Java NIO Overview

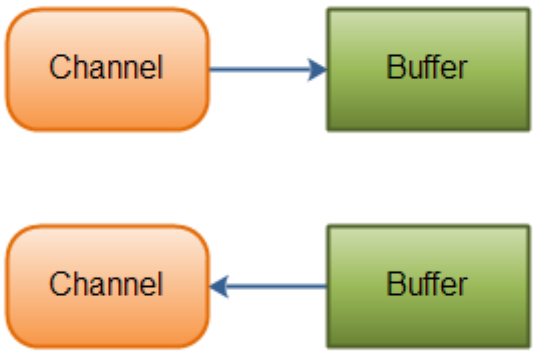
Java NIO consist of the following core components:

- Channels
- Buffers
- Selectors

Java NIO has more classes and components than these, but the `Channel`, `Buffer` and `Selector` forms the core of the API, in my opinion. The rest of the components, like `Pipe` and `FileLock` are merely utility classes to be used in conjunction with the three core components. Therefore, I'll focus on these three components in this NIO overview. The other components are explained in their own texts elsewhere in this tutorial. See the menu at the top corner of this page.

Channels and Buffers

Typically, all IO in NIO starts with a `Channel`. A `Channel` is a bit like a stream. From the `Channel` data can be read into a `Buffer`. Data can also be written from a `Buffer` into a `Channel`. Here is an illustration of that:



Java NIO: Channels read data into Buffers, and Buffers write data into Channels

There are several `Channel` and `Buffer` types. Here is a list of the primary `Channel`implementations in Java NIO:

- FileChannel

- DatagramChannel
- SocketChannel
- ServerSocketChannel

As you can see, these channels cover UDP + TCP network IO, and file IO.

There are a few interesting interfaces accompanying these classes too, but I'll keep them out of this Java NIO overview for simplicity's sake. They'll be explained where relevant, in other texts of this Java NIO tutorial.

Here is a list of the core `Buffer` implementations in Java NIO:

- ByteBuffer
- CharBuffer
- DoubleBuffer
- FloatBuffer
- IntBuffer
- LongBuffer
- ShortBuffer

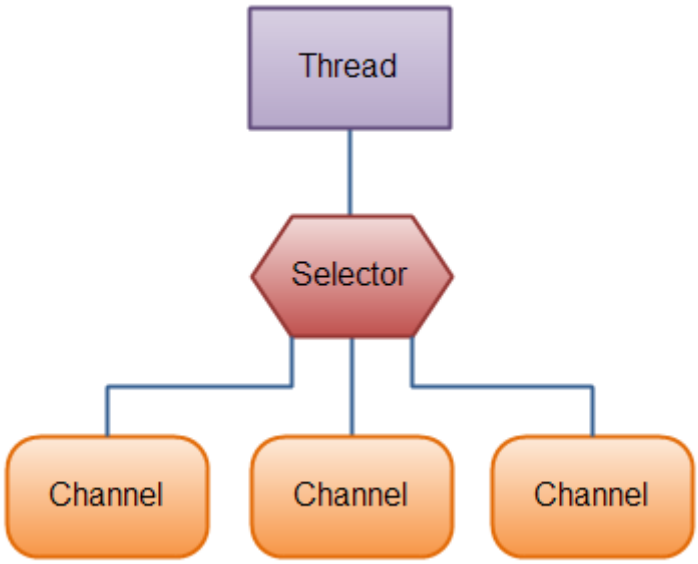
These `Buffer`'s cover the basic data types that you can send via IO: byte, short, int, long, float, double and characters.

Java NIO also has a `MappedByteBuffer` which is used in conjunction with memory mapped files. I'll leave this `Buffer` out of this overview though.

Selectors

A `Selector` allows a single thread to handle multiple `Channel`'s. This is handy if your application has many connections (Channels) open, but only has low traffic on each connection. For instance, in a chat server.

Here is an illustration of a thread using a `Selector` to handle 3 `Channel`'s:



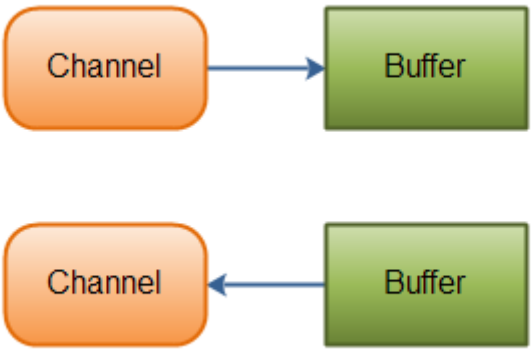
Java NIO: A Thread uses a Selector to handle 3 Channel's

To use a `Selector` you register the `Channel`'s with it. Then you call it's `select()` method. This method will block until there is an event ready for one of the registered channels. Once the method returns, the thread can then process these events. Examples of events are incoming connection, data received etc.

Java NIO Channels are similar to streams with a few differences:

- You can both read and write to a Channels. Streams are typically one-way (read or write).
- Channels can be read and written asynchronously.
- Channels always read to, or write from, a Buffer.

As mentioned above, you read data from a channel into a buffer, and write data from a buffer into a channel. Here is an illustration of that:



Java NIO: Channels read data into Buffers, and Buffers write data into Channels

Channel Implementations

Here are the most important Channel implementations in Java NIO:

- FileChannel
- DatagramChannel
- SocketChannel
- ServerSocketChannel

The `FileChannel` reads data from and to files.

The `DatagramChannel` can read and write data over the network via UDP.

The `SocketChannel` can read and write data over the network via TCP.

The `ServerSocketChannel` allows you to listen for incoming TCP connections, like a web server does. For each incoming connection a `SocketChannel` is created.

Basic Channel Example

Here is a basic example that uses a `FileChannel` to read some data into a `Buffer`:

```
    RandomAccessFile aFile = new RandomAccessFile("data/nio-data.txt",
"rw");
```

```
    FileChannel inChannel = aFile.getChannel();

    ByteBuffer buf = ByteBuffer.allocate(48);

    int bytesRead = inChannel.read(buf);
    while (bytesRead != -1) {

      System.out.println("Read " + bytesRead);
      buf.flip();

      while(buf.hasRemaining()){
          System.out.print((char) buf.get());
      }

      buf.clear();
      bytesRead = inChannel.read(buf);
    }
    aFile.close();
```

Notice the `buf.flip()` call. First you read into a Buffer. Then you flip it. Then you read out of it. I'll get into more detail about that in the next text about `Buffer`'s.

Buffers

Java NIO Buffers are used when interacting with NIO Channels. As you know, data is read from channels into buffers, and written from buffers into channels.

A buffer is essentially a block of memory into which you can write data, which you can then later read again. This memory block is wrapped in a NIO Buffer object, which provides a set of methods that makes it easier to work with the memory block.

Basic Buffer Usage

Using a `Buffer` to read and write data typically follows this little 4-step process:

1. Write data into the Buffer
2. Call `buffer.flip()`
3. Read data out of the Buffer
4. Call `buffer.clear()` or `buffer.compact()`

When you write data into a buffer, the buffer keeps track of how much data you have written. Once you need to read the data, you need to switch the

buffer from writing mode into reading mode using the `flip()` method call. In reading mode the buffer lets you read all the data written into the buffer.

Once you have read all the data, you need to clear the buffer, to make it ready for writing again. You can do this in two ways: By calling `clear()` or by calling `compact()`. The `clear()` method clears the whole buffer. The `compact()` method only clears the data which you have already read. Any unread data is moved to the beginning of the buffer, and data will now be written into the buffer after the unread data.

Here is a simple `Buffer` usage example, with the write, flip, read and clear operations maked in bold:

```
RandomAccessFile aFile = new RandomAccessFile("data/nio-data.txt", "rw");
FileChannel inChannel = aFile.getChannel();

//create buffer with capacity of 48 bytes
ByteBuffer buf = ByteBuffer.allocate(48);

int bytesRead = inChannel.read(buf); //read into buffer.
while (bytesRead != -1) {

  buf.flip();  //make buffer ready for read

  while(buf.hasRemaining()){
      System.out.print((char) buf.get()); // read 1 byte at a time
  }

  buf.clear(); //make buffer ready for writing
  bytesRead = inChannel.read(buf);
}
aFile.close();
```

Buffer Capacity, Position and Limit

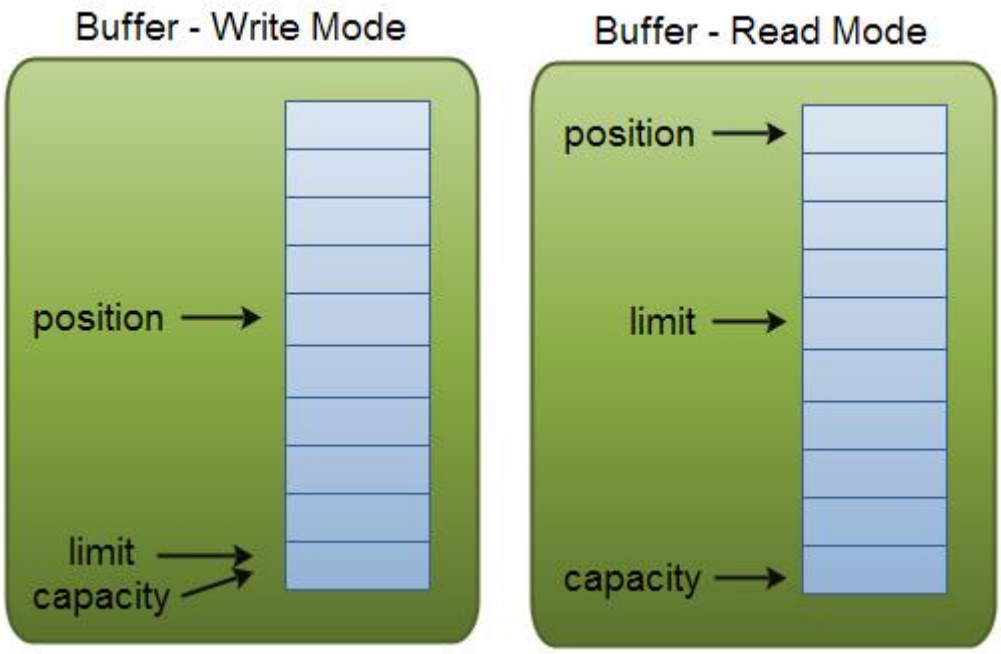
A buffer is essentially a block of memory into which you can write data, which you can then later read again. This memory block is wrapped in a NIO Buffer object, which provides a set of methods that makes it easier to work with the memory block.

A `Buffer` has three properties you need to be familiar with, in order to understand how a `Buffer` works. These are:

- capacity
- position
- limit

The meaning of `position` and `limit` depends on whether the `Buffer` is in read or write mode. Capacity always means the same, no matter the buffer mode.

Here is an illustration of capacity, position and limit in write and read modes. The explanation follows in the sections after the illustration.



Buffer capacity, position and limit in write and read mode.

Capacity

Being a memory block, a `Buffer` has a certain fixed size, also called its "capacity". You can only write `capacity` bytes, longs, chars etc. into the Buffer. Once the Buffer is full, you need to empty it (read the data, or clear it) before you can write more data into it.

Position

When you write data into the `Buffer`, you do so at a certain position. Initially the position is 0. When a byte, long etc. has been written into the `Buffer` the position is advanced to point to the next cell in the buffer to insert data into. Position can maximally become`capacity - 1`.

When you read data from a `Buffer` you also do so from a given position. When you flip a `Buffer` from writing mode to reading mode, the position

is reset back to 0. As you read data from the `Buffer` you do so from `position`, and `position` is advanced to next position to read.

Limit

In write mode the limit of a `Buffer` is the limit of how much data you can write into the buffer. In write mode the limit is equal to the capacity of the `Buffer`.

When flipping the `Buffer` into read mode, limit means the limit of how much data you can read from the data. Therefore, when flipping a `Buffer` into read mode, limit is set to write position of the write mode. In other words, you can read as many bytes as were written (limit is set to the number of bytes written, which is marked by position).

Buffer Types

Java NIO comes with the following **Buffer** types:

- ByteBuffer
- MappedByteBuffer
- CharBuffer
- DoubleBuffer
- FloatBuffer
- IntBuffer
- LongBuffer
- ShortBuffer

As you can see, these `Buffer` types represent different data types. In other words, they let you work with the bytes in the buffer as char, short, int, long, float or double instead.

The `MappedByteBuffer` is a bit special, and will be covered in its own text.

Allocating a Buffer

To obtain a `Buffer` object you must first allocate it.
Every `Buffer` class has an `allocate()` method that does this. Here is an example showing the allocation of a`ByteBuffer`, with a capacity of 48 bytes:

```
ByteBuffer buf = ByteBuffer.allocate(48);
```

Here is an example allocating a `CharBuffer` with space for 1024 characters:

```
CharBuffer buf = CharBuffer.allocate(1024);
```

Writing Data to a Buffer

You can write data into a `Buffer` in two ways:

1. Write data from a `Channel` into a `Buffer`
2. Write data into the `Buffer` yourself, via the buffer's `put()` methods.

Here is an example showing how a `Channel` can write data into a `Buffer`:

```
int bytesRead = inChannel.read(buf); //read into buffer.
```

Here is an example that writes data into a `Buffer` via the `put()` method:

```
buf.put(127);
```

There are many other versions of the `put()` method, allowing you to write data into the`Buffer` in many different ways. For instance, writing at specific positions, or writing an array of bytes into the buffer. See the JavaDoc for the concrete buffer implementation for more details.

flip()

The `flip()` method switches a `Buffer` from writing mode to reading mode. Calling `flip()` sets the `position` back to 0, and sets the `limit` to where position just was.

In other words, `position` now marks the reading position, and `limit` marks how many bytes, chars etc. were written into the buffer - the limit of how many bytes, chars etc. that can be read.

Reading Data from a Buffer

There are two ways you can read data from a `Buffer`.

1. Read data from the buffer into a channel.
2. Read data from the buffer yourself, using one of the get() methods.

Here is an example of how you can read data from a buffer into a channel:

```
//read from buffer into channel.
int bytesWritten = inChannel.write(buf);
```

Here is an example that reads data from a `Buffer` using the get() method:

```
byte aByte = buf.get();
```

There are many other versions of the `get()` method, allowing you to read data from the`Buffer` in many different ways. For instance, reading at specific positions, or reading an array of bytes from the buffer. See the JavaDoc for the concrete buffer implementation for more details.

rewind()

The `Buffer.rewind()` sets the `position` back to 0, so you can reread all the data in the buffer. The `limit` remains untouched, thus still marking how many elements (bytes, chars etc.) that can be read from the `Buffer`.

clear() and compact()

Once you are done reading data out of the `Buffer` you have to make the `Buffer` ready for writing again. You can do so either by calling `clear()` or by calling `compact()`.

If you call `clear()` the `position` is set back to 0 and the `limit` to `capacity`. In other words, the `Buffer` is cleared. The data in the `Buffer` is not cleared. Only the markers telling where you can write data into the `Buffer` are.

If there is any unread data in the `Buffer` when you call `clear()` that data will be "forgotten", meaning you no longer have any markers telling what data has been read, and what has not been read.

If there is still unread data in the `Buffer`, and you want to read it later, but you need to do some writing first, call `compact()` instead of `clear()`.

`compact()` copies all unread data to the beginning of the `Buffer`. Then it sets `position`to right after the last unread element. The `limit` property is still set to `capacity`, just like `clear()` does. Now the `Buffer` is ready for writing, but you will not overwrite the unread data.

mark() and reset()

You can mark a given position in a `Buffer` by calling the `Buffer.mark()` method. You can then later reset the position back to the marked position by calling the `Buffer.reset()` method. Here is an example:

```
buffer.mark();

//call buffer.get() a couple of times, e.g. during parsing.

buffer.reset();  //set position back to mark.
```

equals() and compareTo()

It is possible to compare two buffers using `equals()` and `compareTo()`.

equals()

Two buffers are equal if:

1. They are of the same type (byte, char, int etc.)

2. They have the same amount of remaining bytes, chars etc. in the buffer.
3. All remaining bytes, chars etc. are equal.

As you can see, equals only compares part of the `Buffer`, not every single element inside it. In fact, it just compares the remaining elements in the `Buffer`.

compareTo()

The `compareTo()` method compares the remaining elements (bytes, chars etc.) of the two buffers, for use in e.g. sorting routines. A buffer is considered "smaller" than another buffer if:

1. The first element which is equal to the corresponding element in the other buffer, is smaller than that in the other buffer.
2. All elements are equal, but the first buffer runs out of elements before the second buffer does (it has fewer elements).