Contents

Benefits of this Library

The library was intended to satisfy the following primary goals:

- **Parsing of all host name and ipv4/ipv6 address formats in common usage** plus some additional formats (see below or see javadoc for the `IPAddressString` class for the extensive list)
- **Parsing and representation of subnets**, either those specified by network prefix length or those specified with ranges of segment values. For example, all strings in the list below represent the same IPv4 subnet:
  - with CIDR network prefix length:`1.2.0.0/16`
  - with mask: `1.2.0.0/255.255.0.0`
  - wildcard segments: `1.2.*.*`
  - range segments: `1.2.0-255.0-255`
  - range using inet_aton format: `0x1.0x2.0x0-0xffff`
  - SQL-style single wildcards to end segments: `1.2.___.___`
  - IPv4 mapped IPv6: `::ffff:1.2.0.0/112`
- **Allow the separation of address parsing from host parsing**. In some cases you may have an address, in others you may have a host name, in some cases either one, so this supports all three options (for instance, when validating invalid input "1.2.3.a" as an address only, it will not be treated as a host with DNS lookup attempted in the way that `InetAddress.getByName` does)
- **Allow control over which formats are allowed when parsing**, whether IPv4/6, or subnets, or inet_aton formats, and so on.
- **Produce all common address strings of different formats for a given IPv4 or IPv6 address and produce collections of such strings** Some addresses can have hundreds of thousands of potential string representations (when you consider hex capitalization, ipv6 compression, and leading zeros, the various IPv4 and IPv6 formats, and combinations of all the above), although there are generally a handful of commonly used formats. Generating these strings, whether the handful of commonly used strings or whether the exhaustive lists of all possible strings, can help when searching or matching addresses in databases or text.
- **Support parsing of all common MAC Address formats in usage**
- **Produce all common MAC address strings of different formats**
- **Integration of MAC Address with IPv6**
- **Polymorphism** in the code for IPv4 and IPv6 for applications which must support both transparently. You can write generic non-version-specific code to validate addresses, connect to addresses, print addresses, mask addresses, etc. You can make use of the address framework.
- **Thread-safety and immutability**. The core objects (host names, address strings, addresses, address sections, address segments) are all immutable (like `java.lang.String` or `java.lang.Integer` instances). They do not change their underlying value.
- **Manipulation of addresses with prefixes, masks, sections, segments and subnetting**: applying network prefixes, masking, splitting addresses into sections, joining address segments into larger segments, generating new subnets and supernets from existing addresses and subnets, iterating through subnets, checking containment within subnets, ipv4-ipv6 conversion, ipv6-mac conversion
- **Sorting and comparison** of host names, addresses, address strings and subnets
- **Integrate with the primitive java types and the standard java classes `InetAddress`, `Inet6Address`, `Inet4Address`, and `BigInteger`.**

Supported IP Address Formats

This includes, those supported by the well-known routines inet_aton and inet_pton, the subnet formats listed above, all combinations of the above, and others:

- all the formats supported by inet_pton and inet_aton
- all the formats supported by nmap
- the subnet formats listed above, whether prefixed, masked, wildcards, ranges
- IPv6 canonical, compressed (1::1), mixed (1:2:3:4:5:6:1.2.3.4), [bracketed]:port, and so on
- Hex values
- IPv6 base 85 values
- * represents all addresses both ipv4 and ipv6
- /x with no associated address is interpreted as the mask for prefix length x
- "" the empty string is considered the default loopback

For a more detailed list or formats parsed, some examples are below, or see the javadoc for IPAddressString.

Subnet formats

- **CIDR (Classless Inter-Domain Routing) prefix length subnets**
  Adding the prefix length /x creates the address or subnet for that network prefix length, depending upon the configuration for prefix handling. The subnet 1.2.0.0/16 is the set of all addresses starting with 1.2
- **Wildcard (* _) and range (-) subnets:**
  * denotes all possible values in one or more segments, so 1.*.*.* or just 1.* is equivalent to 1.0.0.0/8
  0-1 denotes the range from 0 to 1
  _ replaces any digit at the end of a segment, for example 1_ represents 10 to 19 in decimal or 10 to 1f in hex
- **Combinations:**
  Applying a prefix length to a subnet simply applies the prefix to every element of the subnet. 1.*.0.0/16 is the same subnet of addresses as 1.0.0.0/8

For a more detailed list or formats parsed, some examples are below, or see the javadoc for IPAddressString.

Core classes

The core classes are **`HostName`**, **`IPAddressString`**, and **`MACAddressString`** along with the **`Address`** base class and its subclasses **`IPAddress`**, **`IPv4Address`**, **`IPv6Address`**, and **`MACAddress`**. If you have a textual representation of an IP address, then start with `HostName` or `IPAddressString`. If you have numeric bytes or integers, then start with `IPV4Address`, `IPV6Address` or `MACAddress`. Note that address instances can represent either a single address or a subnet. If you have an address or host name with a port, then use `HostName`.

Parse String Representation of IP Address or Host Name

IPAddressString is used to convert. You can use one of `getAddress` or `toAddress`, the difference being whether parsing errors are handled by exception or not.

```
IPAddress address = new IPAddressString("1.2.3.4").getAddress();
if(address != null) {
	//use address here
}
```

or

```
String str = "1.2.3.4";
try {
	IPAddress address = new IPAddressString(str).toAddress();
	//use address here
} catch (AddressStringException e) {
	String msg = e.getMessage();//detailed message indicating issue
}
```

If you have either a host name or an address, you can use HostName:

```
public static void main(String[] args) {
	check(new HostName("[::1]"));
	check(new HostName("*"));
	check(new HostName("a.b.com"));
}

static void check(HostName host) {
	if(host.isAddress()) {
		System.out.println("address: " + host.asAddress().toCanonicalString());
	} else if(host.isAddressString()) {
		System.out.println("address string with ambiguous address: " +
			host.asAddressString());
	} else {
		System.out.println("host name with labels: " +
			Arrays.asList(host.getNormalizedLabels()));
	}
}
```

Output:

```
address: ::1
address string with ambiguous address: *
```

```
host name with labels: [a, b, com]
```

Format Examples

Many formats are supported. For instance, the address 1:2:3:0:0:6:: can be represented many ways as shown.

```
static void parse(String formats[]) {
	for(String format : formats) {
		System.out.println(new IPAddressString(format).getAddress());
	}
}

static void parseHost(String formats[]) {
	for(String format : formats) {
		System.out.println(new HostName(format).getAddress());
	}
}

public static void main(String[] args) {
	String formats[] = {
		"1:2:3:0:0:6::",
		"1:2:3:0:0:6:0:0",
		"1:2:3::6:0:0",
		"0001:0002:0003:0000:0000:0006:0000:0000",
		"1:2:3::6:0.0.0.0",
		"1:2:3:0:0:6::",
		"008JQWOV7O(=61h*;$LC",
		"0x00010002000300000000000600000000"
	};
	parse(formats);
	String hostFormats[] = {
		"[1:2:3:0:0:6::]",
		"[1:2:3:0:0:6:0:0]",
		"[1:2:3::6:0:0]",
		"[0001:0002:0003:0000:0000:0006:0000:0000]",
		"[1:2:3::6:0.0.0.0]",
		"[1:2:3:0:0:6::]",
		"[008JQWOV7O(=61h*;$LC]",
		"[0x00010002000300000000000600000000]",
		"0.0.0.0.0.0.0.0.6.0.0.0.0.0.0.0.0.0.0.0.3.0.0.0.2.0.0.0.1.0.0.0.ip6.arpa",
		"1-2-3-0-0-6-0-0.ipv6-literal.net"
	};
	parseHost(hostFormats);
}
```

Output:

```
1:2:3::6:0:0
1:2:3::6:0:0
1:2:3::6:0:0
1:2:3::6:0:0
1:2:3::6:0:0
1:2:3::6:0:0
1:2:3::6:0:0
1:2:3::6:0:0
1:2:3::6:0:0
1:2:3::6:0:0
1:2:3::6:0:0
1:2:3::6:0:0
1:2:3::6:0:0
1:2:3::6:0:0
```

Subnet strings are supported as well, using CIDR prefix notation or characters indicating range (‘-‘ for a specific range or ‘*’ for full range segments).

For instance, the subnet `ffff::/104` can be represented many ways:

```
static void parse(String formats[]) {
	for(String format : formats) {
		System.out.println(new IPAddressString(format).getAddress().assignPrefixForSingleBlock());
	}
}

static void parseHost(String formats[]) {
	for(String format : formats) {
		System.out.println(new HostName(format).getAddress().assignPrefixForSingleBlock ());
	}
}

public static void main(String[] args) {
	String prefixedFormats[] = {
		"ffff::/104",
		"ffff:0:0:0:0:0:0:0/104",
		"ffff:0000:0000:0000:0000:0000:0000:0000/104",
		"ffff::/104",
		"ffff::0.0.0.0/104",
		"=q{+M|w0(OeO5^EGP660/104"
	};
	String rangeFormats[] = {
		"ffff:0:0:0:0:0-ff:*",
		"ffff::0-ff:*",
		"ffff::0-ff:*",
		"0xffff0000000000000000000000000000-0xffff0000000000000000000000ffffff"
	};
	parse(prefixedFormats);
	parse(rangeFormats);
	String hostFormats[] = {
```

```
         "[ffff::]/104",
          "[ffff:0:0:0:0:0:0:0]/104",
          "[ffff:0000:0000:0000:0000:0000:0000:0000]/104",
          "[ffff::]/104",
          "[ffff::0.0.0.0]/104",
          "[=q{+M|w0(OeO5^EGP660]/104",

         "[ffff:0:0:0:0:0:0-ff:*]",
          "[ffff::0-ff:*]",
          "[ffff::0-ff:*]",
          "[0xffff0000000000000000000000000000-0xffff0000000000000000000000ffffff]",
          "*.*.*.*.*.*.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.f.f.f.f.ip6.arpa",
          "ffff-0-0-0-0-0-0-0.ipv6-literal.net/104"
    };
    parseHost(hostFormats);
}
```

Output:

```
ffff::/104
ffff::/104
ffff::/104
ffff::/104
ffff::/104
ffff::/104
ffff::/104
ffff::/104
ffff::/104
ffff::/104
ffff::/104
ffff::/104
ffff::/104
ffff::/104
ffff::/104
ffff::/104
ffff::/104
ffff::/104
ffff::/104
ffff::/104
ffff::/104
ffff::/104
```

Delimited Segments

The subnet formats allow you to specify ranges of values. However, if you wish to parse addresses in which values are delimited, then you can use the methods `parseDelimitedSegments(String)` and `countDelimitedAddresses(String)` in `IPAddressString`. The method `parseDelimitedSegments` will provide an iterator to traverse through the individual addresses.

For example, given "1,2.3.4,5.6" `parseDelimitedSegments` will iterate through "1.3.4.6", "1.3.5.6", "2.3.4.6" and "2.3.5.6". You can then construct `IPAddressString` instances from those individual strings for parsing.

Address or Host Name Validation Options

Validation options allow you to restrict the allowed formats, whether you wish to support just IPv4 or IPv6, or whether you wish to support just single addresses, or whether you wish to allow different variants.

For IP addresses, you have the class `IPAddressStringParameters` which can be passed into `IPAddressString`, and for host names you have the class `HostNameParameters` which can be passed into `HostName`.

You constrict validation options using the appropriate builder classes that are nested classes in the options classes. Here is an example constructing host options along with nested address options within:

```
HostNameParameters HOST_OPTIONS_EXAMPLE = new HostNameParameters.Builder().
        allowEmpty(false).
        setEmptyAsLoopback(false).
        setNormalizeToLowercase(true).
        allowBracketedIPv6(true).
        allowBracketedIPv4(true).getAddressOptionsBuilder().
              allowPrefix(true).
              allowMask(true).
              setRangeOptions(RangeParameters.WILDCARD_AND_RANGE).
              allow_inet_aton(true).
              allowEmpty(false).
              setEmptyAsLoopback(false).
              allowAll(false).
              allowPrefixOnly(false).
              getIPv4AddressParametersBuilder().
                     allowPrefixLengthLeadingZeros(true).
                     allowPrefixesBeyondAddressSize(false).
                     allowWildcardedSeparator(true).
                     getParentBuilder().getParentBuilder().toParams();
```

The default options used by the library are permissive and not restrictive.

Host Name or Address with Port

For an address or host with port, use `HostName`. IPv6 addresses with ports must appear as [ipv6Address]:port to resolve the ambiguity of the colon separator, consistent with RFC 2732, 3986, 4038 and other RFCs.

```
HostName hostName = new HostName("[::1]:80");
System.out.println("host: " + hostName.getHost() + " address: " + hostName.getAddress() + " port: " + hostName.getPort());
```

```
        hostName = new HostName("localhost:80");
        System.out.println("host: " + hostName.getHost() + " port: " + hostName.getPort());
        hostName = new HostName("127.0.0.1:80");
        System.out.println("host: " + hostName.getHost() + " address: " + hostName.getAddress() + " port: " + hostName.getPort());
```

Output:

```
host: ::1 address: ::1 port: 80
host: localhost port: 80
host: 127.0.0.1 address: 127.0.0.1 port: 80
```

IP Version Determination and IPv4/v6 Conversion

With an `IPAddress` or `IPAddressString` object, you can check the version with `isIPv4()` and `isIPv6()` and get the appropriate subclass with `toIPv4()` or `toIPv6()`. You can also make use of `isIPv4Convertible()` and `isIPv6Convertible()` to do further conversions if the address is IPv4 mapped, or you can use your own instance of `IPAddressConverter` for some other suitable conversion (IPv4 translated, 6to4, 6over4, IPv4 compatible, or other).

```
IPAddressString str = new IPAddressString("::ffff:1.2.3.4");
if(str.isIPv6()) {
        IPv6Address ipv6Address = str.getAddress().toIPv6();
        System.out.println(ipv6Address.toMixedString());
        if(ipv6Address.isIPv4Convertible()) {
                IPv4Address ipv4Address = ipv6Address.toIPv4();
                System.out.println(ipv4Address.toNormalizedString());
        }
}
```

Output:

```
::ffff:1.2.3.4
1.2.3.4
```

Should you wish to change the default IPv4/IPv6 conversions from IPv4 mapped to something else, you can override the pair of methods `toIPv4()` and `isIPv4Convertible()` in your own `IPv6Address` subclass and/or the pair of methods `toIPv6()` and `isIPv6Convertible()` in your own `IPv4Address` subclass.

Prefixed Addresses and toHostAddress()

This library will parse CIDR prefix IP addresses such as 10.1.2.3/24.

When you have a prefixed address, like 10.1.2.3/24 which has the prefix length of 24, this notation may typically denote the single, distinct interface address 10.1.2.3 with the first 24 bits indicating the IPv4 block, or it may denote the the IPv4 block of 255 addresses which includes 10.1.2.3 (although typically the block would be denoted 10.1.2.0/24, with all host bits as zero).

As explained further below, you can configure the library to handle prefixed addresses in three different ways, to control whether prefixed addresses are considered addresses or subnets.

Regardless of the prefix configuration, if you have an individual address or a subnet with prefix length and you want to get the address instance representing the entire block for that prefix, you can call `toPrefixBlock()`. In the reverse direction, given an entire block for a prefix, you can get the IPv4 network address or the IPv6 anycast address by calling `getLower()`.

When parsing, you can always obtain the individual address without the prefix length attached. For that there are the methods `getHostAddress()` or `toHostAddress()` which will provide the original host address 10.1.2.3 when parsing 10.1.2.3/24. You can also get the prefix length by calling `getNetworkPrefixLength()` on the `IPAddressString` or `IPAddress` instance.

The example code below shows these methods and the default prefix length handling behavior.

```
static void printPrefixedAddresses(String addressStr) {
        IPAddressString ipAddressString = new IPAddressString(addressStr);
        IPAddress address = ipAddressString.getAddress();
        System.out.println("count: " + address.getCount());
        IPAddress hostAddress = ipAddressString.getHostAddress();
        IPAddress prefixBlock = address.toPrefixBlock();
        Integer prefixLength = ipAddressString.getNetworkPrefixLength();
        System.out.println(address);
        System.out.println(address.toCanonicalWildcardString());
        System.out.println(hostAddress);
        System.out.println(prefixLength);
        System.out.println(prefixBlock);
        System.out.println();
}

printPrefixedAddresses("10.1.2.3/24");//individual address
printPrefixedAddresses("10.1.2.0/24");//network
```

Output:

```
count: 1
10.1.2.3/24
10.1.2.3
10.1.2.3
24
10.1.2.0/24

count: 256
10.1.2.0/24
10.1.2.*
10.1.2.0
24
10.1.2.0/24
```

Parse Non-Segmented Addresses – Hex, Octal, IPv6 Base 85

Typically, the segments or other punctuation identify a string as a host name, as an IPv4 address, or as an IPv6 address. The parser will also parse single segment values or a range of single segment values.

With non-segmented addresses, ambiguity between IPv4 and IPv6 is resolved by the number of digits in the string. The number of digits is 32 for IPv6 hexadecimal, 20 for IPv6 base 85 (see RFC 1924), and 11 or less for IPv4, which can be octal, hexadecimal, or decimal. For IPv4, digits are presumed decimal unless preceded by 0x for hexadecimal or 0 for octal, as is consistent with the inet_aton routine. For IPv6, 32 digits are considered hexadecimal and the preceding 0x is optional.

```
IPAddressString ipAddressString = new IPAddressString("4)+k&C#VzJ4br>0wv%Yp");//base 85
IPAddress address = ipAddressString.getAddress();
System.out.println(address);

ipAddressString = new IPAddressString("108000000000000000080800200c417a");//hex IPv6
address = ipAddressString.getAddress();
System.out.println(address);

ipAddressString = new IPAddressString("0x01020304");//hex IPv4
address = ipAddressString.getAddress();
System.out.println(address);

ipAddressString = new IPAddressString("000100401404");//octal IPv4
address = ipAddressString.getAddress();
System.out.println(address);
```

Output:

```
1080::8:800:200c:417a
1080::8:800:200c:417a
1.2.3.4
1.2.3.4
```

Parse Special Host Names – Reverse DNS Host Name, IPv6 Literal UNC Host Name

A couple of standardized host formats are recognized, namely the reverse DNS host format, and the UNC IPv6 literal host format.

```
HostName hostName = new HostName("a.7.1.4.c.0.0.2.0.0.8.0.8.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.8.0.1.ip6.arpa");
System.out.println(hostName.asAddress());
hostName = new HostName("4.3.2.1.in-addr.arpa");
System.out.println(hostName.asAddress());
hostName = new HostName("1080-0-0-0-8-800-200c-417a.ipv6-literal.net");
System.out.println(hostName.asAddress());
```

Output:

```
1080::8:800:200c:417a
1.2.3.4
1080::8:800:200c:417a
```

A couple of methods in `HostName` are available as well:

```
public boolean isUNCIPv6Literal()
public boolean isReverseDNS()
```

Parse IPv6 Zone or Scope ID

The IPv6 zone or scope ID is recognized, denoted by the '%' character. It can be retrieved by `IPv6Address.getZone()`.

```
IPAddress addr = new IPAddressString("::%eth0").getAddress();
if(addr.isIPv6()) {
	System.out.println(addr.toIPv6().getZone());
}
```

Output:

```
eth0
```

IP Address and Numeric Values

In addition to the range of string formats that can be parsed to produce `IPAddress` instances, you can also obtain instances of `IPAddress` from byte arrays, `java.net.InetAddress`, arrays of address segments, or individual integer segment values.

For IPv4 you have the additional option of constructing an address from a 32-bit integer. For IPv6, you have the additional options of constructing from a `java.lang.BigInteger` and constructing from MAC addresses.

Once you have an `IPAddress` instance, there are methods to convert to bytes, to a `java.lang.BigInteger`, to sections, to subnets or network prefixes, to masks, to `java.net.InetAddress`, to different string representations, and so on.

Networks

Each of the different address types (IPv6, IPv4, MAC) has an associated singleton network object. The network objects are used for caching, for configuration, and have methods for obtaining masks and loopbacks. The network objects have singleton creator objects that are used to create addresses, sections, and segments, and those creator objects perform caching of these address components for efficient memory usage and performance. All internally created address components are created by the creator object, whether by the string parsing engine or by address object manipulation.

The `defaultIpv6Network()`, `defaultIpv4Network()`, and `defaultMACNetwork()` methods in `Address` provide access to the respective network objects. Each network's associated creator object is accessible from `getAddressCreator()`.

Using your own address classes

Users can create their own subclasses of the address and address component classes (eg your own subclasses of `IPv6Address`, `IPv6AddressSection` and/or `IPv6AddressSegment`).

When doing so, you may wish to use your own network classes as well. To do so, you

- override `getNetwork()`
- override `getIPv6Network()`, `getIPv4Network()`, and `getMACNetwork()`, if any of those methods exist in the class you are subclassing. These methods may exists because address components sometimes create components of other address versions or types (eg embedding IPv4 in IPv6, or MAC integration with IPv6).

Once you have done so, your new address classes are using your own network classes as well.

You can make the string parsing engines use your own address or network classes. To do this, your code will create your own string validation objects using the builder classes `MACAddressStringParameters.Builder`, `IPAddressStringParameters.Builder` and `HostNameParameters.Builder`. With `HostNameParameters.Builder` you must get the `IPAddressStringParameters.Builder` sub-builder by calling `getAddressOptionsBuilder()`. With `IPAddressStringParameters.Builder` you must get the IPv4 or IPv6 sub-builder by calling one of `getIPv6Parameters()` or `getIPv4Parameters()`. You then call `setNetwork()` on the builder or sub-builder objects to supply your own network. The initial builder can create your own validation objects with `toParams()`. Those validation objects can be supplied to the appropriate constructor of `IPAddressString` or `MACAddressString`. If you have supplied new networks to those validation objects, then subsequent string parsing with those `IPAddressString` or `MACAddressString` instances will use the supplied networks.

When using your own network classes, you can override the method `createAddressCreator()` or the method `getAddressCreator()` in `AddressNetwork`, and in so doing provide your own creator objects, in which you may have overridden any or all of the creation methods. At this point your code controls the types being instantiated by the library's string parsing engine.

Prefix Length Handling

As indicated in the section on parsing, when constructing an IP address with prefix length, you can end up with subnets or individual addresses. This is also true for address and address sections constructed directly.

In version 3 and earlier, prefixed addresses and sections were always converted to the subnet block of addresses for that prefix.

In the current version, there are three options available:

1. **`ALL_PREFIXED_ADDRESSES_ARE_SUBNETS`**: An address with a prefix length is the subnet block for that prefix. This is the legacy behavior, the behaviour for versions 3 and under of this library. An address like 1.2.3.4/16 is equivalent to 1.2.*.*/16, and a:b:c:d::/64 is equivalent to a:b:c:d:*:*:*:*/64

2. **`PREFIXED_ZERO_HOSTS_ARE_SUBNETS`***:* An address with a prefix length and a zero-valued host is the subnet block for that prefix. An address with a host value of non-zero is a single address corresponding to a single host. This is the new default behavior for this library since it is a convention with common usage.

   For example, the IPv4 address 1.2.3.4/16 is just a single address and not a subnet, while 1.2.0.0/16 is the prefix block, it is the subnet 1.2.*.*/16.

   This behavior is akin to the common convention used by many network administrators, many routers and many applications. With IPv4, an address with a host value of zero is known as the network address. It often represents the subnet of all addresses with that same prefix. It is often used for routing. The all-zero address 0.0.0.0 is conventionally known as INADDR_ANY (any address on the local machine), it is the address that returns true for java.net.Inet4Address.isAnyLocalAddress(), and when paired with prefix zero it is known as the default route (the route for all addresses).

   With IPv6, the convention is similar and this option results in the same behaviour. It is a standard convention with IPv6 to denote a subnet like 1:2:3:4::/64, with a zero-valued (and usually compressed) host, and that subnet represents the prefix block all addresses starting with that prefix 1:2:3:4. An address with a host of zero is known as the anycast address. The all-zero address '::' is the value of IN6ADDR_ANY_INIT, the analog to the IPv4 INADDR_ANY), and the address that returns true for java.net.Inet6Address.isAnyLocalAddress().

3. **`EXPLICIT_SUBNETS`**: The third option is the one in which a subnet block derived from a prefix length must be explicitly defined, you must list the range of values explicitly. Any subnet must be explicitly defined, like 1.2.*.*/16, while 1.2.0.0/16 is just a single address.

Version 3 and earlier versions of the library provided only the first behavior. All three options are available starting with version 4 of this library, while the default behavior is the second.

The options above are generally geared towards IP addresses. With MAC Addresses prefix lengths are implicit for the most part, particularly when it comes to strings. With MAC there is no difference between options 2 and 3 since there is no analog to the zero-host/network/anycast address. With MAC, when using an operation that allows you to supply a prefix, the first option above results in addresses that span all values beyond the prefix, while the other two options do not.

Configuring Non-Default Prefix Length Handling

To choose one of the non-default prefix length handling options, such as the legacy option, you make use of the `PrefixConfiguration` enum type and the network objects.

Each address version/type (IPv4, IPv6, MAC) has an associated network object and each network object has a `PrefixConfiguration` setting. Prefix length has a similar meaning for MAC but with some key differences outlined below. By default, all networks use the same setting of `PREFIXED_ZERO_HOSTS_ARE_SUBNETS` stored in a single static field in the `AddressNetwork` class.

By calling `setPrefixConfiguration` in `AddressNetwork` and you can change this default setting for all networks. Or, you can call `setPrefixConfiguration` in one or more of `IPv4AddressNetwork`, `IPv6AddressNetwork`, or `MACAddressNetwork`, to set each one individually. Typically, you would change the setting when the application starts. Should you choose to do so at a different point in the application lifetime, it should be noted that the behavior is undefined when using pre-existing address objects following such a change. It is recommended that the prefix length configuration remain constant throughout the lifetime of an application, or that existing address objects be discarded when the configuration is changed.

If discarding existing address objects, keep in mind that the library caches address and address component objects. To discard those cached objects you can clear those caches by calling `defaultIpv6Network()`, `defaultIpv4Network()`, and `defaultMACNetwork()` to get the default network objects and then call `clearCaches()` on each one.

If two applications using the IPAddress library at the same time in the same process require conflicting prefix configurations, then one option to achieve this is to use different class loaders in the separate apps, loading the IPAddress library in separate class loaders. In fact, many popular java applications already use class loaders for code separation, such as the Eclipse framework which uses them to separate plugins and the Apache Tomcat web server which uses them to separate webapps.

If you cannot load the library in separate class loaders, then another option is available to you. This option is to use your own network classes. The procedure for using your own network classes is described above in the section of this document on networks. The first step us to subclass the address and address component classes. The next step is to override the key methods for accessing the networks in those classes to supply your own network subclasses which will have their own non-default configuration. When using your own network classes, you can override the `getPrefixConfiguration()` method of `AddressNetwork` to avoid using the default configuration setting and use your own. In your network, you will also need to override either the `createAddressCreator()` or `getAddressCreator()` methods to supply your own address creator subclass instance that will create your own address and address component classes.

The following example shows how to create an IPAddressString that will use a customized network class along with customized address component classes:

```
static class MyIPv6Address extends IPv6Address {

	public MyIPv6Address(byte[] bytes, Integer prefixLength) {
		super(bytes, prefixLength);
	}

	public MyIPv6Address(MyIPv6AddressSection section, CharSequence zone) {
		super(section, zone);
	}

	public MyIPv6Address(MyIPv6AddressSection section) {
		super(section);
	}

	@Override
	public IPv6AddressNetwork getNetwork() {
		return myIPv6Network;
	}
}


static class MyIPv6AddressSection extends IPv6AddressSection {

	public MyIPv6AddressSection(byte[] bytes, Integer prefixLength) {
		super(bytes, prefixLength);
	}

	public MyIPv6AddressSection(IPv6AddressSegment[] segments, int startIndex, boolean cloneSegments) {
		super(segments, startIndex, cloneSegments);
	}

	public MyIPv6AddressSection(IPv6AddressSegment[] segments, Integer prefixLength) {
		super(segments, prefixLength);
	}

	@Override
	public IPv6AddressNetwork getNetwork() {
		return myIPv6Network;
	}
}

static class MyIPv6AddressSegment extends IPv6AddressSegment {

	public MyIPv6AddressSegment(int lower, Integer segmentPrefixLength) {
		super(lower, segmentPrefixLength);
	}

	public MyIPv6AddressSegment(int lower, int upper, Integer segmentPrefixLength) {
		super(lower, upper, segmentPrefixLength);
	}

	@Override
	public IPv6AddressNetwork getNetwork() {
		return myIPv6Network;
	}
}


static IPv6AddressNetwork myIPv6Network = new IPv6AddressNetwork() {
	@Override
	public PrefixConfiguration getPrefixConfiguration() {
		return PrefixConfiguration.ALL_PREFIXED_ADDRESSES_ARE_SUBNETS;
	}

	@Override
	protected IPv6AddressCreator createAddressCreator() {
		return new IPv6AddressCreator() {
			@Override
			public IPv6AddressSection createSection(byte bytes[], Integer prefix) {
				return new MyIPv6AddressSection(bytes, prefix);
			}

			@Override
			public IPv6AddressSegment createSegment(int value, Integer segmentPrefixLength) {
				return new MyIPv6AddressSegment(value, segmentPrefixLength);
			}

			@Override
			public IPv6AddressSegment createSegment(int lower, int upper, Integer segmentPrefixLength) {
```

```
                return new MyIPv6AddressSegment(lower, upper, segmentPrefixLength);
            }

            @Override
            protected IPv6AddressSegment createSegmentInternal(int value, Integer segmentPrefixLength, CharSequence addressStr, int 
originalVal,
                    boolean isStandardString, int lowerStringStartIndex, int lowerStringEndIndex) {
                return new MyIPv6AddressSegment(value, segmentPrefixLength);
            }

            @Override
            protected IPv6AddressSection createPrefixedSectionInternal(IPv6AddressSegment segments[], Integer prefix) {
                return new MyIPv6AddressSection(segments, prefix);
            }

            @Override
            protected IPv6AddressSection createSectionInternal(IPv6AddressSegment segments[]) {
                return new MyIPv6AddressSection(segments, 0, false);
            }

            @Override
            protected IPv6Address createAddressInternal(IPv6AddressSection section, HostIdentifierString from) {
                return new MyIPv6Address((MyIPv6AddressSection) section);
            }

            @Override
            protected IPv6Address createAddressInternal(IPv6AddressSection section, CharSequence zone, HostIdentifierString from) {
                return new MyIPv6Address((MyIPv6AddressSection) section, zone);
            }
        };
    }
};


IPAddressStringParameters params = new IPAddressStringParameters.Builder().
    getIPv6AddressParametersBuilder().setNetwork(myIPv6Network).getParentBuilder().toParams();
IPv6Address myAddr = new IPAddressString("1::1/64", params).getAddress().toIPv6();
```

Prefix Length and Equality

In this library, the subnet with prefix length 10.1.2.*/24 is equivalent the non-prefixed address 10.1.2.* as they both contain the same set of addresses. When it comes to equality or comparison, the prefix length has no effect. However, the prefix length is stored in the address, so an address or subnet with prefix length will be aware that it is "prefixed", printing strings that incorporate the prefix, or providing the network section upon calls to `getNetworkSection()` in `IPAddress`.

Given an address with no prefix length, you can convert to an address with prefix length using the methods `assignPrefixForSingleBlock()` or `assignMinPrefixForBlock()` in `IPAddress`, or any of the methods that allow you to set any given prefix length directly such as `setPrefixLength(int)`.

Address Sections

Addresses can be broken up into sections, and reconstituted from sections. A section is a series of segments. You can get the section for the full address by calling `getSection()`, or you can get subsections by calling one of the variants, either `getSection(int)` or `getSection(int, int)`, which return a subsection spanning the given indices. You can also get the segments in an address by calling `getSegment(int)` or one of the variants of `getSegments`, either on the address or on a section of the address.

You can also reconstitute an address from a section or array of segments using the appropriate address constructor, if your section or array of segments has the correct number of segments for the address type.

Host and Network Sections of IP Address

Use `getHostSection()` and `getNetworkSection()` to get the host and network sections of an IP address as indicated by prefix length.

```
IPAddress address = new IPAddressString("1.2.3.4").getAddress();
IPAddressSection network = address.getNetworkSection(16, true);
IPAddressSection host = address.getHostSection(16);
System.out.println(network.toCanonicalString());
System.out.println(host.toCanonicalString());
```

Output:

```
1.2/16
3.4
```

Once you have a section of an address, most of the same methods are available as those available with addresses themselves.

IP Address Operations

There are various methods for obtaining masking, subnets, and so on.

The methods `mask`, `maskNetwork`, `bitwiseOr`, `bitwiseOrNetwork`, `removePrefixLength`, `adjustPrefixBySegment`, `adjustPrefixLength`, `applyPrefixLength`, and `setPrefixLength` allow you to apply and adjust prefix lengths and masks to addresses and subnets. When applying an operation to a subnet, the operation is applied to every member of the subnet, so the result must something be representable with contiguous ranges, or you will get `IncompatibleAddressException` (formerly `AddressTypeException`). For instance, masking the subnet block of 255 addresses 0.0.0.0/24 with 0.0.0.128 results in the two addresses 0.0.0.0 and 0.0.0.128 which is not contiguous. However, this will not happen when using standard masking and subnetting techniques typical with IPv4 and IPv6 routing.

The following code demonstrates how to get the lowest address in a prefixed subnet using any one of three methods: `getLowest`, `mask`, or `removePrefixLength`.

```
String addr = "1.2.3.4";
IPAddress address = new IPAddressString(addr).getAddress();
int prefixLength = 16;
IPAddress maskWithPrefixLength = new IPAddressString("/" + prefixLength).
        getAddress(address.getIPVersion());

IPAddress mask = address.getNetwork().getNetworkMask(16, false);
System.out.println("mask with prefix length " + maskWithPrefixLength);
System.out.println("mask " + mask);

IPAddress maskedAddress = address.mask(mask);
System.out.println("address " + address + " masked " + maskedAddress);

//create the subnet
IPAddress subnet = address.applyPrefixLength(prefixLength).toPrefixBlock();

//mask
IPAddress maskedSubnet = subnet.mask(mask);
System.out.println("subnet " + subnet + " masked " + maskedSubnet);
System.out.println(maskedAddress.equals(maskedSubnet));

//getLower
IPAddress lowestAddressInSubnet = subnet.getLower();
System.out.println("lowest in subnet " + lowestAddressInSubnet);
System.out.println("lowest in subnet no prefix " + lowestAddressInSubnet.removePrefixLength(false));
System.out.println(maskedAddress.equals(lowestAddressInSubnet));

//removePrefixLength
IPAddress prefixRemoved = subnet.removePrefixLength(true);
System.out.println("prefix removed " + prefixRemoved);
```

Output:

```
mask with prefix length 255.255.0.0/16
mask 255.255.0.0
address 1.2.3.4 masked 1.2.0.0
subnet 1.2.0.0/16 masked 1.2.0.0
true
lowest in subnet 1.2.0.0/16
lowest in subnet no prefix 1.2.0.0
true
prefix removed 1.2.0.0
```

Polymorphism

Simply change the string `"1.2.3.4"` in the code above to an IPv6 address like `"a:ffff:b:c:d::f"` and the code all works the same.

Output:

```
mask with prefix length ffff::/16
mask ffff::
address a:ffff:b:c:d::f masked a::
subnet a::/16 masked a::
true
lowest in subnet a::/16
lowest in subnet no prefix a::
true
prefix removed a::
```

Summary of IP Address Operations

There are various additional methods for managing networks not listed above, as well as some additional operations that are available, such as:

- **`assignPrefixForSingleBlock`** (formerly `toPrefixedEquivalent`): Converts an address with wildcards to an equivalent address with a prefix length. The resulting address will span the same range of values as the original. You can use **`getPrefixLengthForSingleBlock`** (formerly `getEquivalentPrefix`) to get the resultant prefix prior to the operation, or **`isSinglePrefixBlock`** (formerly `isRangeEquivalentToPrefix`): to determine if the operation would have no effect on the address because it is already a single prefix block.
- **`assignMinPrefixForBlock`** (formerly `toMinPrefixedEquivalent`): Converts an address to an equivalent address with the smallest possible prefix length. The resulting address will span the same range of values as the original. You can use **`getMinPrefixLengthForBlock`** (formerly `getMinPrefix`) to get the resultant prefix prior to the operation.
- **`toPrefixBlock`** (formerly `isRangeEquivalent` and `isRangeUnchanged`): Provides the subnet for the entire prefix block using the existing or a supplied prefix length (`toPrefixBlock` with the existing prefix has no effect when using prefix configuration `ALL_PREFIXED_ADDRESSES_ARE_SUBNETS` because prefixed addresses are always already a prefix block). You can use **`isPrefixBlock`** to determine if the operation would have no effect on the address because it is already a prefix block.
- **`getBlockMaskPrefixLength`** (formerly `getMaskPrefixLength`): Will return the prefix length for a network or host mask, or null otherwise
- **`append`**, **`prepend`**, **`replace`**: Add or replace segments in sections and addresses. On addresses you must always maintain the correct number of segments, so only the replace operation is provided. You can obtain a section by either constructing one directly or by calling a variant of **`getSection`** on an address.
- **`adjustPrefixBySegment`**: Will create a larger network or smaller subnet address by increasing or decreasing the prefix length to the next segment boundary. If prefix length is increased, the additional prefix bits can be either zero or the full range of possible values.
- **`removePrefixLength, adjustPrefixLength, applyPrefixLength, setPrefixLength`**: Add, remove or adjust prefix lengths by the indicated values. There are variants to control whether extended prefix lengths have zeros for the added bits, or whether the bits remain full range.

The default behavior when extending a prefix length is to insert zeros in the bits added to the prefix. The difference between `applyPrefixLength` and `setPrefixLength` is that the former does not shorten a prefix length; `applyPrefixLength` will not decrease the size of a subnet.

- **`mask`, `maskNetwork`, `bitwiseOr`, `bitwiseOrNetwork`**: apply masks to subnets and addresses. The network variants allow you to mask just the network portion and apply a prefix length, while the others remove any existing prefix length.
- **`reverseBits`, `reverseBytes`, `reverseBytesPerSegment`, `reverseSegments`**: useful for handling endianness (network byte order sometimes requires bytes be reversed), or DNS lookup, or other reasons for reversing bits and bytes.
- **`subtract`**: Computes the subnet difference, the set of addresses in the subnet but not in the argument subnet. Subtracts a given subnet from the receiver subnet, returning an array of subnets for the result.
- **`intersect`**: Computes the subnet conjunction, the set of addresses in both the receiver subnet and the argument subnet.

Subnetting

Subnetting can be accomplished using various address manipulation methods. Given a prefixed IP address, you can extend the prefix length and insert bits for an extended prefix and new subnet of the previous address block, as shown in the following example.

```
int originalPrefix = 18, adjustment = 4;
IPAddress address = new IPAddressString("207.0.64.0").getAddress();
IPAddress address2 = address.setPrefixLength(originalPrefix);
IPAddress prefixExtension = new IPAddressString("0.0.4.0").getAddress();

IPAddress subnet1 = address2.adjustPrefixLength(adjustment);//extend the prefix length
System.out.println(subnet1);

IPAddress subnet2 = subnet1.bitwiseOrNetwork(prefixExtension, originalPrefix + adjustment); //adjust the extended prefix
System.out.println(subnet2);
```

Output:

```
207.0.64.0/18
207.0.64.0/22
207.0.68.0/22
```

Here is the same subnetting operation using segment replacement:

```
IPv4Address address = new IPAddressString("207.0.64.0/18").getAddress().toIPv4();
IPv4AddressSection replacementSection = new IPAddressString("0.0.68.0/22").getAddress().toIPv4().getSection(2);
IPAddress subnet = new IPv4Address(address.getSection().replace(2, replacementSection));
System.out.println(subnet);
```

Output:

```
207.0.68.0/22
```

Parse String Representation of MAC Address

Conversion is like IP address. `MACAddressString` is used to convert. You can use one of `getAddress` or `toAddress`, the difference being whether parsing errors are handled by exception or not.

```
MACAddress address = new MACAddressString("01:02:03:04:0a:0b").getAddress();
if(address != null) {
	//use address here
}
```

or

```
try {
	MACAddress address = new MACAddressString ("01:02:03:04:0a:0b").toAddress();
	//use address here
} catch (AddressStringException e) {
	String msg = e.getMessage();//detailed message indicating issue
}
```

Various Formats of MAC Addresses

MAC Addresses are expected to be in hexadecimal. However, there are a wide variety of accepted formats for MAC addresses:

```
aa:bb:cc:dd:ee:ff
aa-bb-cc-dd-ee-ff
aa bb cc dd ee ff
aabb.ccdd.eeff
aabbccddeeff
aabbcc-ddeeff
```

For the non-segmented format (`aabbccddeeff`), all 12 digits are required to avoid ambiguity. Additionally, MAC addresses can be either 48 or 64 bits, and so for each such format there is the 64-bit equivalent:

```
aa:bb:cc:dd:ee:ff:11:22
aa-bb-cc-dd-ee-ff-11-22
aa bb cc dd ee ff 11 22
aabb.ccdd.eeff.1122
aabbccddeeff1122
aabbcc-ddeeff1122
```

For the non-segmented 64-bit format (`aabbccddeeff1122`), all 16 digits are required to avoid ambiguity.

As with IP addresses, you can specify ranges using `‘*’` and `‘-’` like `aa-bb:*:*:cc:dd:ee.` The range character for addresses that use the dash `‘-’` character as a separator is `‘|’,` like `aa|bb-*-*-cc-dd-ee.`

Format Examples

For instance, the address 0a:0b:0c:0d:0e:0f can be represented many ways:

```
static void parseMAC(String formats[]) {
	for(String format : formats) {
		System.out.println(new MACAddressString(format).getAddress());
	}
}

public static void main(String[] args) {
	String formats[] = {
		"a:b:c:d:e:f",
		"0a:0b:0c:0d:0e:0f",
		"a:b:c:d:e:f",
		"0a-0b-0c-0d-0e-0f",
		"0a0b0c-0d0e0f",
		"0a0b.0c0d.0e0f",
		"0a 0b 0c 0d 0e 0f",
		"0a0b0c0d0e0f"
	};
	parseMAC(formats);
}
```

Output:

```
0a:0b:0c:0d:0e:0f
0a:0b:0c:0d:0e:0f
0a:0b:0c:0d:0e:0f
0a:0b:0c:0d:0e:0f
0a:0b:0c:0d:0e:0f
0a:0b:0c:0d:0e:0f
0a:0b:0c:0d:0e:0f
0a:0b:0c:0d:0e:0f
```

Ranges can be specified in the same way as for IP addresses (‘-’ for a specific range or ‘*’ for full range segments).

For instance, the address range `ff:0f:aa-ff:00-ff:00-ff:00-ff` can be represented many ways:

```
static void parseMAC(String formats[]) {
	for(String format : formats) {
		System.out.println(new MACAddressString(format).getAddress());
	}
}

public static void main(String[] args) {
	String formats[] = {
		"ff:f:aa-ff:00-ff:00-ff:00-ff",
		"ff:f:aa-ff:*:*:*",
		"ff:0f:aa-ff:*:*:*",
		"ff-0f-aa|ff-*-*-*",
		"ff0faa|ff0fff-*",
		"ff0f.aa00-ffff.*",
		"ff 0f aa-ff * * *",
		"ff0faa000000-ff0fffffffff"
	};
	parseMAC(formats);
}
```

Output:

```
ff:0f:aa-ff:*:*:*
ff:0f:aa-ff:*:*:*
ff:0f:aa-ff:*:*:*
ff:0f:aa-ff:*:*:*
ff:0f:aa-ff:*:*:*
ff:0f:aa-ff:*:*:*
ff:0f:aa-ff:*:*:*
ff:0f:aa-ff:*:*:*
```

Delimited Segments

The range formats allow you to specify ranges of values. However, if you wish to parse addresses in which values are delimited, then you can use the methods `parseDelimitedSegments(String)` and `countDelimitedAddresses(String)` in `MACAddressString`. `parseDelimitedSegments` will provide an iterator to traverse through the individual addresses.

For example, given "1,2:3:4,5:6:7:8", `countDelimitedAddresses` will return 4 for the possible combinations: "1:3:4:6:7:8", "1:3:5:6:7:8", "2:3:4:6:7:8" and "2:3:5:6:7:8". With each string obtained from `parseDelimitedSegments` you can construct a `MACAddressString` instance.

MAC Address Validation Options

Validation options allow you to restrict the allowed formats.

You have the class `MACAddressStringParameters` which can be passed into `MACAddressString`

You constrict validation options using the appropriate builder classes that are nested classes in the options classes. Here is an example:

```
MACAddressStringParameters MAC_ADDRESS_OPTIONS_EXAMPLE = new MACAddressStringParameters.Builder().
            allowEmpty(false).
             allowAll(false).
             getFormatBuilder().
                  setRangeOptions(RangeParameters.NO_RANGE).
                  allowLeadingZeros(true).
                  allowUnlimitedLeadingZeros(false).
                  allowWildcardedSeparator(false).
                  allowShortSegments(true).
             getParentBuilder().
             toParams();
```

The default options used by the library are permissive and not restrictive.

MAC Address Prefix Lengths

Prefix length in this library is defined general as the bit-length of the portion of the address that is not specific to an individual address but common amongst a group of addresses. For IP addresses, this is explicitly defined as part of the address using the '/' character. For IP addresses, the prefix is potentially variable and depends on how subnets have been allocated.

MAC Addresses don't have the exact same concept of prefix length as IP addresses. But concept of prefix can be applied in a more implicit sense. For instance, a MAC address is typically divided into an OUI (Organizationally Unique Identifier) and ODI (Organizational Defined Identifier), so you might consider the OUI bits as the prefix. There are other ways of assigning MAC address blocks as well, such as IAB (individual address block), or MA-S/MA-M/MA-L (MAC Address block small, medium, and large), in which a certain number of higher bits are provided as an identifier to organizations from which they can create various extended identifiers using the lower bits. There is generally a pre-defined set of high bits that can be considered a prefix. This prefix is not variable and was typically assigned by the IEEE. However, there is no explicit way to represent a MAC address with an associated prefix, so the prefix is implicit to the address when it is created.

Within this library, the prefix for a MAC address is defined as the largest number of high bits for which an address represents all addresses with the same set of higher bits.

For instance, the prefix length of aa:*:*:*:*:* is 8 because the address represents all addresses that start with the same 8 bits "aa". The prefix length of aa:*:cc:*:*:* is 24 because the address represents all addresses that start with the same 16 bits aa:*:cc. The address aa:bb:cc:dd:ee:ff does not have a prefix or prefix length as it represents just a single address.

Once a MAC address as an associated prefix length, that prefix length remains the same when any operations are applied to the address.

In summary, on the MAC side, the prefix length is implicit and based upon the address, while on the IP address side, the prefix length is explicitly defined.

MAC Address Operations

Many of the same address operations available for IP addresses are available for MAC addresses, including the prefix operations (although prefixes have somewhat different meaning for MAC as described in the previous section of this document), the section and segment access methods, iterators, containment, and reversal of bits, bytes and segments.

The reverse operations are useful for for "MSB format", "IBM format", "Token-Ring format", and "non-canonical form", where the bits are reversed in each byte of a MAC address.

IPv6 – MAC Address Integration

There is a standardized procedure for converting MAC addresses to IPv6 given a IPv6 64 bit prefix, as described in IETF RFC 2464, RFC 3513, and RFC 4944.

It details how to combine a 48 bit MAC address with a 64 bit IPv6 network prefix to produce a 128 bit IPv6 address. This is done by first constructing a 64-bit extended unique IPv6 interface identifier (EUI-64) from the MAC address. This library has implemented the same MAC / IPv6 integration in multiple ways.

Starting with a MAC address or section and with the IPv6 prefix, you can construct an IPv6 address.

```
public IPv6Address(IPv6Address prefix, MACAddress eui)
public IPv6Address(IPv6AddressSection section, MACAddress eui)
public IPv6Address(IPv6AddressSection section, MACAddressSection eui)
public IPv6Address(IPv6AddressSection section, MACAddressSection eui, CharSequence zone)
```

There are equivalent methods in the class `MACAddress` for producing the link local address which has a pre-defined prefix, or for producing the host (interface identifier) address section of an IPv6 address.

```
public IPv6Address toLinkLocalIPv6()
public IPv6AddressSection toEUI64IPv6()
```

There is a similar method in MACAddressSection

```
public IPv6AddressSection toEUI64IPv6()
```

A MAC address is either 48 or 64 bits. To be converted to IPv6, the 48 bit address has segments inserted (two 1 byte MAC segments with value 0xfffe) to extend the address to 64 bits. For a 64 bit MAC address to be convertible, those same two segments must match the expected value of 0xffe. The following methods in `MACAddress` check will 64 bit addresses to ensure that are compatible with IPv6 by checking that the value of those two segments matches 0xfffe. Note that the `asMAC` argument allows you to extend using 0xffff rather than 0xfffe which is another manner by which a 48 bit MAC address can be extended to 64 bits. However, for purposes of extending to an IPv6 address the argument should be `false` so that the EUI-64 format is used.

```
public boolean isEUI64(boolean asMAC)
public MACAddress toEUI64(boolean asMAC)
```

There are similar methods in `MACAddressSection`

```
public boolean isEUI64(boolean asMAC)
public boolean isEUI64(boolean asMAC, boolean partial)
public MACAddressSection toEUI64(boolean asMAC)
```

Given an existing EUI-64 section you can use the prepend and append methods to create a full IPv6 address section containing all segments:

```
public IPv6AddressSection prepend(IPv6AddressSection other)
public IPv6AddressSection append(IPv6AddressSection other)
```

and from there you just construct the address:

```
public IPv6Address(IPv6AddressSection section)
```

To go the reverse direction IPv6 to MAC, there is a method in `IPv6Address` to produce a MAC address:

```
public MACAddress toEUI(boolean extended)
```

and another in `IPv6AddressSection` that uses whatever part of the interface identifier is included in the section to produce a MAC address section:

```
public MACAddressSection toEUI(boolean extended)
```

For instance, if the IPV6 address section is the 8 bytes corresponding to the network prefix of an IPV6 address section, then the resulting MAC address section will be 0 bytes. If the IPV6 address section is the 8 bytes corresponding to the interface identifier, and that identifier has the required 0xfffe values in the 5th and 6th bytes, then the MAC address section will be the full 8 bytes of an EUI-64 MAC address.

The following code is an example of constructing IPv6 addresses from a MAC address:

```
public static void main(String args[]) {
	MACAddressString macStr = new MACAddressString("aa:bb:cc:dd:ee:ff");
	MACAddress macAddress = macStr.getAddress();
	IPv6Address linkLocal = macAddress.toLinkLocalIPv6();
	System.out.println(linkLocal);

	IPAddressString ipv6Str = new IPAddressString("1111:2222:3333:4444::/64");
	IPv6Address ipv6Address = ipv6Str.getAddress().toIPv6();
	IPv6Address macIpv6 = new IPv6Address(ipv6Address, macAddress);
	System.out.println(macIpv6);
}
```

Output:

```
fe80::a8bb:ccff:fedd:eeff
1111:2222:3333:4444:a8bb:ccff:fedd:eeff/64
```

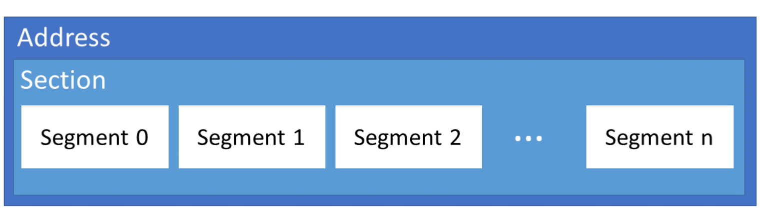
Address Framework

Much like there is a Java collections framework, there is an address framework to the IPAddress library. It is a unified set of inter-related interfaces, abstract implementations, and algorithms for all addresses and address components. It allows you to manipulate these items independently of implementation details, and provides standard interfaces to addresses and address components for code reuse and polymorphism. It represents the common structure of addresses, sections, segments, and so on.

You might wish to manipulate address components of different shapes and sizes transparently, or you may wish to manipulate different types of addresses or different address versions transparently. One element of the interface is the ability to convert any address component to bytes, whether division, segment, section, or address.

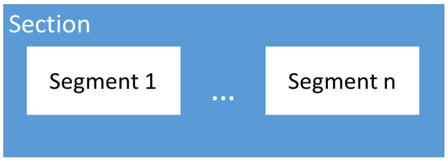
There is a hierarchy for the standard Address and Address Component data structures, which are addresses, sections of addresses, and segments of equal byte size inside those address sections.

Segments are equal length, each an exact number of bytes



Examples
IPv4: 0.0.255.255
IPv6: fe80:0:0:0:204:61ff:aaab:bbbb
MAC: aa-bb-cc-dd-ee-ff

Sections have a variable number of segments

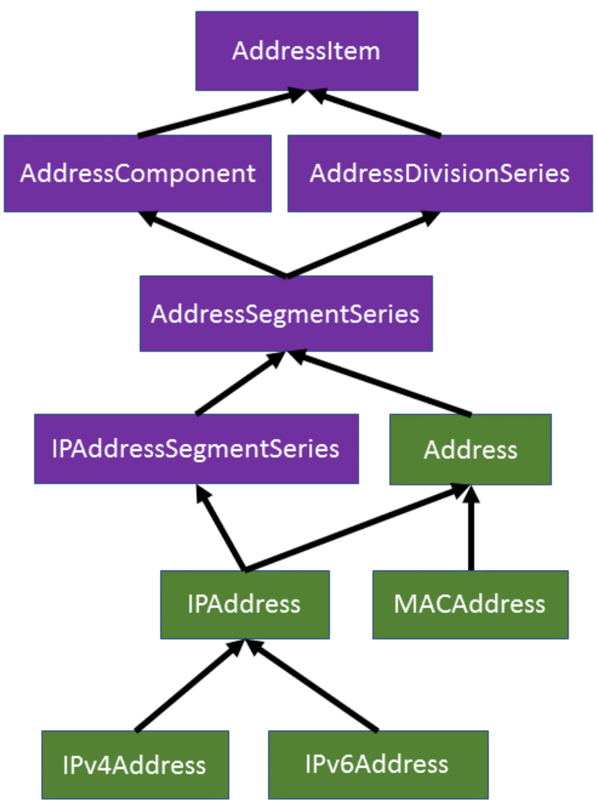


There is a more diversified hierarchy for non-standard address structures, in which addresses or address sections might be divided into divisions of unequal length, or of non-integral bytesize.

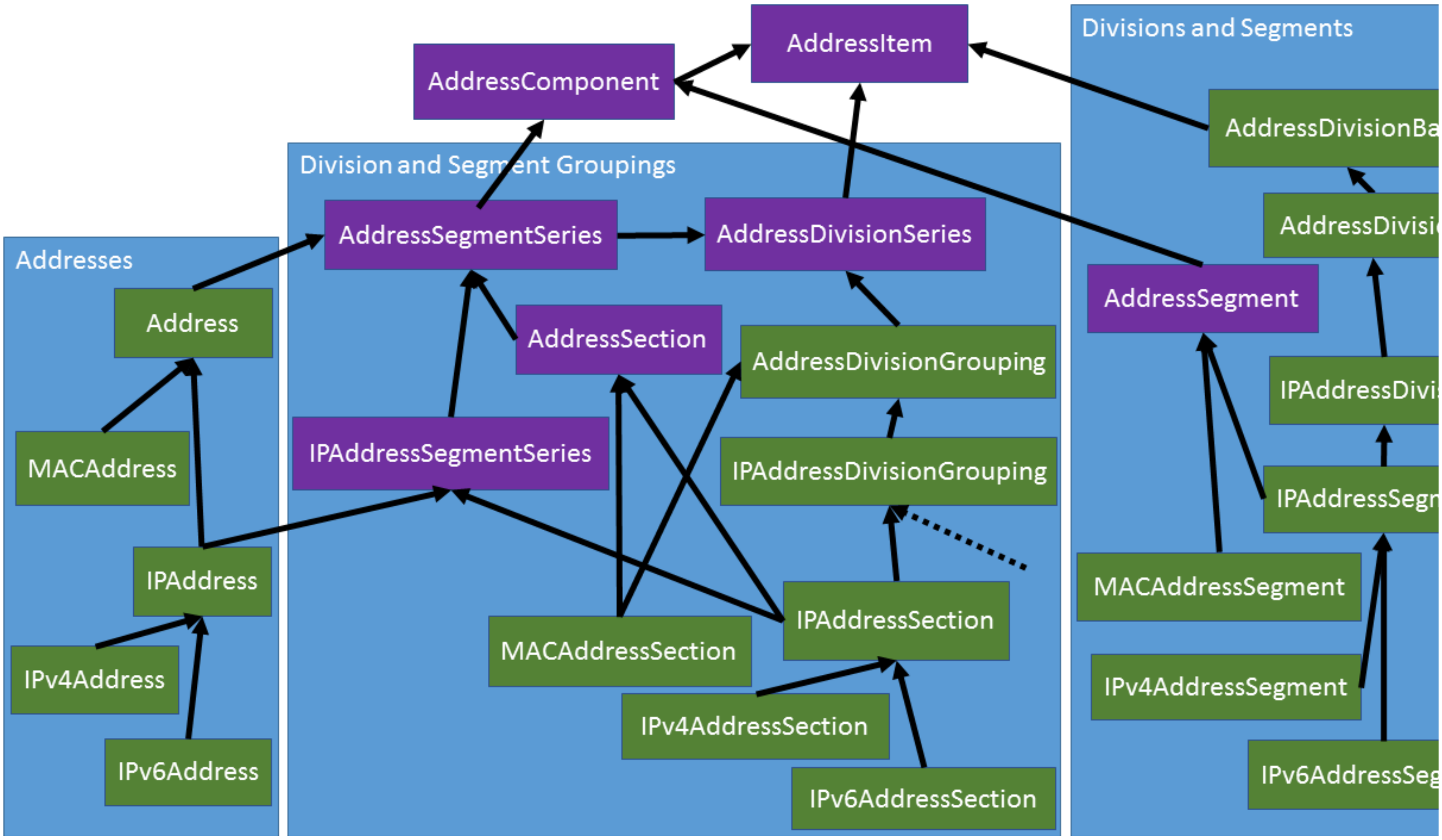
Addresses can be split into sections or reconstituted into division groupings.
Divisions need not be equal length, nor start and end on byte boundaries

Examples
IPv4: 0.0.65535
IPv6 with IPv4 embedded: fe80:0:0:0:204:61ff:254.157.241.86

The address hierarchy of interfaces (purple) and classes (green) is shown:



The full class hierarchy showing addresses, sections, division groupings, segments and divisions is shown here, separated into the three primary categories shown above. The dashed lines indicate there are a few less-prominent classes in the library not shown in the diagram.



Conversion to String Representation of Address

AddressSegmentSeries objects (such as Address and AddressSection) have methods that produce strings in various formats: `toCanonicalString`, `toNormalizedString`, `toCompressedString`, and `toHexString`.

```
	public static void main(String[] args) {
		printStrings(new MACAddressString("a:bb:c:dd:e:ff").getAddress());
		printStrings(new MACAddressString("a:bb:c:*").getAddress());
		printStrings(new IPAddressString("a:bb:c::/64").getAddress());
		printStrings(new IPAddressString("1.2.3.4").getAddress());
		printStrings(new IPAddressString("1.2.0.0/16").getAddress());
		printStrings(new IPAddressString("a:bb:c::dd:e:ff").getAddress());
	}
	static void printStrings(AddressSegmentSeries series) {
		System.out.println(series.toCanonicalString());
		System.out.println(series.toNormalizedString());
		System.out.println(series.toCompressedString());
		System.out.println(series.toHexString(true));
		System.out.print("lower: " + series.getLower() + " bytes:");
		System.out.println(Arrays.toString(series.getBytes()));
		System.out.print("upper: " + series.getUpper() + " bytes:");
		System.out.println(Arrays.toString(series.getUpperBytes()));
		System.out.println();
	}
```

Output:

```
0a-bb-0c-dd-0e-ff
0a:bb:0c:dd:0e:ff
a:bb:c:dd:e:ff
0x0abb0cdd0eff
lower: 0a:bb:0c:dd:0e:ff bytes:[10, -69, 12, -35, 14, -1]
upper: 0a:bb:0c:dd:0e:ff bytes:[10, -69, 12, -35, 14, -1]

0a-bb-0c-*-*-*
0a:bb:0c:*:*:*
a:bb:c:*:*:*
0x0abb0c000000-0x0abb0cffffff
lower: 0a:bb:0c:00:00:00 bytes:[10, -69, 12, 0, 0, 0]
upper: 0a:bb:0c:ff:ff:ff bytes:[10, -69, 12, -1, -1, -1]

a:bb:c::/64
a:bb:c:0:0:0:0:0/64
a:bb:c::/64
0x000a00bb000c00000000000000000000-0x000a00bb000c0000ffffffffffffffff
lower: a:bb:c:0:0:0:0:0 bytes:[0, 10, 0, -69, 0, 12, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0]
upper: a:bb:c:0:ffff:ffff:ffff:ffff bytes:[0, 10, 0, -69, 0, 12, 0, 0, -1, -1, -1, -1, -1, -1, -1, -1]
```

```
1.2.3.4
1.2.3.4
1.2.3.4
0x01020304
lower: 1.2.3.4 bytes:[1, 2, 3, 4]
upper: 1.2.3.4 bytes:[1, 2, 3, 4]

1.2.0.0/16
1.2.0.0/16
1.2.0.0/16
0x01020000-0x0102ffff
lower: 1.2.0.0 bytes:[1, 2, 0, 0]
upper: 1.2.255.255 bytes:[1, 2, -1, -1]

a:bb:c::dd:e:ff
a:bb:c:0:0:dd:e:ff
a:bb:c::dd:e:ff
0x000a00bb000c0000000000dd000e00ff
lower: a:bb:c:0:0:dd:e:ff bytes:[0, 10, 0, -69, 0, 12, 0, 0, 0, 0, 0, -35, 0, 14, 0, -1]
upper: a:bb:c:0:0:dd:e:ff bytes:[0, 10, 0, -69, 0, 12, 0, 0, 0, 0, 0, -35, 0, 14, 0, -1]
```

The `IPAddress` and `IPAddressSection` classes and their version-specific subclasses have additional methods to produce specific strings representing the address:

```java
public static void main(String[] args) {
	IPAddress address = new IPAddressString("a:b:c::e:f").getAddress();
	print(address);
	address = new IPAddressString("a:b:c::").getAddress();
	print(address);

	/a:b:c:*:: cannot be represented as a range of two single values
	//so this throws exception in toBase85String(), toBinaryString(), and toHexString()
	address = new IPAddressString("a:b:c:*::").getAddress();
	print(address);
}

static void print(IPAddress address) {
	System.out.println(address.toCanonicalString());
	System.out.println(address.toFullString());
	System.out.println(address.toNormalizedString());
	System.out.println(address.toSQLWildcardString());
	System.out.println(address.toSubnetString());
	try {
		if(address.isIPv6()) {
			System.out.println(address.toIPv6().toMixedString());
			System.out.println(address.toIPv6().toBase85String());
		}
		System.out.println(address.toBinaryString());
		System.out.println(address.toHexString(true));
	} catch(IncompatibleAddressException e) {}
	System.out.println();
}
```

Output:

```
a:b:c::e:f
000a:000b:000c:0000:0000:0000:000e:000f
a:b:c:0:0:0:e:f
a:b:c:0:0:0:e:f
a:b:c::e:f
a:b:c::0.14.0.15
00|N0s0$N0-%*(tF74+!
00000000000010100000000000001011000000000000110000000000000000000000000000000000000000000000000000000000000011100000000000001111
0x000a000b000c000000000000000e000f

a:b:c::
000a:000b:000c:0000:0000:0000:0000:0000
a:b:c:0:0:0:0:0
a:b:c:0:0:0:0:0
a:b:c::
a:b:c::
00|N0s0$N0-%*(tF5l-X
00000000000010100000000000001011000000000000110000000000000000000000000000000000000000000000000000000000000000000000000000000000
0x000a000b000c00000000000000000000

a:b:c:*::
000a:000b:000c:0000-ffff:0000:0000:0000:0000
a:b:c:*:0:0:0:0
a:b:c:%:0:0:0:0
a:b:c:*::
a:b:c:*::
```

IPv6 string methods

There are additional methods for Ipv6, the methods `toMixedString()` and `toBase85String()`

UNC Strings

The method `toUNCHostName()` produces the UNC IP-literal string.

```java
IPAddressString ipAddressString = new IPAddressString("2001:db8::1");
IPAddress address = ipAddressString.getAddress();
System.out.println(address.toUNCHostName());

ipAddressString = new IPAddressString("1.2.3.4");
address = ipAddressString.getAddress();
System.out.println(address.toUNCHostName());
```

Output:

```
2001-db8-0-0-0-0-0-1.ipv6-literal.net
1.2.3.4
```

DNS Lookup Strings

The methods `toReverseDNSLookupString()` will produce a string for DNS lookup. If you wish to do a DNS lookup for a subnet rather than a full address, you can use `getNetworkSection()` to provide the network section you wish to lookup. You can specify the prefix length in either the string itself or the call to get the network section.

```java
IPAddressString ipAddressString = new IPAddressString("2001:db8::1");
IPAddress address = ipAddressString.getAddress();
System.out.println(address.toReverseDNSLookupString());

IPAddressSection addressSection = address.getNetworkSection(64);
System.out.println(addressSection.toReverseDNSLookupString());

//same with prefix
ipAddressString = new IPAddressString("2001:db8::1/64");
address = ipAddressString.getAddress();
System.out.println(address.toReverseDNSLookupString());

addressSection = address.getNetworkSection();
System.out.println(addressSection.toReverseDNSLookupString());

//prefix block
ipAddressString = new IPAddressString("2001:db8::/64");
address = ipAddressString.getAddress();
System.out.println(address.toReverseDNSLookupString());

addressSection = address.getNetworkSection();
System.out.println(addressSection.toReverseDNSLookupString());
```

Output:

```
1.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.8.b.d.0.1.0.0.2.ip6.arpa
0.0.0.0.0.0.0.0.8.b.d.0.1.0.0.2.ip6.arpa
1.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.8.b.d.0.1.0.0.2.ip6.arpa
0.0.0.0.0.0.0.0.8.b.d.0.1.0.0.2.ip6.arpa
*.*.*.*.*.*.*.*.*.*.*.*.*.*.*.*.0.0.0.0.0.0.0.0.8.b.d.0.1.0.0.2.ip6.arpa
0.0.0.0.0.0.0.0.8.b.d.0.1.0.0.2.ip6.arpa
```

General String Methods

The methods `toCanonicalString` and `toCompressedString` are available for any address or address section.

The methods `toHexString` and `toNormalizedString` are available for any address component.

Avoiding Prefix Length Indicator in Strings

To choose to print wildcards '*' and range characters '-' as opposed to using prefix length, there are additional methods:

```java
public static void main(String[] args) {
	IPAddress address = new IPAddressString("a:b:c::/64").getAddress();
	print(address);
	address = new IPAddressString("a:b:c:*::/64").getAddress();
	print(address);
}

static void print(IPAddress address) {
	System.out.println(address.toCanonicalString());
	System.out.println(address.toCanonicalWildcardString());
	System.out.println(address.toFullString());
	System.out.println(address.toNormalizedString());
	System.out.println(address.toSQLWildcardString());
	System.out.println();
}
```

Output:

```
a:b:c::/64
a:b:c:0:*:*:*:*
000a:000b:000c:0000:0000:0000:0000:0000/64
a:b:c:0:0:0:0:0/64
a:b:c:0:%:%:%:%

a:b:c:*::/64
a:b:c:*:*:*:*:*
000a:000b:000c:0000-ffff:0000:0000:0000:0000/64
```

```
a:b:c:*:0:0:0:0/64
a:b:c:%:%:%:%:%
```

IP Version-dependent Strings

Some strings are version-dependent:

```
public static void main(String[] args) {
	//toSubnetString() prefers '*' for IPv4 and prefix for IPv6
	System.out.println(new IPAddressString("1.2.0.0/16").getAddress().toSubnetString());
	System.out.println(new IPAddressString("a:b::/64").getAddress().toSubnetString());

	//converts IPv4-mapped to a:b:c:d:e:f:1.2.3.4 notation
	System.out.println(new IPAddressString("::ffff:a:b").getAddress().toConvertedString());
}
```

Output:

```
1.2.*.*
a:b::/64
::ffff:0.10.0.11
```

Collections of IP Address Strings

Alternatively, you can produce collections of strings:

```
public static void main(String[] args) {
	IPAddress address = new IPAddressString("a:b:c::e:f").getAddress();
	print(address);
}

private static void print(IPAddress address) {
	//print(address.toAllStrings()); produces many strings
	print(address.toStandardStrings());
	print(new String[] {""});
}

public static void print(String strings[]) {
	for(String str : strings) {
		System.out.println(str);
	}
}
```

Output:

```
a:b:c:0:0:0:0.14.0.15
a:b:c:0:0:0:000.014.000.015
000a:000b:000c:0000:0000:0000:0.14.0.15
000a:000b:000c:0000:0000:0000:000.014.000.015
A:B:C:0:0:0:0.14.0.15
A:B:C:0:0:0:000.014.000.015
000A:000B:000C:0000:0000:0000:0.14.0.15
000A:000B:000C:0000:0000:0000:000.014.000.015
a:b:c::0.14.0.15
a:b:c::000.014.000.015
000a:000b:000c::0.14.0.15
000a:000b:000c::000.014.000.015
A:B:C::0.14.0.15
A:B:C::000.014.000.015
000A:000B:000C::0.14.0.15
000A:000B:000C::000.014.000.015
a:b:c:0:0:0:e:f
000a:000b:000c:0000:0000:0000:000e:000f
A:B:C:0:0:0:E:F
000A:000B:000C:0000:0000:0000:000E:000F
a:b:c::e:f
000a:000b:000c::000e:000f
A:B:C::E:F
000A:000B:000C::000E:000F
```

The String collections can be customized with `toNormalizedString(StringOptions params)`

Note that string collections never have duplicate strings. The String collections can be customized with `toStrings(IPStringBuilderOptions options)`.

Searching Text of Databases for all Addresses in a Subnet

Suppose you wanted to search for all addresses from a subnet in a large amount of text data. For instance, suppose you wanted to search for all addresses in the text from the subnet a:b:0:0::/64. You can start a representation of just the network prefix section of the address, then you can get all such strings for that prefix.

```
IPAddressSection prefix = new IPAddressString("a:b::").getAddress().
	getNetworkSection(64, false);
String strings[] = prefix.toStandardStringCollection().toStrings();
for(String str : strings) {
	System.out.println(str);
}
```

Output:

```
a:b:0:0
000a:000b:0000:0000
A:B:0:0
000A:000B:0000:0000
a:b::
000a:000b::
A:B::
000A:000B::
```

If you need to be more stringent or less stringent about the address formats you wish to search, then you can use `toStringCollection(IPStringBuilderOptions options)` with an instance of `IPv6StringBuilderOptions`.

Searching for those strings will find the subnet addresses. However, you may get a few false positives, like "a:b::d:e:f:a:b". To eliminate the false positives, you can just emulate in Java the SQL code produced below for the SQL database search, using substrings constructed from the segment separators.

For a MySQL database search:

```
public static void main(String[] args) {
	IPAddressSection prefix = new IPAddressString("a:b::").
		getAddress().getNetworkSection(64, false);
	StringBuilder sql = new StringBuilder("Select rows from table where ");
	prefix.getStartsWithSQLClause(sql, "column1");
	System.out.println(sql);
}
```

Output:

```
Select rows from table where ((substring_index(column1,':',4) = 'a:b:0:0') OR ((substring_index(column1,':',3) = 'a:b:') AND (LENGTH (column1) - LENGTH(REPLACE(column1, ':', '')) <= 6)))
```

For IPv4, another way to search for a subnet like 1.2.0.0/16 would be to do a SELECT with the following string

```
public static void main(String[] args) {
	String wildcardString = new IPAddressString("1.2.0.0/16").
		getAddress().toSQLWildcardString();
	System.out.println(wildcardString);
}
```

Output:

```
1.2.%.%
```

Then your SQL search string would be like:

```
Select rows from table where column1 like 1.2.%.%
```

Containment and Subnet Membership

To check whether an IP address is contained by a subnet:

```
IPAddress address = new IPAddressString("1.2.0.0/16").getAddress();
System.out.println(address.contains(new IPAddressString("1.2.3.4").getAddress()));
System.out.println(address.contains(new IPAddressString("1.2.3.0/24").getAddress()));
System.out.println(address.contains(new IPAddressString("1.2.3.0/25").getAddress()));
System.out.println(address.contains(new IPAddressString("1.1.0.0").getAddress()));
```

Output:

```
true
true
true
false
```

The contains method is not restricted to IP addresses or IP address prefixed addresses. There is a `contains` method for every `Address` or `AddressSection`.

There is also an assortment of iterators for addresses, sections, and segments which represent multiple values. There is an `iterator()`, `getLower()` method and `getUpper()` method for every address component.

DNS Resolution and URLs

If you have a string that can be a host or an address and you wish to resolve to an address, create a `HostName` and use `HostName.toResolvedAddress()`. If you wish to obtain a string representation to be part of a URL, use `HostName.toNormalizedString()`.

Sorting and Comparisons

Comparing and sorting can be useful for storing addresses in certain types of data structures. All of the core classes implement `java.lang.Comparable`. Different representations of the same address or subnet are considered equal. Different representations of the same set of addresses are considered equal. However, `HostName` instances, `IPAddressString` instances, and `IPAddress` instances are not equal even when representing the same address or subnet.

The library provides `IPAddressComparator` and some implementations for comparison purposes. `IPAddress` uses the subclass `CountComparator`. When comparing subnets, you can either emphasize the count of addresses, or you can emphasize the values of the lower or upper address represented by the subnet, and comparators are provided for those variations.

Cache Classes

The `IPAddressNetwork` class defines `IPAddressStringCache` and `HostNameCache`. These cache classes allow you to cache identifier strings. Note that identifier strings will cache their associated addresses, whether parsed or resolved. Also note that addresses cache their associated strings and various other objects. Therefore, these cache classes go a long way towards allowing you to avoid creating the same objects and running the same code frequently. These caches do quick lookups using either bytes or strings, which might be ideal for some applications that handle many addresses or host names.