

EVIO 5.2 User's Guide

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Chapter 1

1 Introduction

1.1 Evio Format Version 1

Version 1 of the CODA EVIO package, written in C, was in use at Jefferson Lab for over a decade. It has seen extensive use in Halls A and C, where the raw data is written to disk in EVIO format, and has seen limited use in the Hall B, where PRIMEX and the GlueX BCAL test stored their raw data in EVIO format (CLAS stored raw data in BOS/FPACK format).

1.2 Evio Format Versions 2 & 3

In the past few years, in EVIO format versions 2 and 3 (no difference between them), the JLab DAQ group upgraded and extended the EVIO package to meet some additional needs. First added were XML conversion and other utilities, support for all 1, 2, 4, and 8-byte data types, addition of a new TAGSEGMENT bank type, support for gzipped files and pipes (courtesy of Steve Wood), elimination of obsolete data types, as well as a number of bug fixes and performance enhancements.

With the advent of object-orientation and C++ the DAQ group achieved a major upgrade to the EVIO package beyond simple wrapping of existing C code in C++. Since an EVIO event maps to a directed acyclic graph or tree, a fact which allowed us to write the XML conversion utilities, we based the object-oriented extension on the XML notion of stream and Document Object Model (DOM) parsing and DOM trees. Note that banks in an EVIO event can either be container nodes or leaf nodes, i.e. they can contain either other banks **or** data, but not both (unlike XML, where a node can contain both data **AND** other nodes).

The object-oriented extension to EVIO described below builds upon the modern C++ standard, and makes liberal use of templates and the Standard Template Library (STL) (i.e. containers, iterators, algorithms, function objects, function object adaptors, smart pointers, etc). Fortunately users need only be familiar with a small subset of these, and examples in the tutorial below show how to do the most common tasks. However, advanced users of the EVIO package should be able to take full advantage of the STL.

Note that the object-oriented features build upon the existing C library, and except as noted the C library continues to work as before. On the Java front, the DAQ group adopted, extended, and supports Dave Heddle's jevio package.

1.3 Evio Package Version 4

EVIO version 4 which can be found at <http://coda.jlab.org> . The following outlines the major changes that were made.

1.3.1 File Format Block Size

In previous versions, the EVIO file format had fixed-size blocks generally set to 8192 32-bit ints (32768 bytes) including a block header. EVIO banks were often split across one or more blocks. This was largely done for error recovery when using tape storage.

In version 4, since tape storage considerations are now irrelevant, each block contains an integral number of events. Users can set the nominal block size or events/block. Writing will not exceed the given limit on events/block, but each block may contain significantly less events depending on their size. The nominal block size will be exceeded in the case that a single event larger than that size is written.

1.3.2 Network Communication Format

In order to unify file and network communications, the new file format is used for both. The C library has `evOpenBuffer` and `evOpenSocket` routines to complement the traditional `evOpen` and allows reading and writing with buffers and TCP sockets.

1.3.3 Expanded User Interface

The C library contains several new read routines which differ in their memory handling. Options for the routine `evIoctl` have been expanded. Routines for dictionary handling and other purposes have been added as well.

1.3.4 Dictionary

An xml format dictionary can be seamlessly included as the first bank of a file/network format.

1.3.5 Padding

When using 1 and 2 byte data sizes (short, unsigned short, char, and unsigned char) in previous EVIO versions, there was some ambiguity. Because EVIO format dictates each bank, segment, or tagsegment must be an integral number of 32-bit ints in length, specifying an odd number of shorts or non-multiple of 4 number of chars meant there were extra, unused shorts or chars that the user had to keep track of externally.

In version 4, with banks and segments (**not** tagsegments), these unused shorts/chars or padding are tracked in the header by using the 2 highest bits of the content type. Padding can be 0 or 2 bytes for shorts and 0-3 bytes for chars. All padding operations are completely transparent to the user.

1.3.6 Data Formats

There is a new data format called composite data which is used by Hall B. In a nutshell it consists of a string which describes the format of the data - allowing data of mixed types to be stored together - and is followed by the data itself.

1.3.7 Random Access

There is a read routine which will read a particular event (say #347) directly instead of having to read the previous (346) events.

1.3.8 Append Mode

There is now a writing mode which will append data to the end of an existing file or buffer.

1.3.9 Splitting Files

The C, C++, and Java evio libraries all implement a means to limit the size of an evio file being written by splitting it into multiple files. There are facilities to make the automatic naming of these files simple.

1.3.10 Thread Safety

The libraries are now designed to be thread safe.

1.3.11 Graphics

The Java library has a graphical user interface for viewing evio format files.

1.4 Evio Package Version 5

The major change that was made is that a “first event” can be defined so that when writing files, this event is written into each split file.

Chapter 2

2 Evio Installation

The evio library is available in three languages, C, C++, and Java. All code is contained in the github repository,

<https://github.com/JeffersonLab/evio.git>

The **evio-5.2** branch contains this version of evio. To check it out of github:

```
git clone -b evio-5.2 https://github.com/JeffersonLab/evio.git
```

Documentation is contained in the repository but may also be accessed at the evio home page:

<https://coda.jlab.org/drupal/content/event-io-evio/>

2.1 C

The C library is called libevio. It is a library with limited capabilities. To compile it, follow the directions below for the C++ compilation which will include the C as well. Having said that, the C library and executables can be compiled without any C++. This can be done in 2 ways:

```
scons --C
```

or

```
mkdir build
cd build
cmake .. -DC_ONLY=1
```

For more details concerning scons and cmake, see the following section on C++.

2.2 C++

The C++ library is called libeviocc and is supported on both the MacOS and Linux platforms. C++ version 11 is used.

2.2.1 Building

There are 2 different methods to build the C++ library and executables. The first uses **scons**, a Python-based build software package which is available at <https://scons.org>. The second uses cmake and make.

2.2.1.1 Scons

To get a listing of all the local options available to the **scons** command, run **scons -h** in the top-level directory to get this output:

```
-D                build from subdirectory of package

local scon's OPTIONS:
--C                compile C code only
--dbg             compile with debug flag
--32bits          compile 32bit libs & executables on 64bit system
--prefix=<dir>    use base directory <dir> when doing install
--incdir=<dir>    copy header files to directory <dir> when doing install
--libdir=<dir>    copy library files to directory <dir> when doing install
--bindir=<dir>    copy binary files to directory <dir> when doing install
install           install libs, headers, and binaries
install -c        uninstall libs, headers, and binaries
doc               create doxygen and javadoc (in ./doc)
undoc             remove doxygen and javadoc (in ./doc)
tar               create tar file (in ./tar)

Use scon's -H for help about command-line options.
```

Although this is fairly self-explanatory, executing

```
1) cd <evio dir>
2) scon's install
```

will compile and install all the code. By default, all libraries, executables and includes are placed into the `$CODA/<arch>/lib` and `bin` subdirectories (eg. `Linux-x86_64/lib`) where **CODA** is an environmental variable. If the command line options `-prefix`, `--incdir`, `--libdir`, or `--bindir` are used, they take priority.

To compile a debug version, execute:

```
scon's install --dbg
```

2.2.1.2 Cmake

Evio can also be compiled with cmake using the included CMakeLists.txt file. To build the C and C++ libraries and executables on the Mac:

```
1) cd <evio dir>
2) mkdir build
```

```
3) cd build
4) cmake .. -DCMAKE_BUILD_TYPE=Release
5) make
```

To build only C code, place `-DC_ONLY=1` on the cmake command line. In order to compile all the examples as well, place `-DMAKE_EXAMPLES=1` on the cmake command line.

The above commands will place everything in the current “build” directory and will keep generated files from mixing with the source and config files.

In addition to a having a copy in the build directory, installing the library, binary and include files can be done by calling cmake in 2 ways:

```
1) cmake .. -DCMAKE_BUILD_TYPE=Release -DCODA_INSTALL=<install dir>
2) make install
```

or

```
1) cmake .. -DCMAKE_BUILD_TYPE=Release
2) make install
```

The first option explicitly sets the installation directory. The second option installs in the directory given in the CODA environmental variable. If cmake was run previously, remove the CMakeCache.txt file so new values are generated and used.

To uninstall simply do:

```
make uninstall
```

2.2.2 Documentation

The documentation for this software has already been created and is hosted at <https://codajlab.org/drupal/content/event-io-evio/> (which, perhaps, you are reading right now).

2.2.2.1 Doxygen

All the source code contains doxygen style comments. One may generate the associated documentation by executing

```
scons doc
```

in the top-level directory. The result can be viewed by using your web browser to view the created `doc/doxygen/C/html/index.html` and `doc/doxygen/CC/html/index.html` files. To regenerate these files, call

```
scons undoc
scons doc
```

For those who wish to fine-tune the generated files, the doxygen configuration files, **doc/DoxyfileCC** and **doc/DoxyfileC**, can be modified to suit. The doxygen comments can be viewed from the github pages website as well so explicitly dealing with doxygen is not necessary.

Now the documentation can also be generated by using cmake (assuming it's been run previously at least once):

```
1) cd <evio dir>/build
2) cmake --build . --target docCC docC
```

2.2.2.2 User's Guide

The user's guide (the document you're reading right now) is written and stored as a word document in the doc/users_guide directory. Of course, this can be viewed in Microsoft Word. For user's convenience, it's also available in pdf format.

2.3 Java

The current Java evio package, org.jlab.coda.jevio, was originally written by Dr. Dave Heddle of CNU and was graciously given to the JLAB DAQ group for maintenance and continued development. A large amount of additional work has been done since that time.

A pre-compiled **jevio-5.2.jar** file is found in each of these subdirectories:

- **java8**, which contains a jar compiled with Java 8
- **java15**, which contains a jar compiled with Java 15

In addition, there is an optimized jar file called **jevio-5.2.optimized.jar** in the java8 directory (more on that below). Using these allows the user to skip over all the following compilation instructions.

2.3.1 Building

The java evio uses **ant** to compile. To get a listing of all the options available to the ant command, run **ant help** in the evio top level directory to get this output:

```
help:
[echo] Usage: ant [ant options] <target1> [target2 | target3 | ...]

[echo]          targets:
[echo]          help      - print out usage
[echo]          env       - print out build file variables' values
[echo]          compile   - compile java files
[echo]          clean     - remove class files
[echo]          cleanall  - remove all generated files
[echo]          jar       - compile and create jar file
[echo]          install   - create jar file and install into 'prefix'
```

```

[echo]             if given on command line by -Dprefix=dir',
[echo]             else install into CODA if defined
[echo]      uninstall - remove jar file previously installed into 'prefix'
[echo]             if given on command line by -Dprefix=dir',
[echo]             else installed into CODA if defined
[echo]      all        - clean, compile and create jar file
[echo]      javadoc    - create javadoc documentation
[echo]      developdoc - create javadoc documentation for developer
[echo]      undoc      - remove all javadoc documentation
[echo]      prepare    - create necessary directories

```

Although this is fairly self-explanatory, executing **ant** is the same as **ant compile**. That will compile all the java. All compiled code is placed in the generated **./build** directory. If the user wants a jar file, execute **ant jar** to place the resulting file in the **./build/lib** directory. The **java** command in the user's path will be the one used to do the compilation.

2.3.2 Optimization

Optionally, one can use proguard to optimize the evio jar file. This will shrink, optimize, and improve the performance of the evio jar. Edit the myconfig.pro file to get the directory names correct. Make sure you have gradle installed on your system:

```

1) git clone https://github.com/Guardsquare/proguard-core.git
2) cd proguard-core
3) gradle clean assemble
4) cd ..
5) git clone https://github.com/Guardsquare/proguard.git
6) cd proguard
7) ./gradlew --include-build=../proguard-core assemble
8) cd ../evio-6.0/build/lib
9)      java -jar ../../../../proguard/lib/proguard.jar @../../myconfigfile.pro

```

Note, the last command will only work if the evio, proguard and proguard-core directories are all in the same directory as each other. If they aren't, you must edit `<evio top dir>/myconfigfile.pro` file to reflect the current directory structure. The resulting optimized jar will be written as **<evio top dir>/build/lib/jevio-5.2.optimized.jar** or to what it is edited to be.

2.3.3 Documentation

The documentation for this software has already been created and is hosted at <https://coda.jlab.org/drupal/content/event-io-evio/> (which, perhaps, you are reading right now).

2.3.3.1 Javadoc

All the source code contains javadoc style comments. One may generate the associated documentation by calling

```
ant javadoc
```

in the top-level directory. If more detail is desired, classes and methods which are not public can be seen by, instead, executing the command

```
ant developdoc
```

This is more suitable for a developer. In either case, the resulting javadoc can be accessed by viewing the **doc/javadoc/index.html file** in a web browser. To regenerate this file, call

```
ant undoc  
ant Javadoc
```

2.3.3.2 User's Guide

See the section above for info on the [user's guide](#), which you are reading right now.

Chapter 3

3 Basics of the C Library

The EVIO file format is described in Appendix A while bank structures and content type are described in Appendix B. Appendix C explains the dictionary format.

3.1 *Starting to use Evio*

The first thing a user must do is to "open" evio and obtain a handle to be used as an argument for all other evio functions. There are now 3 possibilities in the 3 open routines:

- 1) **int evOpen(char *filename, char *flags, int *handle)**
- 2) **int evOpenBuffer(char *buffer, int bufLen, char *flags, int *handle)**
- 3) **int evOpenSocket(int sockFd, char *flags, int *handle)**

The first routine is for opening a file. The "flags" argument can "w" for writing, "r" for reading, "a" for appending, "ra" for random access, or "s" for splitting the file while writing. The splitting, appending and random access modes are new in this version of evio and are not backwards compatible. Writing a file will overwrite any existing data, while appending will add new events to the end of a file. Reading a file will allow access to each event in the order in which it exists in the file - in other words, it is a sequential access to the events. The random access mode, on the other hand, does a preliminary scan of the file and allows reading (not writing) of selected events no matter where they are in sequence. When writing large amounts of data it is often convenient to split the output into a number of files. This is supported by specifying the "s" flag. By proper specification of the filename argument and by using the `evIoctl()` function, these split files can be automatically named.

The second routine is for opening a buffer. It takes a pointer to a buffer as well as its length in words (32 bit ints) as the first 2 arguments. The "flags" argument is the same as for `evOpen()` as discussed in the previous paragraph with the exception of "s" since splitting makes no sense for buffers.

The third is for opening evio with a TCP socket. The first argument is the socket file descriptor of a TCP socket which was created elsewhere. The "flags" argument in this case can only be "w" for writing, "r" for reading since splitting, appending or random access makes no sense when talking about a stream-oriented medium.

3.2 *Reading events*

There are now 4 routines able to read an event.

- 1) **int evRead(int handle, uint32_t *buffer, size_t buflen)**
- 2) **int evReadAlloc(int handle, uint32_t **buffer, uint64_t *buflen)**
- 3) **int evReadNoCopy(int handle, const uint32_t **buffer, uint64_t *buflen)**
- 4) **int evReadRandom(int handle, const uint32_t **pEvent, size_t eventNumber)**

The first is the original read routine which reads an event into a user-given buffer. Its main problem is that the caller does not generally know the size of the event before reading it and therefore the supplied buffer may be too small - resulting in an error.

The second reads an event, allocating all the memory necessary to hold it with the caller responsible for freeing that memory.

The way evio works internally is that a file/buffer/socket is read one block at a time into an internal buffer. The third routine simply returns a pointer to the next event residing in the internal buffer - so no memory allocation or copying is done. If the data needs to be swapped, it is swapped in place. Any other calls to read routines will cause the data to be overwritten if a new block needs to be read in. Of course, no writing to the returned pointer is allowed.

Finally, the last read routine works like the 3rd read routine described in the previous paragraph in which a pointer to an internal buffer is returned to the caller. It is valid only when evio has been opened in random access mode and allows the caller to read only the event of interest instead of all previous events as well.

3.3 *Writing events*

As in previous versions there is only 1 write routine simply because the C library will only write in the new format, so no changes here:

int evWrite(int handle, const uint32_t *buffer)

However, there is a complication when writing to a buffer that does not occur when writing to a file or socket. Unlike a file which grows as one writes or a socket that will take any amount of data, the buffer that the caller provides to contain what is written, is of fixed size. Thus an error can be returned if the amount of data written exceeds the buffer size; therefore, it is convenient to keep track of how much has already been written, before continuing to write more. This can be done through the following new routine:

int evGetBufferLength(int handle, uint64_t *length)

This routine returns the number of bytes currently written into a buffer when given a handle provided by calling evOpenBuffer(). After the handle is closed, this no longer returns anything valid.

3.3.1 Splitting files

When writing significant amounts of data to a single file, that file can get very large – too large. Historically, run control was able to split the data into multiple files with an automatic file naming system. For this version of evio, the ability to split files is built in as is the naming system. Start by setting the “flags” parameter in the `evOpen()` call to “s”. In addition to that, the user may choose the number of bytes at which to start writing to a new file by a call to `evIoctl()` (see below). If not explicitly set, the split occurs at 1GB. If a dictionary is defined by calling `evWriteDictionary()` (see below), then that dictionary is included in each of the split files. The split files are named according to the automatic naming system whose details are given in the next section.

3.3.2 Naming files

When splitting files, a base filename is passed to `evOpen()` and may contain characters of the form `$(env)` where “env” is the name of an environmental variable. When a file is created, all such constructs will be substituted with the actual environmental variable’s value (or nothing if it doesn’t exist).

Similarly, the base filename may contain constructs of the form `%s` which will be substituted with the actual run type’s value (if set with `evIoctl()`) or nothing if run type is null or was not set.

Generated file names are distinguished by a split number which starts with 0 for the first file and is incrementing by 1 for each additional file. Up to 2, C-style integer format specifiers (such as `%03d`, or `%x`) are allowed in the base filename. If more than 2 are found, an error is returned. If no “0” precedes any integer between the “%” and the “d” or “x” of the format specifier, it will be added automatically in order to avoid spaces in the generated filename. The first specifier will be substituted with the given run number value (set in `evIoctl()`). The second will be substituted with the split number. If no specifier for the split number exists, it is tacked onto the end of the file name.

Below is an example of how the file naming and splitting is done. Given the list of values below

```
int split          = 100000000; // split at 100MB
int runNumber      = 1;
char *runType      = "myExperiment";
char *directory    = "/myDirectory";
char *baseFilename = "my$(BASE_NAME)_%s_%x_%03d.ext";
```

and a `BASE_NAME` environmental variable of the value “File”, the following happens. The `baseFilename` string will have the environmental variable, `BASE_NAME`, substituted in the obvious location along with the `runType` substituted for the `%s`, the `runNumber` substituted for the `%x` (hex format), and the split number substituted for the `%03d`. The first 3 split files will have the names:

```
myFile_myExperiment_1_001.ext
myFile_myExperiment_1_002.ext
myFile_myExperiment_1_003.ext
```

3.4 Controlling I/O through `evIoctl()`

Some control over evio settings is given to the user with the `evIoctl()` routine, shown below,

int evIoctl (int handle, char *request, void *argp)

It can be used, for example, to set the target block size and the maximum number of events/block for writes. It can also read various quantities including the total number of events in a file or buffer opened for reading or writing.

This routine can obtain a pointer to allocated memory containing the most recently read block header. The size of the memory is 8, 32-bit unsigned integers (words) and the pointer to the memory is obtained by passing its address in argp. This pointer must be freed by the caller to avoid a memory leak.

To summarize, the *request* parameter can be the case independent string value of:

- 1) "B" for setting target block size in words
- 2) "W" for setting writing (to file) internal buffer size in words
- 3) "N" for setting max # of events/block
- 4) "R" for setting run number (used in file splitting)
- 5) "T" for setting run type (used in file splitting)
- 6) "S" for setting file split size in bytes
- 7) "V" for getting evio version #
- 8) "H" for getting 8 words of block header info
- 9) "E" for getting # of events in file/buffer

The *argp* parameter is a:

- 1) pointer to 32 bit unsigned int containing block size in 32-bit words if request = B
- 2) pointer to 32 bit unsigned int containing buffer size in 32-bit words if request = W
- 3) pointer to 32 bit unsigned int containing max # of events/block if request = N
- 4) pointer to 32 bit unsigned int containing run # if request = R
- 5) pointer to character containing run type if request = T
- 6) pointer to 64 bit unsigned int containing file split size in bytes if request = S
- 7) pointer to 32 bit int returning the version # if request = V
- 8) address of pointer to unsigned 32 bit int returning a pointer to 8 uint32_t's of block header if request = H. (This pointer must be freed by caller since it points to allocated memory).
- 9) pointer to unsigned 32 bit int returning the total # of original events in existing file/buffer when reading or appending if request = E

3.5 *String manipulation*

In order to facilitate the handling of strings, 2 routines are provided. The first,

```
int evBufToStrings(char *buffer, int bufLen, char ***pStrArray, int *strCount),
```

takes evio string format data and converts it into an array of strings. The second,

```
int evStringsToBuf(uint32_t *buffer, int bufLen, char **strings,  
int stringCount, int *dataLen),
```

does the reverse and takes an array of strings and places them in evio format into a buffer.

3.6 *Network Communication Format*

In order to unify file and network communications, the new file format is used for both. The C library has evOpenBuffer() and evOpenSocket() routines to complement the traditional evOpen() and allows reading and writing with buffers and TCP sockets.

3.7 *Dictionary*

An xml format dictionary can be seamlessly included as the first event when writing events to a file, buffer, or network. Refer to Appendix C for details on the format of a dictionary. To write a dictionary, simply call the following routine

```
int evWriteDictionary(int handle, char *xmlDictionary)
```

before writing any events and it will be seamlessly included as the first event in the first block. If events have already been written, an error will be returned. When reading events, simply call the following routine to get the dictionary, as a string, if it was defined:

```
int evGetDictionary(int handle, char **dictionary, int *len)
```

Note that if a file is being split, each file contains the dictionary.

3.8 *First Event*

Occasionally it is useful to have the same event appear in each split file, for example including a config event in each file. Such an event is called the first event since typically it is the first event after the dictionary in each of the splits. To define such an event, call the following routine:

```
int evWriteFirstEvent(int handle, const uint32_t *firstEvent)
```

It's wise to call this before other events are written to avoid it being left out of one of the early splits.

3.9 ***Data Formats***

There is a new data format called composite data which is used by Hall B. In a nutshell, it consists of an evio format string which describes the format of the data - allowing data of mixed types to be stored together - and is followed by the data itself.

3.10 ***Documentation***

Besides the document you are now reading, there are doxygen docs which are essentially javadoc web pages for C/C++ code. To those unfamiliar with doxygen, programmers include specially formatted comments in the code itself which is extracted by the doxygen program and formed into web pages for view with a web browser. The user must generate these web pages by going to the top level of the evio distribution and typing "scons doc". Then simply view the doc/doxygen/C[or CC]/html/index.html file in a browser.

Chapter 4

4 Basics of the C++ Library

Important: all symbols in the EVIO C++ library reside in the “evio” namespace.

4.1 *evioChannel*

The foundation for I/O in the C++ object-oriented version of EVIO is the notion of an EVIO channel, an abstract or pure virtual class that includes the methods `open()`, `read()`, `write()`, and `close()`. Real or concrete channels extend the `evioChannel` class and use their constructors to supply information needed to access the underlying EVIO data stream.

There are three flavors of the `write()` method implementing output 1) from the internal `evioChannel` buffer, 2) from a user-supplied buffer, and 3) from the internal buffer in another `evioChannel` object. Additional methods include `getBuffer()` and `getBufSize()`.

4.2 *evioFileChannel*

The `evioFileChannel` class is a subclass of `evioChannel` that implements I/O to and from files or file-like entities (e.g. pipes). The constructor accepts a file name, an optional mode string (default is “r”), and an optional internal buffer size (default is 8192 longwords). One of the constructors also accepts a “first event” argument which is an event which will get written to each split file. The internal buffer is allocated automatically. The `ioctl()` method can be used to set the EVIO file block size in write mode (default is 8192 longwords), and must be called immediately after the `open()` method (`ioctl` is ignored for read mode).

This class is little more than an object-oriented wrapper around the original C function library. See the C++ tutorial for an example of how to use `evioFileChannel`, the C Library API in Appendix A for additional information, or the Doxygen docs for full API information.

4.3 ***evioBufferChannel***

The `evioBufferChannel` class is similar to the `evioFileChannel` but reads and writes from a user-supplied buffer instead of a file. Underneath, the open method calls the C routine `evOpenBuffer`.

4.4 ***evioSocketChannel***

The `evioSocketChannel` class is similar to the `evioFileChannel` and the `evioBufferChannel` classes but reads and writes over a user-supplied TCP socket instead of a file or buffer. Underneath, the open method calls the C routine `evOpenSocket`.

Chapter 5

5 EVIO Stream Parser

Stream parsing an EVIO event involves making a single pass through the event and dispatching to user-supplied callbacks as each new bank is reached. Two versions are supplied, a C version and a C++ version.

In the C version the user supplies two callbacks to `evio_stream_parse()` along with a pointer to the event buffer. `evio_stream_parse()` works its way through all the banks in the event in order, calling the callbacks as each new node or bank is reached. One callback is called when container banks (ones containing other banks, not data) are reached, the other when leaf or data banks are reached.

In the C++ version the `evioStreamParser` constructor is given an `evioChannel` object containing an event (e.g. an `evioFileChannel` object which obtained an event via its `read()` method) and a user-written callback handler object. The latter implements two methods: `containerNodeHandler()` and `leafNodeHandler()`. `containerNodeHandler()` is called when a container node or bank is reached, and `leafNodeHandler()` is called when a leaf or data node is reached.

In general, stream parsing may be useful for a quick pass through the data, but in C++ DOM parsing and DOM trees (see the next section) are the preferred ways to deal with EVIO events in all but the simplest cases.

5.1 *in C*

To use `evio_stream_parser()`:

```
#include "evio.h"

int handle;
unsigned int buffer[10000];
int buflen=10000;

/* open file */
status = evOpen(myFilename, "r", &handle);
```

```

/* read events */
while(evRead(handle, buffer, buflen)==S_SUCCESS) {

    /* parse event and dispatch to callbacks */
    evio_stream_parser(buffer, node_handler, leaf_handler);

}

/* close file */
evclose(handle);

```

where the `node_handler` callback is of type `NH_TYPE`, and the `leaf_handler` callback is of type `LH_TYPE` (either can be `NULL`):

```

typedef void (*NH_TYPE)(int length, int ftype, int tag, int type,
                        int num, int depth);

typedef void (*LH_TYPE)(void *data,
                        int length, int ftype, int tag, int type,
                        int num, int depth);

```

where `length` is the length of the contents of the bank, `ftype` is the type of bank (`BANK`, `SEGMENT`, or `TAGSEGMENT`), `tag` is the bank tag, `type` defines the content type of the bank, `num` is defined only for the `BANK` type (set to 0 for `SEGMENT` and `TAGSEGMENT`), `depth` is the level of the bank in the tree, and `data` is a pointer to the array of data contained by the leaf bank (must be cast to appropriate type before accessing data).

5.2 *In C++*

To use the `evioStreamParser`:

```

#include <evioUtil.hxx>

using namespace evio;
using namespace std;

int main(int argc, char **argv) {

    try {

        // create evio file channel object for reading, argv[1] is filename
        evioFileChannel chan(argv[1], "r");

        // open the file
        chan.open();

        // create parser and node handler objects
        evioStreamParser parser;
        myHandler handler;
    }
}

```

```

// read events and parse channel internal buffer
while(chan.read()) {
    parser.parse(chan.getBuffer(), handler, (void*)NULL);
}

// eof reached...close file
chan.close();

} catch (evioException e) {
    cerr << endl << e.toString() << endl << endl;
    exit(EXIT_FAILURE);
}

// done
exit(EXIT_SUCCESS);
}

```

where:

```

class myHandler : public evioStreamParserHandler {
    void *containerNodeHandler(int length, unsigned short tag,
        int contentType, unsigned char num, int depth, void *userArg) {
        return(NULL);
    }

    void leafNodeHandler(int length, unsigned short tag, int contentType,
        unsigned char num, int depth, const void *data, void *userArg) {
    }
};

```


Chapter 6

6 EVIO DOM Parser and DOM Trees

In analogy with XML DOM parsing, the EVIO DOM parser constructs an in-memory object-oriented representation of an EVIO event. This in-memory representation is stored as an instance of the `evioDOMTree` class. The `evioDOMTree` constructor can automatically construct the tree based on an event contained in an `evioChannel` object (e.g. an instance of `evioFileChannel`). Manual construction and modification of trees is also possible.

The tree itself consists of a hierarchy of nodes of two types, container nodes and leaf nodes. Container nodes hold lists of other nodes; leaf nodes contain vectors of data. Both node types inherit from the abstract base class `evioDOMNode`. The top node in the tree is called the root node. Note that the API is defined entirely by the `evioDOMNode` class, and that user code never calls its sub-classes directly.

6.1 *evioDOMNode*

This is the abstract base class for the two concrete node types described above, and the only class that users deal with directly. The `evioDOMNode` class contains a parent pointer, parent tree pointer, tag, num, and content type. The latter three correspond to the fields in EVIO bank headers in EVIO files. Legal content types are listed in Appendix C.

Nodes are created via static factory methods :

```
evioDOMNodeP evioDOMNode::createEvioDOMNode()
```

where `evioDOMNodeP` is a node pointer and all objects are created on the heap. Other methods include `toString()`, which returns an XML fragment representing the node; `bool isContainer()` and `bool isLeaf()`, and a few others described below. `operator==` and `operator!=` are defined to compare tags if the argument is an integer, or tag and num if the argument is a `tagNum` pair (see API docs).

6.1.1 *getChildList()*

`getChildList()` returns a pointer to the child list of an `evioDOMNode` that actually is a container node. NULL is returned if the node is a leaf node. See the tutorial for more details.

6.1.2 *getVector<T>()*

`getVector<T>()` returns a pointer to the data vector contained in a leaf node of type T, where T is one of the many supported data types (int, unsigned int, double, etc). NULL is returned if the node is a container node, or if it is a leaf node containing a different type. See the tutorial for more details.

6.2 *evioDOMTree*

This class represents the EVIO DOM tree or event in memory. It contains a pointer to the `evioDOMNode` that forms the root of the tree (type is always BANK), and the name of the tree (default is “evio”). It can construct a tree from an event contained in an `evioChannel` object (see the tutorial). Manual construction of a tree is discussed below.

Methods include `toString()`, which returns an XML string representing the entire contents of the tree, and `getNodeList(Predicate P)`, which returns a (pointer to a) list of pointers to all nodes in the tree satisfying the predicate P. See the C++ tutorial or the API docs for details.

6.2.1 *Manual evioDOMTree construction*

Manual construction of an `evioDOMTree` might typically happen in a Monte Carlo program that outputs simulated data. A root node must first be created, then it can be filled with either data if it is a leaf node, or pointers to other `evioDOMNode` objects if it is a container node. This process can be repeated recursively until a complete tree is formed. Then e.g. the tree can be written to a file via use of the `write()` method of an `evioFileChannel` object.

`evioDOMTree` constructors exist that can automatically create the root node. Alternatively, you can create the root node yourself and supply it to the tree constructor directly.

Nodes are created via the static factory methods `evioDOMNode::createEvioDOMNode()`, and can be added to the root node (assuming it is a container) or other container nodes in a variety of ways. See the tutorial for examples of how to create nodes, add nodes to the child lists of container nodes, and add data to leaf nodes.

6.2.2 *Modification of existing trees*

Modification of an existing tree might typically happen in a reconstruction program that first constructs an `evioDOMTree` from data read in by an `evioFileChannel` object, and then adds additional reconstructed data to the tree before writing it out again. The

program might create one or more sub-trees containing the new data, then add the subtrees to the child lists of container nodes in the original tree. Further, sub-trees of the existing tree might be deleted by removing them from the child lists of container nodes, or moved from one container node to another.

These operations are easily carried out via the `evioDOMNode` methods `cut()`, `cutAndDelete()`, and `move()`. See the tutorial for details.

Chapter 7

7 Utilities

The utilities described below can be used to convert from binary EVIO to ASCII XML format and back, and to selectively copy EVIO events from one binary file to another. Below the term “event tag” refers to the tag of the outermost bank in an event, which is always of type BANK (two-word header, includes num).

7.1 *evio2xml*

evio2xml, part of the C library, is a flexible utility that reads a binary EVIO file and dumps selected events in XML format to stdout or to a file:

```
$ evio2xml -h
```

```
evio2xml [-max max_event] [-pause] [-skip skip_event]
         [-dict dictfilename] [-dtag dtag]
         [-ev evttag] [-noev evttag] [-frag frag] [-nofrag frag]
         [-max_depth max_depth]
         [-n8 n8] [-n16 n16] [-n32 n32] [-n64 n64]
         [-verbose] [-brief] [-no_data] [-xtod] [-m main_tag]
         [-e event_tag]
         [-indent indent_size] [-no_typename] [-maxbuf maxbuf]
         [-debug]
         [-out outfilenema] [-gz] filenameee
```

where most options customize the look and feel of the XML output, and defaults should be satisfactory. `-max` specifies the maximum number of events to dump, `-pause` causes *evio2xml* to pause between events, `-skip` causes it to skip events before starting to dump them. By default the bank tags are printed as numbers. The user can specify ASCII strings to be used instead in a tag dictionary (via `-dict`). Contact the DAQ group to get an example dictionary file.

7.2 **eviocopy**

eviocopy, part of the C library, copies selected events from a binary EVIO file to another binary EVIO file.

```
$ eviocopy -h

eviocopy [-max max_event] [-skip skip_event] [-ev evttag]
        [-noev evttag] [-nonum evnum] [-debug]
        input_filename output_filename
```

where `-max` specifies the maximum number of events to copy, `-skip` cause eviocopy to skip events, `-ev` causes eviocopy to only copy events with the specified event tag, and `-noev` inhibits copying of events with the specified tag. `-ev` and `-noev` can be specified multiple times on the command line.

7.3 **evioCat**

evioCat, part of the C++ library, concatenates multiple EVIO binary files into 1 file.

```
$ evioCat -h usage:

evioCat [-maxev maxEvent] [-maxevFile maxEventFile] [-debug]
        -o outputFile file1 file2 file3 ...
```

where `-maxev` specifies the max number of events to add, `-maxevFile` is the max number of files to add, `-debug` causes debugging output to screen, `-o` specifies the output file name and the rest of the arguments are the files containing evio events to concatenate.

7.4 **Xml2evio**

Xml2evio, part of the Java library, takes a file containing an xml representation of evio events and converts it into an evio format file and/or displays it on screen.

```
$ Usage: java org.jlab.coda.jevio.apps.Xml2evio -x <xml file> -f <evio file>
        [-v] [-hex] [-d <dictionary file>]
        [-max <count>] [-skip <count>]

-h    help
-v    verbose output
-x    xml input file name
-f    evio output file name
-d    xml dictionary file name
-hex  display ints in hex with verbose option
-max  maximum number of events to convert to evio
-skip number of initial events to skip in xml file
```

```
This program takes evio events in an xml file and
converts it to a binary evio file
```

Chapter 8

8 C++ Tutorial

Below are examples showing: how to read an event from a file into an evioDOMTree; how to query the tree to get lists of node pointers that satisfy various criteria and how to work with the lists; and how to modify the tree. Some advanced topics follow.

8.1 *Simple event I/O*

Below is a simple example that uses an evioFileChannel object to open and read an EVIO file, then create an evioDOMTree from the event in the evioFileChannel object, then dump the event to stdout:

```
#include <evioUtil.hxx>

using namespace evio;
using namespace std;

int main(int argc, char **argv) {

    try {

        // create evio file channel object for reading, argv[1] is filename
        evioFileChannel chan(argv[1], "r");

        // open the file
        chan.open();

        // loop over events
        while(chan.read()) {

            // create tree from contents of file channel object
            evioDOMTree tree(chan);

            // print tree
            cout << tree.toString() << endl;
        }

        // eof reached...close file
        chan.close();

    } catch (evioException e) {
        cerr << endl << e.toString() << endl << endl;
        exit(EXIT_FAILURE);
    }

    // done
    exit(EXIT_SUCCESS);
}
```

The tree can be written to a file via the write() method of the evioChannel class.

8.2 *Querying the event tree*

There are many ways to query an `evioDOMTree` to get lists of subsets of nodes in the tree. To get an STL list of pointers to all nodes in the tree:

```
evioDOMNodeListP pList = tree.getNodeList();
```

(Note to experts: `evioDOMNodeListP` is actually `auto_ptr< list<evioDOMNodeP> >`, where `evioDOMNodeP` is `evioDOMNode*`)

Here no predicate is given to `getNodeList()` so all pointers are returned. To get a list of pointers to just container nodes:

```
evioDOMNodeListP pContainerList = tree.getNodeList(isContainer());
```

where `isContainer()` is a function object provided with the EVIO package (see Appendix D for a list of all supplied function objects). Similarly, to get a list of just leaf nodes:

```
evioDOMNodeListP pLeafList = tree.getNodeList(isLeaf());
```

To get a list of pointers to nodes satisfying arbitrary user criteria:

```
evioDOMNodeListP pMyList = tree.getNodeList(myChooser);
```

where `myChooser()` is a simple C function instead of a function object. An example that specifies particular tag/num combinations is:

```
bool myChooser(const evioDOMNodeP node) {
    return(
        ((node->tag==3) && (node->num==0)) ||
        ((node->tag==2) && (node->num==1))
    );
}
```

To print all the nodes in the list (there are many ways to do this):

```
for_each(pList->begin(), pList->end(), toCout());
```

`for_each()` is one of a large number of STL algorithms. It accepts an STL iterator range (`pList->begin()`, `pList->end()`) and applies the function object in its third argument to each object in the iterator range in turn. Here `toCout()` is another of the many function objects supplied by the EVIO package. `toCout()` invokes the `toString()` method of the objects pointed to by the iterator, then streams the result to `cout`.

To print just leaf nodes, this time using iterators:

```
evioDOMNodeList::iterator iter;
for(iter=pLeafList->begin(); iter!=pLeafList->end(); iter++) {
    cout << endl << (*iter)->toString() << endl;
}
```


Note that (*iter) is an evioDOMNodeP, i.e. a pointer to an evioDOMNode object.

To count the number of leaf nodes with tags between 0 and 20 (this is an inefficient algorithm shown for illustration only):

```
for(int tag=0; tag<=20; tag++) {
    cout << "There are "
         << count_if(pLeafList->begin(), pLeafList->end(), tagEquals(tag))
         << " leaf nodes with tag " << tag << endl;
}
```

count_if() is another STL algorithm that counts all objects within the iterator range for which the predicate in the third argument is true. tagEquals() is another EVIO function object that returns true if the tag of the object pointed to by the iterator is equal to the argument given to the tagEquals() constructor, in this case the loop index "tag".

To search the full list and print the data from all leaf nodes containing floats (i.e. vector<float>) using the evioDOMNode member function getVector():

```
evioDOMNodeList::iterator iter;
for(iter=pList->begin(); iter!=pList->end(); iter++) {

    vector<float> *v = (*iter)->getVector<float>();
    if(v!=NULL) {
        cout << endl << endl << "Float node data:" << endl;
        for(int i=0; i<v->size(); i++) cout << (*v)[i] << endl;
    }
}
```

Note that getVector<T>() returns NULL if the node is not a leaf node containing (in this case) floats. You can tell what type of data is contained in a node via the getContentTypes() member function. See Appendix C for a list of legal content types.

To search the full list and access the child lists of container nodes using getChildList():

```
evioDOMNodeList::iterator iter;
for(iter=pList->begin(); iter!=pList->end(); iter++) {

    evioDOMNodeList *pChildList = (*iter)->getChildList();

    cout << "Node has " << pChildList->size() << " children" << endl;

    if(pChildList->size()>0) {
        evioDOMNodeList::const_iterator cIter;
        for(cIter=pChildList->begin(); cIter!=pChildList->end(); cIter++) {
            cout << "child has tag: " << (*cIter)->tag << endl;
        }
    }
}
```

8.3 *Manipulation of the event tree*

To add a new leaf node containing integers to the root node (must be container) of a tree:

```
unsigned short tag;
unsigned char num;
vector<int> myIntVec(100,1);

tree.addBank(tag=5, num=10, myIntVec);
```

or:

```
tree << evioDOMNode::createEvioDOMNode(tag=5, num=10, myIntVec);
```

or:

```
tree.root->addNode(evioDOMNode::createEvioDOMNode(tag=5, num=10, myIntVec));
```

If `cn1` is a container node somewhere in the tree hierarchy you can add a new node `ln2` to `cn1` (here `ln2` is a leaf node containing ints) via:

```
evioDOMNodeP ln2 = evioDOMNode::createEvioDOMNode(tag=2, num=8, myIntVec);
cn1->addNode(ln2);
```

or:

```
*cn1 << ln2;
```

To append more data to `ln2`:

```
vector<int> myIntVec2(100,2)
ln2->append(myIntVec2);
```

or:

```
*ln2 << myIntVec2;
```

To replace the data in `ln2` with new data:

```
ln2->replace(myIntVec2);
```

To move `ln2` from `cn1` to another container node `cn3`:

```
ln2->move(cn3);
```

To cut `cn1` out of the tree:

```
cn1->cut(); // just cut it out
```

or:

```
cn1->cutAndDelete(); // also delete cn1 and all of its contents
```

8.4 *Example programs*

A number of annotated example programs exist in the examples directory in the EVIO distribution. These demonstrate how to read and write files; query and manipulate event trees; create, manipulate, modify, and delete banks; etc.

8.5 *Advanced topics*

The following examples cover some more advanced features and topics that can be ignored by most users:

`evioDOMNodeListP` is a smart pointer (`auto_ptr<>`) that is used to ensure the memory used by the lists returned by `getNodeList()` is released when the lists go out of scope. While in most respects smart pointers act like normal pointers, they have some unusual assignment semantics. If one smart pointer is set equal to another, ownership of the contents is transferred, and the original loses ownership, e.g:

```
evioDOMNodeListP p1(...);    // p1 points to something
evioDOMNodeListP p2();       // p2 empty
p2=p1;                       // p2 points to something, p1 is now empty!!!
```

Further, smart pointers must not be stored in STL containers. See the STL documentation for more information on smart pointers and `auto_ptr`.

Note that if a standard shared pointer ever appears `auto_ptr<>` will be replaced. We decided not to use the Boost shared pointer as Boost is not part of the standard Linux distribution. We are considering incorporating a third-party shared pointer into the EVIO library if nothing else appears. Contact EJW for more information.

Chapter 9

9 Java Evio (Jevio)

The current Java EVIO package (org.jlab.coda.jevio) was originally written by Dr. Dave Heddle of CNU and was graciously given to the JLAB DAQ group for maintenance and continued development. Since it was created independently of the C++ implementation, it differs in its interface but contains much of the same functionality.

9.1 *Building*

The java evio uses *ant* to compile. To get a listing of all the options available to the ant command, run *ant help* in the evio top level directory to get this output:

```
help:
  [echo] Usage: ant [ant options] <target1> [target2 | target3 | ...]

  [echo]          targets:
  [echo]          help      - print out usage
  [echo]          env        - print out build file variables' values
  [echo]          compile     - compile java files
  [echo]          clean       - remove class files
  [echo]          cleanall    - remove all generated files
  [echo]          jar         - compile and create jar file
  [echo]          install     - create jar file and install into 'prefix'
  [echo]                      if given on command line by -Dprefix=dir',
  [echo]                      else install into CODA if defined
  [echo]          uninstall  - remove jar file previously installed into
  [echo]          'prefix'
  [echo]                      if given on command line by -Dprefix=dir',
  [echo]                      else installed into CODA if defined
  [echo]          all         - clean, compile and create jar file
  [echo]          javadoc     - create javadoc documentation
  [echo]          developdoc  - create javadoc documentation for developer
  [echo]          undoc       - remove all javadoc documentation
  [echo]          prepare     - create necessary directories
```

Although this is fairly self-explanatory, executing *ant* is the same as *ant compile*. That will compile all the java. All compiled code is placed in the generated *./build* directory. If the user wants a jar file, execute *ant jar* to place the resulting file in the *./build/lib* directory.

9.2 **Documentation**

In addition to the documentation in this file, there is javadoc which can be generated from the full source distribution of evio. While not as detailed in explanation as this chapter, it will be much more complete with each publicly accessible class and method being listed. Javadoc can be generated by going into the top level evio directory and executing the command *ant javadoc*. If more detail is desired, classes and methods which are not public can be seen by creating the javadoc by executing the command *ant developdoc*. This is more suitable for a developer. The resulting javadoc is placed in the *./doc/javadoc* directory. Look in that directory at the file named *index.html* in a browser.

9.3 **Basics**

There are some things necessary to know before reading and writing evio format files. However, this is **not** intended to be a full evio tutorial. First, let's look at the classes which form the basis of evio data and do some basic manipulations.

Evio's container structures are banks, segments, and tagsegments. These entities are implemented with 4 different classes. At the very top level is the *EvioEvent* which is just a special case (subclass) of an *EvioBank* with dictionary and other extra data included. Banks, of course, have 2 words (8 bytes) of header followed by data. The *EvioSegment* and *EvioTagSegment* classes represent segments and tagsegments respectively, each have 1 word of header, no num value and differing amounts of tag and type data.

To get information contained in a header, call `getHeader()` with event, bank, seg, or tagseg objects. Using the returned *BaseStructureHeader* object, there are methods available to get & set values for content type, tag, num, length, and padding.

Events of any complexity (containing container structures) are created using the *EventBuilder* class. The writing of events is done through *EventWriter* objects, and the reading of events through *EvioReader*. There is also a graphical viewer of events available in *EventTreeFrame*.

In previous versions of evio, only files could be written and read. Currently, however, evio data can be handled by buffers as well.

The next 2 sections have examples which work together. The reading example will read what the writing example produces.

9.4 **Event Creating**

There are 2 ways to create an evio event. Start with the simplest first -- use the *EventBuilder* class to do it. This takes care of all the little details and requires only the initial calling of the constructor and subsequent calling of the `addChild()` method to create an evio event. The builder will check all arguments, the byte order of added data, type mismatches between parent & child, and will set all evio header lengths

automatically. The following code uses the EventBuilder to create an event (bank) of banks with 1 child which is a bank of segments. The bank of segments also has 1 child which is a segment of shorts.

```
// Use the EventBuilder class to create event of banks, tag=1, num=1
EventBuilder builder = new EventBuilder(1, DataType.BANK, 1);
EvioEvent event = builder.getEvent();

// bank of segments
EvioBank bankSegs = new EvioBank(2, DataType.SEGMENT, 2);
builder.addChild(event, bankSegs);

// segment of 3 shorts
EvioSegment segShorts = new EvioSegment(3, DataType.SHORT16);
short[] sdata = new short[] {1,2,3};
segShorts.setShortData(sdata);
builder.addChild(bankSegs, segShorts);

// To remove a structure
builder.remove(segShorts);
```

There are methods to create and add banks, segments and tagesgments as containers as well as methods to add all the various data types like chars, shorts, ints, longs, doubles, floats and their arrays. The only tricky thing is handling Composite format data. Look at [Appendix B](#) to get more information on handling this format.

The second means is to call the insert() method of the event or its children. This method requires the event to call setAllHeaderLengths() at the end to make sure all the evio headers in the event have the proper lengths set. The following code does exactly what the previous example does but does not check for the issues mentioned above:

```
// Use event constructor and insert() calls
EvioEvent event = new EvioEvent(1, DataType.BANK, 1);

// bank of segments
EvioBank bankSegs = new EvioBank(2, DataType.SEGMENT, 2);
event.insert(bankSegs);

// segment of 3 shorts
EvioSegment segShorts = new EvioSegment(3, DataType.SHORT16);
short[] sdata = new short[] {1,2,3};
segShorts.setShortData(sdata);
bankSegs.insert(segShorts);

// To remove a structure
bankSegs.remove(segShorts);

// Make sure all evio headers have correct lengths
event.setAllHeaderLengths();
```

9.5 *Writing*

9.5.1 Writing to file or buffer

Start writing an evio format file or buffer with an *EventWriter* object. Simply pick among the various constructors for your medium of choice. There are optional parameters including allowing the user to choose whether to append to or overwrite any previously existing data. The user can also set the block size and number of events per block as well as specify a dictionary and data byte order among other things. Refer to the javadoc for all of the possibilities.

Below is some example code with comments showing how the writing is done. It shows how to write to both files and buffers as well as how to define a dictionary and how to create evio data. If the reader is unfamiliar with Java's *ByteBuffer* class, take some time to read up on it when using buffers. It will allow you to do many things.

```
// For WRITING a file or buffer
public static void main(String args[]) {

    // Define xml dictionary
    String xmlDictionary =
        "<xmlDict>\n" +
        "  <bank name=\"bank of banks\"          tag=\"1\"    num=\"1\">\n" +
        "    <bank name=\"bank of segments\"      tag=\"2\"    num=\"2\">\n" +
        "      <leaf name=\"segment of shorts\"    tag=\"3\"    />\n" +
        "    </bank>\n" +
        "    <bank name=\"bank of banks\"          tag=\"4\"    num=\"4\">\n" +
        "      <leaf name=\"bank of chars\"        tag=\"5\"    num=\"5\" />\n" +
        "    </bank>\n" +
        "  </bank>\n" +
        "  <dictEntry name=\"last bank\"          tag=\"33\"   num=\"66\" />\n" +
        "</xmlDict>";

    // Data to write
    byte[]  byteData1 = new byte[]  {1,2,3,4,5};
    int[]   intData1  = new int[]   {4,5,6};
    int[]   intData2  = new int[]   {7,8,9};
    short[] shortData = new short[] {11,22,33};

    // Do we append or overwrite?
    boolean append = false;

    // Do we write to file or buffer?
    boolean toFile = true;

    ByteBuffer myBuf = null;

    try {
        EventWriter writer;

        if (toFile) {
            // Create an event writer to write out the test events to file
            // along with a dictionary
            String fileName = "./myData";
            File file = new File(fileName);
            writer = new EventWriter(file, xmlDictionary, append);
        }
        else {
            // Or create an event writer to write to buffer
            myBuf = ByteBuffer.allocate(10000);
            myBuf.order(ByteOrder.LITTLE_ENDIAN);
        }
    }
}
```

```

        writer = new EventWriter(myBuf, xmlDictionary, append);
    }

    // event - bank of banks
    EventBuilder builder = new EventBuilder(1, DataType.BANK, 1);
    EvioEvent event = builder.getEvent();

    // bank of segments
    EvioBank bankSegs = new EvioBank(2, DataType.SEGMENT, 2);
    builder.addChild(event, bankSegs);

    // segment of 3 shorts
    EvioSegment segShorts = new EvioSegment(3, DataType.SHORT16);
    segShorts.setShortData(shortData);
    builder.addChild(bankSegs, segShorts);

    // another bank of banks
    EvioBank bankBanks = new EvioBank(4, DataType.BANK, 4);
    builder.addChild(event, bankBanks);

    // bank of chars
    EvioBank charBank = new EvioBank(5, DataType.CHAR8, 5);
    charBank.setByteData(byteData1);
    builder.addChild(bankBanks, charBank);

    // Write event to file
    writer.writeEvent(event);

    // How much room do I have left in the buffer now?
    if (!toFile) {
        System.out.println("I have " + myBuf.remaining() + " bytes left");
    }

    // event - bank of ints
    EvioEvent lastEvent = new EvioEvent(33, DataType.INT32, 66);

    // Tell jevio what the data's endianness is.
    // This will not swap anything now but will
    // enable it to be written out properly.
    // NOT necessary to call if data is big endian.
    // Call this BEFORE dealing with data!
    lastEvent.setByteOrder(ByteOrder.LITTLE_ENDIAN);

    // Overwrite all previous data with "setIntData"
    lastEvent.setIntData(intData1);
    // Append data to end with "appendIntData"
    lastEvent.appendIntData(intData2);

    // Write last event to file or buffer
    writer.writeEvent(lastEvent);

    // All done writing
    writer.close();
}
catch (IOException e) {
    e.printStackTrace();
}
catch (EvioException e) {
    e.printStackTrace();
}
}
}

```



```
bitInfo, overWriteOK, append);
```

The baseFilename string will have the environmental variable, `BASE_NAME`, substituted in the obvious location along with the runType substituted for the %s, the runNumber substituted for the %x (hex format), and the split number substituted for the %03d. If `BASE_NAME` has the value "File", then the first 3 split files will have the names:

```
myFile_myExperiment_1_001.ext  
myFile_myExperiment_1_002.ext  
myFile_myExperiment_1_003.ext
```

9.6 *Reading*

Start reading an evio format file or buffer with an *EvioReader* object. Simply pick among the various constructors for your medium of choice. There is an optional parameter allowing the user to make sure the incoming block numbers are sequential. (Find out about block numbers by reading through Appendix A which describes the evio file format). There is also an optional parameter for choosing between sequential and random-access methods for reading a file.

Looking "under the hood" for a moment, the preferred, random-access (and default) method of reading a file is to use a memory-mapped ByteBuffer to be able to address each byte. It is much faster than using streams to read a file sequentially. However, using a memory-mapped file is not always possible. There is a fundamental limitation built into the Java JVM which only allows indexes of arrays to be ints (and not longs). Since ints are signed 32 bit entities, and since a ByteBuffer object is backed by an array in which each byte is addressable, the result is that only files less than or equal to $2^{31} - 1$ (2.147G) bytes in size can be mapped. Files larger than that are read sequentially using streams. This version of jevio is the first to be able to read and write large files. The option exists to also read smaller files in a sequential manner but that would only slow things down. One possibly confusing part of the jevio interface is that methods that are random-access in nature are implemented using sequential reads for large files. Thus, jevio allows for a random-access style of approach even when the underlying reading mechanism is sequential. To implement this, all files and buffers are initially scanned to find the positions of each event. Note that this may take significant time for large files.

On this matter of random-access vs. sequentially oriented method calls, these are the 2 independent means of retrieving events from a file/buffer. The following are the random-access methods of the EvioReader class:

```
getEvent(int i)  
parseEvent(int i)  
gotoEventNumber(int i)
```

and the sequential methods:

```
nextEvent()  
parseNextEvent()  
rewind()
```

When mixing calls of these two categories in one application, there is no need to worry about one type interfering with the other. For example, if an application does a series of `parseNextEvent()` calls to look at a file, then doing a `parseEvent(20)` method call in the middle of the series will **not** change the sequence of the events returned by `parseNextEvent()`.

Now for a word on performance. As previously mentioned, do not choose to read sequentially when reading files < 2.1 GB in size. When reading larger files, it is usually faster to use the sequential methods. The reason for that is they read in whole blocks (not individual events) at a time. If the file was written with block sizes substantially greater in size than a single event (the default when using small events), then it will be faster. The random-access methods will, on the other hand, hop to the event of interest and only read in that single event.

It's easier to give an example of code used to read a file than to explain things abstractly. Various lines show how to get and use a dictionary, read events with the sequential or random-access methods, get the total number of events, and get & print data. The code below uses many of the available evio features for reading and will read the file or buffer created in the previous section.

```
// For READING a file or buffer
public static void main(String args[]) {

    String fileName = "/home/myAccount/myData";
    File fileIn = new File(fileName);
    ByteBuffer myBuf = null;

    // Do we read from file or buffer?
    boolean useFile = true;

    try {
        EvioReader evioReader;
        if (useFile) {
            evioReader = new EvioReader(fileName);
        }
        else {
            myBuf.flip();
            evioReader = new EvioReader(myBuf);
        }

        // Get any existing dictionary
        String xmlDictString = evioReader.getDictionaryXML();
        EvioXMLDictionary dictionary = null;

        if (xmlDictString == null) {
            System.out.println("Ain't got no dictionary!");
        }
        else {
            // Create dictionary object from xml string
            dictionary = new EvioXMLDictionary(xmlDictString);
            System.out.println("Dictionary:\n" + dictionary.toString());
        }

        // How many events in the file?
        int evCount = evioReader.getEventCount();
        System.out.println("Read file, got " + evCount + " events:\n");

        // Use "random access" capability to look at last event (starts at 1)
```

```

EvioEvent ev = evioReader.parseEvent(evCount);
System.out.println("Last event = " + ev.toString());

// Print out any data in the last event.
// In the writing example, the data for this event was set to
// be little endian so we need to read it in that way too.
ev.setByteOrder(ByteOrder.LITTLE_ENDIAN);
int[] intData = ev.getIntData();
if (intData != null) {
    for (int i=0; i < intData.length; i++) {
        System.out.println("intData[" + i + "] = " + intData[i]);
    }
}

// Use the dictionary
if (dictionary != null) {
    String eventName = dictionary.getName(ev);
    System.out.println("Name of last event = " + eventName);
}

// Use sequential access to events
while ( (ev = evioReader.parseNextEvent()) != null) {
    System.out.println("Event = " + ev.toString());
}

// Go back to the beginning of file/buffer for sequential methods
evioReader.rewind();
}
catch (Exception e) { e.printStackTrace(); }
}

```

9.7 Searching

Most users are also interested in searching an event, a bank, a segment, or a tagsegment for various things. To this end, jevio has a couple of built in searches for ease of use. See the javadoc for the *StructureFinder* class for details. Custom searches can be done by creating filters conforming to the *IEvioFilter* interface. Simply define an *accept()* method to determine which structures to add to a returned list. Following is an example of code that uses both the built in search for banks with particular tag/num values and also a simple, user-defined search for finding *EvioSegment* type structures with odd numbered tags.

```

// Take some event (not defined here)
EvioEvent event;

// Search it for banks (not segs, tagsegs) with particular tag & num values
int tag=1, num=1;
List<BaseStructure> list = StructureFinder.getMatchingBanks(
    event, tag, num);
if (list != null) {
    for (BaseStructure bs : list) {
        System.out.println("Evio structure named \"" +
            dictionary.getName(bs) +
            "\" has tag=1 & num=1");
    }
}

```

```

}

// -----
// Search for banks/segs/tagsegs with a custom search criteria
// -----

// Define a filter to select Segment structures with odd numbered tags.
class myEvioFilter implements IEvioFilter {
    public boolean accept(StructureType type, IEvioStructure struct){
        return (type == StructureType.SEGMENT &&
            (struct.getHeader().getTag() % 2 == 1));
    }
};

// Create the defined filter
myEvioFilter filter = new myEvioFilter();

// Use the filter to search "event"
list = StructureFinder.getMatchingStructures(event, filter);
if (list != null) {
    for (BaseStructure bs : list) {
        System.out.println("Evio structure named " +
            dictionary.getName(bs) + " is Segment with odd tag");
    }
}
}

```

Note that any bank, segment, or tagsegment structure can call `getMatchingStructures()` directly instead of through the `StructureFinder` class.

9.8 *Parsing*

Users have some options while parsing events. Listeners and filters may be added to an `EvioReader` to be used while events are being parsed. The previous section has a good example of how to create a filter. One such filter can be set for a reader object allowing the user to weed out events of no interest.

Jevio also has an ***IEvioListener*** interface that can be used to define multiple listeners that operate during parsing in a SAX-like manner. For each listener, simply define 3 methods to be run -- before an event is parsed, just after a structure in the event (bank, segment, or tagsegment) has been parsed, and after the entire event has been parsed. Following is an example of code that uses both a listener and a filter.

```

// Read some evio format file
EvioReader evioReader = new EvioReader(fileName);

// Get the parser which is contained in the reader
EventParser parser = evioReader.getParser();

// Define a listener to be used with an event parser
IEvioListener listener = new IEvioListener() {

    // Run this method after each bank/seg/tagseg has been parsed
    public void gotStructure(BaseStructure topStructure,
        IEvioStructure structure) {
        System.out.println("Parsed structure of type " +
            structure.getStructureType());
    }
}

```

```

    // Run this method before the event is parsed
    public void startEventParse(BaseStructure structure) {
        System.out.println("Starting event parse");
    }

    // Run this method after the event has been parsed
    public void endEventParse(BaseStructure structure) {
        System.out.println("Ended event parse");
    }
};

// Add the listener to the parser
parser.addEvioListener(listener);

// Define a filter to select everything (not much of a filter!)
class myEvioFilter implements IEvioFilter {
    public boolean accept(StructureType type, IEvioStructure struct){
        return true;
    }
};

// Create the above-defined filter
myEvioFilter filter = new myEvioFilter();

// Add the filter to the parser
parser.setEvioFilter(filter);

// Now parse some event
EvioEvent ev = evioReader.parseEvent(1);

```

9.9 **Transforming**

Occasionally there can arise problems with the "num" parameter defined by a EvioBank header but not the header of the EvioSegment or EvioTagsegment. The **StructureTransformer** class can be used to transform objects between these 3 classes while taking care of the troublesome num. For example:

```

// Take an existing EvioSegment
EvioSegment seg;
int num = 10;

// Turn that segment into a bank
EvioBank bank = StructureTransformer.transform(seg, num);

```

9.10 **Dictionaries**

This section describes how dictionaries can be used (refer to Appendix C for the format). In general it is easiest to have one global dictionary defined when manipulating evio data. For jevio this can be set in the singleton **NameProvider** class/object. To set this global dictionary simply do something like:

```

// Define xml dictionary String
String xmlDictString =
    "<xmlDict>\n" +

```

```

    " <dictEntry name=\"first bank\"    tag=\"1\"    num=\"1\"/>\n" +
    " <dictEntry name=\"second bank\"  tag=\"2\"    num=\"2\"/>\n" +
    "</xmlDict>";

    // Create a dictionary object from xml String
    EvioXmlDictionary dict = new EvioXmlDictionary(xmlDictString);

    // Make it the global dictionary
    NameProvider.setProvider(dict);

```

Once the global dictionary is set, the question is, "how is it used"? The section in this chapter for "Searching" uses the *StructureFinder* class and that is the case here as well. This class uses the global dictionary if defined, but another dictionary may be specified as an argument to its methods. There three methods in this class that use the dictionary as seen below:

```

    // Take some event (not defined here)
    EvioEvent event;

    // Names to look for
    String name      = "dictionaryEntry";
    String childName = "childEntry";
    String parentName = "parentEntry";

    // Search for structures (banks, segs, tagsegs) with a particular name
    List<BaseStructure> list1 = StructureFinder.getMatchingStructures(
        event, name, dict);

    // Search for structures whose parent has a particular name
    List<BaseStructure> list2 = StructureFinder.getMatchingParent(
        event, parentName, dict);

    // Search for structures who have a child with a particular name
    List<BaseStructure> list3 = StructureFinder.getMatchingChild(
        event, childName, dict);

    // Print out the list of structures
    if (list2 != null) {
        for (BaseStructure bs : list2) {
            System.out.println("Structure named \"" + dictionary.getName(bs) +
                "\" has a parent named " + parentName);
        }
    }

```

In order to implement other types of searches, it would be relatively simple to copy the code for any of the three methods and modify it to suit.

When a file or buffer is read, it may have a dictionary in xml format associated with it. That dictionary is accessible through the *EvioReader.getDictionaryXML()* method. For convenience, the *EvioEvent* class has a place to store and retrieve an xml dictionary string by using its *setDictionaryXML()*, *getDictionaryXML()*, and *hasDictionaryXML()* methods.

The dictionary can also be used directly as an object of the *EvioXmlDictionary* class. Once an xml string is parsed into such an object (by means of its constructor), there are methods to retrieve the parsed information. These methods can obtain tag/num pairs

associated with a name and vice versa. They can also obtain data types, data formats, and descriptive comments associated with either a name or tag/num pair.

```
// Define xml dictionary String
String xmlDictString =
"<xmlDict>\n" +
" <dictEntry name=\"me\" tag=\"10\" num=\"0\" type=\"composite\" />\n" +
" <description format=\"2iN(FD)\" >\n" +
"     Any comments can go right here!\n" +
" </description>\n" +
" </dictEntry>\n" +
"</xmlDict>";

// Create a dictionary object from xml String
EvioXmlDictionary dict = new EvioXmlDictionary(xmlDictString);

// Retrieve & print info from dictionary
System.out.println("Getting stuff for name = \"me\":");
System.out.println("    tag          = " + dict.getTag("me"));
System.out.println("    num           = " + dict.getNum("me"));
System.out.println("    type          = " + dict.getType("me"));
System.out.println("    format        = " + dict.getFormat("me"));
System.out.println("    description   = " + dict.getDescription("me"));

System.out.println("Getting stuff for tag = 10, num = 0:");
System.out.println("    type          = " + dict.getType(10,0));
System.out.println("    name          = " + dict.getName(10,0));
System.out.println("    format        = " + dict.getFormat(10,0));
System.out.println("    description   = " + dict.getDescription(10,0));
```

There are also a couple of ways in which to iterate through the entries of a dictionary to see what it contains using the *dict.getMap()* method.

Method 1:

```
Map<String, EvioDictionaryEntry> map = dict.getMap();
Set<String> keys = map.keySet();
for (String key : keys) {
    System.out.println("key = " + key +
        ", tag = " + dict.getTag(key) +
        ", num = " + dict.getTag(key));
}
```

Method 2:

```
int i=0;
Map<String, EvioDictionaryEntry> map = dict.getMap();
Set<Map.Entry<String, EvioDictionaryEntry>> set = map.entrySet();
for (Map.Entry<String, EvioDictionaryEntry> entry : set) {
    String entryName = entry.getKey();
    EvioDictionaryEntry entryData = entry.getValue();
    System.out.println("entry " + (++i) + ": name = " + entryName +
        ", tag = " + entryData.getTag() +
        ", num = " + entryData.getTag());
}
```


9.11 *First Event*

If the user wants the same (first) event in each split file, then simply select the *EventWriter* constructor that has an argument for the first event (for either file or buffer writing). An alternative method is to call the *EventWriter*'s:

```
setFirstEvent ( EvioBank firstEvent );
```

method. If calling the method, make sure it's called before any other events are written in order to ensure that it is written to each of the split files.

9.12 *XML format events*

If the user wants to view an event in xml format, that is easily possible:

```
EvioEvent ev;  
boolean asHex = true;  
String xml1 = ev.toXML();  
String xml2 = ev.toXML(asHex);
```

It's also possible to go in the other direction and parse a file of xml events into *EvioEvent* objects. In this case, if there is more than one event, the top-level xml element must be:

```
<evio-data>
```

If there is no dictionary, the events must be indicated by the xml element:

```
<event>
```

otherwise it can be any valid xml element whose value exists in the dictionary. Elements whose tag/num/type info is not in the xml may have it supplied by a dictionary entry.

```
String xml;  
List<EvioEvent> list;  
list = Utilities.toEvents(xml);  
  
int maxEvents = 20, skip = 1;  
EvioXmlDictionary dictionary;  
boolean debug = false;  
list = Utilities.toEvents(xml, maxEvents, skip, dictionary, debug);
```

Chapter 10

10 Compact Java Evio

When communicating EvioEvents (java objects) over the network, the user must serialize such events and all its contained objects into an array or buffer of bytes when sending and must deserialize the same bytes into objects on the receiving end. This can lead to a serious performance penalty. To avoid having to serialize and deserialize continually, a new API was developed to allow the handling of evio data in byte buffer form. For lack of a better term, **compact** was the word chosen to describe it since all evio data handled in this API are contained in ByteBuffer objects and never expanded into EvioEvent objects.

10.1 *Basics*

There are 4 classes comprising all the functionality: *EvioCompactReader*, *EvioCompactStructureHandler*, *CompactEventBuilder*, and *EvioNode*. Starting with the simplest (and given a buffer of evio data) the EvioNode class stores information about a single evio structure (bank, segment, or tagsegment) in that buffer, but does not contain information about its internal structure. In other words, there is no expansion into a tree and its necessarily accompanying deserialization. It stores all the header information along with locations of the header and data in the buffer itself.

The EvioCompactReader (compact reader for short) plays a similar role as the EvioReader in that it parses a buffer or file (not bigger than 2.1 GB) in evio format. Its constructor creates an EvioNode object for each event and stores it in a list. Methods allow searching an event for structures of a given tag & num pair or dictionary entry. Once an EvioNode object is obtained from a search, its structure's data can be retrieved. A user-created evio structure can be added as the last child of any event by calling *EvioCompactReader.addStructure()*. Banks and entire events can be removed by calling *EvioCompactReader.removeEvent()* or *removeStructure()*. Perhaps the most powerful feature of the compact reader is that the user can obtain a ByteBuffer representing just a single structure - an event, bank, segment, or tagsegment (no block headers / no full evio file format). This allows for the extraction of bytes representing a single structure to be sent over the network. In this way it almost acts as a writer as well as being a reader.

Working hand-in-hand with the compact reader, the EvioCompactStructureHandler (structure handler for short) can parse the bytes representing a single structure previously

produced by the compact reader. Actually any EvioEvent, EvioBank, EvioSegment, or EvioTagSegment object can produce a byte representation of itself by calling its write() method which the structure handler can parse. The structure handler has methods to search for structures of a given tag & num pair or dictionary entry. Once an EvioNode object is obtained from a search, its structure's data can be retrieved. User-created evio structures can be added to the end of any structure (which contains structures, cannot add bank to bank of ints for example). As in the compact reader, the user can obtain a ByteBuffer representing just a single structure.

There is no special class for writing compact events, just use EventWriter which can write events that are in ByteBuffer form. A simple measurement shows that using compact classes to search a file for structures of a given tag/num pair is about 9x faster than using EvioReader.

Instead of using the *EventBuilder* class to create events, one can use the *CompactEventBuilder* class to do it. The advantage is that the CompactEventBuilder minimizes the creation of objects and constructs an event directly in a ByteBuffer and takes care of all the little details. Because the event is created in a single buffer, it must be done sequentially creating each evio element in its proper order.

There are methods to create and add banks, segments and tagsegments as containers as well as methods to add all the various data types like chars, shorts, ints, longs, doubles, floats. One can even add EvioNode objects. The only tricky thing is handling Composite format data. Look at [Appendix B](#) to get more information on handling this format.

10.2 Example 1

```
// -----  
// Use CompactEventBuilder to create event  
// -----  
public static void main(String args[]) {  
  
    try {  
        int tag=1, num=1;  
        // Create buffer to store event in  
        ByteBuffer buf = ByteBuffer.allocate(1024);  
  
        // Use the CompactEventBuilder to create event  
        CompactEventBuilder builder = new CompactEventBuilder(buf);  
  
        // create bank of banks  
        builder.openBank(tag, num, DataType.BANK);  
  
        // create bank of segments  
        builder.openBank(tag+1, DataType.SEGMENT);  
  
        // create segment of 3 shorts  
        builder.openSegment(tag+2, DataType.SHORT16);  
        short[] sdata = new short[] {1,2,3};  
        builder.addShortData(sdata);  
  
        // Finish things up  
        builder.closeAll();  
    }  
}
```

```

// Get buffer in ready-to-read form
buf = builder.getBuffer();

// -----
// Write event to file
// -----
File file = new File("/tmp/myFile");
EventWriter writer = new EventWriter(file);
writer.writeEvent(buf);
writer.close();

// -----
// Read event from file and printout
// -----
EvioCompactReader reader = new EvioCompactReader("/tmp/myFile");
EvioNode node = reader.getScannedEvent(1);
String xml = Utilities.toXML(node);
System.out.println("XML:\n" + xml);

}
catch (EvioException e) {
    e.printStackTrace();
}
}

```

10.3 **Example 2**

```

// -----
// Read file, search for tag/num, print data, add bank
// -----
public static void main(String args[]) {

    try {
        // Read file /tmp/myFile with compact reader
        EvioCompactReader reader = new EvioCompactReader("/tmp/myFile");

        // -----
        // Search for structure and print its data
        // -----
        // Search first event for tag = 3, num = 4
        List<EvioNode> returnList = reader.searchEvent(1, 3, 4);
        if (returnList.size() < 1) {
            throw new Exception("Found nothing in search");
        }

        // First structure found in event 1 with tag = 3, num = 4
        EvioNode node = returnList.get(0);
        // Get data in structure
        ByteBuffer buf = reader.getData(node);
        // Type of data in structure
        DataType dType = node.getDataTypeObj();
        // Print data in structure
        if (dType == DataType.DOUBLE64) {
            System.out.println("Double data =");
            DoubleBuffer dbuf = buf.asDoubleBuffer();
            for (int i=0; i < dbuf.limit(); i++) {
                System.out.println(i + "    " + dbuf.get(i));
            }
        }
    }
}

```

```

    }

    // -----
    // Add user bank to first event
    // -----
    // Create a bank to add to end of event, tag = 5, num = 6
    EvioBank bank = new EvioBank(5, DataType.INT32, 6);
    int[] intData = new int[] {1,2,3};
    try {
        bank.appendIntData(intData);
    }
    catch (EvioException e) {}

    ByteBuffer bb = ByteBuffer.allocate(4*12);
    bank.write(bb);
    bb.flip();

    // Add bank to event 1
    reader.addStructure(1, bb);
}
catch (EvioException e) {
    e.printStackTrace();
}
}
}

```

10.4 **Example 3**

```

// -----
// Read file, remove first event.
// Get new first event (previously 2nd), remove structure,
// write to file
// -----
public static void main(String args[]) {

    try {
        // Read file /tmp/myFile with compact reader
        EvioCompactReader reader = new EvioCompactReader("/tmp/myFile");

        // Remove first event
        if (reader.getEventCount() < 2) {
            return;
        }
        reader.removeEvent(1);

        // Get new first event (previously second)
        EvioNode node = reader.getScannedEvent(1);

        // Remove first child of event
        ByteBuffer newBuffer = reader.removeStructure(node.getChildAt(0));

        // Write to file
        readerToFile("/tmp/filename");

    }
    catch (EvioException e) {
        e.printStackTrace();
    }
}
}

```

10.5 *Example 4*

```
// -----  
// Read file, get events, obtain their buffers,  
// and write them to another file.  
// -----  
public static void main(String args[]) {  
  
    try {  
        // Read file /tmp/myFile with compact reader  
        EvioCompactReader reader = new EvioCompactReader("/tmp/myFile");  
        // Number of events in file  
        int evCount = reader.getEventCount();  
  
        // Create writer to file /home/user/outputFile  
        int runNumber = 1, split = 0, internalBufSize = 1000000;  
        String dictionary = null;  
        EvioCompactEventWriter compactWriter =  
            new EvioCompactEventWriter("outputFile", "/home/user",  
                                       runNumber, split, internalBufSize,  
                                       ByteOrder.BIG_ENDIAN, dictionary);  
  
        // Loop over all events  
        for (int i=0; i < evCount; i++) {  
            // Read event #i from input file  
            ByteBuffer evBuf = reader.getEventBuffer(i);  
            // Write event to output file  
            compactWriter.writeEvent(evBuf);  
        }  
        // Flush internal buffer to file & close  
        compactWriter.close();  
    }  
    catch (EvioException e) {  
        e.printStackTrace();  
    }  
}
```

10.6 *XML format events*

If the user wants to view an event or any evio structure in xml format, that is easily possible.

```
EvioNode node;  
boolean asHex = true;  
String xml = Utilities.toXML(node, asHex);
```

Chapter 11

11 Java Evio Event-Viewing Gui

In the jevio jar file, there is a graphical user interface for looking at EVIO format files event-by-event. To run it simply type:

```
java org/jlab/coda/jevio/graphics/EventTreeFrame
```

HOWEVER, the simple gui above was further developed with many more features and put into its own package called JEventViewer. The newest viewer has the capability of grabbing ET events and cMsg messages and parsing them as evio data. It can also look at any file as a list of 32 bit integers – very useful for debugging. To run it:

```
java org/jlab/coda/eventViewer/EventTreeFrame
```

For this to work the JEventViewer-2.0.jar and the latest jevio jar file must be in your CLASSPATH. If you want to look at ET and cMsg data, then the ET and cMsg jar files must be in the CLASSPATH as well. For further documentation look at:

<https://github.com/JeffersonLab/JEventViewer>

- The event count is the number of events in this block - always integral. Note that: this value should not be used to parse the following events since the very first block may have a dictionary whose presence is not included in this count.
- Reserved 2 is unused. Reserved 1 is used in the CODA online to store the CODA id of the data source if bits 10-13 of the bit-info word show a ROC Raw type.
- And the magic number is the value 0xc0da0100 and is used to check endianness.
- That leaves only the bit info and version word for discussion. The version is the current evio format version number (4) and takes up the lowest 8 bits. The other bits are used to store the various useful data listed below:

BIT INFO WORD

Bit # (0 = LSB)	Function
0-7	Version # = 4
8	= 1 if dictionary is included (first block only)
9	= 1 if this block is the last block in file, buffer, or network transmission
13-10	type of events in block: ROC Raw = 0, Physics = 1, Partial Physics = 2, Disentangled Physics = 3, User = 4, Control = 5, Other = 15
14	= 1 if the next event (non-dictionary) is a “first event” to be placed at the beginning of each written file and its splits
31-15	unused

Bits 8-14 are only useful for the CODA online use of evio. That’s because only a single CODA event *type* is placed into a single (ET, cMsg) buffer, and each user or control event has its own buffer as well. That buffer is then parsed by an EvioReader or EvioCompactReader object. Thus all events will be of a single CODA type.

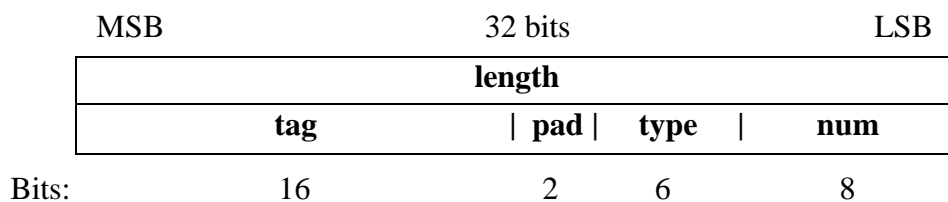
Appendix B

B. EVIO Data Format

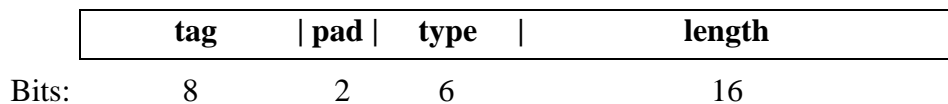
B.1 Bank Structures & Content

EVIO data is composed of a hierarchy of banks of different types. Container banks contain other banks, and leaf banks contain an array of a single primitive data type. Three types of banks exist: BANK, SEGMENT, and TAGSEGMENT. BANK has a two-word header, the latter two have a one-word header. All banks contain a **length**, **tag** and **type**. BANK additionally has a **num** field. SEGMENT and TAGSEGMENT differ on the number of bits allocated to the tag and type. Tag and num are user-defined while type denotes the bank contents and the codes listed in the table below **MUST** be used or endian swapping will fail. Length is always the number of 32-bit longwords to follow (i.e. bank length minus one). New to this version of EVIO is the **pad** for both BANK and SEGMENT banks which indicates the number of bytes used for padding when type indicates 8 or 16 bit integers.

BANK HEADER



SEGMENT HEADER



TAGSEGMENT HEADER

EVIO DATA FORMAT

	tag	 type 	length
Bits:	12	4	16

CONTENT TYPES

contentType	Primitive Data Type
0x0	32-bit unknown (not swapped)
0x1	32 bit unsigned int
0x2	32-bit float
0x3	8-bit char*
0x4	16-bit signed short
0x5	16-bit unsigned short
0x6	8-bit signed char
0x7	8-bit unsigned char
0x8	64-bit double
0x9	64-bit signed int
0xa	64-bit unsigned int
0xb	32-bit signed int
0xc	TAGSEGMENT
0xd	SEGMENT
0xe	BANK
0xf	Composite
0x10	BANK
0x20	SEGMENT
0x21	Hollerit*
0x22	N value*

*this type is only used internally for composite data

There are a few more things that the user must keep in mind:

- bank contents immediately follow the bank header
- the first bank in a buffer or event must be a BANK
- the CODA DAQ system defines specific conventions for tag and num values.

B.2 Changes From Previous Versions

There are a few changes from previous EVIO versions to take note of. A backwards-compatible change has been made for strings (type 0x3). Previously, a single ASCII, null-terminated string with undefined padding was contained in this type. Starting with version 4, an array of strings may be contained. Each string is separated by a null-termination (value of 0). A final termination of at least one 4 (ASCII char of value 4) is

EVIO DATA FORMAT

required in order to differentiate it from the earlier versions and to signify an end to the array. It is a self-padded type meaning it always ends on the 32 bit boundary.

Another change is that the type of 0x40, which was redundantly defined to be a TAGSEGMENT, has been removed since its value uses bits necessary to store the padding. This is unlikely to cause any problems since it was never used.

The pad in the BANK and SEGMENT types indicates the number of bytes used for padding to 32 bit boundaries when type indicates 8 or 16 bit integers (type = 0x4, 0x5, 0x6, or 0x7). For 16 bit types pad will be 0 or 2 while for the 8 bit types it will be 0-3. Unlike previous versions, this allows EVIO to contain odd numbers of these types with no ambiguity. For example, since a bank of 3 shorts is the same length as a bank of 4 shorts (banks must end on a 32 bit boundary) previously there was no way to tell if the last short was valid data or not. Now there is. Note, however, this is **not** the case with the TAGSEGMENT bank and so it is not recommended for storing these types.

B.3 Composite Data Type

B.3.1 General Type Info

A new type - Composite - has been added which originated with Hall B but also allows for future expansion if there is a need. Basically the user specifies a custom format by means of a string. Although in practice it acts like a primitive type in that you can have a bank containing an array of them, a single Composite type looks more like 2 banks glued together. The first word comprises a TAGSEGMENT header which is followed by a string describing the data to come. After this TAGSEGMENT containing the data format string, is a BANK containing the actual data.

COMPOSITE TYPE

tag	type	length	
data format string ...			
length			
tag	pad	type	num
actual data ...			

The routine to swap this data must be provided by the definer of the composite type - in this case Hall B. This swapping function is plugged into the EVIO library's swapping routine. Currently its types, tags, pad, and num values are not used. Only the lengths are significant.

EVIO DATA FORMAT

There is actually another new type defined - the Hollerit type, but that is only used inside of the Composite type and refers to characters in an integer form. Following is a table of characters allowed in the data format string.

DATA FORMAT CHARACTERS

Data format char	Meaning
((
))
i	32-bit unsigned int
F	32-bit floating point
a	8-bit ASCII char
S	16-bit short
s	16-bit unsigned short
C	8-bit char
c	8-bit unsigned char
D	64-bit double
L	64-bit int
l	64-bit unsigned int
I	32-bit int
A	Hollerit
N	Multiplier in 32-bit int

In the format string, each of the allowed characters (except ")" or "N") may be preceded by an integer which is a multiplier. Items are separated by commas. Instead of trying to explain the format abstractly, let's look at the following example:

i,L,2(s,2D,NF)

This format translates into the data being read and processed in the following order: a single 32-bit unsigned int, a single 64-bit int, a multiplier of 2 (32 bit int) of everything inside the parentheses, an unsigned short, 2 doubles, a multiplier, multiplier number of 32-bit floats, an unsigned short, 2 doubles, a multiplier, multiplier number of 32-bit floats. The data is read in according to this recipe.

There are a couple of data processing rules that are very important:

- 1) If the format ends but the end of the data is not reached, the format in the last parenthesis will be repeated until all data is processed. If there are no parentheses in the format, data processing will start again from the beginning of the format until all data is processed.

EVIO DATA FORMAT

- 2) The explicitly given multiplier must be a number between 2 and 15 - inclusive. If the number of repeats is the symbol 'N' instead of a number, that multiplier will be read from data assuming 'I' format and may be any positive integer.

The Composite data type allows compact storage of different primitive data types and eliminates the need for extra banks and their accompanying headers. It does, however, pay a penalty in the amount of computing power needed to read, write, and swap it. For example, each time a Composite bank needs to be swapped, EVIO must read the format string, process it, and convert it into an array of ints. Then, with the converted format as a guide, EVIO must read through the data item-by-item, swapping each one. It is quite compute intensive.

B.3.1 Creating Events with Composite Data

Handling composite data is best done through the *CompositeData* and its contained *CompositeData.Data* classes. Generally one defines a *CompositeData.Data* object and uses that to create an instance of the *CompositeData* class which can, in turn, be used when building an event. The building can be done with either the *EventBuilder* or *CompactEventBuilder* class. It's easiest to look at a couple examples to see how it's done.

```
// Format to write a N shorts, 1 float, 1 double a total of N times
String format1 = "N(NS,F,D)";

// Now create some data
CompositeData.Data myData1 = new CompositeData.Data();
// First N (describing # of groups) is 2
myData1.addN(2);
// Next N (describing # of shorts) is 3
myData1.addN(3);
// Since N=3, there are 3 shorts and we must provide them all
myData1.addShort(new short[]{1, 2, 3}); // use array for convenience
myData1.addFloat(1.0F);
myData1.addDouble(Math.PI);
// Since the first N says there are 2 groups, this is N (1) to describe the
// number of shorts in the second group
myData1.addN(1);
// Add the single short in the second group
myData1.addShort((short) 4); // use array for convenience
myData1.addFloat(2.0F);
myData1.addDouble(2. * Math.PI);
```

The next example is tricky because it uses strings. An array of strings in evio is described by the *DATACHAR8* data type and we don't immediately know how long it is because evio does some internal packaging of the strings into a form which falls on a 4 byte boundary. Thus we don't know the format right off the bat but need to do a little work to figure it out.

```
// We want a format for writing an unsigned int, unsigned char,
// and N number of M (to be found) ascii characters & 1 64-bit int.
```

EVIO DATA FORMAT

```
// We need to wait before we can create this format string because we
// don't know yet how many String characters (M) we have.
// The format will be something like "i,c,N(Ma,L)";

// Now create some data
CompositeData.Data myData2 = new CompositeData.Data();
// Add unsigned int
myData2.addUInt(21);
// Add unsigned char
myData2.addUchar((byte) 22);
// Group of 1 (string + long)
myData2.addN(1);
// Now define our ascii data
String s[] = new String[2];
s[0] = "str1";
s[1] = "str2";
// Find out what the composite format representation of these strings is
String asciiFormat = CompositeData.stringsToFormat(s);
// Full format is:
String format2 = "i,c,N(" + asciiFormat + ",L)";
// Add string data now
myData2.addString(s);
// Finally the long
myData2.addLong(24L);
```

We now have two composite data items and we can add them to the event we're creating.

```
// Create CompositeData array
CompositeData[] cData = new CompositeData[2];
try {
    // fTag is the tag in tagsegment header describing format string.
    // dataTag and dataNum are tag and num of bank describing actual data
    cData[0] = new CompositeData(format1, fTag1, myData1, dataTag1, dataNum1);
    cData[1] = new CompositeData(format2, fTag2, myData2, dataTag2, dataNum2);
}
catch (EvioException e) {
    e.printStackTrace();
}

// Using a CompactEventBuilder do something like:
builder.openBank(tag, num, DataType.COMPOSITE);
builder.addCompositeData(cdata);
builder.closeStructure();

// Using an EventBuilder do something like:
EvioBank bankComps = new EvioBank(tag, DataType.COMPOSITE, num);
bankComps.appendCompositeData(cdata);
builder.addChild(bankBanks, bankComps);
```


Appendix C

C. EVIO Dictionary Format

Since names are easier for humans to deal with than pairs of numbers, the basic idea behind the dictionary is to associate a single string, a name, with 2 integers, an evio tag and an evio num. The xml protocol was used to accomplish this. The following gives the different xml formats used by the different versions of evio.

C.1 Evio versions 2 & 3

The xml format has been evolving. Originally, because EVIO data is stored in a hierarchical manner with banks containing banks containing data, the dictionary format was also hierarchical. In other words, a string was associated with not only the 2 numbers but a place in the hierarchy as well. The idea was that a given pair of tag/num values could occur in more than one location in the hierarchy and must be distinguishable from each other. Following is an example of the first format used:

```
<xmlDict>

  <xmldumpDictEntry name="event_1"          tag="1"          num="1"/>

  <!-- DC -->
  <xmldumpDictEntry name="DC"              tag="500"        num="0"/>
  <xmldumpDictEntry name="DC_id"           tag="500.1"      num="0.0"/>

  <xmldumpDictEntry name="DC_output"       tag="500.2"      num="0.100"/>
  <xmldumpDictEntry name="sector5"        tag="500.2.5"    num="0.100.23"/>

</xmlDict>
```

There is only one possible element - *xmldumpDictEntry*. Notice the dotted notation of the *tag & num* attributes. This notation, for example the tag 500.2.5, simply means that this dictionary entry has a tag value of 5, its parent has a tag value of 2, and its grandparent has a tag value of 500. Basically it is a way of specifying a place in the evio tree or hierarchy.

C.1.1 Jevio problems

The jevio-1.0 software package did **not** allow dotted notation for the tag, but did allow it for the num. The rules that jevio uses to determine whether a bank, event, segment, or tagegment object matches a particular dictionary entry is:

- 1) if it is an EvioSegment or EvioTagSegment object, the first entry that matches its tag value is returned
- 2) if it is an EvioEvent object, the first entry that matches its tag value and the first level num value is returned
- 3) if it is an EvioBank object, the first entry that matches its tag value and the complete hierarchy of num values is returned

Although this works after a fashion, it unfortunately does not match tag values in a hierarchical manner.

C.1.2 C++ Evio problems

The C++ library's handling of the dictionary's tags & nums is not perfect either. The difficulty arises from the fact that when **creating** an evio tree of banks, segments, and tagegments, C++ evio does not distinguish between them. Each container is simply a node that may be added, removed, cut, and pasted anywhere in the tree. Only upon serializing the tree to a file does the fact that a node is one of the 3 types come into play. In order for this model to function, all segments and tagegments are essentially treated as banks with num = 0. Thus a dictionary entry with tag = 1 & num = 0 will match both a bank with those parameters and a segment with tag = 1 but no num. Worse yet, a node can set num = 1, be written out as a segment, and then be read back in with num = 0. This limitation must be taken into consideration when creating dictionaries & evio trees.

C.2 Evio version 4

A number changes to the previous evio dictionary format have been made. Let's start with what has been eliminated. Previously the num and tag values could be hierarchical with each level separated by a period such as:

```
tag = '1.2.3'   num = '2.5'
```

These types of values for tag and num were stored in the dictionary making the matching of a bank to a dictionary entry tricky since now the parents and children of the bank became involved. Not only was the matching complicated but a dictionary entry would have to change depending on where a particular bank was moved to in an evio event tree - very inconvenient and prone to error.

The first change eliminates these hierarchical tags & nums. Each dictionary entry is a single name associated with a single tag value and a single num value (with segments and tagegments given a num value of 0). It becomes a simple matter to build hierarchies into the name as will be demonstrated below.

The C/C++ dictionary and the Java dictionary now have identical formats. In the old xml format, there was only one entry type namely, the xml element of *xmldumpDictEntry*. There are now 3 types of XML dictionary elements: *dictEntry* (replaces xmldumpDictEntry which is too long), *bank* and *leaf*.

For each of these elements, the only attributes a dictionary parser will look at are *name*, *tag*, *num*, and the newly added *type* (of contained data). All other elements and attributes are ignored, so the XML can be used to define whatever else is desired. Note that only the following case-independent values are valid for type with all other values being ignored:

```
int32, uint32, long64, ulong64, short16, ushort16, char8, uchar8,  
charstar8, float32, double64, bank, segment, tagsegment, composite,  
unknown32
```

The simplest xml element is dictEntry, it just makes an entry into the map of names vs tag/num pairs:

```
<dictEntry name="fred" tag="1" num="1" />
```

Here the name "fred" is a synonym for the tag/num pair (1,1).

The elements "bank" and "leaf" are used for describing hierarchical bank structures. Take a look at the following:

```
<bank name="CLAS12" tag="1" num="0">  
  <bank name="DC" tag="20" num="0">  
    <leaf name="xpos" tag="20" num="1"/>  
    <leaf name="ypos" tag="20" num="2"/>  
    <leaf name="zpos" tag="20" num="3"/>  
  </bank>  
  <bank name="SC" tag="30" num="0">  
    <leaf name="xpos" tag="30" num="1"/>  
    <leaf name="ypos" tag="30" num="2"/>  
    <leaf name="zpos" tag="30" num="3"/>  
  </bank>  
</bank>
```

where "bank" means an evio container (bank, segment, or tagsegment), and "leaf" means an evio container with no children. The parser will generate map entries equivalent to the following:

```
<dictEntry name="CLAS12" tag="1" num="0"/>  
<dictEntry name="CLAS12.DC" tag="20" num="0"/>  
<dictEntry name="CLAS12.DC.xpos" tag="20" num="1"/>  
<dictEntry name="CLAS12.DC.ypos" tag="20" num="2"/>  
<dictEntry name="CLAS12.DC.zpos" tag="20" num="3"/>  
<dictEntry name="CLAS12.SC" tag="30" num="0"/>  
<dictEntry name="CLAS12.SC.xpos" tag="30" num="1"/>  
<dictEntry name="CLAS12.SC.ypos" tag="30" num="2"/>  
<dictEntry name="CLAS12.SC.zpos" tag="30" num="3"/>
```

This scheme works well if all tag/num pairs are unique. That way there is a unique string associated with each tag/num pair. If multiple names are linked with the same pair, then searching for a particular name may not return the appropriate values, and searching for a tag/num pair may not return the appropriate name. Likewise, if a single name is linked with multiple pairs, the same confusion can result. In order to avoid these problems, both the C++ and Java implementations of the dictionary only allow unique mappings.

In addition to the tag, num, and name attributes, the dictionary can also hold the type information about the contents of an evio container (unknown types are ignored). For example the following associates "fred" with 32 bit signed integers:

```
<dictEntry name="fred" tag="1" num="1" type="int32" />
```

The new composite type of data requires even more information about the format of the data inside. To accommodate this, all dictionary entries may now have a *description* xml subelement defined. These descriptions may have the *format* attribute defined as well:

```
<xmlDict>
  <dictEntry name='myName' tag='123' num='456' type='composite' >
    <description format='F,D,Ni' >
      F TDC
      D ADC min=5.0 max=10.0
      N multiplier
      i scaler bits0-15=counter1 bits15-32=counter2
    </description>
  </dictEntry>
</xmlDict>
```

The description and format can be anything meaningful to the user. Hall D will use a set format for both entries when using composite type data so they can be parsed and additional information extracted from it. This is done to allow flexibility to the user but not in a way that would be a constantly changing specification for evio.

C.2.1 Pretty Printing

Dictionary entries without the *num* attribute may be defined in order to beautify any printed output:

```
<dictEntry name="GeneralTag" tag="1" />
<dictEntry name="SpecificTag" tag="1" num="1" type="int32" />
```

For example, say the 2 dictionary entries above are the only ones defined for tag = 1. Now, if an evio data file is being printed and contains a bank with tag = 1 and num = 2, what this does is assigned the name "GeneralTag" to such a bank whose specific tag/num pair has no corresponding dictionary entry.

C.2.2 Behaviors

There are a few other issues that need to be addressed. The use of the "leaf" element is optional and may be replaced by "bank". However, if "leaf" is used, it may not have any children. Even though XML is case-sensitive, in the parsing of the dictionary, all the accepted elements' and attributes' cases are ignored.

The rules that jevio now uses to determine whether a bank, event, segment, or tagegment object matches a particular dictionary entry is:

- 1) if it is an EvioEvent, EvioBank, EvioSegment or EvioTagSegment (any kind of container) object, the first and only entry that matches its "tag" value and its "num" value is returned
- 2) if it is an EvioSegment or EvioTagSegment object, its num value is assumed to be 0 (zero) for purposes of matching

The xml representation of a dictionary can be embedded in a larger xml document. Giving this larger document as the dictionary to be parsed is perfectly acceptable and the code will pick out the dictionary portion. If multiple dictionaries are included, only the first is used and the rest are ignored.

Furthermore, irrelevant xml elements and attributes may be present and are simply ignored. When the jevio toXml() method of a dictionary is called, only the dictionary portion of the original, full xml document is returned as a String.

C.2.3 Differences between C++ and Java

There still are a couple differences between Java and C++. The first is if a "leaf" entry has any children, jevio will print a warning and ignore any such children while evio will throw an exception. Similarly, if there are duplicate entries - either names or tag/num pairs - an exception is thrown in C++ but in Java they are ignored (including any of their children) and a warning is printed. These differences are allowed for backwards compatibility purposes in jevio. Be aware that in jevio all the dictEntry elements are processed before the bank and node elements. So if there are duplicate entries, any dictEntry elements are given preference over the bank or leaf.

Appendix D

D. EVIO Function Objects

A number of useful adaptable function objects for applying STL algorithms to the lists returned by `getNodeList()` are provided. Adaptable means they can be used with STL function object adaptors (see the STL documentation). Their constructors are:

operator() returns bool:

```
typeIs<T>(void)
typeEquals(int aType)
tagEquals(unsigned short aTag)
numEquals(unsigned char aNum)
tagNumEquals(unsigned short aTag, unsigned char aNum)
parentTypeEquals(int aType)
parentTagEquals(unsigned short aTag)
parentNumEquals(unsigned char aNum)
parentTagNumEquals(unsigned short aTag, unsigned char aNum)
isContainer(void)
isLeaf(void)
```

operator() returns void:

```
toCout(void)
```