF2 labels

HDR2, EOF2			
Bytes	Length	Offset	Content
0-3	4	0x00	Header label: the caracters "HDR2 or EOF2"
4	1	0x04	Record format. An alphabetic character that indicates the format of the records in the associated data set. For the AUL it could be only: F - fixed length (U - was used for HDR2 for prelabeled tapes)
5-9	5	0x05	Block length in bytes (maximum). For the block size greater than 100000 the value is 00000.
10-14	5	0x0A	Record length in bytes (maximum). For the record size greater than 100000 the value is 00000.
15	1	0x0F	Tape density. Depends on the tape density values are following: '2' for D800, '3' for D1600, '4' for D6250
16-33	18	0x10	Reserved
34	2	0x22	Tape recording technique. The only technique available for 9-track tape is odd parity with no translation. For a magnetic tape subsystem with Improved Data Recording Capability, the values are: 'P '- Record data in compacted format, ' ' - Record data in standard uncompacted format. For CASTOR is is 'P' if the drive configured to use compression (i.e. xxxGC)
35-49	14	0x24	Reserved
50-51	2	0x32	Buffer offset '00' for AL and AUL tapes
52-79	28	0x34	Reserved

CAStor example for the first file on the tape:

```
00000000  48 44 52 32 46 30 30 30  30 30 30 30 30 30 30 20  |HDR2F0000000000 |
00000010  20 20 20 20 20 20 20 20  20 20 20 20 20 20 20 20  |                |
00000010  20 20 20 20 20 20 20 20  20 20 20 20 20 20 20 20  |                |
00000030  20 20 30 30 20 20 20 20  20 20 20 20 20 20 20 20  |  00            |
00000040  20 20 20 20 20 20 20 20  20 20 20 20 20 20 20 20  |                |
```

Table 1.6: The structure of the UHL1, UTL1 labels

UHL1, UTL1			
Bytes	Length	Offset	Content
0-3	4	0x00	User header label: the caracters "UHL1 or UTL1".
4-13	10	0x04	Actual file sequence number ('0' padded from left).
14-23	10	0x0E	Actual block size ('0' padded from left).
24-33	10	0x18	Actual record length ('0' padded from left).
34-41	8	0x22	Site : a part of the domain name uppercase.
42-51	10	0x2A	Tape mover host name uppercase without domain name.
52-59	8	0x34	Drive manufacturer.
60-67	8	0x3C	Drive model (first 8 bytes from the field PRODUCT IDENTIFICATION in the SCSI INQUIRY replay).
68-79	12	0x44	Drive serial number.

CAStor example for the second file on the tape:

```
00000000  55 48 4c 31 30 30 30 30  30 30 30 30 30 32 30 30  |UHL1000000000200|
00000010  30 30 32 36 32 31 34 34  30 30 30 30 32 36 32 31  |0026214400002621|
00000020  34 34 43 45 52 4e 20 20  20 20 4c 58 43 32 44 45  |44CERN    LXC2DE|
00000030  56 35 44 32 53 54 4b 20  20 20 20 20 54 31 30 30  |V5D2STK     T100|
00000040  30 30 42 20 58 59 5a 5a  59 5f 42 31 20 20 20 20  |00B XYZZY_B1    |
```

1.5.5.2 File block management

Some files tapes have mixed block sizes, some files used to have mixed block sizes. Current proposal is to have a fixed block size per tape, and to have operators choose the optimal block size for drive performance (too small blocks reduce performance).

Currently 256kB is used everywhere, so hardcoding this block size for writing to this value is an acceptable for the time being. On the long run, this should be a configurable parameter by the operators.

Ideally, only the Tape::File class should handle all aspects of cutting the disk file, which is a continuous stream, into fixed size blocks. But this would have the downside of having the Tape::File class a client of the FIFOs, and potentially have its own thread, which is far beyond the scope of this class. Therefore, it is the duty of the caller to provide the file cut into fixed size blocks. The Tape::File class will require pre-declaration of the block size, and enforce it.

1.5.5.3 Responsibilities of the class

This class will have the responsibility to check file structure and content, including checksum, block sizes and header/trailer content. In case of non-fatal errors, the warnings will be reported through the warning interface described in **??**.

1.5.5.4 Checksums

The checksum in CAStor uses the Adler32 checksum. Adler32 can be computed incrementally on a stream of data. The zlib contains an implementation of adler32 [23]. The checksum will be computer automatically when writing or reading the file to tape. Reading a file with a wrong checksum will throw an exception. TODO: define writing behavior (is the checksum pre-declared?).

[23] http://www.zlib.net/manual.html#Checksum

1.5.5.5 Tape::File API

TODO.

1.5.6 Memory chunk manager

The memory block manager allocates (usually all at once) a large chunk of memory. This memory is then shared between the various FIFOs in the system. Deallocation of memory on exit will allow memory leak checks. This class will have to be thread safe.

TODO: Define API.

1.5.7 FIFOs

FIFOs will be used to synchronize the data transfer between the tape thread and disk threads. The Tape thread will manage the block-to-stream transformation. The FIFO might not always be able to provide blocks in one piece at chunk boundary. The first attempt solution for this case will be a copy of the cut block. With a chunk size significantly bigger than the block size, the event should be rare enough to not affect performance. FIFOs will probably need some thread safety, but as they will be single user, single consumer, some parts might possible be lockless.

1.5.8 Disk client library

1.5.9 VDQM client library

TODO: describe how we will link with the VDQM client library. The VDQM is also the initial client which triggers the tape sessions. It carries a feature where the tape drive can recycle a tape mount. This is not very useful today, and the first release of the TapeServer will not support it. All sessions will be force-closed by the TapeServer.

1.5.10 VMGR client library

1.5.11 Stager/TapeGateway client library

1.5.12 Logging system client library

1.5.13 Application architecture

1.5.13.1 Session spawner

1.5.13.2 Session process

1.5.13.3 Tape read thread

1.5.13.4 Tape write thread

1.5.13.5 Disk read thread

1.5.13.6 Disk write thread

Chapter 2

Administrator's manual

2.1 Pending questions

- Is the option `ST_BUFFER_WRITES` from `castor.conf` still used?