Developer Guide

Welcome to the developer documentation for protocol buffers – a language-neutral, platform-neutral, extensible way of serializing structured data for use in communications protocols, data storage, and more.

This documentation is aimed at Java, C++, or Python developers who want to use protocol buffers in their applications. This overview introduces protocol buffers and tells you what you need to do to get started – you can then go on to follow the tutorials or delve deeper into protocol buffer encoding. API reference documentation is also provided for all three languages, as well as language and style guides for writing `.proto` files.

What are protocol buffers?

Protocol buffers are a flexible, efficient, automated mechanism for serializing structured data – think XML, but smaller, faster, and simpler. You define how you want your data to be structured once, then you can use special generated source code to easily write and read your structured data to and from a variety of data streams and using a variety of languages. You can even update your data structure without breaking deployed programs that are compiled against the "old" format.

How do they work?

You specify how you want the information you're serializing to be structured by defining protocol buffer message types in `.proto` files. Each protocol buffer message is a small logical record of information, containing a series of name-value pairs. Here's a very basic example of a `.proto` file that defines a message containing information about a person:

```
message Person {
  required string name = 1;
  required int32 id = 2;
  optional string email = 3;

  enum PhoneType {
    MOBILE = 0;
    HOME = 1;
    WORK = 2;
  }

  message PhoneNumber {
    required string number = 1;
    optional PhoneType type = 2 [default = HOME];
  }

  repeated PhoneNumber phone = 4;
}
```

As you can see, the message format is simple – each message type has one or more uniquely numbered fields, and each field has a name and a value type, where value types can be numbers (integer or floating-point), booleans, strings, raw bytes, or even (as in the example above) other protocol buffer message types, allowing you to structure your data hierarchically. You can specify optional fields, required fields, and repeated fields. You can find more information about writing `.proto` files in the Protocol Buffer Language Guide.

Once you've defined your messages, you run the protocol buffer compiler for your application's language on your `.proto` file to generate data access classes. These provide simple accessors for each field (like `query()` and `set_query()`) as well as methods to serialize/parse the whole structure to/from raw bytes – so, for instance, if your chosen language is C++, running the compiler on the above example will generate a class called `Person`. You can then use this class in your application to populate, serialize, and retrieve `Person` protocol buffer messages. You might then write some code like this:

```
Person person;
person.set_name("John Doe");
person.set_id(1234);
person.set_email("jdoe@example.com");
fstream output("myfile", ios::out | ios::binary);
person.SerializeToOstream(&output);
```

Then, later on, you could read your message back in:

```
fstream input("myfile", ios::in | ios::binary);
Person person;
person.ParseFromIstream(&input);
cout << "Name: " << person.name() << endl;
cout << "E-mail: " << person.email() << endl;
```

You can add new fields to your message formats without breaking backwards-compatibility; old binaries simply ignore the new field when parsing. So if you have a communications protocol that uses protocol buffers as its data format, you can extend your protocol without having to worry about breaking existing code.

You'll find a complete reference for using generated protocol buffer code in the API Reference section, and you can find out more about how protocol buffer messages are encoded in Protocol Buffer Encoding.

Why not just use XML?

Protocol buffers have many advantages over XML for serializing structured data. Protocol buffers:

- are simpler
- are 3 to 10 times smaller
- are 20 to 100 times faster
- are less ambiguous
- generate data access classes that are easier to use programmatically

For example, let's say you want to model a `person` with a `name` and an `email`. In XML, you need to do:

```
<person>
  <name>John Doe</name>
  <email>jdoe@example.com</email>
</person>
```

while the corresponding protocol buffer message (in protocol buffer text format) is:

```
# Textual representation of a protocol buffer.
# This is *not* the binary format used on the wire.
person {
  name: "John Doe"
  email: "jdoe@example.com"
}
```

When this message is encoded to the protocol buffer binary format (the text format above is just a convenient human-readable representation for debugging and editing), it would probably be 28 bytes long and take around 100-200 nanoseconds to parse. The XML version is at least 69 bytes if you remove whitespace, and would take around 5,000-10,000 nanoseconds to parse.

Also, manipulating a protocol buffer is much easier:

```
  cout << "Name: " << person.name() << endl;
  cout << "E-mail: " << person.email() << endl;
```

Whereas with XML you would have to do something like:

```
  cout << "Name: "
       << person.getElementsByTagName("name")->item(0)->innerText()
       << endl;
  cout << "E-mail: "
       << person.getElementsByTagName("email")->item(0)->innerText()
       << endl;
```

However, protocol buffers are not always a better solution than XML – for instance, protocol buffers would not be a good way to model a text-based document with markup (e.g. HTML), since you cannot easily interleave structure with text. In addition, XML is human-readable and human-editable; protocol buffers, at least in their native format, are not. XML is also – to some extent – self-describing. A protocol buffer is only meaningful if you have the message definition (the `.proto` file).

Sounds like the solution for me! How do I get started?

Download the package – this contains the complete source code for the Java, Python, and C++ protocol buffer compilers, as well as the classes you need for I/O and testing. To build and install your compiler, follow the instructions in the README.

Once you're all set, try following the tutorial for your chosen language – this will step you through creating a simple application that uses protocol buffers.

A bit of history

Protocol buffers were initially developed at Google to deal with an index server request/response protocol. Prior to protocol buffers, there was a format for requests and responses that used hand marshalling/unmarshalling of requests and responses, and that supported a number of versions of the protocol. This resulted in some very ugly code, like:

```
if (version == 3) {
  ...
} else if (version > 4) {
  if (version == 5) {
    ...
  }
  ...
}
```

Explicitly formatted protocols also complicated the rollout of new protocol versions, because developers had to make sure that all servers between the originator of the request and the actual server handling the request understood the new protocol before they could flip a switch to start using the new protocol.

Protocol buffers were designed to solve many of these problems:

- New fields could be easily introduced, and intermediate servers that didn't need to inspect the data could simply parse it and pass through the data without needing to know about all the fields.
- Formats were more self-describing, and could be dealt with from a variety of languages (C++, Java, etc.)

However, users still needed to hand-write their own parsing code.

As the system evolved, it acquired a number of other features and uses:

- Automatically-generated serialization and deserialization code avoided the need for hand parsing.
- In addition to being used for short-lived RPC (Remote Procedure Call) requests, people started to use protocol buffers as a handy self-describing format for storing data persistently (for example, in Bigtable).
- Server RPC interfaces started to be declared as part of protocol files, with the protocol compiler generating stub classes that users could override with actual implementations of the server's interface.

Protocol buffers are now Google's *lingua franca* for data – at time of writing, there are 48,162 different message types defined in the Google code tree across 12,183 `.proto` files. They're used both in RPC systems and for persistent storage of data in a variety of storage systems.

Last updated 四月 *2, 2012.*

Language Guide

This guide describes how to use the protocol buffer language to structure your protocol buffer data, including `.proto` file syntax and how to generate data access classes from your `.proto` files.

This is a reference guide – for a step by step example that uses many of the features described in this document, see the tutorial for your chosen language.

Defining A Message Type

First let's look at a very simple example. Let's say you want to define a search request message format, where each search request has a query string, the particular page of results you are interested in, and a number of results per page. Here's the `.proto` file you use to define the message type.

```
message SearchRequest {
  required string query = 1;
  optional int32 page_number = 2;
  optional int32 result_per_page = 3;
}
```

The `SearchRequest` message definition specifies three fields (name/value pairs), one for each piece of data that you want to include in this type of message. Each field has a name and a type.

Specifying Field Types

In the above example, all the fields are scalar types: two integers (`page_number` and `result_per_page`) and a string (`query`). However, you can also specify composite types for your fields, including enumerations and other message types.

Assigning Tags

As you can see, each field in the message definition has a **unique numbered tag**. These tags are used to identify your fields in the message binary format, and should not be changed once your message type is in use. Note that tags with values in the range 1 through 15 take one byte to encode, including the identifying number and the field's type (you can find out more about this in Protocol Buffer Encoding). Tags in the range 16 through 2047 take two bytes. So you should reserve the tags 1 through 15 for very frequently occurring message elements. Remember to leave some room for frequently occurring elements that might be added in the future.

The smallest tag number you can specify is 1, and the largest is 2^{29} - 1, or 536,870,911. You also cannot use the numbers 19000 though 19999 (`FieldDescriptor::kFirstReservedNumber` through `FieldDescriptor::kLastReservedNumber`), as they are reserved for the Protocol Buffers implementation - the protocol buffer compiler will complain if you use one of these reserved numbers in your `.proto`.

Specifying Field Rules

You specify that message fields are one of the following:

- `required`: a well-formed message must have exactly one of this field.
- `optional`: a well-formed message can have zero or one of this field (but not more than one).
- `repeated`: this field can be repeated any number of times (including zero) in a well-formed message. The order of the repeated values will be preserved.

For historical reasons, `repeated` fields of basic numeric types aren't encoded as efficiently as they could be. New code should use the special option `[packed=true]` to get a more efficient encoding. For example:

```
repeated int32 samples = 4 [packed=true];
```

> **Required Is Forever** You should be very careful about marking fields as `required`. If at some point you wish to stop writing or sending a required field, it will be problematic to change the field to an optional field – old readers will consider messages without this field to be incomplete and may reject or drop them unintentionally. You should consider writing application-specific custom validation routines for your buffers instead. Some engineers at Google have come to the conclusion that using `required` does more harm than good; they prefer to use only `optional` and `repeated`. However, this view is not universal.

Adding More Message Types

Multiple message types can be defined in a single `.proto` file. This is useful if you are defining multiple related messages – so, for example, if you wanted to define the reply message format that corresponds to your `SearchResponse` message type, you could add it to the same `.proto`:

```
message SearchRequest {
  required string query = 1;
  optional int32 page_number = 2;
  optional int32 result_per_page = 3;
}

message SearchResponse {
 ...
}
```

Adding Comments

To add comments to your `.proto` files, use C/C++-style `//` syntax.

```
message SearchRequest {
  required string query = 1;
  optional int32 page_number = 2;// Which page number do we want?
  optional int32 result_per_page = 3;// Number of results to return per page.
}
```

What's Generated From Your `.proto`?

When you run the protocol buffer compiler on a `.proto`, the compiler generates the code in your chosen language you'll need to work with the message types you've described in the file, including getting and setting field values, serializing your messages to an output stream, and parsing your messages from an input stream.

For **C++**, the compiler generates a `.h` and `.cc` file from each `.proto`, with a class for each message type described in your file.

For **Java**, the compiler generates a `.java` file with a class for each message type, as well as a special `Builder` classes for creating message class instances.

Python is a little different — the Python compiler generates a module with a static descriptor of each message type in your `.proto`, which is then used with a *metaclass* to create the necessary Python data access class at runtime.

You can find out more about using the APIs for each language by following the tutorial for your chosen language. For even more API details, see the relevant API reference.

Scalar Value Types

A scalar message field can have one of the following types – the table shows the type specified in the `.proto` file, and the corresponding type in the automatically generated class:

.proto Type	Notes	C++ Type	Java Type	Python Type[2]
double		double	double	float
float		float	float	float
int32	Uses variable-length encoding. Inefficient for encoding negative numbers – if your field is likely to have negative values, use sint32 instead.	int32	int	int
int64	Uses variable-length encoding. Inefficient for encoding negative numbers – if your field is likely to have negative values, use sint64 instead.	int64	long	int/long[3]
uint32	Uses variable-length encoding.	uint32	int[1]	int/long[3]
uint64	Uses variable-length encoding.	uint64	long[1]	int/long[3]
sint32	Uses variable-length encoding. Signed int value. These more efficiently encode negative numbers than regular int32s.	int32	int	int

sint64	Uses variable-length encoding. Signed int value. These more efficiently encode negative numbers than regular int64s.	int64	long	int/long[3]
fixed32	Always four bytes. More efficient than uint32 if values are often greater than 2^{28}.	uint32	int[1]	int
fixed64	Always eight bytes. More efficient than uint64 if values are often greater than 2^{56}.	uint64	long[1]	int/long[3]
sfixed32	Always four bytes.	int32	int	int
sfixed64	Always eight bytes.	int64	long	int/long[3]
bool		bool	boolean	boolean
string	A string must always contain UTF-8 encoded or 7-bit ASCII text.	string	String	str/unicode[4]
bytes	May contain any arbitrary sequence of bytes.	string	ByteString	str

You can find out more about how these types are encoded when you serialize your message in Protocol Buffer Encoding.

[1] In Java, unsigned 32-bit and 64-bit integers are represented using their signed counterparts, with the top bit simply being stored in the sign bit.

[2] In all cases, setting values to a field will perform type checking to make sure it is valid.

[3] 64-bit or unsigned 32-bit integers are always represented as long when decoded, but can be an int if an int is given when setting the field. In all cases, the value must fit in the type represented when set. See [2].

[4] Python strings are represented as unicode on decode but can be str if an ASCII string is given (this is subject to change).

Optional Fields And Default Values

As mentioned above, elements in a message description can be labeled `optional`. A well-formed message may or may not contain an optional element. When a message is parsed, if it does not contain an optional element, the corresponding field in the parsed object is set to the default value for that field. The default value can be specified as part of the message description. For example, let's say you want to provide a default value of 10 for a `SearchRequest`'s `result_per_page` value.

```
optional int32 result_per_page = 3 [default = 10];
```

If the default value is not specified for an optional element, a type-specific default value is used instead: for strings, the default value is the empty string. For bools, the default value is false. For numeric types, the default value is zero. For enums, the default value is the first value listed in the enum's type definition.

Enumerations

When you're defining a message type, you might want one of its fields to only have one of a pre-defined list of values. For example, let's say you want to add a `corpus` field for each `SearchRequest`, where the corpus can be `UNIVERSAL`, `WEB`, `IMAGES`, `LOCAL`, `NEWS`, `PRODUCTS` or `VIDEO`. You can do this very simply by adding an `enum` to your message definition - a field with an

`enum` type can only have one of a specified set of constants as its value (if you try to provide a different value, the parser will treat it like an unknown field). In the following example we've added an `enum` called `Corpus` with all the possible values, and a field of type `Corpus`:

```
message SearchRequest {
  required string query = 1;
  optional int32 page_number = 2;
  optional int32 result_per_page = 3 [default = 10];
  enum Corpus {
    UNIVERSAL = 0;
    WEB = 1;
    IMAGES = 2;
    LOCAL = 3;
    NEWS = 4;
    PRODUCTS = 5;
    VIDEO = 6;
  }
  optional Corpus corpus = 4 [default = UNIVERSAL];
}
```

You can define aliases by assigning the same value to different enum constants. To do this you need to set the `allow_alias` option to `true`, otherwise protocol compiler will generate an error message when aliases are found.

```
enum EnumAllowingAlias {
  option allow_alias = true;
  UNKNOWN = 0;
  STARTED = 1;
  RUNNING = 1;
}
enum EnumNotAllowingAlias {
  UNKNOWN = 0;
  STARTED = 1;
  // RUNNING = 1;  // Uncommenting this line will cause a compile error inside Google and a warning messag
e outside.
}
```

Enumerator constants must be in the range of a 32-bit integer. Since `enum` values use varint encoding on the wire, negative values are inefficient and thus not recommended. You can define `enum`s within a message definition, as in the above example, or outside – these `enum`s can be reused in any message definition in your `.proto` file. You can also use an `enum` type declared in one message as the type of a field in a different message, using the syntax `MessageType.EnumType`.

When you run the protocol buffer compiler on a `.proto` that uses an `enum`, the generated code will have a corresponding `enum` for Java or C++, or a special `EnumDescriptor` class for Python that's used to create a set of symbolic constants with integer values in the runtime-generated class.

For more information about how to work with message `enum`s in your applications, see the generated code guide for your chosen language.

Using Other Message Types

You can use other message types as field types. For example, let's say you wanted to include `Result` messages in each `SearchResponse` message – to do this, you can define a `Result` message type in the same `.proto` and then specify a field of type `Result` in `SearchResponse`:

```
message SearchResponse {
  repeated Result result = 1;
}

message Result {
  required string url = 1;
  optional string title = 2;
  repeated string snippets = 3;
}
```

Importing Definitions

In the above example, the `Result` message type is defined in the same file as `SearchResponse` – what if the message type you want to use as a field type is already defined in another `.proto` file?

You can use definitions from other `.proto` files by *importing* them. To import another `.proto`'s definitions, you add an import statement to the top of your file:

```
import "myproject/other_protos.proto";
```

By default you can only use definitions from directly imported `.proto` files. However, sometimes you may need to move a `.proto` file to a new location. Instead of moving the `.proto` file directly and updating all the call sites in a single change, now you can put a dummy `.proto` file in the old location to forward all the imports to the new location using the `import public` notion. `import public` dependencies can be transitively relied upon by anyone importing the proto contaning the `import public` statement. For example:

```
// new.proto
// All definitions are moved here
```

```
// old.proto
// This is the proto that all clients are importing.
import public "new.proto";
import "other.proto";
```

```
// client.proto
import "old.proto";
// You use definitions from old.proto and new.proto, but not other.proto
```

The protocol compiler searches for imported files in a set of directories specified on the protocol compiler command line using the `-I`/`--proto_path` flag. If no flag was given, it looks in the directory in which the compiler was invoked. In general you should set the `--proto_path` flag to the root of your project and use fully qualified names for all imports.

Nested Types

You can define and use message types inside other message types, as in the following example – here the `Result` message is defined inside the `SearchResponse` message:

```
message SearchResponse {
  message Result {
    required string url = 1;
    optional string title = 2;
    repeated string snippets = 3;
  }
  repeated Result result = 1;
}
```

If you want to reuse this message type outside its parent message type, you refer to it as `Parent.Type`:

```
message SomeOtherMessage {
  optional SearchResponse.Result result = 1;
}
```

You can nest messages as deeply as you like:

```
message Outer {                  // Level 0
  message MiddleAA {  // Level 1
    message Inner {   // Level 2
      required int64 ival = 1;
      optional bool  booly = 2;
    }
  }
  message MiddleBB {  // Level 1
    message Inner {   // Level 2
      required int32 ival = 1;
      optional bool  booly = 2;
    }
  }
}
```

Groups

Note that this feature is deprecated and should not be used when creating new message types – use nested message types instead.

Groups are another way to nest information in your message definitions. For example, another way to specify a `SearchResponse` containing a number of `Result`s is as follows:

```
message SearchResponse {
  repeated group Result = 1 {
    required string url = 2;
    optional string title = 3;
    repeated string snippets = 4;
  }
}
```

A group simply combines a nested message type and a field into a single declaration. In your code, you can treat this message just as if it had a `Result` type field called `result` (the latter name is converted to lower-case so that it does not conflict with the former). Therefore, this example is exactly equivalent to the `SearchResponse` above, except that the message has a different wire format.

Updating A Message Type

If an existing message type no longer meets all your needs – for example, you'd like the message format to have an extra field – but you'd still like to use code created with the old format, don't worry! It's very simple to update message types without breaking any of your existing code. Just remember the following rules:

- Don't change the numeric tags for any existing fields.
- Any new fields that you add should be `optional` or `repeated`. This means that any messages serialized by code using your "old" message format can be parsed by your new generated code, as they won't be missing any `required` elements. You should set up sensible default values for these elements so that new code can properly interact with messages generated by old code. Similarly, messages created by your new code can be parsed by your old code: old binaries simply ignore the new field when parsing. However, the unknown fields are not discarded, and if the message is later serialized, the unknown fields are serialized along with it – so if the message is passed on to new code, the new fields are still available. Note that preservation of unknown fields is currently not available for Python.
- Non-required fields can be removed, as long as the tag number is not used again in your updated message type (it may be better to rename the field instead, perhaps adding the prefix "OBSOLETE_", so that future users of your `.proto` can't accidentally reuse the number).
- A non-required field can be converted to an extension and vice versa, as long as the type and number stay the same.
- `int32`, `uint32`, `int64`, `uint64`, and `bool` are all compatible – this means you can change a field from one of these types to another without breaking forwards- or backwards-compatibility. If a number is parsed from the wire which doesn't fit in the corresponding type, you will get the same effect as if you had cast the number to that type in C++ (e.g. if a 64-bit number is read as an int32, it will be truncated to 32 bits).
- `sint32` and `sint64` are compatible with each other but are *not* compatible with the other integer types.
- `string` and `bytes` are compatible as long as the bytes are valid UTF-8.
- Embedded messages are compatible with `bytes` if the bytes contain an encoded version of the message.
- `fixed32` is compatible with `sfixed32`, and `fixed64` with `sfixed64`.
- `optional` is compatible with `repeated`. Given serialized data of a repeated field as input, clients that expect this field to be `optional` will take the last input value if it's a primitive type field or merge all input elements if it's a message type field.
- Changing a default value is generally OK, as long as you remember that default values are never sent over the wire. Thus, if a program receives a message in which a particular field isn't set, the program will see the default value as it was defined in that program's version of the protocol. It will NOT see the default value that was defined in the sender's code.

Extensions

Extensions let you declare that a range of field numbers in a message are available for third-party extensions. Other people can then declare new fields for your message type with those numeric tags in their own `.proto` files without having to edit the original file. Let's look at an example:

```
message Foo {
  // ...
  extensions 100 to 199;
```

```
}
```

This says that the range of field numbers [100, 199] in `Foo` is reserved for extensions. Other users can now add new fields to `Foo` in their own `.proto` files that import your `.proto`, using tags within your specified range – for example:

```
extend Foo {
  optional int32 bar = 126;
}
```

This says that `Foo` now has an optional `int32` field called `bar`.

When your user's `Foo` messages are encoded, the wire format is exactly the same as if the user defined the new field inside `Foo`. However, the way you access extension fields in your application code is slightly different to accessing regular fields – your generated data access code has special accessors for working with extensions. So, for example, here's how you set the value of `bar` in C++:

```
Foo foo;
foo.SetExtension(bar, 15);
```

Similarly, the `Foo` class defines templated accessors `HasExtension()`, `ClearExtension()`, `GetExtension()`, `MutableExtension()`, and `AddExtension()`. All have semantics matching the corresponding generated accessors for a normal field. For more information about working with extensions, see the generated code reference for your chosen language.

Note that extensions can be of any field type, including message types.

Nested Extensions

You can declare extensions in the scope of another type:

```
message Baz {
  extend Foo {
    optional int32 bar = 126;
  }
  ...
}
```

In this case, the C++ code to access this extension is:

```
Foo foo;
foo.SetExtension(Baz::bar, 15);
```

In other words, the only effect is that `bar` is defined within the scope of `Baz`.

> This is a common source of confusion: Declaring an `extend` block nested inside a message type *does not* imply any relationship between the outer type and the extended type. In particular, the above example *does not* mean that `Baz` is any sort of subclass of `Foo`. All it means is that the symbol `bar` is declared inside the scope of `Baz`; it's simply a static member.

A common pattern is to define extensions inside the scope of the extension's field type – for example, here's an extension to `Foo` of type `Baz`, where the extension is defined as part of `Baz`:

```
message Baz {
  extend Foo {
    optional Baz foo_ext = 127;
  }
  ...
}
```

However, there is no requirement that an extension with a message type be defined inside that type. You can also do this:

```
message Baz {
  ...
}

// This can even be in a different file.
extend Foo {
  optional Baz foo_baz_ext = 127;
}
```

In fact, this syntax may be preferred to avoid confusion. As mentioned above, the nested syntax is often mistaken for subclassing by users who are not already familiar with extensions.

Choosing Extension Numbers

It's very important to make sure that two users don't add extensions to the same message type using the same numeric tag – data corruption can result if an extension is accidentally interpreted as the wrong type. You may want to consider defining an extension numbering convention for your project to prevent this happening.

If your numbering convention might involve extensions having very large numbers as tags, you can specify that your extension range goes up to the maximum possible field number using the `max` keyword:

```
message Foo {
  extensions 1000 to max;
}
```

`max` is $2^{29} - 1$, or 536,870,911.

As when choosing tag numbers in general, your numbering convention also needs to avoid field numbers 19000 though 19999 (`FieldDescriptor::kFirstReservedNumber` through `FieldDescriptor::kLastReservedNumber`), as they are reserved for the Protocol Buffers implementation. You can define an extension range that includes this range, but the protocol compiler will not allow you to define actual extensions with these numbers.

Packages

You can add an optional `package` specifier to a `.proto` file to prevent name clashes between protocol message types.

```
package foo.bar;
message Open { ... }
```

You can then use the package specifier when defining fields of your message type:

```
message Foo {
  ...
  required foo.bar.Open open = 1;
  ...
}
```

The way a package specifier affects the generated code depends on your chosen language:

- In **C++** the generated classes are wrapped inside a C++ namespace. For example, `Open` would be in the namespace `foo::bar`.
- In **Java**, the package is used as the Java package, unless you explicitly provide a `option java_package` in your `.proto` file.
- In **Python**, the package directive is ignored, since Python modules are organized according to their location in the file system.

Packages and Name Resolution

Type name resolution in the protocol buffer language works like C++: first the innermost scope is searched, then the next-innermost, and so on, with each package considered to be "inner" to its parent package. A leading '.' (for example, `.foo.bar.Baz`) means to start from the outermost scope instead.

The protocol buffer compiler resolves all type names by parsing the imported `.proto` files. The code generator for each language knows how to refer to each type in that language, even if it has different scoping rules.

Defining Services

If you want to use your message types with an RPC (Remote Procedure Call) system, you can define an RPC service interface in a `.proto` file and the protocol buffer compiler will generate service interface code and stubs in your chosen language. So, for example, if you want to define an RPC service with a method that takes your `SearchRequest` and returns a `SearchResponse`, you can define it in your `.proto` file as follows:

```
service SearchService {
  rpc Search (SearchRequest) returns (SearchResponse);
}
```

The protocol compiler will then generate an abstract interface called `SearchService` and a corresponding "stub" implementation. The stub forwards all calls to an `RpcChannel`, which in turn is an abstract interface that you must define yourself in terms of your own RPC system. For example, you might implement an `RpcChannel` which serializes the message and sends it to a server via HTTP. In other words, the generated stub provides a type-safe interface for making protocol-buffer-based RPC calls, without locking you into any particular RPC implementation. So, in C++, you might end up with code like this:

```
using google::protobuf;

protobuf::RpcChannel* channel;
protobuf::RpcController* controller;
SearchService* service;
SearchRequest request;
```

```
SearchResponse response;

void DoSearch() {
  // You provide classes MyRpcChannel and MyRpcController, which implement
  // the abstract interfaces protobuf::RpcChannel and protobuf::RpcController.
  channel = new MyRpcChannel("somehost.example.com:1234");
  controller = new MyRpcController;

  // The protocol compiler generates the SearchService class based on the
  // definition given above.
  service = new SearchService::Stub(channel);

  // Set up the request.
  request.set_query("protocol buffers");

  // Execute the RPC.
  service->Search(controller, request, response, protobuf::NewCallback(&Done));
}

void Done() {
  delete service;
  delete channel;
  delete controller;
}
```

All service classes also implement the `Service` interface, which provides a way to call specific methods without knowing the method name or its input and output types at compile time. On the server side, this can be used to implement an RPC server with which you could register services.

```
using google::protobuf;

class ExampleSearchService : public SearchService {
 public:
  void Search(protobuf::RpcController* controller,
              const SearchRequest* request,
              SearchResponse* response,
              protobuf::Closure* done) {
    if (request->query() == "google") {
      response->add_result()->set_url("http://www.google.com");
    } else if (request->query() == "protocol buffers") {
      response->add_result()->set_url("http://protobuf.googlecode.com");
    }
    done->Run();
  }
};

int main() {
  // You provide class MyRpcServer.  It does not have to implement any
  // particular interface; this is just an example.
  MyRpcServer server;

  protobuf::Service* service = new ExampleSearchService;
  server.ExportOnPort(1234, service);
  server.Run();
```

```
  delete service;
  return 0;
}
```

There are a number of ongoing third-party projects to develop RPC implementations for Protocol Buffers. For a list of links to projects we know about, see the third-party add-ons wiki page.

Options

Individual declarations in a `.proto` file can be annotated with a number of *options*. Options do not change the overall meaning of a declaration, but may affect the way it is handled in a particular context. The complete list of available options is defined in `google/protobuf/descriptor.proto`.

Some options are file-level options, meaning they should be written at the top-level scope, not inside any message, enum, or service definition. Some options are message-level options, meaning they should be written inside message definitions. Some options are field-level options, meaning they should be written inside field definitions. Options can also be written on enum types, enum values, service types, and service methods; however, no useful options currently exist for any of these.

Here are a few of the most commonly used options:

- `java_package` (file option): The package you want to use for your generated Java classes. If no explicit `java_package` option is given in the `.proto` file, then by default the proto package (specified using the "package" keyword in the `.proto` file) will be used. However, proto packages generally do not make good Java packages since proto packages are not expected to start with reverse domain names. If not generating Java code, this option has no effect.

  ```
  option java_package = "com.example.foo";
  ```

- `java_outer_classname` (file option): The class name for the outermost Java class (and hence the file name) you want to generate. If no explicit `java_outer_classname` is specified in the `.proto` file, the class name will be constructed by converting the `.proto` file name to camel-case (so `foo_bar.proto` becomes `FooBar.java`). If not generating Java code, this option has no effect.

  ```
  option java_outer_classname = "Ponycopter";
  ```

- `optimize_for` (file option): Can be set to `SPEED`, `CODE_SIZE`, or `LITE_RUNTIME`. This affects the C++ and Java code generators (and possibly third-party generators) in the following ways:
  - `SPEED` (default): The protocol buffer compiler will generate code for serializing, parsing, and performing other common operations on your message types. This code is extremely highly optimized.
  - `CODE_SIZE`: The protocol buffer compiler will generate minimal classes and will rely on shared, reflection-based code to implement serialialization, parsing, and various other operations. The generated code will thus be much smaller than with `SPEED`, but operations will be slower. Classes will still implement exactly the same public API as they do in `SPEED` mode. This mode is most useful in apps that contain a very large number `.proto` files and do not need all of them to be blindingly fast.
  - `LITE_RUNTIME`: The protocol buffer compiler will generate classes that depend only on the "lite" runtime library (`libprotobuf-lite` instead of `libprotobuf`). The lite runtime is much smaller than the full library (around an order of magnitude smaller) but omits certain features like descriptors and reflection. This is particularly useful for apps running on constrained platforms like mobile phones. The compiler will still generate fast

implementations of all methods as it does in SPEED mode. Generated classes will only implement the MessageLite interface in each language, which provides only a subset of the methods of the full Message interface.

```
option optimize_for = CODE_SIZE;
```

- cc_generic_services, java_generic_services, py_generic_services (file options): Whether or not the protocol buffer compiler should generate abstract service code based on services definitions in C++, Java, and Python, respectively. For legacy reasons, these default to true. However, as of version 2.3.0 (January 2010), it is considered preferrable for RPC implementations to provide code generator plugins to generate code more specific to each system, rather than rely on the "abstract" services.

```
// This file relies on plugins to generate service code.
option cc_generic_services = false;
option java_generic_services = false;
option py_generic_services = false;
```

- message_set_wire_format (message option): If set to true, the message uses a different binary format intended to be compatible with an old format used inside Google called MessageSet. Users outside Google will probably never need to use this option. The message must be declared exactly as follows:

```
message Foo {
  option message_set_wire_format = true;
  extensions 4 to max;
}
```

- packed (field option): If set to true on a repeated field of a basic integer type, a more compact encoding will be used. There is no downside to using this option. However, note that prior to version 2.3.0, parsers that received packed data when not expected would ignore it. Therefore, it was not possible to change an existing field to packed format without breaking wire compatibility. In 2.3.0 and later, this change is safe, as parsers for packable fields will always accept both formats, but be careful if you have to deal with old programs using old protobuf versions.

```
repeated int32 samples = 4 [packed=true];
```

- deprecated (field option): If set to true, indicates that the field is deprecated and should not be used by new code. In most languages this has no actual effect. In Java, this becomes a @Deprecated annotation. In the future, other language-specific code generators may generate deprecation annotations on the field's accessors, which will in turn cause a warning to be emitted when compiling code which attempts to use the field.

```
optional int32 old_field = 6 [deprecated=true];
```

Custom Options

Protocol Buffers even allow you to define and use your own options. Note that this is an **advanced feature** which most people don't need. Since options are defined by the messages defined in google/protobuf/descriptor.proto (like FileOptions or FieldOptions), defining your own options is simply a matter of extending those messages. For example:

```
import "google/protobuf/descriptor.proto";

extend google.protobuf.MessageOptions {
```

```
  optional string my_option = 51234;
}

message MyMessage {
  option (my_option) = "Hello world!";
}
```

Here we have defined a new message-level option by extending `MessageOptions`. When we then use the option, the option name must be enclosed in parentheses to indicate that it is an extension. We can now read the value of `my_option` in C++ like so:

```
string value = MyMessage::descriptor()->options().GetExtension(my_option);
```

Here, `MyMessage::descriptor()->options()` returns the `MessageOptions` protocol message for `MyMessage`. Reading custom options from it is just like reading any other extension.

Similarly, in Java we would write:

```
String value = MyProtoFile.MyMessage.getDescriptor().getOptions()
  .getExtension(MyProtoFile.myOption);
```

In Python it would be:

```
value = my_proto_file_pb2.MyMessage.DESCRIPTOR.GetOptions()
  .Extensions[my_proto_file_pb2.my_option]
```

Custom options can be defined for every kind of construct in the Protocol Buffers language. Here is an example that uses every kind of option:

```
import "google/protobuf/descriptor.proto";

extend google.protobuf.FileOptions {
  optional string my_file_option = 50000;
}
extend google.protobuf.MessageOptions {
  optional int32 my_message_option = 50001;
}
extend google.protobuf.FieldOptions {
  optional float my_field_option = 50002;
}
extend google.protobuf.EnumOptions {
  optional bool my_enum_option = 50003;
}
extend google.protobuf.EnumValueOptions {
  optional uint32 my_enum_value_option = 50004;
}
extend google.protobuf.ServiceOptions {
  optional MyEnum my_service_option = 50005;
}
extend google.protobuf.MethodOptions {
  optional MyMessage my_method_option = 50006;
}
```

```
option (my_file_option) = "Hello world!";

message MyMessage {
  option (my_message_option) = 1234;

  optional int32 foo = 1 [(my_field_option) = 4.5];
  optional string bar = 2;
}

enum MyEnum {
  option (my_enum_option) = true;

  FOO = 1 [(my_enum_value_option) = 321];
  BAR = 2;
}

message RequestType {}
message ResponseType {}

service MyService {
  option (my_service_option) = FOO;

  rpc MyMethod(RequestType) returns(ResponseType) {
    // Note:  my_method_option has type MyMessage.  We can set each field
    //   within it using a separate "option" line.
    option (my_method_option).foo = 567;
    option (my_method_option).bar = "Some string";
  }
}
```

Note that if you want to use a custom option in a package other than the one in which it was defined, you must prefix the option name with the package name, just as you would for type names. For example:

```
// foo.proto
import "google/protobuf/descriptor.proto";
package foo;
extend google.protobuf.MessageOptions {
  optional string my_option = 51234;
}
```

```
// bar.proto
import "foo.proto";
package bar;
message MyMessage {
  option (foo.my_option) = "Hello world!";
}
```

One last thing: Since custom options are extensions, they must be assigned field numbers like any other field or extension. In the examples above, we have used field numbers in the range 50000-99999. This range is reserved for internal use within individual organizations, so you can use numbers in this range freely for in-house applications. If you intend to use custom options in public applications, however, then it is important that you make sure that your field numbers are globally unique. To obtain globally unique field numbers, please send a request to protobuf-global-extension-registry@google.com. Simply provide your project name (e.g. Object-C plugin) and your project website (if available). Usually you only need one extension number. You can declare multiple options with only one extension number by putting them in a sub-message:

```
message FooOptions {
  optional int32 opt1 = 1;
  optional string opt2 = 2;
}

extend google.protobuf.FieldOptions {
  optional FooOptions foo_options = 1234;
}

// usage:
message Bar {
  optional int32 a = 1 [(foo_options).opt1 = 123, (foo_options).opt2 = "baz"];
  // alternative aggregate syntax (uses TextFormat):
  optional int32 b = 2 [(foo_options) = { opt1: 123 opt2: "baz" }];
}
```

Also, note that each option type (file-level, message-level, field-level, etc.) has its own number space, so e.g. you could declare extensions of FieldOptions and MessageOptions with the same number.

Generating Your Classes

To generate the Java, Python, or C++ code you need to work with the message types defined in a `.proto` file, you need to run the protocol buffer compiler `protoc` on the `.proto`. If you haven't installed the compiler, download the package and follow the instructions in the README.

The Protocol Compiler is invoked as follows:

```
protoc --proto_path=IMPORT_PATH --cpp_out=DST_DIR --java_out=DST_DIR --python_out=DST_DIR path/to/file.proto
```

- `IMPORT_PATH` specifies a directory in which to look for `.proto` files when resolving `import` directives. If omitted, the current directory is used. Multiple import directories can be specified by passing the `--proto_path` option multiple times; they will be searched in order. `-I=IMPORT_PATH` can be used as a short form of `--proto_path`.
- You can provide one or more *output directives*:
  - `--cpp_out` generates C++ code in `DST_DIR`. See the C++ generated code reference for more.
  - `--java_out` generates Java code in `DST_DIR`. See the Java generated code reference for more.
  - `--python_out` generates Python code in `DST_DIR`. See the Python generated code reference for more.

  As an extra convenience, if the `DST_DIR` ends in `.zip` or `.jar`, the compiler will write the output to a single ZIP-format archive file with the given name. `.jar` outputs will also be given a manifest file as required by the Java JAR specification. Note that if the output archive already exists, it will be overwritten; the compiler is not smart enough to add files to an existing archive.
- You must provide one or more `.proto` files as input. Multiple `.proto` files can be specified at once. Although the files are named relative to the current directory, each file must reside in one of the `IMPORT_PATH`s so that the compiler can determine its canonical name.

Last updated 四月 *22, 2014.*

Style Guide

This document provides a style guide for `.proto` files. By following these conventions, you'll make your protocol buffer message definitions and their corresponding classes consistent and easy to read.

Message And Field Names

Use CamelCase (with an initial capital) for message names – for example, `SongServerRequest`. Use underscore_separated_names for field names – for example, `song_name`.

```
message SongServerRequest {
  required string song_name = 1;
}
```

Using this naming convention for field names gives you accessors like the following:

```
C++:
  const string& song_name() { ... }
  void set_song_name(const string& x) { ... }

Java:
  public String getSongName() { ... }
  public Builder setSongName(String v) { ... }
```

Enums

Use CamelCase (with an initial capital) for enum type names and CAPITALS_WITH_UNDERSCORES for value names:

```
enum Foo {
  FIRST_VALUE = 1;
  SECOND_VALUE = 2;
}
```

Each enum value should end with a semicolon, not a comma.

Services

If your `.proto` defines an RPC service, you should use CamelCase (with an initial capital) for both the service name and any RPC method names:

```
service FooService {
  rpc GetSomething(FooRequest) returns (FooResponse);
}
```


Last updated 四月 *2, 2012.*

Encoding

This document describes the binary wire format for protocol buffer messages. You don't need to understand this to use protocol buffers in your applications, but it can be very useful to know how different protocol buffer formats affect the size of your encoded messages.

A Simple Message

Let's say you have the following very simple message definition:

```
message Test1 {
  required int32 a = 1;
}
```

In an application, you create a `Test1` message and set `a` to 150. You then serialize the message to an output stream. If you were able to examine the encoded message, you'd see three bytes:

```
08 96 01
```

So far, so small and numeric – but what does it mean? Read on...

Base 128 Varints

To understand your simple protocol buffer encoding, you first need to understand *varints*. Varints are a method of serializing integers using one or more bytes. Smaller numbers take a smaller number of bytes.

Each byte in a varint, except the last byte, has the *most significant bit* (msb) set – this indicates that there are further bytes to come. The lower 7 bits of each byte are used to store the two's complement representation of the number in groups of 7 bits, **least significant group first**.

So, for example, here is the number 1 – it's a single byte, so the msb is not set:

```
0000 0001
```

And here is 300 – this is a bit more complicated:

```
1010 1100 0000 0010
```

How do you figure out that this is 300? First you drop the msb from each byte, as this is just there to tell us whether we've reached the end of the number (as you can see, it's set in the first byte as there is more than one byte in the varint):

```
1010 1100 0000 0010
→ 010 1100  000 0010
```

You reverse the two groups of 7 bits because, as you remember, varints store numbers with the least significant group first. Then you concatenate them to get your final value:

```
000 0010  010 1100
→  000 0010 ++ 010 1100
→  100101100
→  256 + 32 + 8 + 4 = 300
```

Message Structure

As you know, a protocol buffer message is a series of key-value pairs. The binary version of a message just uses the field's number as the key – the name and declared type for each field can only be determined on the decoding end by referencing the message type's definition (i.e. the `.proto` file).

When a message is encoded, the keys and values are concatenated into a byte stream. When the message is being decoded, the parser needs to be able to skip fields that it doesn't recognize. This way, new fields can be added to a message without breaking old programs that do not know about them. To this end, the "key" for each pair in a wire-format message is actually two values – the field number from your `.proto` file, plus a *wire type* that provides just enough information to find the length of the following value.

The available wire types are as follows:

Type	Meaning	Used For
0	Varint	int32, int64, uint32, uint64, sint32, sint64, bool, enum
1	64-bit	fixed64, sfixed64, double
2	Length-delimited	string, bytes, embedded messages, packed repeated fields
3	Start group	groups (deprecated)
4	End group	groups (deprecated)
5	32-bit	fixed32, sfixed32, float

Each key in the streamed message is a varint with the value `(field_number << 3) | wire_type` – in other words, the last three bits of the number store the wire type.

Now let's look at our simple example again. You now know that the first number in the stream is always a varint key, and here it's 08, or (dropping the msb):

```
000 1000
```

You take the last three bits to get the wire type (0) and then right-shift by three to get the field number (1). So you now know that the tag is 1 and the following value is a varint. Using your varint-decoding knowledge from the previous section, you can see that the next two bytes store the value 150.

```
96 01 = 1001 0110  0000 0001
       → 000 0001  ++  001 0110 (drop the msb and reverse the groups of 7 bits)
       → 10010110
       → 2 + 4 + 16 + 128 = 150
```

More Value Types

Signed Integers

As you saw in the previous section, all the protocol buffer types associated with wire type 0 are encoded as varints. However, there is an important difference between the signed int types (`sint32` and `sint64`) and the "standard" int types (`int32` and `int64`) when it comes to encoding negative numbers. If you use `int32` or `int64` as the type for a negative number, the resulting varint is *always ten bytes long* – it is, effectively, treated like a very large unsigned integer. If you use one of the signed types, the resulting varint uses ZigZag encoding, which is much more efficient.

ZigZag encoding maps signed integers to unsigned integers so that numbers with a small *absolute value* (for instance, -1) have a small varint encoded value too. It does this in a way that "zig-zags" back and forth through the positive and negative integers, so that -1 is encoded as 1, 1 is encoded as 2, -2 is encoded as 3, and so on, as you can see in the following table:

Signed Original	Encoded As
0	0
-1	1
1	2
-2	3
2147483647	4294967294
-2147483648	4294967295

In other words, each value `n` is encoded using

```
(n << 1) ^ (n >> 31)
```

for `sint32`s, or

```
(n << 1) ^ (n >> 63)
```

for the 64-bit version.

Note that the second shift – the `(n >> 31)` part – is an arithmetic shift. So, in other words, the result of the shift is either a number that is all zero bits (if `n` is positive) or all one bits (if `n` is negative).

When the `sint32` or `sint64` is parsed, its value is decoded back to the original, signed version.

Non-varint Numbers

Non-varint numeric types are simple – `double` and `fixed64` have wire type 1, which tells the parser to expect a fixed 64-bit lump of data; similarly `float` and `fixed32` have wire type 5, which tells it to expect 32 bits. In both cases the values are stored in little-endian byte order.

Strings

A wire type of 2 (length-delimited) means that the value is a varint encoded length followed by the specified number of bytes of data.

```
message Test2 {
  required string b = 2;
}
```

Setting the value of b to "testing" gives you:

```
12 07 74 65 73 74 69 6e 67
```

The red bytes are the UTF8 of "testing". The key here is 0x12 → tag = 2, type = 2. The length varint in the value is 7 and lo and behold, we find seven bytes following it – our string.

Embedded Messages

Here's a message definition with an embedded message of our example type, Test1:

```
message Test3 {
  required Test1 c = 3;
}
```

And here's the encoded version, again with the Test1's `a` field set to 150:

```
 1a 03 08 96 01
```

As you can see, the last three bytes are exactly the same as our first example (`08 96 01`), and they're preceded by the number 3 – embedded messages are treated in exactly the same way as strings (wire type = 2).

Optional And Repeated Elements

If your message definition has `repeated` elements (without the `[packed=true]` option), the encoded message has zero or more key-value pairs with the same tag number. These repeated values do not have to appear consecutively; they may be interleaved with other fields. The order of the elements with respect to each other is preserved when parsing, though the ordering with respect to other fields is lost.

If any of your elements are `optional`, the encoded message may or may not have a key-value pair with that tag number.

Normally, an encoded message would never have more than one instance of an `optional` or `required` field. However, parsers are expected to handle the case in which they do. For numeric types and strings, if the same value appears multiple times, the parser accepts the *last* value it sees. For embedded message fields, the parser merges multiple instances of the same field, as if with the `Message::MergeFrom` method – that is, all singular scalar fields in the latter instance replace those in the former, singular embedded messages are merged, and repeated fields are concatenated. The effect of these rules is that parsing the concatenation of two encoded messages produces exactly the same result as if you had parsed the two messages separately and merged the resulting objects. That is, this:

```
MyMessage message;
message.ParseFromString(str1 + str2);
```

is equivalent to this:

```
MyMessage message, message2;
message.ParseFromString(str1);
message2.ParseFromString(str2);
message.MergeFrom(message2);
```

This property is occasionally useful, as it allows you to merge two messages even if you do not know their types.

Packed Repeated Fields

Version 2.1.0 introduced packed repeated fields, which are declared like repeated fields but with the special `[packed=true]` option. These function like repeated fields, but are encoded differently. A packed repeated field containing zero elements does not appear in the encoded message. Otherwise, all of the elements of the field are packed into a single key-value pair with wire type 2 (length-delimited). Each element is encoded the same way it would be normally, except without a tag preceding it.

For example, imagine you have the message type:

```
message Test4 {
  repeated int32 d = 4 [packed=true];
}
```

Now let's say you construct a `Test4`, providing the values 3, 270, and 86942 for the repeated field `d`. Then, the encoded form would be:

```
22        // tag (field number 4, wire type 2)
06        // payload size (6 bytes)
03        // first element (varint 3)
8E 02     // second element (varint 270)
9E A7 05  // third element (varint 86942)
```

Only repeated fields of primitive numeric types (types which use the varint, 32-bit, or 64-bit wire types) can be declared "packed".

Note that although there's usually no reason to encode more than one key-value pair for a packed repeated field, encoders must be prepared to accept multiple key-value pairs. In this case, the payloads should be concatenated. Each pair must contain a whole number of elements.

Field Order

While you can use field numbers in any order in a `.proto`, when a message is serialized its known fields should be written sequentially by field number, as in the provided C++, Java, and Python serialization code. This allows parsing code to use optimizations that rely on field numbers being in sequence. However, protocol buffer parsers must be able to parse fields in any order, as not all messages are created by simply serializing an object – for instance, it's sometimes useful to merge two messages by simply concatenating them.

If a message has unknown fields, the current Java and C++ implementations write them in arbitrary order after the sequentially-ordered known fields. The current Python implementation does not track unknown fields.

Last updated 四月 *2, 2012.*

Tutorials

Each tutorial in this section shows you how to implement a simple application using protocol buffers in your favourite language, introducing you to the language's protocol buffer API as well as showing you the basics of creating and using .proto files. The complete sample code for each application is also provided.

The tutorials don't assume that you know anything about protocol buffers, but do assume that you are comfortable writing code in your chosen language, including using file I/O.

- C++ Tutorial
- Java Tutorial
- Python Tutorial

Last updated 四月 *2, 2012.*

Protocol Buffer Basics: C++

This tutorial provides a basic C++ programmer's introduction to working with protocol buffers. By walking through creating a simple example application, it shows you how to

- Define message formats in a `.proto` file.
- Use the protocol buffer compiler.
- Use the C++ protocol buffer API to write and read messages.

This isn't a comprehensive guide to using protocol buffers in C++. For more detailed reference information, see the Protocol Buffer Language Guide, the C++ API Reference, the C++ Generated Code Guide, and the Encoding Reference.

Why Use Protocol Buffers?

The example we're going to use is a very simple "address book" application that can read and write people's contact details to and from a file. Each person in the address book has a name, an ID, an email address, and a contact phone number.

How do you serialize and retrieve structured data like this? There are a few ways to solve this problem:

- The raw in-memory data structures can be sent/saved in binary form. Over time, this is a fragile approach, as the receiving/reading code must be compiled with exactly the same memory layout, endianness, etc. Also, as files accumulate data in the raw format and copies of software that are wired for that format are spread around, it's very hard to extend the format.
- You can invent an ad-hoc way to encode the data items into a single string – such as encoding 4 ints as "12:3:-23:67". This is a simple and flexible approach, although it does require writing one-off encoding and parsing code, and the parsing imposes a small run-time cost. This works best for encoding very simple data.
- Serialize the data to XML. This approach can be very attractive since XML is (sort of) human readable and there are binding libraries for lots of languages. This can be a good choice if you want to share data with other applications/projects. However, XML is notoriously space intensive, and encoding/decoding it can impose a huge performance penalty on applications. Also, navigating an XML DOM tree is considerably more complicated than navigating simple fields in a class normally would be.

Protocol buffers are the flexible, efficient, automated solution to solve exactly this problem. With protocol buffers, you write a `.proto` description of the data structure you wish to store. From that, the protocol buffer compiler creates a class that implements automatic encoding and parsing of the protocol buffer data with an efficient binary format. The generated class provides getters and setters for the fields that make up a protocol buffer and takes care of the details of reading and writing the protocol buffer as a unit. Importantly, the protocol buffer format supports the idea of extending the format over time in such a way that the code can still read data encoded with the old format.

Where to Find the Example Code

The example code is included in the source code package, under the "examples" directory. Download it here.

Defining Your Protocol Format

To create your address book application, you'll need to start with a `.proto` file. The definitions in a `.proto` file are simple: you add a *message* for each data structure you want to serialize, then specify a name and a type for each field in the message. Here is the `.proto` file that defines your messages, `addressbook.proto`.

```
package tutorial;

message Person {
  required string name = 1;
  required int32 id = 2;
  optional string email = 3;

  enum PhoneType {
    MOBILE = 0;
    HOME = 1;
    WORK = 2;
  }

  message PhoneNumber {
    required string number = 1;
    optional PhoneType type = 2 [default = HOME];
  }

  repeated PhoneNumber phone = 4;
}

message AddressBook {
  repeated Person person = 1;
}
```

As you can see, the syntax is similar to C++ or Java. Let's go through each part of the file and see what it does.

The `.proto` file starts with a package declaration, which helps to prevent naming conflicts between different projects. In C++, your generated classes will be placed in a namespace matching the package name.

Next, you have your message definitions. A message is just an aggregate containing a set of typed fields. Many standard simple data types are available as field types, including `bool`, `int32`, `float`, `double`, and `string`. You can also add further structure to your messages by using other message types as field types – in the above example the `Person` message contains `PhoneNumber` messages, while the `AddressBook` message contains `Person` messages. You can even define message types nested inside other messages – as you can see, the `PhoneNumber` type is defined inside `Person`. You can also define `enum` types if you want one of your fields to have one of a predefined list of values – here you want to specify that a phone number can be one of `MOBILE`, `HOME`, or `WORK`.

The " = 1", " = 2" markers on each element identify the unique "tag" that field uses in the binary encoding. Tag numbers 1-15 require one less byte to encode than higher numbers, so as an optimization you can decide to use those tags for the commonly used or repeated elements, leaving tags 16 and higher for less-commonly used optional elements. Each element in a repeated field requires re-encoding the tag number, so repeated fields are particularly good candidates for this optimization.

Each field must be annotated with one of the following modifiers:

- `required`: a value for the field must be provided, otherwise the message will be considered "uninitialized". If `libprotobuf` is compiled in debug mode, serializing an uninitialized message will cause an assertion failure. In optimized builds, the check is skipped and the message will be written anyway. However, parsing an uninitialized message will always fail (by returning `false` from the parse method). Other than this, a required field behaves exactly like an optional field.
- `optional`: the field may or may not be set. If an optional field value isn't set, a default value is used. For simple types, you can specify your own default value, as we've done for the phone number `type` in the example. Otherwise, a system default is used: zero for numeric types, the empty string for strings, false for bools. For embedded messages, the default value is always the "default instance" or "prototype" of the message, which has none of its fields set. Calling the accessor to get the value of an optional (or required) field which has not been explicitly set always returns that field's default value.
- `repeated`: the field may be repeated any number of times (including zero). The order of the repeated values will be preserved in the protocol buffer. Think of repeated fields as dynamically sized arrays.

> **Required Is Forever** You should be very careful about marking fields as `required`. If at some point you wish to stop writing or sending a required field, it will be problematic to change the field to an optional field – old readers will consider messages without this field to be incomplete and may reject or drop them unintentionally. You should consider writing application-specific custom validation routines for your buffers instead. Some engineers at Google have come to the conclusion that using `required` does more harm than good; they prefer to use only `optional` and `repeated`. However, this view is not universal.

You'll find a complete guide to writing `.proto` files – including all the possible field types – in the Protocol Buffer Language Guide. Don't go looking for facilities similar to class inheritance, though – protocol buffers don't do that.

Compiling Your Protocol Buffers

Now that you have a `.proto`, the next thing you need to do is generate the classes you'll need to read and write `AddressBook` (and hence `Person` and `PhoneNumber`) messages. To do this, you need to run the protocol buffer compiler `protoc` on your `.proto`:

1. If you haven't installed the compiler, download the package and follow the instructions in the README.
2. Now run the compiler, specifying the source directory (where your application's source code lives – the current directory is used if you don't provide a value), the destination directory (where you want the generated code to go; often the same as `$SRC_DIR`), and the path to your `.proto`. In this case, you...:

   ```
   protoc -I=$SRC_DIR --cpp_out=$DST_DIR $SRC_DIR/addressbook.proto
   ```

   Because you want C++ classes, you use the `--cpp_out` option – similar options are provided for other supported languages.

This generates the following files in your specified destination directory:

- `addressbook.pb.h`, the header which declares your generated classes.
- `addressbook.pb.cc`, which contains the implementation of your classes.

The Protocol Buffer API

Let's look at some of the generated code and see what classes and functions the compiler has created for you. If you look in `tutorial.pb.h`, you can see that you have a class for each message you specified in `tutorial.proto`. Looking closer at the `Person` class, you can see that the complier has generated accessors for each field. For example, for the `name`, `id`, `email`, and `phone` fields, you have these methods:

```
  // name
  inline bool has_name() const;
  inline void clear_name();
  inline const ::std::string& name() const;
  inline void set_name(const ::std::string& value);
  inline void set_name(const char* value);
  inline ::std::string* mutable_name();

  // id
  inline bool has_id() const;
  inline void clear_id();
  inline int32_t id() const;
  inline void set_id(int32_t value);

  // email
  inline bool has_email() const;
  inline void clear_email();
  inline const ::std::string& email() const;
  inline void set_email(const ::std::string& value);
  inline void set_email(const char* value);
  inline ::std::string* mutable_email();

  // phone
  inline int phone_size() const;
  inline void clear_phone();
  inline const ::google::protobuf::RepeatedPtrField< ::tutorial::Person_PhoneNumber >& phone() cons
t;
  inline ::google::protobuf::RepeatedPtrField< ::tutorial::Person_PhoneNumber >* mutable_phone();
  inline const ::tutorial::Person_PhoneNumber& phone(int index) const;
  inline ::tutorial::Person_PhoneNumber* mutable_phone(int index);
  inline ::tutorial::Person_PhoneNumber* add_phone();
```

As you can see, the getters have exactly the name as the field in lowercase, and the setter methods begin with `set_`. There are also `has_` methods for each singular (required or optional) field which return true if that field has been set. Finally, each field has a `clear_` method that un-sets the field back to its empty state.

While the numeric `id` field just has the basic accessor set described above, the `name` and `email` fields have a couple of extra methods because they're strings – a `mutable_` getter that lets you get a direct pointer to the string, and an extra setter. Note that you can call `mutable_email()` even if `email` is not already set; it will be initialized to an empty string automatically. If you had a singular message field in this example, it would also have a `mutable_` method but not a `set_` method.

Repeated fields also have some special methods – if you look at the methods for the repeated `phone` field, you'll see that you can

- check the repeated field's `_size` (in other words, how many phone numbers are associated with this `Person`).
- get a specified phone number using its index.
- update an existing phone number at the specified index.
- add another phone number to the message which you can then edit (repeated scalar types have an `add_` that just lets you pass in the new value).

For more information on exactly what members the protocol compiler generates for any particular field definition, see the C++ generated code reference.

Enums and Nested Classes

The generated code includes a `PhoneType` enum that corresponds to your `.proto` enum. You can refer to this type as `Person::PhoneType` and its values as `Person::MOBILE`, `Person::HOME`, and `Person::WORK` (the implementation details are a little more complicated, but you don't need to understand them to use the enum).

The compiler has also generated a nested class for you called `Person::PhoneNumber`. If you look at the code, you can see that the "real" class is actually called `Person_PhoneNumber`, but a typedef defined inside `Person` allows you to treat it as if it were a nested class. The only case where this makes a difference is if you want to forward-declare the class in another file – you cannot forward-declare nested types in C++, but you can forward-declare `Person_PhoneNumber`.

Standard Message Methods

Each message class also contains a number of other methods that let you check or manipulate the entire message, including:

- `bool IsInitialized() const;`: checks if all the required fields have been set.
- `string DebugString() const;`: returns a human-readable representation of the message, particularly useful for debugging.
- `void CopyFrom(const Person& from);`: overwrites the message with the given message's values.
- `void Clear();`: clears all the elements back to the empty state.

These and the I/O methods described in the following section implement the `Message` interface shared by all C++ protocol buffer classes. For more info, see the complete API documentation for `Message`.

Parsing and Serialization

Finally, each protocol buffer class has methods for writing and reading messages of your chosen type using the protocol buffer binary format. These include:

- `bool SerializeToString(string* output) const;`: serializes the message and stores the bytes in the given string. Note that the bytes are binary, not text; we only use the `string` class as a convenient container.
- `bool ParseFromString(const string& data);`: parses a message from the given string.
- `bool SerializeToOstream(ostream* output) const;`: writes the message to the given C++ `ostream`.
- `bool ParseFromIstream(istream* input);`: parses a message from the given C++ `istream`.

These are just a couple of the options provided for parsing and serialization. Again, see the `Message` API reference for a complete list.

> **Protocol Buffers and O-O Design** Protocol buffer classes are basically dumb data holders (like structs in C++); they don't make good first class citizens in an object model. If you want to add richer behaviour to a generated class, the best way to do this is to wrap the generated protocol buffer class in an application-specific class. Wrapping protocol buffers is also a good idea if you don't have control over the design of the `.proto` file (if, say, you're reusing one from another project). In that case, you can use the wrapper class to craft an interface better suited to the unique environment of your application: hiding some data and methods, exposing convenience functions, etc. **You should never add behaviour to the generated classes by inheriting from them**. This will break internal mechanisms and is not good object-oriented practice anyway.

Writing A Message

Now let's try using your protocol buffer classes. The first thing you want your address book application to be able to do is write personal details to your address book file. To do this, you need to create and populate instances of your protocol buffer classes and then write them to an output stream.

Here is a program which reads an `AddressBook` from a file, adds one new `Person` to it based on user input, and writes the new `AddressBook` back out to the file again. The parts which directly call or reference code generated by the protocol compiler are highlighted.

```
#include <iostream>
#include <fstream>
#include <string>
#include "addressbook.pb.h"
using namespace std;

// This function fills in a Person message based on user input.
void PromptForAddress(tutorial::Person* person) {
  cout << "Enter person ID number: ";
  int id;
  cin >> id;
  person->set_id(id);
  cin.ignore(256, '\n');

  cout << "Enter name: ";
  getline(cin, *person->mutable_name());

  cout << "Enter email address (blank for none): ";
  string email;
  getline(cin, email);
  if (!email.empty()) {
    person->set_email(email);
  }

  while (true) {
    cout << "Enter a phone number (or leave blank to finish): ";
    string number;
    getline(cin, number);
    if (number.empty()) {
      break;
    }

    tutorial::Person::PhoneNumber* phone_number = person->add_phone();
    phone_number->set_number(number);

    cout << "Is this a mobile, home, or work phone? ";
    string type;
    getline(cin, type);
    if (type == "mobile") {
      phone_number->set_type(tutorial::Person::MOBILE);
    } else if (type == "home") {
      phone_number->set_type(tutorial::Person::HOME);
    } else if (type == "work") {
      phone_number->set_type(tutorial::Person::WORK);
    } else {
      cout << "Unknown phone type.  Using default." << endl;
```

```
    }
  }
}

// Main function:  Reads the entire address book from a file,
//   adds one person based on user input, then writes it back out to the same
//   file.
int main(int argc, char* argv[]) {
  // Verify that the version of the library that we linked against is
  // compatible with the version of the headers we compiled against.
  GOOGLE_PROTOBUF_VERIFY_VERSION;

  if (argc != 2) {
    cerr << "Usage:  " << argv[0] << " ADDRESS_BOOK_FILE" << endl;
    return -1;
  }

  tutorial::AddressBook address_book;

  {
    // Read the existing address book.
    fstream input(argv[1], ios::in | ios::binary);
    if (!input) {
      cout << argv[1] << ": File not found.  Creating a new file." << endl;
    } else if (!address_book.ParseFromIstream(&input)) {
      cerr << "Failed to parse address book." << endl;
      return -1;
    }
  }

  // Add an address.
  PromptForAddress(address_book.add_person());

  {
    // Write the new address book back to disk.
    fstream output(argv[1], ios::out | ios::trunc | ios::binary);
    if (!address_book.SerializeToOstream(&output)) {
      cerr << "Failed to write address book." << endl;
      return -1;
    }
  }

  // Optional:  Delete all global objects allocated by libprotobuf.
  google::protobuf::ShutdownProtobufLibrary();

  return 0;
}
```

Notice the `GOOGLE_PROTOBUF_VERIFY_VERSION` macro. It is good practice – though not strictly necessary – to execute this macro before using the C++ Protocol Buffer library. It verifies that you have not accidentally linked against a version of the library which is incompatible with the version of the headers you compiled with. If a version mismatch is detected, the program will abort. Note that every `.pb.cc` file automatically invokes this macro on startup.

Also notice the call to `ShutdownProtobufLibrary()` at the end of the program. All this does is delete any global objects that were allocated by the Protocol Buffer library. This is unnecessary for most programs, since the process is just going to exit anyway and the OS will take care of reclaiming all of its memory. However, if you use a memory leak checker that requires

that every last object be freed, or if you are writing a library which may be loaded and unloaded multiple times by a single process, then you may want to force Protocol Buffers to clean up everything.

Reading A Message

Of course, an address book wouldn't be much use if you couldn't get any information out of it! This example reads the file created by the above example and prints all the information in it.

```
#include <iostream>
#include <fstream>
#include <string>
#include "addressbook.pb.h"
using namespace std;

// Iterates though all people in the AddressBook and prints info about them.
void ListPeople(const tutorial::AddressBook& address_book) {
  for (int i = 0; i < address_book.person_size(); i++) {
    const tutorial::Person& person = address_book.person(i);

    cout << "Person ID: " << person.id() << endl;
    cout << "  Name: " << person.name() << endl;
    if (person.has_email()) {
      cout << "  E-mail address: " << person.email() << endl;
    }

    for (int j = 0; j < person.phone_size(); j++) {
      const tutorial::Person::PhoneNumber& phone_number = person.phone(j);

      switch (phone_number.type()) {
        case tutorial::Person::MOBILE:
          cout << "  Mobile phone #: ";
          break;
        case tutorial::Person::HOME:
          cout << "  Home phone #: ";
          break;
        case tutorial::Person::WORK:
          cout << "  Work phone #: ";
          break;
      }
      cout << phone_number.number() << endl;
    }
  }
}

// Main function:  Reads the entire address book from a file and prints all
//   the information inside.
int main(int argc, char* argv[]) {
  // Verify that the version of the library that we linked against is
  // compatible with the version of the headers we compiled against.
  GOOGLE_PROTOBUF_VERIFY_VERSION;

  if (argc != 2) {
    cerr << "Usage:  " << argv[0] << " ADDRESS_BOOK_FILE" << endl;
    return -1;
  }
```

```
  tutorial::AddressBook address_book;

  {
    // Read the existing address book.
    fstream input(argv[1], ios::in | ios::binary);
    if (!address_book.ParseFromIstream(&input)) {
      cerr << "Failed to parse address book." << endl;
      return -1;
    }
  }

  ListPeople(address_book);

  // Optional:  Delete all global objects allocated by libprotobuf.
  google::protobuf::ShutdownProtobufLibrary();

  return 0;
}
```

Extending a Protocol Buffer

Sooner or later after you release the code that uses your protocol buffer, you will undoubtedly want to "improve" the protocol buffer's definition. If you want your new buffers to be backwards-compatible, and your old buffers to be forward-compatible – and you almost certainly do want this – then there are some rules you need to follow. In the new version of the protocol buffer:

- you *must not* change the tag numbers of any existing fields.
- you *must not* add or delete any required fields.
- you *may* delete optional or repeated fields.
- you *may* add new optional or repeated fields but you must use fresh tag numbers (i.e. tag numbers that were never used in this protocol buffer, not even by deleted fields).

(There are some exceptions to these rules, but they are rarely used.)

If you follow these rules, old code will happily read new messages and simply ignore any new fields. To the old code, optional fields that were deleted will simply have their default value, and deleted repeated fields will be empty. New code will also transparently read old messages. However, keep in mind that new optional fields will not be present in old messages, so you will need to either check explicitly whether they're set with `has_`, or provide a reasonable default value in your `.proto` file with `[default = value]` after the tag number. If the default value is not specified for an optional element, a type-specific default value is used instead: for strings, the default value is the empty string. For booleans, the default value is false. For numeric types, the default value is zero. Note also that if you added a new repeated field, your new code will not be able to tell whether it was left empty (by new code) or never set at all (by old code) since there is no `has_` flag for it.

Optimization Tips

The C++ Protocol Buffers library is extremely heavily optimized. However, proper usage can improve performance even more. Here are some tips for squeezing every last drop of speed out of the library:

- Reuse message objects when possible. Messages try to keep around any memory they allocate for reuse, even when they are cleared. Thus, if you are handling many messages with the same type and similar structure in succession, it is a good idea to reuse the same message object each time to take load off the memory allocator. However,

objects can become bloated over time, especially if your messages vary in "shape" or if you occasionally construct a message that is much larger than usual. You should monitor the sizes of your message objects by calling the `SpaceUsed` method and delete them once they get too big.

- Your system's memory allocator may not be well-optimized for allocating lots of small objects from multiple threads. Try using Google's tcmalloc instead.

Advanced Usage

Protocol buffers have uses that go beyond simple accessors and serialization. Be sure to explore the C++ API reference to see what else you can do with them.

One key feature provided by protocol message classes is *reflection*. You can iterate over the fields of a message and manipulate their values without writing your code against any specific message type. One very useful way to use reflection is for converting protocol messages to and from other encodings, such as XML or JSON. A more advanced use of reflection might be to find differences between two messages of the same type, or to develop a sort of "regular expressions for protocol messages" in which you can write expressions that match certain message contents. If you use your imagination, it's possible to apply Protocol Buffers to a much wider range of problems than you might initially expect!

Reflection is provided by the `Message::Reflection` interface.

Last updated 四月 *2, 2012.*

Protocol Buffer Basics: Java

This tutorial provides a basic Java programmer's introduction to working with protocol buffers. By walking through creating a simple example application, it shows you how to

- Define message formats in a `.proto` file.
- Use the protocol buffer compiler.
- Use the Java protocol buffer API to write and read messages.

This isn't a comprehensive guide to using protocol buffers in Java. For more detailed reference information, see the Protocol Buffer Language Guide, the Java API Reference, the Java Generated Code Guide, and the Encoding Reference.

Why Use Protocol Buffers?

The example we're going to use is a very simple "address book" application that can read and write people's contact details to and from a file. Each person in the address book has a name, an ID, an email address, and a contact phone number.

How do you serialize and retrieve structured data like this? There are a few ways to solve this problem:

- Use Java Serialization. This is the default approach since it's built into the language, but it has a host of well-known problems (see Effective Java, by Josh Bloch pp. 213), and also doesn't work very well if you need to share data with applications written in C++ or Python.
- You can invent an ad-hoc way to encode the data items into a single string – such as encoding 4 ints as "12:3:-23:67". This is a simple and flexible approach, although it does require writing one-off encoding and parsing code, and the parsing imposes a small run-time cost. This works best for encoding very simple data.
- Serialize the data to XML. This approach can be very attractive since XML is (sort of) human readable and there are binding libraries for lots of languages. This can be a good choice if you want to share data with other applications/projects. However, XML is notoriously space intensive, and encoding/decoding it can impose a huge performance penalty on applications. Also, navigating an XML DOM tree is considerably more complicated than navigating simple fields in a class normally would be.

Protocol buffers are the flexible, efficient, automated solution to solve exactly this problem. With protocol buffers, you write a `.proto` description of the data structure you wish to store. From that, the protocol buffer compiler creates a class that implements automatic encoding and parsing of the protocol buffer data with an efficient binary format. The generated class provides getters and setters for the fields that make up a protocol buffer and takes care of the details of reading and writing the protocol buffer as a unit. Importantly, the protocol buffer format supports the idea of extending the format over time in such a way that the code can still read data encoded with the old format.

Where to Find the Example Code

The example code is included in the source code package, under the "examples" directory. Download it here.

Defining Your Protocol Format

To create your address book application, you'll need to start with a `.proto` file. The definitions in a `.proto` file are simple: you add a *message* for each data structure you want to serialize, then specify a name and a type for each field in the message. Here is the `.proto` file that defines your messages, `addressbook.proto`.

```
package tutorial;

option java_package = "com.example.tutorial";
option java_outer_classname = "AddressBookProtos";

message Person {
  required string name = 1;
  required int32 id = 2;
  optional string email = 3;

  enum PhoneType {
    MOBILE = 0;
    HOME = 1;
    WORK = 2;
  }

  message PhoneNumber {
    required string number = 1;
    optional PhoneType type = 2 [default = HOME];
  }

  repeated PhoneNumber phone = 4;
}

message AddressBook {
  repeated Person person = 1;
}
```

As you can see, the syntax is similar to C++ or Java. Let's go through each part of the file and see what it does.

The `.proto` file starts with a package declaration, which helps to prevent naming conflicts between different projects. In Java, the package name is used as the Java package unless you have explicitly specified a `java_package`, as we have here. Even if you do provide a `java_package`, you should still define a normal `package` as well to avoid name collisions in the Protocol Buffers name space as well as in non-Java languages.

After the package declaration, you can see two options that are Java-specific: `java_package` and `java_outer_classname`. `java_package` specifies in what Java package name your generated classes should live. If you don't specify this explicitly, it simply matches the package name given by the `package` declaration, but these names usually aren't appropriate Java package names (since they usually don't start with a domain name). The `java_outer_classname` option defines the class name which should contain all of the classes in this file. If you don't give a `java_outer_classname` explicitly, it will be generated by converting the file name to camel case. For example, "my_proto.proto" would, by default, use "MyProto" as the outer class name.

Next, you have your message definitions. A message is just an aggregate containing a set of typed fields. Many standard simple data types are available as field types, including `bool`, `int32`, `float`, `double`, and `string`. You can also add further structure to your messages by using other message types as field types – in the above example the `Person` message contains `PhoneNumber` messages, while the `AddressBook` message contains `Person` messages. You can even define message

types nested inside other messages – as you can see, the `PhoneNumber` type is defined inside `Person`. You can also define `enum` types if you want one of your fields to have one of a predefined list of values – here you want to specify that a phone number can be one of `MOBILE`, `HOME`, or `WORK`.

The " = 1", " = 2" markers on each element identify the unique "tag" that field uses in the binary encoding. Tag numbers 1-15 require one less byte to encode than higher numbers, so as an optimization you can decide to use those tags for the commonly used or repeated elements, leaving tags 16 and higher for less-commonly used optional elements. Each element in a repeated field requires re-encoding the tag number, so repeated fields are particularly good candidates for this optimization.

Each field must be annotated with one of the following modifiers:

- `required`: a value for the field must be provided, otherwise the message will be considered "uninitialized". Trying to build an uninitialized message will throw a `RuntimeException`. Parsing an uninitialized message will throw an `IOException`. Other than this, a required field behaves exactly like an optional field.
- `optional`: the field may or may not be set. If an optional field value isn't set, a default value is used. For simple types, you can specify your own default value, as we've done for the phone number `type` in the example. Otherwise, a system default is used: zero for numeric types, the empty string for strings, false for bools. For embedded messages, the default value is always the "default instance" or "prototype" of the message, which has none of its fields set. Calling the accessor to get the value of an optional (or required) field which has not been explicitly set always returns that field's default value.
- `repeated`: the field may be repeated any number of times (including zero). The order of the repeated values will be preserved in the protocol buffer. Think of repeated fields as dynamically sized arrays.

> **Required Is Forever** You should be very careful about marking fields as `required`. If at some point you wish to stop writing or sending a required field, it will be problematic to change the field to an optional field – old readers will consider messages without this field to be incomplete and may reject or drop them unintentionally. You should consider writing application-specific custom validation routines for your buffers instead. Some engineers at Google have come to the conclusion that using `required` does more harm than good; they prefer to use only `optional` and `repeated`. However, this view is not universal.

You'll find a complete guide to writing `.proto` files – including all the possible field types – in the Protocol Buffer Language Guide. Don't go looking for facilities similar to class inheritance, though – protocol buffers don't do that.

Compiling Your Protocol Buffers

Now that you have a `.proto`, the next thing you need to do is generate the classes you'll need to read and write `AddressBook` (and hence `Person` and `PhoneNumber`) messages. To do this, you need to run the protocol buffer compiler `protoc` on your `.proto`:

1. If you haven't installed the compiler, download the package and follow the instructions in the README.
2. Now run the compiler, specifying the source directory (where your application's source code lives – the current directory is used if you don't provide a value), the destination directory (where you want the generated code to go; often the same as `$SRC_DIR`), and the path to your `.proto`. In this case, you...:

   ```
   protoc -I=$SRC_DIR --java_out=$DST_DIR $SRC_DIR/addressbook.proto
   ```

   Because you want Java classes, you use the `--java_out` option – similar options are provided for other supported languages.

This generates `com/example/tutorial/AddressBookProtos.java` in your specified destination directory.

The Protocol Buffer API

Let's look at some of the generated code and see what classes and methods the compiler has created for you. If you look in `AddressBookProtos.java`, you can see that it defines a class called `AddressBookProtos`, nested within which is a class for each message you specified in `addressbook.proto`. Each class has its own `Builder` class that you use to create instances of that class. You can find out more about builders in the Builders vs. Messages section below.

Both messages and builders have auto-generated accessor methods for each field of the message; messages have only getters while builders have both getters and setters. Here are some of the accessors for the `Person` class (implementations omitted for brevity):

```
// required string name = 1;
public boolean hasName();
public String getName();

// required int32 id = 2;
public boolean hasId();
public int getId();

// optional string email = 3;
public boolean hasEmail();
public String getEmail();

// repeated .tutorial.Person.PhoneNumber phone = 4;
public List<PhoneNumber> getPhoneList();
public int getPhoneCount();
public PhoneNumber getPhone(int index);
```

Meanwhile, `Person.Builder` has the same getters plus setters:

```
// required string name = 1;
public boolean hasName();
public java.lang.String getName();
public Builder setName(String value);
public Builder clearName();

// required int32 id = 2;
public boolean hasId();
public int getId();
public Builder setId(int value);
public Builder clearId();

// optional string email = 3;
public boolean hasEmail();
public String getEmail();
public Builder setEmail(String value);
public Builder clearEmail();

// repeated .tutorial.Person.PhoneNumber phone = 4;
public List<PhoneNumber> getPhoneList();
public int getPhoneCount();
public PhoneNumber getPhone(int index);
```

```
public Builder setPhone(int index, PhoneNumber value);
public Builder addPhone(PhoneNumber value);
public Builder addAllPhone(Iterable<PhoneNumber> value);
public Builder clearPhone();
```

As you can see, there are simple JavaBeans-style getters and setters for each field. There are also `has` getters for each singular field which return true if that field has been set. Finally, each field has a `clear` method that un-sets the field back to its empty state.

Repeated fields have some extra methods – a `Count` method (which is just shorthand for the list's size), getters and setters which get or set a specific element of the list by index, an `add` method which appends a new element to the list, and an `addAll` method which adds an entire container full of elements to the list.

Notice how these accessor methods use camel-case naming, even though the `.proto` file uses lowercase-with-underscores. This transformation is done automatically by the protocol buffer compiler so that the generated classes match standard Java style conventions. You should always use lowercase-with-underscores for field names in your `.proto` files; this ensures good naming practice in all the generated languages. See the style guide for more on good `.proto` style.

For more information on exactly what members the protocol compiler generates for any particular field definition, see the Java generated code reference.

Enums and Nested Classes

The generated code includes a `PhoneType` Java 5 enum, nested within `Person`:

```
public static enum PhoneType {
  MOBILE(0, 0),
  HOME(1, 1),
  WORK(2, 2),
  ;
  ...
}
```

The nested type `Person.PhoneNumber` is generated, as you'd expect, as a nested class within `Person`.

Builders vs. Messages

The message classes generated by the protocol buffer compiler are all *immutable*. Once a message object is constructed, it cannot be modified, just like a Java `String`. To construct a message, you must first construct a builder, set any fields you want to set to your chosen values, then call the builder's `build()` method.

You may have noticed that each method of the builder which modifies the message returns another builder. The returned object is actually the same builder on which you called the method. It is returned for convenience so that you can string several setters together on a single line of code.

Here's an example of how you would create an instance of `Person`:

```
Person john =
  Person.newBuilder()
    .setId(1234)
    .setName("John Doe")
    .setEmail("jdoe@example.com")
```

```
    .addPhone(
      Person.PhoneNumber.newBuilder()
        .setNumber("555-4321")
        .setType(Person.PhoneType.HOME))
    .build();
```

Standard Message Methods

Each message and builder class also contains a number of other methods that let you check or manipulate the entire message, including:

- `isInitialized()`: checks if all the required fields have been set.
- `toString()`: returns a human-readable representation of the message, particularly useful for debugging.
- `mergeFrom(Message other)`: (builder only) merges the contents of `other` into this message, overwriting singular fields and concatenating repeated ones.
- `clear()`: (builder only) clears all the fields back to the empty state.

These methods implement the `Message` and `Message.Builder` interfaces shared by all Java messages and builders. For more information, see the complete API documentation for `Message`.

Parsing and Serialization

Finally, each protocol buffer class has methods for writing and reading messages of your chosen type using the protocol buffer binary format. These include:

- `byte[] toByteArray();`: serializes the message and returns a byte array containing its raw bytes.
- `static Person parseFrom(byte[] data);`: parses a message from the given byte array.
- `void writeTo(OutputStream output);`: serializes the message and writes it to an `OutputStream`.
- `static Person parseFrom(InputStream input);`: reads and parses a message from an `InputStream`.

These are just a couple of the options provided for parsing and serialization. Again, see the `Message` API reference for a complete list.

> **Protocol Buffers and O-O Design** Protocol buffer classes are basically dumb data holders (like structs in C++); they don't make good first class citizens in an object model. If you want to add richer behaviour to a generated class, the best way to do this is to wrap the generated protocol buffer class in an application-specific class. Wrapping protocol buffers is also a good idea if you don't have control over the design of the `.proto` file (if, say, you're reusing one from another project). In that case, you can use the wrapper class to craft an interface better suited to the unique environment of your application: hiding some data and methods, exposing convenience functions, etc. **You should never add behaviour to the generated classes by inheriting from them**. This will break internal mechanisms and is not good object-oriented practice anyway.

Writing A Message

Now let's try using your protocol buffer classes. The first thing you want your address book application to be able to do is write personal details to your address book file. To do this, you need to create and populate instances of your protocol buffer classes and then write them to an output stream.

Here is a program which reads an `AddressBook` from a file, adds one new `Person` to it based on user input, and writes the new `AddressBook` back out to the file again. The parts which directly call or reference code generated by the protocol

compiler are highlighted.

```
import com.example.tutorial.AddressBookProtos.AddressBook;
import com.example.tutorial.AddressBookProtos.Person;
import java.io.BufferedReader;
import java.io.FileInputStream;
import java.io.FileNotFoundException;
import java.io.FileOutputStream;
import java.io.InputStreamReader;
import java.io.IOException;
import java.io.PrintStream;

class AddPerson {
  // This function fills in a Person message based on user input.
  static Person PromptForAddress(BufferedReader stdin,
                                 PrintStream stdout) throws IOException {
    Person.Builder person = Person.newBuilder();

    stdout.print("Enter person ID: ");
    person.setId(Integer.valueOf(stdin.readLine()));

    stdout.print("Enter name: ");
    person.setName(stdin.readLine());

    stdout.print("Enter email address (blank for none): ");
    String email = stdin.readLine();
    if (email.length() > 0) {
      person.setEmail(email);
    }

    while (true) {
      stdout.print("Enter a phone number (or leave blank to finish): ");
      String number = stdin.readLine();
      if (number.length() == 0) {
        break;
      }

      Person.PhoneNumber.Builder phoneNumber =
        Person.PhoneNumber.newBuilder().setNumber(number);

      stdout.print("Is this a mobile, home, or work phone? ");
      String type = stdin.readLine();
      if (type.equals("mobile")) {
        phoneNumber.setType(Person.PhoneType.MOBILE);
      } else if (type.equals("home")) {
        phoneNumber.setType(Person.PhoneType.HOME);
      } else if (type.equals("work")) {
        phoneNumber.setType(Person.PhoneType.WORK);
      } else {
        stdout.println("Unknown phone type.  Using default.");
      }

      person.addPhone(phoneNumber);
    }

    return person.build();
  }
```

```
  // Main function:  Reads the entire address book from a file,
  //   adds one person based on user input, then writes it back out to the same
  //   file.
  public static void main(String[] args) throws Exception {
    if (args.length != 1) {
      System.err.println("Usage:  AddPerson ADDRESS_BOOK_FILE");
      System.exit(-1);
    }

    AddressBook.Builder addressBook = AddressBook.newBuilder();

    // Read the existing address book.
    try {
      addressBook.mergeFrom(new FileInputStream(args[0]));
    } catch (FileNotFoundException e) {
      System.out.println(args[0] + ": File not found.  Creating a new file.");
    }

    // Add an address.
    addressBook.addPerson(
      PromptForAddress(new BufferedReader(new InputStreamReader(System.in)),
                       System.out));

    // Write the new address book back to disk.
    FileOutputStream output = new FileOutputStream(args[0]);
    addressBook.build().writeTo(output);
    output.close();
  }
}
```

Reading A Message

Of course, an address book wouldn't be much use if you couldn't get any information out of it! This example reads the file created by the above example and prints all the information in it.

```
import com.example.tutorial.AddressBookProtos.AddressBook;
import com.example.tutorial.AddressBookProtos.Person;
import java.io.FileInputStream;
import java.io.IOException;
import java.io.PrintStream;

class ListPeople {
  // Iterates though all people in the AddressBook and prints info about them.
  static void Print(AddressBook addressBook) {
    for (Person person: addressBook.getPersonList()) {
      System.out.println("Person ID: " + person.getId());
      System.out.println("  Name: " + person.getName());
      if (person.hasEmail()) {
        System.out.println("  E-mail address: " + person.getEmail());
      }

      for (Person.PhoneNumber phoneNumber : person.getPhoneList()) {
        switch (phoneNumber.getType()) {
          case MOBILE:
            System.out.print("  Mobile phone #: ");
            break;
```

```
          case HOME:
            System.out.print("  Home phone #: ");
            break;
          case WORK:
            System.out.print("  Work phone #: ");
            break;
        }
        System.out.println(phoneNumber.getNumber());
      }
    }
  }

  // Main function:  Reads the entire address book from a file and prints all
  //   the information inside.
  public static void main(String[] args) throws Exception {
    if (args.length != 1) {
      System.err.println("Usage:  ListPeople ADDRESS_BOOK_FILE");
      System.exit(-1);
    }

    // Read the existing address book.
    AddressBook addressBook =
      AddressBook.parseFrom(new FileInputStream(args[0]));

    Print(addressBook);
  }
}
```

Extending a Protocol Buffer

Sooner or later after you release the code that uses your protocol buffer, you will undoubtedly want to "improve" the protocol buffer's definition. If you want your new buffers to be backwards-compatible, and your old buffers to be forward-compatible – and you almost certainly do want this – then there are some rules you need to follow. In the new version of the protocol buffer:

- you *must not* change the tag numbers of any existing fields.
- you *must not* add or delete any required fields.
- you *may* delete optional or repeated fields.
- you *may* add new optional or repeated fields but you must use fresh tag numbers (i.e. tag numbers that were never used in this protocol buffer, not even by deleted fields).

(There are some exceptions to these rules, but they are rarely used.)

If you follow these rules, old code will happily read new messages and simply ignore any new fields. To the old code, optional fields that were deleted will simply have their default value, and deleted repeated fields will be empty. New code will also transparently read old messages. However, keep in mind that new optional fields will not be present in old messages, so you will need to either check explicitly whether they're set with `has_`, or provide a reasonable default value in your `.proto` file with `[default = value]` after the tag number. If the default value is not specified for an optional element, a type-specific default value is used instead: for strings, the default value is the empty string. For booleans, the default value is false. For numeric types, the default value is zero. Note also that if you added a new repeated field, your new code will not be able to tell whether it was left empty (by new code) or never set at all (by old code) since there is no `has_` flag for it.

Advanced Usage

Protocol buffers have uses that go beyond simple accessors and serialization. Be sure to explore the Java API reference to see what else you can do with them.

One key feature provided by protocol message classes is *reflection*. You can iterate over the fields of a message and manipulate their values without writing your code against any specific message type. One very useful way to use reflection is for converting protocol messages to and from other encodings, such as XML or JSON. A more advanced use of reflection might be to find differences between two messages of the same type, or to develop a sort of "regular expressions for protocol messages" in which you can write expressions that match certain message contents. If you use your imagination, it's possible to apply Protocol Buffers to a much wider range of problems than you might initially expect!

Reflection is provided as part of the `Message` and `Message.Builder` interfaces.

Last updated 四月 *2, 2012.*

Protocol Buffer Basics: Python

This tutorial provides a basic Python programmer's introduction to working with protocol buffers. By walking through creating a simple example application, it shows you how to

- Define message formats in a `.proto` file.
- Use the protocol buffer compiler.
- Use the Python protocol buffer API to write and read messages.

This isn't a comprehensive guide to using protocol buffers in Python. For more detailed reference information, see the Protocol Buffer Language Guide, the Python API Reference, the Python Generated Code Guide, and the Encoding Reference.

Why Use Protocol Buffers?

The example we're going to use is a very simple "address book" application that can read and write people's contact details to and from a file. Each person in the address book has a name, an ID, an email address, and a contact phone number.

How do you serialize and retrieve structured data like this? There are a few ways to solve this problem:

- Use Python pickling. This is the default approach since it's built into the language, but it doesn't deal well with schema evolution, and also doesn't work very well if you need to share data with application written in C++ or Java.
- You can invent an ad-hoc way to encode the data items into a single string – such as encoding 4 ints as "12:3:-23:67". This is a simple and flexible approach, although it does require writing one-off encoding and parsing code, and the parsing imposes a small run-time cost. This works best for encoding very simple data.
- Serialize the data to XML. This approach can be very attractive since XML is (sort of) human readable and there are binding libraries for lots of languages. This can be a good choice if you want to share data with other applications/projects. However, XML is notoriously space intensive, and encoding/decoding it can impose a huge performance penalty on applications. Also, navigating an XML DOM tree is considerably more complicated than navigating simple fields in a class normally would be.

Protocol buffers are the flexible, efficient, automated solution to solve exactly this problem. With protocol buffers, you write a `.proto` description of the data structure you wish to store. From that, the protocol buffer compiler creates a class that implements automatic encoding and parsing of the protocol buffer data with an efficient binary format. The generated class provides getters and setters for the fields that make up a protocol buffer and takes care of the details of reading and writing the protocol buffer as a unit. Importantly, the protocol buffer format supports the idea of extending the format over time in such a way that the code can still read data encoded with the old format.

Where to Find the Example Code

The example code is included in the source code package, under the "examples" directory. Download it here.

Defining Your Protocol Format

To create your address book application, you'll need to start with a `.proto` file. The definitions in a `.proto` file are simple: you add a *message* for each data structure you want to serialize, then specify a name and a type for each field in the message. Here is the `.proto` file that defines your messages, `addressbook.proto`.

```
package tutorial;

message Person {
  required string name = 1;
  required int32 id = 2;
  optional string email = 3;

  enum PhoneType {
    MOBILE = 0;
    HOME = 1;
    WORK = 2;
  }

  message PhoneNumber {
    required string number = 1;
    optional PhoneType type = 2 [default = HOME];
  }

  repeated PhoneNumber phone = 4;
}

message AddressBook {
  repeated Person person = 1;
}
```

As you can see, the syntax is similar to C++ or Java. Let's go through each part of the file and see what it does.

The `.proto` file starts with a package declaration, which helps to prevent naming conflicts between different projects. In Python, packages are normally determined by directory structure, so the `package` you define in your `.proto` file will have no effect on the generated code. However, you should still declare one to avoid name collisions in the Protocol Buffers name space as well as in non-Python languages.

Next, you have your message definitions. A message is just an aggregate containing a set of typed fields. Many standard simple data types are available as field types, including `bool`, `int32`, `float`, `double`, and `string`. You can also add further structure to your messages by using other message types as field types – in the above example the `Person` message contains `PhoneNumber` messages, while the `AddressBook` message contains `Person` messages. You can even define message types nested inside other messages – as you can see, the `PhoneNumber` type is defined inside `Person`. You can also define `enum` types if you want one of your fields to have one of a predefined list of values – here you want to specify that a phone number can be one of `MOBILE`, `HOME`, or `WORK`.

The " = 1", " = 2" markers on each element identify the unique "tag" that field uses in the binary encoding. Tag numbers 1-15 require one less byte to encode than higher numbers, so as an optimization you can decide to use those tags for the commonly used or repeated elements, leaving tags 16 and higher for less-commonly used optional elements. Each element in a repeated field requires re-encoding the tag number, so repeated fields are particularly good candidates for this optimization.

Each field must be annotated with one of the following modifiers:

- `required`: a value for the field must be provided, otherwise the message will be considered "uninitialized". Serializing an uninitialized message will raise an exception. Parsing an uninitialized message will fail. Other than this, a required field behaves exactly like an optional field.
- `optional`: the field may or may not be set. If an optional field value isn't set, a default value is used. For simple types, you can specify your own default value, as we've done for the phone number `type` in the example. Otherwise, a system default is used: zero for numeric types, the empty string for strings, false for bools. For embedded messages, the default value is always the "default instance" or "prototype" of the message, which has none of its fields set. Calling the accessor to get the value of an optional (or required) field which has not been explicitly set always returns that field's default value.
- `repeated`: the field may be repeated any number of times (including zero). The order of the repeated values will be preserved in the protocol buffer. Think of repeated fields as dynamically sized arrays.

> **Required Is Forever** You should be very careful about marking fields as `required`. If at some point you wish to stop writing or sending a required field, it will be problematic to change the field to an optional field – old readers will consider messages without this field to be incomplete and may reject or drop them unintentionally. You should consider writing application-specific custom validation routines for your buffers instead. Some engineers at Google have come to the conclusion that using `required` does more harm than good; they prefer to use only `optional` and `repeated`. However, this view is not universal.

You'll find a complete guide to writing `.proto` files – including all the possible field types – in the Protocol Buffer Language Guide. Don't go looking for facilities similar to class inheritance, though – protocol buffers don't do that.

Compiling Your Protocol Buffers

Now that you have a `.proto`, the next thing you need to do is generate the classes you'll need to read and write `AddressBook` (and hence `Person` and `PhoneNumber`) messages. To do this, you need to run the protocol buffer compiler `protoc` on your `.proto`:

1. If you haven't installed the compiler, download the package and follow the instructions in the README.
2. Now run the compiler, specifying the source directory (where your application's source code lives – the current directory is used if you don't provide a value), the destination directory (where you want the generated code to go; often the same as `$SRC_DIR`), and the path to your `.proto`. In this case, you...:

   ```
   protoc -I=$SRC_DIR --python_out=$DST_DIR $SRC_DIR/addressbook.proto
   ```

   Because you want Python classes, you use the `--python_out` option – similar options are provided for other supported languages.

This generates `addressbook_pb2.py` in your specified destination directory.

The Protocol Buffer API

Unlike when you generate Java and C++ protocol buffer code, the Python protocol buffer compiler doesn't generate your data access code for you directly. Instead (as you'll see if you look at `addressbook_pb2.py`) it generates special descriptors for all your messages, enums, and fields, and some mysteriously empty classes, one for each message type:

```
class Person(message.Message):
  __metaclass__ = reflection.GeneratedProtocolMessageType

  class PhoneNumber(message.Message):
    __metaclass__ = reflection.GeneratedProtocolMessageType
    DESCRIPTOR = _PERSON_PHONENUMBER
  DESCRIPTOR = _PERSON

class AddressBook(message.Message):
  __metaclass__ = reflection.GeneratedProtocolMessageType
  DESCRIPTOR = _ADDRESSBOOK
```

The important line in each class is `__metaclass__ = reflection.GeneratedProtocolMessageType`. While the details of how Python metaclasses work is beyond the scope of this tutorial, you can think of them as like a template for creating classes. At load time, the `GeneratedProtocolMessageType` metaclass uses the specified descriptors to create all the Python methods you need to work with each message type and adds them to the relevant classes. You can then use the fully-populated classes in your code.

The end effect of all this is that you can use the `Person` class as if it defined each field of the `Message` base class as a regular field. For example, you could write:

```
import addressbook_pb2
person = addressbook_pb2.Person()
person.id = 1234
person.name = "John Doe"
person.email = "jdoe@example.com"
phone = person.phone.add()
phone.number = "555-4321"
phone.type = addressbook_pb2.Person.HOME
```

Note that these assignments are not just adding arbitrary new fields to a generic Python object. If you were to try to assign a field that isn't defined in the `.proto` file, an `AttributeError` would be raised. If you assign a field to a value of the wrong type, a `TypeError` will be raised. Also, reading the value of a field before it has been set returns the default value.

```
person.no_such_field = 1  # raises AttributeError
person.id = "1234"        # raises TypeError
```

For more information on exactly what members the protocol compiler generates for any particular field definition, see the Python generated code reference.

Enums

Enums are expanded by the metaclass into a set of symbolic constants with integer values. So, for example, the constant `addressbook_pb2.Person.WORK` has the value 2.

Standard Message Methods

Each message class also contains a number of other methods that let you check or manipulate the entire message, including:

- `IsInitialized()`: checks if all the required fields have been set.

- `__str__()`: returns a human-readable representation of the message, particularly useful for debugging. (Usually invoked as `str(message)` or `print message`.)
- `CopyFrom(other_msg)`: overwrites the message with the given message's values.
- `Clear()`: clears all the elements back to the empty state.

These methods implement the `Message` interface. For more information, see the complete API documentation for `Message`.

Parsing and Serialization

Finally, each protocol buffer class has methods for writing and reading messages of your chosen type using the protocol buffer binary format. These include:

- `SerializeToString()`: serializes the message and returns it as a string. Note that the bytes are binary, not text; we only use the `str` type as a convenient container.
- `ParseFromString(data)`: parses a message from the given string.

These are just a couple of the options provided for parsing and serialization. Again, see the `Message` API reference for a complete list.

> **Protocol Buffers and O-O Design** Protocol buffer classes are basically dumb data holders (like structs in C++); they don't make good first class citizens in an object model. If you want to add richer behaviour to a generated class, the best way to do this is to wrap the generated protocol buffer class in an application-specific class. Wrapping protocol buffers is also a good idea if you don't have control over the design of the `.proto` file (if, say, you're reusing one from another project). In that case, you can use the wrapper class to craft an interface better suited to the unique environment of your application: hiding some data and methods, exposing convenience functions, etc. **You should never add behaviour to the generated classes by inheriting from them**. This will break internal mechanisms and is not good object-oriented practice anyway.

Writing A Message

Now let's try using your protocol buffer classes. The first thing you want your address book application to be able to do is write personal details to your address book file. To do this, you need to create and populate instances of your protocol buffer classes and then write them to an output stream.

Here is a program which reads an `AddressBook` from a file, adds one new `Person` to it based on user input, and writes the new `AddressBook` back out to the file again. The parts which directly call or reference code generated by the protocol compiler are highlighted.

```
#! /usr/bin/python

import addressbook_pb2
import sys

# This function fills in a Person message based on user input.
def PromptForAddress(person):
  person.id = int(raw_input("Enter person ID number: "))
  person.name = raw_input("Enter name: ")

  email = raw_input("Enter email address (blank for none): ")
  if email != "":
    person.email = email
```

```
  while True:
    number = raw_input("Enter a phone number (or leave blank to finish): ")
    if number == "":
      break

    phone_number = person.phone.add()
    phone_number.number = number

    type = raw_input("Is this a mobile, home, or work phone? ")
    if type == "mobile":
      phone_number.type = addressbook_pb2.Person.MOBILE
    elif type == "home":
      phone_number.type = addressbook_pb2.Person.HOME
    elif type == "work":
      phone_number.type = addressbook_pb2.Person.WORK
    else:
      print "Unknown phone type; leaving as default value."

# Main procedure:  Reads the entire address book from a file,
#   adds one person based on user input, then writes it back out to the same
#   file.
if len(sys.argv) != 2:
  print "Usage:", sys.argv[0], "ADDRESS_BOOK_FILE"
  sys.exit(-1)

address_book = addressbook_pb2.AddressBook()

# Read the existing address book.
try:
  f = open(sys.argv[1], "rb")
  address_book.ParseFromString(f.read())
  f.close()
except IOError:
  print sys.argv[1] + ": Could not open file.  Creating a new one."

# Add an address.
PromptForAddress(address_book.person.add())

# Write the new address book back to disk.
f = open(sys.argv[1], "wb")
f.write(address_book.SerializeToString())
f.close()
```

Reading A Message

Of course, an address book wouldn't be much use if you couldn't get any information out of it! This example reads the file created by the above example and prints all the information in it.

```
#! /usr/bin/python

import addressbook_pb2
import sys

# Iterates though all people in the AddressBook and prints info about them.
def ListPeople(address_book):
```

```
  for person in address_book.person:
    print "Person ID:", person.id
    print "  Name:", person.name
    if person.HasField('email'):
      print "  E-mail address:", person.email

    for phone_number in person.phone:
      if phone_number.type == addressbook_pb2.Person.MOBILE:
        print "  Mobile phone #: ",
      elif phone_number.type == addressbook_pb2.Person.HOME:
        print "  Home phone #: ",
      elif phone_number.type == addressbook_pb2.Person.WORK:
        print "  Work phone #: ",
      print phone_number.number

# Main procedure:  Reads the entire address book from a file and prints all
#   the information inside.
if len(sys.argv) != 2:
  print "Usage:", sys.argv[0], "ADDRESS_BOOK_FILE"
  sys.exit(-1)

address_book = addressbook_pb2.AddressBook()

# Read the existing address book.
f = open(sys.argv[1], "rb")
address_book.ParseFromString(f.read())
f.close()

ListPeople(address_book)
```

Extending a Protocol Buffer

Sooner or later after you release the code that uses your protocol buffer, you will undoubtedly want to "improve" the protocol buffer's definition. If you want your new buffers to be backwards-compatible, and your old buffers to be forward-compatible – and you almost certainly do want this – then there are some rules you need to follow. In the new version of the protocol buffer:

- you *must not* change the tag numbers of any existing fields.
- you *must not* add or delete any required fields.
- you *may* delete optional or repeated fields.
- you *may* add new optional or repeated fields but you must use fresh tag numbers (i.e. tag numbers that were never used in this protocol buffer, not even by deleted fields).

(There are some exceptions to these rules, but they are rarely used.)

If you follow these rules, old code will happily read new messages and simply ignore any new fields. To the old code, optional fields that were deleted will simply have their default value, and deleted repeated fields will be empty. New code will also transparently read old messages. However, keep in mind that new optional fields will not be present in old messages, so you will need to either check explicitly whether they're set with `has_`, or provide a reasonable default value in your `.proto` file with `[default = value]` after the tag number. If the default value is not specified for an optional element, a type-specific default value is used instead: for strings, the default value is the empty string. For booleans, the default value is false. For numeric types, the default value is zero. Note also that if you added a new repeated field, your new code will not be able to tell whether it was left empty (by new code) or never set at all (by old code) since there is no `has_` flag for it.

Advanced Usage

Protocol buffers have uses that go beyond simple accessors and serialization. Be sure to explore the Python API reference to see what else you can do with them.

One key feature provided by protocol message classes is *reflection*. You can iterate over the fields of a message and manipulate their values without writing your code against any specific message type. One very useful way to use reflection is for converting protocol messages to and from other encodings, such as XML or JSON. A more advanced use of reflection might be to find differences between two messages of the same type, or to develop a sort of "regular expressions for protocol messages" in which you can write expressions that match certain message contents. If you use your imagination, it's possible to apply Protocol Buffers to a much wider range of problems than you might initially expect!

Reflection is provided as part of the `Message` interface.

Last updated 四月 *2, 2012.*

Techniques

This page describes some commonly-used design patterns for dealing with Protocol Buffers. You can also send design and usage questions to the Protocol Buffers discussion group.

Streaming Multiple Messages

If you want to write multiple messages to a single file or stream, it is up to you to keep track of where one message ends and the next begins. The Protocol Buffer wire format is not self-delimiting, so protocol buffer parsers cannot determine where a message ends on their own. The easiest way to solve this problem is to write the size of each message before you write the message itself. When you read the messages back in, you read the size, then read the bytes into a separate buffer, then parse from that buffer. (If you want to avoid copying bytes to a separate buffer, check out the `CodedInputStream` class (in both C++ and Java) which can be told to limit reads to a certain number of bytes.)

Large Data Sets

Protocol Buffers are not designed to handle large messages. As a general rule of thumb, if you are dealing in messages larger than a megabyte each, it may be time to consider an alternate strategy.

That said, Protocol Buffers are great for handling individual messages *within* a large data set. Usually, large data sets are really just a collection of small pieces, where each small piece may be a structured piece of data. Even though Protocol Buffers cannot handle the entire set at once, using Protocol Buffers to encode each piece greatly simplifies your problem: now all you need is to handle a set of byte strings rather than a set of structures.

Protocol Buffers do not include any built-in support for large data sets because different situations call for different solutions. Sometimes a simple list of records will do while other times you may want something more like a database. Each solution should be developed as a separate library, so that only those who need it need to pay the costs.

Union Types

You may sometimes want to send a message that could be one of several different types. However, protocol buffer parsers cannot necessarily determine the type of a message based on the contents alone. So how do you make sure that the recipient application knows how to decode your message? One solution is to create a wrapper message that has one optional field for each possible message type.

For example, if you have message types `Foo`, `Bar`, and `Baz`, you can combine them with a type like:

```
message OneMessage {
  // One of the following will be filled in.
  optional Foo foo = 1;
  optional Bar bar = 2;
  optional Baz baz = 3;
}
```

You may also want to have an enum field that identifies which message is filled in, so that you can `switch` on it:

```
message OneMessage {
  enum Type { FOO = 1; BAR = 2; BAZ = 3; }

  // Identifies which field is filled in.
  required Type type = 1;

  // One of the following will be filled in.
  optional Foo foo = 2;
  optional Bar bar = 3;
  optional Baz baz = 4;
}
```

If you have a very large number of possible types, listing every one of them in your container type may be unwieldy. Instead, you should consider using extensions:

```
message OneMessage {
  extensions 100 to max;
}

// Elsewhere...
extend OneMessage {
  optional Foo foo_ext = 100;
  optional Bar bar_ext = 101;
  optional Baz baz_ext = 102;
}
```

Note that you can use the `ListFields` reflection method (in C++, Java, and Python) to get a list of all fields present in the message, including extensions. You might use this as part of a scheme for registering handlers for diverse message types.

Self-describing Messages

Protocol Buffers do not contain descriptions of their own types. Thus, given only a raw message without the corresponding `.proto` file defining its type, it is difficult to extract any useful data.

However, note that the contents of a .proto file can itself be represented using protocol buffers. The file `src/google/protobuf/descriptor.proto` in the source code package defines the message types involved. `protoc` can output a `FileDescriptorSet` – which represents a set of .proto files – using the `--descriptor_set_out` option. With this, you could define a self-describing protocol message like so:

```
message SelfDescribingMessage {
  // Set of .proto files which define the type.
  required FileDescriptorSet proto_files = 1;
```

```
  // Name of the message type.  Must be defined by one of the files in
  // proto_files.
  required string type_name = 2;

  // The message data.
  required bytes message_data = 3;
}
```

By using classes like `DynamicMessage` (available in C++ and Java), you can then write tools which can manipulate `SelfDescribingMessage`s.

All that said, the reason that this functionality is not included in the Protocol Buffer library is because we have never had a use for it inside Google.

Last updated 四月 *2, 2012.*

ThirdPartyAddOns

Links to third-party add-ons.

Updated Aug 13 (4 days ago) by xiaof...@google.com

Third-Party Add-ons for Protocol Buffers

This page lists code related to Protocol Buffers which is developed and maintained by third parties. You may find this code useful, but note that **none of these projects are affiliated with or endorsed by Google**; try them at your own risk. Also note that many projects here are in the early stages of development and not production-ready.

If you have a project that should be listed here, please send a message to the discussion group:

http://groups.google.com/group/protobuf

Programming Languages

These are projects we know about implementing Protocol Buffers for other programming languages:

- Action Script: http://code.google.com/p/protobuf-actionscript3/
- Action Script: https://code.google.com/p/protoc-gen-as3/
- Action Script: https://github.com/matrix3d/JProtoc
- C: https://github.com/protobuf-c/protobuf-c
- C: http://koti.kapsi.fi/jpa/nanopb/
- C++: http://protobuf.googlecode.com/ (Google-official implementation)
- C/C++: http://spbc.sf.net/
- C#: http://code.google.com/p/protobuf-csharp-port
- C#: http://code.google.com/p/protosharp/
- C#: https://silentorbit.com/protobuf/
- C#/.NET/WCF/VB: http://code.google.com/p/protobuf-net/
- Clojure: http://github.com/ninjudd/clojure-protobuf
- Common Lisp: http://www.prism.gatech.edu/~ndantam3/docs/s-protobuf/
- Common Lisp: http://github.com/brown/protobuf
- D: http://256.makerslocal.org/wiki/index.php/ProtocolBuffer
- Dart: https://github.com/dart-lang/dart-protobuf (runtime) https://github.com/dart-lang/dart-protoc-plugin (code generator)
- Elixir: https://github.com/jeremyong/exprotoc
- Erlang: http://github.com/ngerakines/erlang_protobuffs/tree/master
- Erlang: http://piqi.org/
- Go: http://code.google.com/p/goprotobuf/
- Haskell: http://hackage.haskell.org/package/hprotoc
- Haxe: https://github.com/Atry/protoc-gen-haxe
- Java: http://protobuf.googlecode.com/ (Google-official implementation)
- Java/Android: https://github.com/square/wire
- Java ME: http://code.google.com/p/protobuf-javame/
- Java ME: http://swingme.sourceforge.net/encode.shtml
- Java ME: http://github.com/ponderingpanda/protobuf-j2me
- Java ME: http://code.google.com/p/protobuf-j2me/
- Javascript: http://code.google.com/p/protobuf-js/
- Javascript: http://github.com/sirikata/protojs
- Javascript: https://github.com/dcodeIO/ProtoBuf.js
- Julia: https://github.com/tanmaykm/ProtoBuf.jl
- Lua: http://code.google.com/p/protoc-gen-lua/

- Lua: http://github.com/indygreg/lua-protobuf
- Matlab: http://code.google.com/p/protobuf-matlab/
- Mercury: http://code.google.com/p/protobuf-mercury/
- Objective C: http://code.google.com/p/protobuf-objc/
- OCaml: http://piqi.org/
- Perl: http://groups.google.com/group/protobuf-perl
- Perl: http://search.cpan.org/perldoc?Google::ProtocolBuffers
- Perl/XS: http://code.google.com/p/protobuf-perlxs/
- PHP: http://code.google.com/p/pb4php/
- PHP: https://github.com/allegro/php-protobuf/
- PHP: https://github.com/chobie/php-protocolbuffers
- Python: http://protobuf.googlecode.com/ (Google-official implementation)
- R: http://cran.r-project.org/package=RProtoBuf
- Ruby: http://code.google.com/p/ruby-protobuf/
- Ruby: http://github.com/mozy/ruby-protocol-buffers
- Ruby: https://github.com/bmizerany/beefcake/tree/master/lib/beefcake
- Ruby: https://github.com/localshred/protobuf
- Rust: https://github.com/stepancheg/rust-protobuf/
- Scala: http://github.com/jeffplaisance/scala-protobuf
- Scala: http://code.google.com/p/protobuf-scala
- Vala: https://launchpad.net/protobuf-vala
- Visual Basic: http://code.google.com/p/protobuf-net/

RPC Implementations

These are RPC implementations that work with Protocol Buffers. Some of these actually work with Protocol Buffers service definitions (defined using the `service` keyword in `.proto` files) while others just use Protocol Buffers message objects.

- http://zeroc.com/ice.html (Multiple languages)
- http://code.google.com/p/protobuf-net/ (C#/.NET/WCF/VB)
- http://protorpc.lekebilen.com/ (Qt/C++, Java, Python)
- https://launchpad.net/txprotobuf/ (Python)
- http://code.google.com/p/protobuf-rpc/ (Python)
- http://code.google.com/p/protobuf-socket-rpc/ (Java, Python)
- http://github.com/bitiboy/fepss-rpc/tree/master (Java)
- http://code.google.com/p/proto-streamer/ (Java)
- http://code.google.com/p/server1/ (C++)
- http://deltavsoft.com/RcfUserGuide/Protobufs (C++)
- http://code.google.com/p/protobuf-mina-rpc/ (Python client, Java server)
- http://code.google.com/p/casocklib/ (C++)
- http://code.google.com/p/cxf-protobuf/ (Java)
- http://code.google.com/p/protobuf-remote/ (C++/C#)
- http://code.google.com/p/protobuf-rpc-pro/ (Java)
- https://code.google.com/p/protorpc/ (Go/C++)
- https://code.google.com/p/eneter-protobuf-serializer/ (Java/.NET)
- http://www.deltavsoft.com/RCFProto.html (C++/Java/Python/C#)
- https://github.com/robbinfan/claire-protorpc (C++)
- https://github.com/BaiduPS/sofa-pbrpc (C++)

Other Utilities

There are miscellaneous other things you may find useful as a Protocol Buffers developer.

- NetBeans IDE plugin
- Wireshark/Ethereal packet sniffer plugin
- Alternate encodings (JSON, XML, HTML) for Java protobufs
- Another JSON encoder/decoder for Java
- Editor for serialized protobufs
- Intellij IDEA plugin
- TextMate syntax highlighting
- Oracle PL SQL plugin
- XSDs to proto files converter
- Eclipse editor for protobuf (from Google)

- C++ Builder compatible protobuf
- Maven Protocol Compiler Plugin
  - https://github.com/sergei-ivanov/maven-protoc-plugin/
  - http://igor-petruk.github.com/protobuf-maven-plugin/
  - http://code.google.com/p/maven-protoc-plugin/
  - https://github.com/os72/protoc-jar-maven-plugin
- DocBook generator for .proto files
- Protobuf for nginx module
- RSpec matchers and Cucumber step defs for testing Protocol Buffers
- Sbt plugin for Protocol Buffers
- Gradle Protobuf Plugin
- Multi-platform executable JAR and Java API for protoc

Comment by s...@sbhr.dk, Mar 29, 2011

JavaScript?/Node implementation: http://code.google.com/p/protobuf-for-node/

Comment by michael....@gmail.com, Apr 12, 2011

I've added java-me output and ported the runtime library for protostuff, for yet another java-me protobuffer library.

Comment by rfug...@gmail.com, May 21, 2011

Another erlang implementation: http://code.google.com/p/protoc-gen-erl/

Comment by rjakabo...@gmail.com, Jun 23, 2011

Another Lua implementation: https://github.com/Neopallium/lua-pb

Comment by drsl...@pollinimini.net, Jun 25, 2011

Another PHP implementation: http://drslump.github.com/Protobuf-PHP

Comment by eigenein, Aug 9, 2011

Another Python implementation: http://eigenein.github.com/protobuf/

Comment by grzegorz....@gmail.com, Aug 27, 2011

SWI-Prolog Google Protocol Buffers support is in my opinion a nice addition to list : http://www.swi-prolog.org/pldoc/package/protobufs.html .

Comment by Petteri.Aimonen, Aug 31, 2011

Small code-size C implementation: http://koti.kapsi.fi/jpa/nanopb/

Comment by zhangyin...@gmail.com, Nov 2, 2011

A RPC framework based on ProtoBuf? and ZMQ. It is still under developing.

You can write client programs in Python, and implement RPC services server in C++.

https://github.com/ebencheung/arab

Comment by tvxqli...@yahoo.com, Nov 12, 2011

There are different types of shoes for various occasions such as for

school, sports, parties, etc, as well as according to seasons like

snowfall and rain. You can find all kinds of shoes in vibrant color

options to match your little one's attire. Go in for children's shoes

with Velcro straps or buckles instead of laces, as they are easy to wear

and remove for the child.

Comment by matt.ev...@plexxi.com, Nov 22, 2011

An Erlang implementation from Basho

https://github.com/basho/erlang_protobuffs

Comment by Grig...@gmail.com, Dec 13, 2011

C# RPC library for protobuf defined services using protobuf-csharp-port http://code.google.com/p/protobuf-csharp-rpc/

Comment by igor.pet...@gmail.com, Feb 9, 2012

This is a Maven Plugin that supports compilation of protoc files. The next release I'll try to make it compile .proto without protoc.exe installation. It will download appropriate version of protoc.exe in a jar from central, unpack it to temp dir and run from there. Unix version will require installation of protoc because it is nicely done with package managers.

http://igor-petruk.github.com/protobuf-maven-plugin/

Comment by clou...@gmail.com, Mar 1, 2012

A C library (code generation) from Cloud Wu , https://github.com/cloudwu/pbc/ And there is also a lua binding library (including lua parser).

Comment by PaulJHer...@gmail.com, Jun 14, 2012

"none of these projects are affiliated with or endorsed by Google"

Except the ones that are?

Comment by meepmeep...@gmail.com, Jun 16, 2012

https://github.com/haberman/upb/wiki C implementation with good documentation.

Comment by tunes@google.com, Jun 20, 2012

Another Common Lisp implementation: cl-protobufs, published by ITA (now part of Google) as part of http://common-lisp.net/project/qitab/

Comment by gulin.se...@gmail.com, Jul 7, 2012

Is there an RPC implementation for ZMQ?

Comment by milandin...@gmail.com, Nov 12, 2012

Delphi implementation http://sourceforge.net/projects/protobuf-delphi/

Comment by marasak...@gmail.com, Dec 1, 2012

3

Comment by philippe...@gmail.com, Jan 15, 2013

I found a C++/Python RPC implementation based on ZeroMQ at http://code.google.com/p/rpcz/ . In my own opinion, this seem to be the best C++ implementation I've seen so far. I think it would be in everyone's interest that you add it on this page.

Comment by lstar...@gmail.com, Jan 16, 2013

I write a plugin for VC2005-VC2012, which can be used to viewing the content of google::protobuf::RepeatedPtrField?<T>. Now I build an installing package, but how can I upload it?

Comment by lstar...@gmail.com, Jan 16, 2013

I create a project for my plugin, please visit http://code.google.com/p/w2-vc-debugger-addin/downloads/list

Comment by seiflo...@gmail.com, Jan 28, 2013

Hey guys, I wrote a small python converter from json/dict to protobuf and vice versa. https://github.com/NextTuesday/py-pb-converters It should cover even repeated fields. Only requirment is that one needs the classes generated by protobuf on the .proto files... Hope its useful, and feel free to report issues. Cheers Seif

Comment by maw...@ymail.com, Feb 24, 2013

Found this implementation for Javascript: http://code.google.com/p/protostuff/

Comment by dc...@dcode.io, Mar 6, 2013

https://github.com/dcodeIO/ProtoBuf.js

A protobuf implementation including a .proto parser, reflection, message class building and simple encoding and decoding in plain JavaScript?. No compilation step required, works out of the box on .proto files.

Comment by bo...@comoyo.com, Apr 4, 2013

I wish there was a more consolidated effort towards building an RPC system using protobuffers. The above list makes me want to cry.

Comment by awalterschulze, Apr 5, 2013

Hi

I have another Go implementation with some extensions

https://code.google.com/p/gogoprotobuf/

Comment by chaishus...@gmail.com, May 8, 2013

Google Protocol RPC for Go and C++:

https://bitbucket.org/chai2010/protorpc

https://code.google.com/p/protorpc/

Comment by akun....@gmail.com, Jul 3, 2013

a protobuf implementation for golang https://github.com/akunspy/gopbuf

Comment by dc...@dcode.io, Jul 11, 2013

PSON is a binary serialization format built on the simplicity of JSON and the encoding capabilities of Google's Protocol Buffers.

https://github.com/dcodeIO/PSON

Comment by Jesse.K....@gmail.com, Jul 29, 2013

Most recent developments for the D code is found: https://github.com/opticron/ProtocolBuffer

Comment by danr...@gmail.com, Aug 25, 2013

Please add a link for Wire, a lightweight implementation for Android: github.com/square/wire

Comment by robert.c...@costain.com, Aug 29, 2013

The link for http://code.google.com/p/protosharp/ no longer works. Should be removed.

Comment by Andrey.lletkin, Nov 18, 2013

Broken link in RPC Implementations : http://protorpc.lekebilen.com/ (Qt/C++, Java, Python)

Comment by q...@daurnimator.com, Nov 23, 2013

> Comment by rjakabo...@gmail.com, Jun 23, 2011 Another Lua implementation: https://github.com/Neopallium/lua-pb

Still missing

Comment by rayt...@gmail.com, Dec 7, 2013

i hope you read my info **ASUS Fonepad Tablet 7 Inci Dengan Fungsi Telepon**

Comment by diego...@google.com, Dec 11, 2013

You should add the following scala compiler: https://github.com/SandroGrzicic/ScalaBuff It was created under the supervision of Viktor Klang, which says a lot.

Comment by dimon.e...@gmail.com, Dec 18, 2013

Delphi Google Protocol Buffers Impolementation Fundamentals Protocol Buffers 4.00.01 (10 Feb 2013) http://fundementals.sourceforge.net/dl.html It's also compatible with a FreePascal

Comment by sergei...@gmail.com, Dec 27, 2013

> Protocol Buffers is used by SCaVis computational environment (http://jwork.org/scavis), see the method PFile to write data in a platform-neutral approach

Comment by mre...@googlemail.com, Jan 20, 2014

I wrote a language service for visual studio. can be found here: http://visualstudiogallery.msdn.microsoft.com/4bc0f38c-b058-4e05-ae38-155e053c19c5

Comment by monsterk...@gmail.com, Feb 14, 2014

Jual Knalpot Motor Racing

Comment by wangqiying@gmail.com, Mar 3, 2014

A fast C++ serialization and de-serialization of Google's protobuf Messages into/from JSON format. https://github.com/yinqiwen/pbjson

Comment by tanma...@gmail.com, Mar 13, 2014

A Julia language implementation, including a code generator is at : https://github.com/tanmaykm/ProtoBuf.jl

Comment by scsappin...@gmail.com, Mar 19, 2014

(No comment was entered for this change.)

Comment by scsappin...@gmail.com, Mar 19, 2014

(No comment was entered for this change.)

Comment by raydrax...@gmail.com, May 27, 2014

kata kata cinta | **kata kata bijak terbaru** | **cara menghilangkan jerawat**

Comment by couponci...@gmail.com, Jul 28, 2014

I have tried and implement one using proto buff, Need some changes in the function of Js and they are working for mainly simple useful features required for websites. thanks for such a useful resource. i tried it on one of my website http://www.icouponsindia.com and those functions worked like a charm.

Comment by elvst...@gmail.com, Aug 6, 2014

Hi, would be cool if someone could add a link to my new Google Protocol Buffers documentation generator plugin (Markdown / HTML / DocBook?) under "Other Utilities".

The plugin is at:

https://github.com/estan/protoc-gen-doc

Thanks!

Elvis Stansvik

Comment by cedric.l...@gmail.com, Aug 9, 2014

Hi,

Please consider to add a link to this project: https://code.google.com/p/chwthewke-protobuf/ on the ThirdPartyAddOns wiki page, at the maven section.

It's just for enhancement of documentation, I've just lost time to search where was this project ^^

Thanks

Comment by ara...@gmail.com, Aug 10, 2014

Yet another protocol buffer to json encoder https://github.com/myexpr/protobuf2json

Enter a comment: Hint: You can use Wiki Syntax.

Submit

API Reference

This section contains reference documentation for working with protocol buffer classes in C++, Java, and Python. The documentation for each language includes:

- A reference guide to the code generated by the protocol buffer compiler from your `.proto` files.
- Generated API documentation for the provided source code.

Note that there are APIs for several more languages in the pipeline – for details, see the other languages wiki page.

C++ Reference

- C++ Generated Code Guide
- C++ API

Java Reference

- Java Generated Code Guide
- Java API (Javadoc)

Python Reference

- Python Generated Code Guide
- Python API (Epydoc)

Last updated 四月 *2, 2012.*

C++ Generated Code

This page describes exactly what C++ code the protocol buffer compiler generates for any given protocol definition. You should read the language guide before reading this document.

Compiler Invocation

The protocol buffer compiler produces C++ output when invoked with the `--cpp_out=` command-line flag. The parameter to the `--cpp_out=` option is the directory where you want the compiler to write your C++ output. The compiler creates a header file and an implementation file for each `.proto` file input. The names of the output files are computed by taking the name of the `.proto` file and making two changes:

- The extension (`.proto`) is replaced with either `.pb.h` or `.pb.cc` for the header or implementation file, respectively.
- The proto path (specified with the `--proto_path=` or `-I` command-line flag) is replaced with the output path (specified with the `--cpp_out=` flag).

So, for example, let's say you invoke the compiler as follows:

```
protoc --proto_path=src --cpp_out=build/gen src/foo.proto src/bar/baz.proto
```

The compiler will read the files `src/foo.proto` and `src/bar/baz.proto` and produce four output files: `build/gen/foo.pb.h`, `build/gen/foo.pb.cc`, `build/gen/bar/baz.pb.h`, `build/gen/bar/baz.pb.cc`. The compiler will automatically create the directory `build/gen/bar` if necessary, but it will *not* create `build` or `build/gen`; they must already exist.

Packages

If a `.proto` file contains a `package` declaration, the entire contents of the file will be placed in a corresponding C++ namespace. For example, given the `package` declaration:

```
package foo.bar;
```

All declarations in the file will reside in the `foo::bar` namespace.

Messages

Given a simple message declaration:

```
message Foo {}
```

The protocol buffer compiler generates a class called `Foo`, which publicly derives from `google::protobuf::Message`. The class is a concrete class; no pure-virtual methods are left unimplemented. Methods that are virtual in `Message` but not pure-virtual may or may not be overridden by `Foo`, depending on the optimization mode. By default, `Foo` implements specialized versions of all methods for maximum speed. However, if the `.proto` file contains the line:

```
option optimize_for = CODE_SIZE;
```

then `Foo` will override only the minimum set of methods necessary to function and rely on reflection-based implementations of the rest. This significantly reduces the size of the generated code, but also reduces performance. Alternatively, if the `.proto` file contains:

```
option optimize_for = LITE_RUNTIME;
```

then `Foo` will include fast implementations of all methods, but will implement the `google::protobuf::MessageLite` interface, which only contains a subset of the methods of `Message`. In particular, it does not support descriptors or reflection. However, in this mode, the generated code only needs to link against `libprotobuf-lite.so` (`libprotobuf-lite.lib` on Windows) instead of `libprotobuf.so` (`libprotobuf.lib`). The "lite" library is much smaller than the full library, and is more appropriate for resource-constrained systems such as mobile phones.

You should *not* create your own `Foo` subclasses. If you subclass this class and override a virtual method, the override may be ignored, as many generated method calls are de-virtualized to improve performance.

The `Message` interface defines methods that let you check, manipulate, read, or write the entire message, including parsing from and serializing to binary strings. In addition to these methods, the `Foo` class defines the following methods:

- `Foo()`: Default constructor.
- `~Foo()`: Default destructor.
- `Foo(const Foo& other)`: Copy constructor.
- `Foo& operator=(const Foo& other)`: Assignment operator.
- `void Swap(Foo* other)`: Swap content with another message.
- `const UnknownFieldSet& unknown_fields() const`: Returns the set of unknown fields encountered while parsing this message.
- `UnknownFieldSet* mutable_unknown_fields()`: Returns a mutable pointer to the set of unknown fields encountered while parsing this message.

The class also defines the following static methods:

- `static const Descriptor& descriptor()`: Returns the type's descriptor. This contains information about the type, including what fields it has and what their types are. This can be used with reflection to inspect fields programmatically.
- `static const Foo& default_instance()`: Returns a const singleton instance of `Foo` which is identical to a newly-constructed instance of `Foo` (so all singular fields are unset and all repeated fields are empty). Note that the default instance of a message can be used as a factory by calling its `New()` method.

A message can be declared inside another message. For example: `message Foo { message Bar { } }`

In this case, the compiler generates two classes: `Foo` and `Foo_Bar`. In addition, the compiler generates a typedef inside `Foo` as follows:

```
typedef Foo_Bar Bar;
```

This means that you can use the nested type's class as if it was the nested class `Foo::Bar`. However, note that C++ does not allow nested types to be forward-declared. If you want to forward-declare `Bar` in another file and use that declaration, you must identify it as `Foo_Bar`.

Fields

In addition to the methods described in the previous section, the protocol buffer compiler generates a set of accessor methods for each field defined within the message in the `.proto` file.

As well as accessor methods, the compiler generates an integer constant for each field containing its field number. The constant name is the letter `k`, followed by the field name converted to camel-case, followed by `FieldNumber`. For example, given the field `optional int32 foo_bar = 5;`, the compiler will generate the constant `static const int kFooBarFieldNumber = 5;`.

Singular Numeric Fields

For either of these field definitions:

```
optional int32 foo = 1;
required int32 foo = 1;
```

The compiler will generate the following accessor methods:

- `bool has_foo() const`: Returns `true` if the field is set.
- `int32 foo() const`: Returns the current value of the field. If the field is not set, returns the default value.
- `void set_foo(int32 value)`: Sets the value of the field. After calling this, `has_foo()` will return `true` and `foo()` will return `value`.
- `void clear_foo()`: Clears the value of the field. After calling this, `has_foo()` will return `false` and `foo()` will return the default value.

For other numeric field types (including `bool`), `int32` is replaced with the corresponding C++ type according to the scalar value types table.

Singular String Fields

For any of these field definitions:

```
optional string foo = 1;
required string foo = 1;
optional bytes foo = 1;
required bytes foo = 1;
```

The compiler will generate the following accessor methods:

- `bool has_foo() const`: Returns `true` if the field is set.
- `const string& foo() const`: Returns the current value of the field. If the field is not set, returns the default value.
- `void set_foo(const string& value)`: Sets the value of the field. After calling this, `has_foo()` will return `true` and `foo()` will return a copy of `value`.
- `void set_foo(const char* value)`: Sets the value of the field using a C-style null-terminated string. After calling this, `has_foo()` will return `true` and `foo()` will return a copy of `value`.
- `void set_foo(const char* value, int size)`: Like above, but the string size is given explicitly rather than determined by looking for a null-terminator byte.
- `string* mutable_foo()`: Returns a mutable pointer to the `string` object that stores the field's value. If the field was not set prior to the call, then the returned string will be empty (*not* the default value). After calling this, `has_foo()` will return `true` and `foo()` will return whatever value is written into the given string. The pointer is invalidated by a call to `Clear()` or `clear_foo()`.
- `void clear_foo()`: Clears the value of the field. After calling this, `has_foo()` will return `false` and `foo()` will return the default value.
- `void set_allocated_foo(string* value)`: Sets the `string` object to the field and frees the previous field value if it exists. If the `string` pointer is not `NULL`, the message takes ownership of the allocated `string` object and `has_foo()` will return `true`. Otherwise, if the `value` is `NULL`, the behavior is the same as calling `clear_foo()`.
- `string* release_foo()`: Releases the ownership of the field and returns the pointer of the `string` object. After calling this, caller takes the ownership of the allocated `string` object, `has_foo()` will return `false`, and `foo()` will return the default value.

Singular Enum Fields

Given the enum type:

```
enum Bar {
  BAR_VALUE = 1;
}
```

For either of these field definitions:

```
optional Bar foo = 1;
required Bar foo = 1;
```

The compiler will generate the following accessor methods:

- `bool has_foo() const`: Returns `true` if the field is set.
- `Bar foo() const`: Returns the current value of the field. If the field is not set, returns the default value.
- `void set_foo(Bar value)`: Sets the value of the field. After calling this, `has_foo()` will return `true` and `foo()` will return `value`. In debug mode (i.e. NDEBUG is not defined), if `value` does not match any of the values defined for `Bar`, this method will abort the process.
- `void clear_foo()`: Clears the value of the field. After calling this, `has_foo()` will return `false` and `foo()` will return the default value.

Singular Embedded Message Fields

Given the message type:

```
message Bar {}
```

For either of these field definitions:

```
optional Bar foo = 1;
required Bar foo = 1;
```

The compiler will generate the following accessor methods:

- `bool has_foo() const`: Returns `true` if the field is set.
- `const Bar& foo() const`: Returns the current value of the field. If the field is not set, returns a `Bar` with none of its fields set (possibly `Bar::default_instance()`).
- `Bar* mutable_foo()`: Returns a mutable pointer to the `Bar` object that stores the field's value. If the field was not set prior to the call, then the returned `Bar` will have none of its fields set (i.e. it will be identical to a newly-allocated `Bar`). After calling this, `has_foo()` will return `true` and `foo()` will return a reference to the same instance of `Bar`. The pointer is invalidated by a call to `Clear()` or `clear_foo()`.
- `void clear_foo()`: Clears the value of the field. After calling this, `has_foo()` will return `false` and `foo()` will return the default value.
- `void set_allocated_foo(Bar* bar)`: Sets the `Bar` object to the field and frees the previous field value if it exists. If the `Bar` pointer is not `NULL`, the message takes ownership of the allocated `Bar` object and `has_foo()` will return `true`. Otherwise, if the `Bar` is `NULL`, the behavior is the same as calling `clear_foo()`.
- `Bar* release_foo()`: Releases the ownership of the field and returns the pointer of the `Bar` object. After calling this, caller takes the ownership of the allocated `Bar` object, `has_foo()` will return `false`, and `foo()` will return the default value.

Repeated Numeric Fields

For this field definition:

```
repeated int32 foo = 1;
```

The compiler will generate the following accessor methods:

- `int foo_size() const`: Returns the number of elements currently in the field.
- `int32 foo(int index) const`: Returns the element at the given zero-based index.
- `void set_foo(int index, int32 value)`: Sets the value of the element at the given zero-based index.
- `void add_foo(int32 value)`: Appends a new element to the field with the given value.
- `void clear_foo()`: Removes all elements from the field. After calling this, `foo_size()` will return zero.
- `const RepeatedField<int32>& foo() const`: Returns the underlying `RepeatedField` that stores the field's elements. This container class provides STL-like iterators and other methods.
- `RepeatedField<int32>*` mutable_foo(): Returns a mutable pointer to the underlying `RepeatedField` that stores the field's elements. This container class provides STL-like iterators and other methods.

For other numeric field types (including `bool`), `int32` is replaced with the corresponding C++ type according to the scalar value types table.

Repeated String Fields

For either of these field definitions:

```
repeated string foo = 1;
repeated bytes foo = 1;
```

The compiler will generate the following accessor methods:

- `int foo_size() const`: Returns the number of elements currently in the field.
- `const string& foo(int index) const`: Returns the element at the given zero-based index.
- `void set_foo(int index, const string& value)`: Sets the value of the element at the given zero-based index.
- `void set_foo(int index, const char* value)`: Sets the value of the element at the given zero-based index using a C-style null-terminated string.
- `void set_foo(int index, const char* value, int size)`: Like above, but the string size is given explicitly rather than determined by looking for a null-terminator byte.
- `string* mutable_foo(int index)`: Returns a mutable pointer to the `string` object that stores the value of the element at the given zero-based index. The pointer is invalidated by a call to `Clear()` or `clear_foo()`, or by manipulating the underlying `RepeatedPtrField` in a way that would remove this element.
- `void add_foo(const string& value)`: Appends a new element to the field with the given value.
- `void add_foo(const char* value)`: Appends a new element to the field using a C-style null-terminated string.
- `void add_foo(const char* value, int size)`: Like above, but the string size is given explicitly rather than determined by looking for a null-terminator byte.
- `string* add_foo()`: Adds a new empty string element and returns a pointer to it. The pointer is invalidated by a call to `Clear()` or `clear_foo()`, or by manipulating the underlying `RepeatedPtrField` in a way that would remove this element.
- `void clear_foo()`: Removes all elements from the field. After calling this, `foo_size()` will return zero.
- `const RepeatedPtrField<string>& foo() const`: Returns the underlying `RepeatedPtrField` that stores the field's elements. This container class provides STL-like iterators and other methods.
- `RepeatedPtrField<string>*` mutable_foo(): Returns a mutable pointer to the underlying `RepeatedPtrField` that stores the field's elements. This container class provides STL-like iterators and other methods.

Repeated Enum Fields

Given the enum type:

```
enum Bar {
  BAR_VALUE = 1;
}
```

For this field definition:

```
repeated Bar foo = 1;
```

The compiler will generate the following accessor methods:

- `int foo_size() const`: Returns the number of elements currently in the field.
- `Bar foo(int index) const`: Returns the element at the given zero-based index.
- `void set_foo(int index, Bar value)`: Sets the value of the element at the given zero-based index. In debug mode (i.e. NDEBUG is not defined), if `value` does not match any of the values defined for `Bar`, this method will abort the process.
- `void add_foo(Bar value)`: Appends a new element to the field with the given value. In debug mode (i.e. NDEBUG is not defined), if `value` does not match any of the values defined for `Bar`, this method will abort the process.
- `void clear_foo()`: Removes all elements from the field. After calling this, `foo_size()` will return zero.

- `const RepeatedField<int>& foo() const`: Returns the underlying `RepeatedField` that stores the field's elements. This container class provides STL-like iterators and other methods.
- `RepeatedField<int>*` mutable_foo(): Returns a mutable pointer to the underlying `RepeatedField` that stores the field's elements. This container class provides STL-like iterators and other methods.

Repeated Embedded Message Fields

Given the message type:

```
message Bar {}
```

For this field definitions:

```
repeated Bar foo = 1;
```

The compiler will generate the following accessor methods:

- `int foo_size() const`: Returns the number of elements currently in the field.
- `const Bar& foo(int index) const`: Returns the element at the given zero-based index.
- `Bar* mutable_foo(int index)`: Returns a mutable pointer to the `Bar` object that stores the value of the element at the given zero-based index. The pointer is invalidated by a call to `Clear()` or `clear_foo()`, or by manipulating the underlying `RepeatedPtrField` in a way that would remove this element.
- `Bar* add_foo()`: Adds a new element and returns a pointer to it. The returned `Bar` will have none of its fields set (i.e. it will be identical to a newly-allocated `Bar`). The pointer is invalidated by a call to `Clear()` or `clear_foo()`, or by manipulating the underlying `RepeatedPtrField` in a way that would remove this element.
- `void clear_foo()`: Removes all elements from the field. After calling this, `foo_size()` will return zero.
- `const RepeatedPtrField<Bar>& foo() const`: Returns the underlying `RepeatedPtrField` that stores the field's elements. This container class provides STL-like iterators and other methods.
- `RepeatedPtrField<Bar>*` mutable_foo(): Returns a mutable pointer to the underlying `RepeatedPtrField` that stores the field's elements. This container class provides STL-like iterators and other methods.

Enumerations

Given an enum definition like:

```
enum Foo {
  VALUE_A = 1;
  VALUE_B = 5;
  VALUE_C = 1234;
}
```

The protocol buffer compiler will generate a C++ enum type called `Foo` with the same set of values. In addition, the compiler will generate the following functions:

- `const EnumDescriptor* Foo_descriptor()`: Returns the type's descriptor, which contains information about what values this enum type defines.
- `bool Foo_IsValid(int value)`: Returns `true` if the given numeric value matches one of `Foo`'s defined values. In the above example, it would return `true` if the input were 1, 5, or 1234.

- `const string& Foo_Name(int value)`: Returns the name for given numeric value. Returns an empty string if no such value exists. If multiple values have this number, the first one defined is returned. In the above example, `Foo_Name(5)` would return `"VALUE_B"`.
- `bool Foo_Parse(const string& name, Foo* value)`: If `name` is a valid value name for this enum, assigns that value into `value` and returns true. Otherwise returns false. In the above example, `Foo_Parse("VALUE_C", &someFoo)` would return true and set `someFoo` to 1234.

> **Be careful when casting integers to enums.** If an integer is cast to an enum value, the integer *must* be one of the valid values for than enum, or the results may be undefined. If in doubt, use the generated `Foo_IsValid()` function to test if the cast is valid. Setting an enum-typed field of a protocol message to an invalid value may cause an assertion failure. If an invalid enum value is read when parsing a message, it will be treated as an unknown field.

You can define an enum inside a message type. In this case, the protocol buffer compiler generates code that makes it appear that the enum type itself was declared nested inside the message's class. The `Foo_descriptor()` and `Foo_IsValid()` functions are declared as static methods. In reality, the enum type itself and its values are declared at the global scope with mangled names, and are imported into the class's scope with a typedef and a series of constant definitions. This is done only to get around problems with declaration ordering. Do not depend on the mangled top-level names; pretend the enum really is nested in the message class.

Extensions

Given a message with an extension range:

```
message Foo {
  extensions 100 to 199;
}
```

The protocol buffer compiler will generate some additional methods for `Foo`: `HasExtension()`, `ExtensionSize()`, `ClearExtension()`, `GetExtension()`, `SetExtension()`, `MutableExtension()`, `AddExtension()`, `SetAllocatedExtension()` and `ReleaseExtension()`. Each of these methods takes, as its first parameter, an extension identifier (described below), which identifies an extension field. The remaining parameters and the return value are exactly the same as those for the corresponding accessor methods that would be generated for a normal (non-extension) field of the same type as the extension identifier. (`GetExtension()` corresponds to the accessors with no special prefix.)

Given an extension definition:

```
extend Foo {
  optional int32 bar = 1;
  repeated int32 repeated_bar = 2;
}
```

For the singular extension field `bar`, the protocol buffer compiler generates an "extension identifier" called `bar`, which you can use with `Foo`'s extension accessors to access this extension, like so:

```
Foo foo;
assert(!foo.HasExtension(bar));
foo.SetExtension(bar, 1);
assert(foo.HasExtension(bar));
```

```
assert(foo.GetExtension(bar) == 1);
foo.ClearExtension(bar);
assert(!foo.HasExtension(bar));
```

Similarly, for the repeated extension field `repeated_bar`, the compiler generates an extension identifier called `repeated_bar`, which you can also use with `Foo`'s extension accessors:

```
Foo foo;
for (int i = 0; i < kSize; ++i) {
  foo.AddExtension(repeated_bar, i)
}
assert(foo.ExtensionSize(repeated_bar) == kSize)
for (int i = 0; i < kSize; ++i) {
  assert(foo.GetExtension(repeated_bar, i) == i)
}
```

(The exact implementation of extension identifiers is complicated and involves magical use of templates – however, you don't need to worry about how extension identifiers work to use them.)

Extensions can be declared nested inside of another type. For example, a common pattern is to do something like this:

```
message Baz {
  extend Foo {
    optional Baz foo_ext = 124;
  }
}
```

In this case, the extension identifier `foo_ext` is declared nested inside `Baz`. It can be used as follows:

```
Foo foo;
Baz* baz = foo.MutableExtension(Baz::foo_ext);
FillInMyBaz(baz);
```

Services

If the `.proto` file contains the following line:

```
option cc_generic_services = true;
```

Then the protocol buffer compiler will generate code based on the service definitions found in the file as described in this section. However, the generated code may be undesirable as it is not tied to any particular RPC system, and thus requires more levels of indirection that code tailored to one system. If you do NOT want this code to be generated, add this line to the file:

```
option cc_generic_services = false;
```

If neither of the above lines are given, the option defaults to `false`, as generic services are deprecated. (Note that prior to 2.4.0, the option defaults to `true`)

RPC systems based on `.proto`-language service definitions should provide plugins to generate code approriate for the system. These plugins are likely to require that abstract services are disabled, so that they can generate their own classes of the same names. Plugins are new in version 2.3.0 (January 2010).

The remainder of this section describes what the protocol buffer compiler generates when abstract services are enabled.

Interface

Given a service definition:

```
service Foo {
  rpc Bar(FooRequest) returns(FooResponse);
}
```

The protocol buffer compiler will generate a class `Foo` to represent this service. `Foo` will have a virtual method for each method defined in the service definition. In this case, the method `Bar` is defined as:

```
virtual void Bar(RpcController* controller, const FooRequest* request,
                 FooResponse* response, Closure* done);
```

The parameters are equivalent to the parameters of `Service::CallMethod()`, except that the `method` argument is implied and `request` and `response` specify their exact type.

These generated methods are virtual, but not pure-virtual. The default implementations simply call `controller->SetFailed()` with an error message indicating that the method is unimplemented, then invoke the `done` callback. When implementing your own service, you must subclass this generated service and implement its methods as appropriate.

`Foo` subclasses the `Service` interface. The protocol buffer compiler automatically generates implementations of the methods of `Service` as follows:

- `GetDescriptor`: Returns the service's `ServiceDescriptor`.
- `CallMethod`: Determines which method is being called based on the provided method descriptor and calls it directly, down-casting the request and response messages objects to the correct types.
- `GetRequestPrototype` and `GetResponsePrototype`: Returns the default instance of the request or response of the correct type for the given method.

The following static method is also generated:

- `static ServiceDescriptor descriptor()`: Returns the type's descriptor, which contains information about what methods this service has and what their input and output types are.

Stub

The protocol buffer compiler also generates a "stub" implementation of every service interface, which is used by clients wishing to send requests to servers implementing the service. For the `Foo` service (above), the stub implementation `Foo_Stub` will be defined. As with nested message types, a typedef is used so that `Foo_Stub` can also be referred to as `Foo::Stub`.

`Foo_Stub` is a subclass of `Foo` which also implements the following methods:

- `Foo_Stub(RpcChannel* channel)`: Constructs a new stub which sends requests on the given channel.
- `Foo_Stub(RpcChannel* channel, ChannelOwnership ownership)`: Constructs a new stub which sends requests on the given channel and possibly owns that channel. If `ownership` is `Service::STUB_OWNS_CHANNEL` then when the stub object is deleted it will delete the channel as well.
- `RpcChannel* channel()`: Returns this stub's channel, as passed to the constructor.

The stub additionally implements each of the service's methods as a wrapper around the channel. Calling one of the methods simply calls `channel->CallMethod()`.

The Protocol Buffer library does not include an RPC implementation. However, it includes all of the tools you need to hook up a generated service class to any arbitrary RPC implementation of your choice. You need only provide implementations of `RpcChannel` and `RpcController`. See the documentation for `service.h` for more information.

Plugin Insertion Points

Code generator plugins which want to extend the output of the C++ code generator may insert code of the following types using the given insertion point names. Each insertion point appears in both the `.pb.cc` file and the `.pb.h` file unless otherwise noted.

- `includes`: Include directives.
- `namespace_scope`: Declarations that belong in the file's package/namespace, but not within any particular class. Appears after all other namespace-scope code.
- `global_scope`: Declarations that belong at the top level, outside of the file's namespace. Appears at the very end of the file.
- `class_scope:TYPENAME`: Member declarations that belong in a message class. `TYPENAME` is the full proto name, e.g. `package.MessageType`. Appears after all other public declarations in the class. This insertion point appears only in the `.pb.h` file.

> Do not generate code which relies on private class members declared by the standard code generator, as these implementation details may change in future versions of Protocol Buffers.

C++ API

Packages

google::protobuf

Core components of the Protocol Buffers runtime library.

google::protobuf::io

Auxiliary classes used for I/O.

google::protobuf::compiler

repeated_field.h

google::protobuf

Core components of the Protocol Buffers runtime library.

The files in this package represent the core of the Protocol Buffer system. All of them are part of the libprotobuf library.

A note on thread-safety:

Thread-safety in the Protocol Buffer library follows a simple rule: unless explicitly noted otherwise, it is always safe to use an object from multiple threads simultaneously as long as the object is declared const in all threads (or, it is only used in ways that would be allowed if it were declared const). However, if an object is accessed in one thread in a way that would not be allowed if it were const, then it is not safe to access that object in any other thread simultaneously.

Put simply, read-only access to an object can happen in multiple threads simultaneously, but write access can only happen in a single thread at a time.

The implementation does contain some "const" methods which actually modify the object behind the scenes -- e.g., to cache results -- but in these cases mutex locking is used to make the access thread-safe.

Files

google/protobuf/descriptor.h

This file contains classes which describe a type of protocol message.

google/protobuf/descriptor.pb.h

Protocol buffer representations of descriptors.

google/protobuf/descriptor_database.h

Interface for manipulating databases of descriptors.

google/protobuf/dynamic_message.h

Defines an implementation of Message which can emulate types which are not known at compile-time.

google/protobuf/message.h

Defines Message, the abstract interface implemented by non-lite protocol message objects.

google/protobuf/message_lite.h

Defines MessageLite, the abstract interface implemented by all (lite and non-lite) protocol message objects.

google/protobuf/repeated_field.h

RepeatedField and RepeatedPtrField are used by generated protocol message classes to manipulate repeated fields.

google/protobuf/service.h

DEPRECATED: This module declares the abstract interfaces underlying proto2 RPC services.

google/protobuf/text_format.h

Utilities for printing and parsing protocol messages in a human-readable, text-based format.

google/protobuf/unknown_field_set.h

Contains classes used to keep track of unrecognized fields seen while parsing a protocol message.

google/protobuf/stubs/common.h

Contains basic types and utilities used by the rest of the library.

google::protobuf::io

Auxiliary classes used for I/O.

The Protocol Buffer library uses the classes in this package to deal with I/O and encoding/decoding raw bytes. Most users will not need to deal with this package. However, users who want to adapt the system to work with their own I/O abstractions -- e.g., to allow Protocol Buffers to be read from a different kind of input stream without the need for a temporary buffer -- should take a closer look.

Files

google/protobuf/io/coded_stream.h

This file contains the CodedInputStream and CodedOutputStream classes, which wrap a ZeroCopyInputStream or ZeroCopyOutputStream, respectively, and allow you to read or write individual pieces of data in various formats.

google/protobuf/io/gzip_stream.h

This file contains the definition for classes GzipInputStream and GzipOutputStream.

google/protobuf/io/printer.h

Utility class for writing text to a ZeroCopyOutputStream.

google/protobuf/io/tokenizer.h

Class for parsing tokenized text from a ZeroCopyInputStream.

google/protobuf/io/zero_copy_stream.h

This file contains the ZeroCopyInputStream and ZeroCopyOutputStream interfaces, which represent abstract I/O streams to and from which protocol buffers can be read and written.

google/protobuf/io/zero_copy_stream_impl.h

This file contains common implementations of the interfaces defined in zero_copy_stream.h which are only included in the full (non-lite) protobuf library.

google/protobuf/io/zero_copy_stream_impl_lite.h

This file contains common implementations of the interfaces defined in zero_copy_stream.h which are included in the "lite" protobuf library.

google::protobuf::compiler

repeated_field.h

Implementation of the Protocol Buffer compiler.

This package contains code for parsing .proto files and generating code based on them. There are two reasons you might be interested in this package:

- You want to parse .proto files at runtime. In this case, you should look at importer.h. Since this functionality is widely useful, it is included in the libprotobuf base library; you do not have to link against libprotoc.
- You want to write a custom protocol compiler which generates different kinds of code, e.g. code in a different language which is not supported by the official compiler. For this purpose, command_line_interface.h provides you with a complete compiler front-end, so all you need to do is write a custom implementation of CodeGenerator and a trivial main() function. You can even make your compiler support the official languages in addition to your own. Since this functionality is only useful to those writing custom compilers, it is in a separate library called "libprotoc" which you will have to link against.

Files

google/protobuf/compiler/code_generator.h

Defines the abstract interface implemented by each of the language-specific code generators.

google/protobuf/compiler/command_line_interface.h

Implements the Protocol Compiler front-end such that it may be reused by custom compilers written to support other languages.

google/protobuf/compiler/importer.h

This file is the public interface to the .proto file parser.

google/protobuf/compiler/parser.h

Implements parsing of .proto files to FileDescriptorProtos.

google/protobuf/compiler/plugin.h

Front-end for protoc code generator plugins written in C++.

google/protobuf/compiler/plugin.pb.h

	API for protoc plugins.
google/protobuf/compiler/cpp/cpp_generator.h	*Generates C++ code for a given .proto file.*
google/protobuf/compiler/java/java_generator.h	*Generates Java code for a given .proto file.*
google/protobuf/compiler/python/python_generator.h	*Generates Python code for a given .proto file.*

Last updated 四月 *2, 2012.*

Java Generated Code

This page describes exactly what Java code the protocol buffer compiler generates for any given protocol definition. You should read the language guide before reading this document.

Compiler Invocation

The protocol buffer compiler produces Java output when invoked with the `--java_out=` command-line flag. The parameter to the `--java_out=` option is the directory where you want the compiler to write your Java output. The compiler creates a single `.java` for each `.proto` file input. This file contains a single outer class definition containing several nested classes and static fields based on the declarations in the `.proto` file.

The outer class's name is chosen as follows: If the `.proto` file contains a line like the following:

```
option java_outer_classname = "Foo";
```

Then the outer class name will be `Foo`. Otherwise, the outer class name is determined by converting the `.proto` file base name to camel case. For example, `foo_bar.proto` will become `FooBar`.

The Java package name is chosen as described under Packages, below.

The output file is chosen by concatenating the parameter to `--java_out=`, the package name (with `.`s replaced with `/`s), and the `.java` file name.

So, for example, let's say you invoke the compiler as follows:

```
protoc --proto_path=src --java_out=build/gen src/foo.proto
```

If `foo.proto`'s java package is `com.example` and its outer classname is `FooProtos`, then the protocol buffer compiler will generate the file `build/gen/com/example/FooProtos.java`. The protocol buffer compiler will automatically create the `build/gen/com` and `build/gen/com/example` directories if needed. However, it will not create `build/gen` or `build`; they must already exist. You can specify multiple `.proto` files in a single invocation; all output files will be generated at once.

> When outputting Java code, the protocol buffer compiler's ability to output directly to JAR archives is particularly convenient, as many Java tools are able to read source code directly from JAR files. To output to a JAR file, simply provide an output location ending in `.jar`. Note that only the Java source code is placed in the archive; you must still compile it separately to produce Java class files.

Packages

The generated class is placed in a Java package based on the `java_package` option. If the option is omitted, the `package` declaration is used instead.

For example, if the `.proto` file contains:

```
package foo.bar;
```

Then the resulting Java class will be placed in Java package `foo.bar`. However, if the `.proto` file also contains a `java_package` option, like so:

```
package foo.bar;
option java_package = "com.example.foo.bar";
```

Then the class is placed in the `com.example.foo.bar` package instead. The `java_package` option is provided because normal `.proto` `package` declarations are not expected to start with a backwards domain name.

Messages

Given a simple message declaration:

```
message Foo {}
```

The protocol buffer compiler generates a class called `Foo`, which implements the `Message` interface. The class is declared `final`; no further subclassing is allowed. `Foo` extends `GeneratedMessage`, but this should be considered an implementation detail. By default, `Foo` overrides many methods of `GeneratedMessage` with specialized versions for maximum speed. However, if the `.proto` file contains the line:

```
option optimize_for = CODE_SIZE;
```

then `Foo` will override only the minimum set of methods necessary to function and rely on `GeneratedMessage`'s reflection-based implementations of the rest. This significantly reduces the size of the generated code, but also reduces performance. Alternatively, if the `.proto` file contains:

```
option optimize_for = LITE_RUNTIME;
```

then `Foo` will include fast implementations of all methods, but will implement the `MessageLite` interface, which only contains a subset of the methods of `Message`. In particular, it does not support descriptors or reflection. However, in this mode, the generated code only needs to link against `libprotobuf-lite.jar` instead of `libprotobuf.jar`. The "lite" library is much smaller than the full library, and is more appropriate for resource-constrained systems such as mobile phones.

The `Message` interface defines methods that let you check, manipulate, read, or write the entire message. In addition to these methods, the `Foo` class defines the following static methods:

- `static Foo getDefaultInstance()`: Returns a singleton instance of `Foo`, which is identical to what you'd get if you called `Foo.newBuilder().build()` (so all singular fields are unset and all repeated fields are empty). Note that the default instance of a message can be used as a factory by calling its `newBuilderForType()` method.
- `static Descriptor getDescriptor()`: Returns the type's descriptor. This contains information about the type, including what fields it has and what their types are. This can be used with the reflection methods of the `Message`, such as `getField()`.
- `static Foo parseFrom(...)`: Parses a message of type `Foo` from the given source and returns it. There is one `parseFrom` method corresponding to each variant of `mergeFrom()` in the `Message.Builder` interface. Note that `parseFrom()` never throws `UninitializedMessageException`; it throws `InvalidProtocolBufferException` if the parsed message is missing required fields. This makes it subtly different from calling `Foo.newBuilder().mergeFrom(...).build()`.
- `Foo.Builder newBuilder()`: Creates a new builder (described below).
- `Foo.Builder newBuilder(Foo prototype)`: Creates a new builder with all fields initialized to the same values that they have in `prototype`. Since embedded message and string objects are immutable, they are shared between the original and the copy.

Builders

Message objects – such as instances of the `Foo` class described above – are immutable, just like a Java `String`. To construct a message object, you need to use a *builder*. Each message class has its own builder class – so in our `Foo` example, the protocol buffer compiler generates a nested class `Foo.Builder` which can be used to build a `Foo`. `Foo.Builder` implements the `Message.Builder` interface. It extends the `GeneratedMessage.Builder` class, but, again, this should be considered an implementation detail. Like `Foo`, `Foo.Builder` may rely on generic method implementations in `GeneratedMessage.Builder` or, when the `optimize_for` option is used, generated custom code that is much faster.

`Foo.Builder` does not define any static methods. Its interface is exactly as defined by the `Message.Builder` interface, with the exception that return types are more specific: methods of `Foo.Builder` that modify the builder return type `Foo.Builder`, and `build()` returns type `Foo`.

Methods that modify the contents of a builder – including field setters – always return a reference to the builder (i.e. they "`return this;`"). This allows multiple method calls to be chained together in one line. For example: `builder.mergeFrom(obj).setFoo(1).setBar("abc").clearBaz();`

Sub Builders

For messages containing sub-messages, the compiler also generates sub builders. This allows you to repeatedly modify deep-nested sub-messages without rebuilding them. For example:

```
message Foo {
  optional int32 val = 1;
  // some other fields.
}

message Bar {
  optional Foo foo = 1;
  // some other fields.
}

message Baz {
```

```
  optional Bar bar = 1;
  // some other fields.
}
```

If you have a `Baz` message already, and want to change the deeply nested `val` in `Foo`. Instead of:

```
baz = baz.toBuilder().setBar(
    baz.getBar().toBuilder().setFoo(
        baz.getBar().getFoo().toBuilder().setVal(10).build()
    ).build()).build();
```

You can write:

```
Baz.Builder builder = baz.toBuilder();
builder.getBarBuilder().getFooBuilder().setVal(10);
baz = builder.build();
```

Nested Types

A message can be declared inside another message. For example: `message Foo { message Bar { } }`

In this case, the compiler simply generates `Bar` as an inner class nested inside `Foo`.

Fields

In addition to the methods described in the previous section, the protocol buffer compiler generates a set of accessor methods for each field defined within the message in the `.proto` file. The methods that read the field value are defined both in the message class and its corresponding builder; the methods that modify the value are only defined in the builder only.

Note that method names always use camel-case naming, even if the field name in the `.proto` file uses lower-case with underscores (as it should). The case-conversion works as follows:

1. For each underscore in the name, the underscore is removed, and the following letter is capitalized.
2. If the name will have a prefix attached (e.g. "get"), the first letter is capitalized. Otherwise, it is lower-cased.

Thus, the field `foo_bar_baz` becomes `fooBarBaz`. If prefixed with `get`, it would be `getFooBarBaz`.

As well as accessor methods, the compiler generates an integer constant for each field containing its field number. The constant name is the field name converted to upper-case followed by `_FIELD_NUMBER`. For example, given the field `optional int32 foo_bar = 5;`, the compiler will generate the constant `public static final int FOO_BAR_FIELD_NUMBER = 5;`.

Singular Fields

For either of these field definitions:

```
optional int32 foo = 1;
required int32 foo = 1;
```

The compiler will generate the following accessor methods in both the message class and its builder:

- `boolean hasFoo()`: Returns `true` if the field is set.
- `int getFoo()`: Returns the current value of the field. If the field is not set, returns the default value.

The compiler will generate the following methods only in the message's builder:

- `Builder setFoo(int value)`: Sets the value of the field. After calling this, `hasFoo()` will return `true` and `getFoo()` will return `value`.
- `Builder clearFoo()`: Clears the value of the field. After calling this, `hasFoo()` will return `false` and `getFoo()` will return the default value.

For other simple field types, the corresponding Java type is chosen according to the scalar value types table. For message and enum types, the value type is replaced with the message or enum class.

Embedded Message Fields

For message types, `setFoo()` also accepts an instance of the message's builder type as the parameter. This is just a shortcut which is equivalent to calling `.build()` on the builder and passing the result to the method.

If the field is not set, `getFoo()` will return a Foo instance with none of its fields set (possiblly the instance returned by `Foo.getDefaultInstance()`).

In addition, the compiler generates the following additional accessor methods in both the message class and its builder for message types, allowing you to access the relevant subbuilders:

- `Builder getFooBuilder()`: Returns the builder for the field.
- `FooOrBuilder getFooOrBuilder()`: Returns the builder for the field, if it already exists, or the message if not.

Repeated Fields

For this field definition:

```
repeated int32 foo = 1;
```

The compiler will generate the following accessor methods in both the message class and its builder:

- `int getFooCount()`: Returns the number of elements currently in the field.
- `int getFoo(int index)`: Returns the element at the given zero-based index.
- `List<Integer> getFooList()`: Returns the entire field as an immutable list. If the field is not set, returns an empty list.

The compiler will generate the following methods only in the message's builder:

- `Builder setFoo(int index, int value)`: Sets the value of the element at the given zero-based index.
- `Builder addFoo(int value)`: Appends a new element to the field with the given value.
- `Builder addAllFoo(List<Integer> value)`: Appends all elements in the given list to the field.
- `Builder clearFoo()`: Removes all elements from the field. After calling this, `getFooCount()` will return zero.

For other simple field types, the corresponding Java type is chosen according to the scalar value types table. For message and enum types, the type is the message or enum class.

Repeated Embedded Message Fields

For message types, `setFoo()` and `addFoo()` also accept an instance of the message's builder type as the parameter. This is just a shortcut which is equivalent to calling `.build()` on the builder and passing the result to the method.

In addition, the compiler generates the following additional accessor methods in both the message class and its builder for message types, allowing you to access the relevant subbuilders:

- `FooOrBuilder getFooOrBuilder(int index)`: Returns the builder for the specified element, if it already exists, or the element if not. If this is called from a message class, it will always return a message rather than a builder.
- `List<FooOrBuilder> getFooOrBuilderList()`: Returns the entire field as a list of builders (if available) or messages if not. If this is called from a message class, it will always return messages rather than builders.

The compiler will generate the following methods only in the message's builder:

- `Builder getFooBuilder(int index)`: Returns the builder for the element at the specified index.
- `Builder addFooBuilder(int index)`: Appends and returns a builder for a default message instance at the specified index.
- `Builder addFooBuilder()`: Appends and returns a builder for a default message instance.
- `List<FooOrBuilder> getFooBuilderList()`: Returns the entire field as a list of builders.

Enumerations

Given an enum definition like:

```
enum Foo {
  VALUE_A = 1;
  VALUE_B = 5;
  VALUE_C = 1234;
}
```

The protocol buffer compiler will generate a Java enum type called `Foo` with the same set of values. Additionally, the values of this enum type have the following special methods:

- `int getNumber()`: Returns the object's numeric value as defined in the `.proto` file.
- `EnumValueDescriptor getValueDescriptor()`: Returns the value's descriptor, which contains information about the value's name, number, and type.
- `EnumDescriptor getDescriptorForType()`: Returns the enum type's descriptor, which contains e.g. information about each defined value.

Additionally, the `Foo` enum type contains the following static methods:

- `static Foo valueOf(int value)`: Returns the enum object corresponding to the given numeric value.
- `static Foo valueOf(EnumValueDescriptor descriptor)`: Returns the enum object corresponding to the given value descriptor. May be faster than `valueOf(int)`.
- `EnumDescriptor getDescriptor()`: Returns the enum type's descriptor, which contains e.g. information about each defined value. (This differs from `getDescriptorForType()` only in that it is a static method.)

An integer constant is also generated with the suffix _VALUE for each enum value.

Note that the `.proto` language allows multiple enum symbols to have the same numeric value. Symbols with the same numeric value are synonyms. For example:

```
enum Foo {
  BAR = 1;
  BAZ = 1;
}
```

In this case, `BAZ` is a synonym for `BAR`. In Java, `BAZ` will be defined as a static final field like so:

```
static final Foo BAZ = BAR;
```

Thus, `BAR` and `BAZ` compare equal, and `BAZ` should never appear in switch statements. The compiler always chooses the first symbol defined with a given numeric value to be the "canonical" version of that symbol; all subsequent symbols with the same number are just aliases.

An enum can be defined nested within a message type. The compiler generates the Java enum definition nested within that message type's class.

Extensions

Given a message with an extension range:

```
message Foo {
  extensions 100 to 199;
}
```

The protocol buffer compiler will make `Foo` extend `GeneratedMessage.ExtendableMessage` instead of the usual `GeneratedMessage`. Similarly, `Foo`'s builder will extend `GeneratedMessage.ExtendableBuilder`. You should never refer to these base types by name (`GeneratedMessage` is considered an implementation detail). However, these superclasses define a number of additional methods that you can use to manipulate extensions.

In particular `Foo` and `Foo.Builder` will inherit the methods `hasExtension()`, `getExtension()`, and `getExtensionCount()`. Additionally, `Foo.Builder` will inherit methods `setExtension()` and `clearExtension()`. Each of these methods takes, as its first parameter, an extension identifier (described below), which identifies an extension field. The remaining parameters and the return value are exactly the same as those for the corresponding accessor methods that would be generated for a normal (non-extension) field of the same type as the extension identifier.

Given an extension definition:

```
extend Foo {
  optional int32 bar = 123;
}
```

The protocol buffer compiler generates an "extension identifier" called `bar`, which you can use with `Foo`'s extension accessors to access this extension, like so:

```
Foo foo =
  Foo.newBuilder()
    .setExtension(bar, 1)
    .build();
assert foo.hasExtension(bar);
assert foo.getExtension(bar) == 1;
```

(The exact implementation of extension identifiers is complicated and involves magical use of generics – however, you don't need to worry about how extension identifiers work to use them.)

Note that `bar` would be declared as a static field of the outer class for the `.proto` file, as described above; we have omitted the outer class name in the example.

Extensions can be declared nested inside of another type. For example, a common pattern is to do something like this:

```
message Baz {
  extend Foo {
    optional Baz foo_ext = 124;
  }
}
```

In this case, the extension identifier `foo_ext` is declared nested inside `Baz`. It can be used as follows:

```
Baz baz = createMyBaz();
Foo foo =
  Foo.newBuilder()
    .setExtension(Baz.fooExt, baz)
    .build();
```

When parsing a message that might have extensions, you must provide an ExtensionRegistry in which you have registered any extensions that you want to be able to parse. Otherwise, those extensions will just be treated like unknown fields. For example:

```
  ExtensionRegistry registry = ExtensionRegistry.newInstance();
  registry.add(Baz.fooExt);
  Foo foo = Foo.parseFrom(input, registry);
```

Services

If the `.proto` file contains the following line:

```
option java_generic_services = true;
```

Then the protocol buffer compiler will generate code based on the service definitions found in the file as described in this section. However, the generated code may be undesirable as it is not tied to any particular RPC system, and thus requires more levels of indirection that code tailored to one system. If you do NOT want this code to be generated, add this line to the file:

```
option java_generic_services = false;
```

If neither of the above lines are given, the option defaults to `false`, as generic services are deprecated. (Note that prior to 2.4.0, the option defaults to `true`)

RPC systems based on `.proto`-language service definitions should provide plugins to generate code approriate for the system. These plugins are likely to require that abstract services are disabled, so that they can generate their own classes of the same names. Plugins are new in version 2.3.0 (January 2010).

The remainder of this section describes what the protocol buffer compiler generates when abstract services are enabled.

Interface

Given a service definition:

```
service Foo {
  rpc Bar(FooRequest) returns(FooResponse);
}
```

The protocol buffer compiler will generate an abstract class `Foo` to represent this service. `Foo` will have an abstract method for each method defined in the service definition. In this case, the method `Bar` is defined as:

```
abstract void bar(RpcController controller, FooRequest request,
                  RpcCallback<FooResponse> done);
```

The parameters are equivalent to the parameters of `Service.CallMethod()`, except that the `method` argument is implied and `request` and `done` specify their exact type.

`Foo` subclasses the `Service` interface. The protocol buffer compiler automatically generates implementations of the methods of `Service` as follows:

- `getDescriptorForType`: Returns the service's `ServiceDescriptor`.
- `callMethod`: Determines which method is being called based on the provided method descriptor and calls it directly, down-casting the request message and callback to the correct types.
- `getRequestPrototype` and `getRequestPrototype`: Returns the default instance of the request or response of the correct type for the given method.

The following static method is also generated:

- `static ServiceDescriptor getDescriptor()`: Returns the type's descriptor, which contains information about what methods this service has and what their input and output types are.

`Foo` will also contain a nested interface `Foo.Interface`. This is a pure interface that again contains methods corresponding to each method in your service definition. However, this interface does not extend the `Service` interface. This is a problem because RPC server implementations are usually written to use abstract `Service` objects, not your particular service. To solve this problem, if you have an object `impl` implementing `Foo.Interface`, you can call `Foo.newReflectiveService(impl)` to construct an instance of `Foo` that simply delegates to `impl`, and implements `Service`.

To recap, when implementing your own service, you have two options:

- Subclass `Foo` and implement its methods as appropriate, then hand instances of your subclass directly to the RPC server implementation. This is usually easiest, but some consider it less "pure".

- Implement `Foo.Interface` and use `Foo.newReflectiveService(Foo.Interface)` to construct a `Service` wrapping it, then pass the wrapper to your RPC implementation.

Stub

The protocol buffer compiler also generates a "stub" implementation of every service interface, which is used by clients wishing to send requests to servers implementing the service. For the `Foo` service (above), the stub implementation `Foo.Stub` will be defined as a nested class.

`Foo.Stub` is a subclass of `Foo` which also implements the following methods:

- `Foo.Stub(RpcChannel channel)`: Constructs a new stub which sends requests on the given channel.
- `RpcChannel getChannel()`: Returns this stub's channel, as passed to the constructor.

The stub additionally implements each of the service's methods as a wrapper around the channel. Calling one of the methods simply calls `channel.callMethod()`.

The Protocol Buffer library does not include an RPC implementation. However, it includes all of the tools you need to hook up a generated service class to any arbitrary RPC implementation of your choice. You need only provide implementations of `RpcChannel` and `RpcController`.

Blocking Interfaces

The RPC classes described above all have non-blocking semantics: when you call a method, you provide a callback object which will be invoked once the method completes. Often it is easier (though possibly less scalable) to write code using blocking semantics, where the method simply doesn't return until it is done. To accomodate this, the protocol buffer compiler also generates blocking versions of your service class. `Foo.BlockingInterface` is equivalent to `Foo.Interface` except that each method simply returns the result rather than call a callback. So, for example, `bar` is defined as:

```
abstract FooResponse bar(RpcController controller, FooRequest request)
                    throws ServiceException;
```

Analogous to non-blocking services, `Foo.newReflectiveBlockingService(Foo.BlockingInterface)` returns a `BlockingService` wrapping some `Foo.BlockingInterface`. Finally, `Foo.BlockingStub` returns a stub implementation of `Foo.BlockingInterface` that sends requests to a particular `BlockingRpcChannel`.

Plugin Insertion Points

Code generator plugins which want to extend the output of the Java code generator may insert code of the following types using the given insertion point names.

- `outer_class_scope`: Member declarations that belong in the file's outer class.
- `class_scope:TYPENAME`: Member declarations that belong in a message class. `TYPENAME` is the full proto name, e.g. `package.MessageType`.
- `builder_scope:TYPENAME`: Member declarations that belong in a message's builder class. `TYPENAME` is the full proto name, e.g. `package.MessageType`.
- `enum_scope:TYPENAME`: Member declarations that belong in an enum class. `TYPENAME` is the full proto enum name, e.g. `package.EnumType`.

Generated code cannot contain import statements, as these are prone to conflict with type names defined within the generated code itself. Instead, when referring to an external class, you must always use its fully-qualified name.

> The logic for determining output file names in the Java code generator is fairly complicated. You should probably look at the `protoc` source code, particularly `java_headers.cc`, to make sure you have covered all cases.

> Do not generate code which relies on private class members declared by the standard code generator, as these implementation details may change in future versions of Protocol Buffers.

Last updated 四月 *22, 2014.*

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Package com.google.protobuf

Interface Summary

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Python Generated Code

This page describes exactly what Python definitions the protocol buffer compiler generates for any given protocol definition. You should read the language guide before reading this document.

The Python Protocol Buffers implementation is a little different from C++ and Java. In Python, the compiler only outputs code to build descriptors for the generated classes, and a Python metaclass does the real work. This document describes what you get *after* the metaclass has been applied.

Compiler Invocation

The protocol buffer compiler produces Python output when invoked with the `--python_out=` command-line flag. The parameter to the `--python_out=` option is the directory where you want the compiler to write your Python output. The compiler creates a `.py` file for each `.proto` file input. The names of the output files are computed by taking the name of the `.proto` file and making two changes:

- The extension (`.proto`) is replaced with `_pb2.py`.
- The proto path (specified with the `--proto_path=` or `-I` command-line flag) is replaced with the output path (specified with the `--python_out=` flag).

So, for example, let's say you invoke the compiler as follows:

```
protoc --proto_path=src --python_out=build/gen src/foo.proto src/bar/baz.proto
```

The compiler will read the files `src/foo.proto` and `src/bar/baz.proto` and produce two output files: `build/gen/foo_pb2.py` and `build/gen/bar/baz_pb2.py`. The compiler will automatically create the directory `build/gen/bar` if necessary, but it will *not* create `build` or `build/gen`; they must already exist.

Note that if the `.proto` file or its path contains any characters which cannot be used in Python module names (for example, hyphens), they will be replaced with underscores. So, the file `foo-bar.proto` becomes the Python file `foo_bar_pb2.py`.

> When outputting Python code, the protocol buffer compiler's ability to output directly to ZIP archives is particularly convenient, as the Python interpreter is able to read directly from these archives if placed in the `PYTHONPATH`. To output to a ZIP file, simply provide an output location ending in `.zip`.

> The number 2 in the extension `_pb2.py` designates version 2 of Protocol Buffers. Version 1 was used primarily inside Google, though you might be able to find parts of it included in other Python code that was released before Protocol Buffers. Since version 2 of Python Protocol Buffers has a completely different interface, and since Python does not have compile-time type checking to catch mistakes, we chose to make the version number be a prominent part of generated Python file names.

Packages

The Python code generated by the protocol buffer compiler is completely unaffected by the package name defined in the `.proto` file. Instead, Python packages are identified by directory structure.

Messages

Given a simple message declaration:

```
message Foo {}
```

The protocol buffer compiler generates a class called `Foo`, which subclasses `google.protobuf.Message`. The class is a concrete class; no abstract methods are left unimplemented. Unlike C++ and Java, Python generated code is unaffected by the `optimize_for` option in the `.proto` file; in effect, all Python code is optimized for code size.

You should *not* create your own `Foo` subclasses. Generated classes are not designed for subclassing and may lead to "fragile base class" problems. Besides, implementation inheritance is bad design.

Python message classes have no particular public members other than those defined by the `Message` interface and those generated for nested fields, messages, and enum types (described below). `Message` provides methods you can use to check, manipulate, read, or write the entire message, including parsing from and serializing to binary strings. In addition to these methods, the `Foo` class defines the following static methods:

- `FromString(s)`: Returns a new message instance deserialized from the given string.

Note that you can also use the `text_format` module to work with protocol messages in text format: for example, the `Merge()` method lets you merge an ASCII representation of a message into an existing message.

A message can be declared inside another message. For example: `message Foo { message Bar { } }`

In this case, the `Bar` class is declared as a static member of `Foo`, so you can refer to it as `Foo.Bar`.

Fields

For each field in a message type, the corresponding class has a member with the same name as the field. How you can manipulate the member depends on its type.

As well as accessor methods, the compiler generates an integer constant for each field containing its field number. The constant name is the field name converted to upper-case followed by `_FIELD_NUMBER`. For example, given the field `optional int32 foo_bar = 5;`, the compiler will generate the constant `FOO_BAR_FIELD_NUMBER = 5`.

Singular Fields

If you have a singular (optional or required) field `foo` of any non-message type, you can manipulate the field `foo` as if it were a regular field. For example, if `foo`'s type is `int32`, you can say:

```
message.foo = 123
print message.foo
```

Note that setting `foo` to a value of the wrong type will raise a `TypeError`.

If `foo` is read when it is not set, its value is the default value for that field. To check if `foo` is set, or to clear the value of `foo`, you must call the `HasField()` or `ClearField()` methods of the `Message` interface. For example:

```
assert not message.HasField("foo")
message.foo = 123
assert message.HasField("foo")
message.ClearField("foo")
assert not message.HasField("foo")
```

Singular Message Fields

Message types work slightly differently. You cannot assign a value to an embedded message field. Instead, assigning a value to any field within the child message implies setting the message field in the parent. So, for example, let's say you have the following `.proto` definition:

```
message Foo {
  optional Bar bar = 1;
}
message Bar {
  optional int32 i = 1;
}
```

You *cannot* do the following:

```
foo = Foo()
foo.bar = Bar()  # WRONG!
```

Instead, to set `bar`, you simply assign a value directly to a field within `bar`, and - presto! - `foo` has a `bar` field:

```
foo = Foo()
assert not foo.HasField("bar")
foo.bar.i = 1
assert foo.HasField("bar")
assert foo.bar.i == 1
foo.ClearField("bar")
assert not foo.HasField("bar")
assert foo.bar.i == 0  # Default value
```

Similarly, you can set `bar` using the Message interface's `CopyFrom()` method. This copies all the values from another message of the same type as `bar`.

```
foo.bar.CopyFrom(baz)
```

Note that simply reading a field inside `bar` does *not* set the field:

```
foo = Foo()
assert not foo.HasField("bar")
print foo.bar.i  # Print i's default value
assert not foo.HasField("bar")
```

Repeated Fields

Repeated fields are represented as an object that acts like a Python sequence. As with embedded messages, you cannot assign the field directly, but you can manipulate it. For example, given this message definition:

```
message Foo {
  repeated int32 nums = 1;
}
```

You can do the following:

```
foo = Foo()
foo.nums.append(15)        # Appends one value
foo.nums.extend([32, 47])  # Appends an entire list

assert len(foo.nums) == 3
assert foo.nums[0] == 15
assert foo.nums[1] == 32
assert foo.nums == [15, 32, 47]

foo.nums[1] = 56    # Reassigns a value
assert foo.nums[1] == 56
for i in foo.nums:  # Loops and print
  print i
del foo.nums[:]     # Clears list (works just like in a Python list)
```

The `ClearField()` method of the `Message` interface works as well in addition to using Python `del`.

Repeated Message Fields

Repeated messages works similar to repeated scalar fields, except the corresponding Python object does not have an `append()` function. Instead, it has an `add()` function that creates a new message object, appends it to the list, and returns it for the caller to fill in. It also has an `extend()` function that appends an entire list of messages, but makes a **copy** of every message in the list. This is done so that messages are always owned by the parent message to avoid circular references and other confusion that can happen when a mutable data structure has multiple owners.

For example, given this message definition:

```
message Foo {
  repeated Bar bars = 1;
}
message Bar {
  optional int32 i = 1;
  optional int32 j = 2;
}
```

You can do the following:

```
foo = Foo()
bar = foo.bars.add()        # Adds a Bar then modify
bar.i = 15
foo.bars.add().i = 32       # Adds and modify at the same time
new_bar = Bar()
new_bar.i = 47
foo.bars.extend([new_bar])  # Uses extend() to copy

assert len(foo.bars) = 3
assert foo.bars[0].i == 15
assert foo.bars[1].i == 32
assert foo.bars[2].i == 47
assert foo.bars[2] == new_bar      # The extended message is equal,
assert foo.bars[2] is not new_bar  # but it is a copy!

foo.bars[1].i = 56    # Modifies a single element
assert foo.bars[1].i == 56
for bar in foo.bars:  # Loops and print
  print bar.i
del foo.bars[:]       # Clears list

# add() also forwards keyword arguments to the concrete class.
# For example, you can do:

foo.bars.add(i = 12, j = 13)
```

Enumerations

In Python, enums are just integers. A set of integral constants are defined corresponding to the enum's defined values. For example, given:

```
message Foo {
  enum SomeEnum {
    VALUE_A = 1;
    VALUE_B = 5;
    VALUE_C = 1234;
  }
  optional SomeEnum bar = 1;
}
```

The constants `VALUE_A`, `VALUE_B`, and `VALUE_C` are defined with values 1, 5, and 1234, respectively. No type corresponding to `SomeEnum` is defined. If an enum is defined in the outer scope, the values are module constants; if it is defined within a message (like above), they become static members of that message class.

An enum field works just like a scalar field. It does **not** do any type checking in the setter or getter.

```
foo = Foo()
foo.bar = Foo.VALUE_A
assert foo.bar == 1
assert foo.bar == Foo.VALUE_A
```

Note that in C++ and Java, an enum field cannot contain a numeric value other than those defined for the enum type. If an unknown enum value is encountered while parsing, the field will be treated as if its tag number were unknown. Therefore, you should never assign an enum field to an undefined value in Python, either. A future version of the library may explicitly disallow this.

Extensions

Given a message with an extension range:

```
message Foo {
  extensions 100 to 199;
}
```

The Python class corresponding to `Foo` will have a member called `Extensions`, which is a dictionary mapping extension identifiers to their current values.

Given an extension definition:

```
extend Foo {
  optional int32 bar = 123;
}
```

The protocol buffer compiler generates an "extension identifier" called `bar`. The identifier acts as a key to the `Extensions` dictionary. The result of looking up a value in this dictionary is exactly the same as if you accessed a normal field of the same type. So, given the above example, you could do:

```
foo = Foo()
foo.Extensions[proto_file_pb2.bar] = 2
assert foo.Extensions[proto_file_pb2.bar] == 2
```

Note that you need to specify the extension identifier constant, not just a string name: this is because it's possible for multiple extensions with the same name to be specified in different scopes.

Analogous to normal fields, `Extensions[...]` returns a message object for singular messages and a sequence for repeated fields.

The `Message` interface's `HasField()` and `ClearField()` methods do not work with extensions; you must use `HasExtension()` and `ClearExtension()` instead.

Services

If the `.proto` file contains the following line:

```
option py_generic_services = true;
```

Then the protocol buffer compiler will generate code based on the service definitions found in the file as described in this section. However, the generated code may be undesirable as it is not tied to any particular RPC system, and thus requires more levels of indirection that code tailored to one system. If you do NOT want this code to be generated, add this line to the file:

```
option py_generic_services = false;
```

If neither of the above lines are given, the option defaults to `false`, as generic services are deprecated. (Note that prior to 2.4.0, the option defaults to `true`)

RPC systems based on `.proto`-language service definitions should provide plugins to generate code approriate for the system. These plugins are likely to require that abstract services are disabled, so that they can generate their own classes of the same names. Plugins are new in version 2.3.0 (January 2010).

The remainder of this section describes what the protocol buffer compiler generates when abstract services are enabled.

Interface

Given a service definition:

```
service Foo {
  rpc Bar(FooRequest) returns(FooResponse);
}
```

The protocol buffer compiler will generate a class `Foo` to represent this service. `Foo` will have a method for each method defined in the service definition. In this case, the method `Bar` is defined as:

```
def Bar(self, rpc_controller, request, done)
```

The parameters are equivalent to the parameters of `Service.CallMethod()`, except that the `method_descriptor` argument is implied.

These generated methods are intended to be overridden by subclasses. The default implementations simply call `controller.SetFailed()` with an error message indicating that the method is unimplemented, then invoke the `done` callback. When implementing your own service, you must subclass this generated service and implement its methods as appropriate.

`Foo` subclasses the `Service` interface. The protocol buffer compiler automatically generates implementations of the methods of `Service` as follows:

- `GetDescriptor`: Returns the service's `ServiceDescriptor`.
- `CallMethod`: Determines which method is being called based on the provided method descriptor and calls it directly.
- `GetRequestClass` and `GetResponseClass`: Returns the class of the request or response of the correct type for the given method.

Stub

The protocol buffer compiler also generates a "stub" implementation of every service interface, which is used by clients wishing to send requests to servers implementing the service. For the `Foo` service (above), the stub implementation `Foo_Stub` will be defined.

`Foo_Stub` is a subclass of `Foo`. Its constructor takes an `RpcChannel` as a parameter. The stub then implements each of the service's methods by calling the channel's `CallMethod()` method.

The Protocol Buffer library does not include an RPC implementation. However, it includes all of the tools you need to hook up a generated service class to any arbitrary RPC implementation of your choice. You need only provide implementations of `RpcChannel` and `RpcController`.

Plugin Insertion Points

Code generator plugins which want to extend the output of the Python code generator may insert code of the following types using the given insertion point names.

- `imports`: Import statements.
- `module_scope`: Top-level declarations.
- `class_scope:TYPENAME`: Member declarations that belong in a message class. `TYPENAME` is the full proto name, e.g. `package.MessageType`.

> Do not generate code which relies on private class members declared by the standard code generator, as these implementation details may change in future versions of Protocol Buffers.

C++ Implementation

There is also an experimental C++ implementation for Python messages via a Python extension for better performance. Implementation type is controlled by an environment variable `PROTOCOL_BUFFERS_PYTHON_IMPLEMENTATION` (valid values: "cpp" and "python"). The default value is currently "python" but will be changed to "cpp" in future release.

Note that the environment variable needs to be set before installing the protobuf library, in order to build and install the python extension. The C++ implementation also requires CPython platforms. See `python/INSTALL.txt` for detailed install instructions.

Last updated 三月 5, 2013.

Package google :: Package protobuf [frames] | no frames]

Package protobuf

source code

Submodules

- **google.protobuf.descriptor**: *Descriptors essentially contain exactly the information found in a .proto file, in types that make this information accessible in Python.*
- **google.protobuf.descriptor_pb2**
- **google.protobuf.message**: *Contains an abstract base class for protocol messages.*
- **google.protobuf.reflection**: *Contains a metaclass and helper functions used to create protocol message classes from Descriptor objects at runtime.*
- **google.protobuf.service**: *DEPRECATED: Declares the RPC service interfaces.*
- **google.protobuf.service_reflection**: *Contains metaclasses used to create protocol service and service stub classes from ServiceDescriptor objects at runtime.*
- **google.protobuf.text_format**: *Contains routines for printing protocol messages in text format.*

Variables

	__package__ = None

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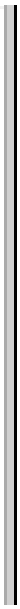

Other Languages

While the current release just includes compilers and APIs for C++, Java, and Python, the compiler code is designed so that it's easy to add support for other languages. There are several ongoing projects to add new language implementations to Protocol Buffers, including C, C#, Haskell, Perl, Ruby, and more.

For a list of links to projects we know about, see the third-party add-ons wiki page.

Compiler Plugins

As of version 2.3.0 (January 2010), `protoc`, the Protocol Buffers Compiler, can be extended to support new languages via plugins. A plugin is just a program which reads a `CodeGeneratorRequest` protocol buffer from standard input and then writes a `CodeGeneratorResponse` protocol buffer to standard output. These message types are defined in `plugin.proto`. We recommend that all third-party code generators be written as plugins, as this allows all generators to provide a consistent interface and share a single parser implementation.

Additionally, plugins are able to insert code into the files generated by other code generators. See the comments about "insertion points" in `plugin.proto` for more on this. This could be used, for example, to write a plugin which genreates RPC service code that is tailored for a particular RPC system. See the documentation for the generated code in each language to find out what insertion points they provide.

Last updated 四月 2, 2012.

Frequently Asked Questions

This document answers some frequently asked questions about the Protocol Buffers open source project. If you have a question that isn't answered here, join the discussion group and ask away!

General

Why did you release protocol buffers?

There are several reasons:

- Protocol buffers are used by practically everyone inside Google. We have many other projects we would like to release as open source that use protocol buffers, so to do this, we needed to release protocol buffers first. In fact, bits of the technology have already found their way into the open – if you dig into the code for Google AppEngine, you might find some of it.
- We would like to provide public APIs that accept protocol buffers as well as XML, both because it is more efficient and because we're just going to convert that XML to protocol buffers on our end anyway.
- We thought that people outside Google might find protocol buffers useful.
- Getting protocol buffers into a form we were happy to release was a fun 20% project.

Why is the first release version 2? What happened to version 1?

The initial version of protocol buffers (aka "Proto1") was developed in Google starting in early 2001, and evolved over the course of many years, sprouting new features whenever someone needed them and was willing to do the work themselves. Like anything created in such a way, it was a bit of a mess. We came to the conclusion that it would not be feasible to release the code as it was.

Version 2 ("Proto2") is a complete rewrite, though it keeps most of the design and uses many of the implementation ideas from Proto1. Some features have been added, some removed. Most importantly, though, the code is cleaned up and does not have any dependencies on Google libraries that have not yet been open-sourced.

Why the name "Protocol Buffers"?

The name originates from the early days of the format, before we had the protocol buffer compiler to generate classes for us. At the time, there was a class called `ProtocolBuffer` which actually acted as a buffer for an individual method. Users would add tag/value pairs to this buffer individually by calling methods like `AddValue(tag, value)`. The raw bytes were stored in a buffer which could then be written out once the message had been constructed.

Since that time, the "buffers" part of the name has lost its meaning, but it is still the name we use. Today, people usually use the term "protocol message" to refer to a message in an abstract sense, "protocol buffer" to refer to a serialized copy of a message, and "protocol message object" to refer to an in-memory object representing the parsed message.

Does Google have any patents on Protocol Buffers?

Google currently has no issued patents on Protocol Buffers, and we are happy to address any concerns around Protocol Buffers and patents that people may have.

Similar Technologies

How do protocol buffers differ from XML?

See the answer on the overview page.

How do protocol buffers differ from ASN.1, COM, CORBA, Thrift, etc?

We think all of these systems have strengths and weaknesses. Google relies on protocol buffers internally and they are a vital component of our success, but that doesn't mean they are the ideal solution for every problem. You should evaluate each alternative in the context of your own project.

It is worth noting, though, that several of these technologies define both an interchange format and an RPC (remote procedure call) protocol. Protocol buffers are just an interchange format. They could easily be used for RPC – and, indeed, they do have limited support for defining RPC services – but they are not tied to any one RPC implementation or protocol.

Contributing

Can I add support for a new language to protocol buffers?

Yes! In fact, the protocol buffer compiler is designed such that it's easy to write your own compiler. Check out the `CommandLineInterface` class, which is available as part of the `libprotoc` library.

We encourage you to create code generators and runtime libraries for new languages. You should start your own, independent project for this – this way, you will have the freedom to manage your project as you see fit, and will not be held back by our release process. Please also join the Protocol Buffers discussion group and let us know about your project; we will be happy to link to it and help you out with design issues.

Can I contribute patches to protocol buffers?

Yes! Please join the Protocol Buffers discussion group and talk to us about it.

Can I add new features to protocol buffers?

Maybe. We always like suggestions, but we're very cautious about adding things. One thing we've learned over the years is that lots of people have interesting ideas for new features. Most of these features are very useful in specific cases, but if we accepted all of them, protocol buffers would become a bloated, confusing mess. So, we have to be very picky. When evaluating new features, we look for additions that are very widely useful or very simple – or hopefully both. We regularly turn down feature additions from Google employees. We even regularly turn down feature additions from our own team members.

That said, we'd still like to hear what you have in mind. Join the Protocol Buffers discussion group and let us know. We might be able to help you find a way to do what you want without changing the underlying library. Or, maybe we'll decide that your feature is so useful or so simple that it should be added.

Last updated 四月 *22, 2014.*