Cloudy Message Passing Library

Documentation

The Cloudy Message Passing Library is a .NET library for development of scalable parallel applications.

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1 Overview 3
2 Components 3
2.1 Protocol Buffers – the Protobuf namespace 3
2.1.1 Getting Started 3
2.1.2 Optional and Required Fields 3
2.1.3 Repeated Fields 3
2.1.4 Packed Repeated Fields 4
2.1.5 Types Mapping 4
2.2 Messaging – the Messaging namespace 5
2.2.1 Messaging Overview 5
2.2.2 MessageStream 5
2.2.3 MessageDispatcher 5
2.2.4 Understanding Data Transfer Objects 6
2.3 Helper Classes – the Helpers namespace 7
2.3.1 UdpStream 7

1 Overview

The library consists of the following separate parts interacting with one another:

- Protobuf namespace (Protocol Buffers implementation)
- Messaging namespace
- Connections namespace
- Helper classes

2 Components

2.1 Protocol Buffers – the Protobuf namespace

2.1.1 Getting Started

In order to serialize an object of the specific class you should firstly mark this class with the `ProtobufSerializable` attribute and each serializable field – with the `ProtobufField` attribute:

```
[ProtobufSerializable]
public class A
{
    /// <summary>
    /// Initializes the default values.
    /// </summary>
    public A()
    {
        B = 666;
    }

    [ProtobufField(1)]
    public uint B { get; set; }
}
```

Then you'll be able to serialize an object by creating the serializer and calling the Serialize method and deserialize calling the Deserialize method:

```
[Test]
public void TestSerializeBasic()
{
    Serializer serializer = Serializer.CreateSerializer(typeof(A));
    object o = new A { B = 150 };
    AssertExtensions.AreEqual(new byte[] { 0x08, 0x96, 0x01 },
            serializer.Serialize(o));
}
```

2.1.2 Optional and Required Fields

All properties are optional by default. This means that if a field has no value set then the related tag will not appear in a target message. This behavior is recommended because you'll not be able to remove a required field and not break a protocol.

But the possibility to define a required field there is:

```
[ProtobufField(1, required: true)]
public string D { get; set; }
```

2.1.3 Repeated Fields

The Cloudy can serialize collections. All you need is to define a property as `ICollection`:

```
[ProtobufField(1)]
public ICollection<uint> List { get; set; }
...
Serializer serializer = Serializer.CreateSerializer(typeof(D));
object o = new D { List = new uint[] { 1, 2, 3 } };
AssertExtensions.AreEqual(new byte[] { 0x08, 0x01, 0x08, 0x02, 0x08, 0x03 },
    serializer.Serialize(o));
```

2.1.4 Packed Repeated Fields

Packed repeated field is serialized as length-delimited field: sequentially serialized values are used instead of repeating of a single tag with a single value.

```
[ProtobufSerializable]
public class E
{
    [ProtobufField(4, packed: true)]
    public ICollection<uint> List { get; set; }
}
```

2.1.5 Types Mapping

By default the .NET types are serialized into the following Protobuf types:

.NET Type	Protobuf Type
bool	Unsigned Varint
int	Signed Varint
long	Signed Varint
uint	Unsigned Varint
ulong	Unsigned Varint
string	String
byte[]	Length-Delimited
Guid	Length-Delimited (16 bytes)
Enum	Unsigned Varint
ICollection<T>	Repeated T
Nullable<T>	Optional T
Any other class	Attempted to be serialized as an Embedded Message

If you want to change a target Protobuf type (e.g. serialize int as Fixed32) then you may specify the `dataType` parameter of the `ProtobufSerializable` attribute:

```
[ProtobufSerializable]
public class H
{
    [ProtobufField(2, dataType: DataType.FixedInt32)]
    public int Fixed32 { get; set; }
}
```

Data types are mapped into the target Protobuf types as follows:

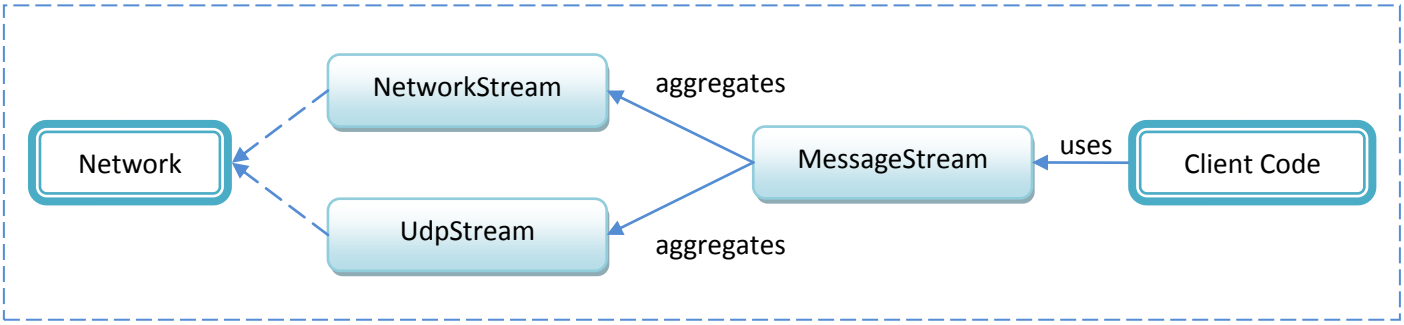
DataType	Protobuf Type
Bool	Varint
Bytes	Length-Delimited
Embedded Message	Length-Delimited
FixedInt32	Fixed32
FixedInt64	Fixed64
FixedUInt32	Fixed32
FixedUInt64	Fixed64

SignedVarint	Signed Varint
String	String
UnsignedVarint	Varint
Guid	Length-Delimited (16 bytes)

2.2 Messaging – the Messaging namespace

2.2.1 Messaging Overview

A client code reads messages from and writes messages to a network using the `MessageStream` class. In general, this looks like this:



By design, a slave node has one TCP connection to a master node and several UDP peer-to-peer connections to other nodes. A slave node listens for incoming messages on a specific port and (maybe) replies to other nodes on specific addresses and ports. In order to track messages and ensure they are delivered the `MessageDispatcher` class is used.

All messages are packed into DTOs (Data Transfer Objects).

2.2.2 MessageStream

This is the utility class for convenient sequential reading and writing of messages. Wraps a Stream object and provides the Read and Write methods. Thread-safe.

2.2.2.1 Example

```
using (MemoryStream stream = new MemoryStream())
{
    MessageStream messageStream = new MessageStream(stream);
    foreach (object message in
        new object[] { new A { B = 1 }, new A { B = 2 } })
    {
        messageStream.Write(message);
    }
}
```

2.2.3 MessageDispatcher

The core messaging class. It's responsibilities:

1. Ensuring messages are delivered by sending delivery notifications.
2. Buffering of incoming message.
3. Asynchronous sending and receiving messages.

The `MessageDispatcher` class aggregates at least one message stream that is used to read incoming messages from. In the case of TCP connection this stream is also output stream (to which messages and delivery notifications are sent).

In the case of UDP the situation is rather different. The problem is that an input stream will receive messages from all other nodes together, while sending to other nodes should be done through different output streams. Thus:

1. Each dispatcher has a FromId (an unique ID of a sender).

2. `MessageDispatcher` invokes a specific *stream resolver* in order to determine the output stream.

A user of a `MessageDispatcher` should pass these in the constructor:

```
dispatcher = new MessageDispatcher(Options.ClientId,
    ResolveStream, new MessageStream(client.GetStream()));
```

In the simplest case (TCP) a stream resolver can simply return the input stream:

```
private static bool ResolveStream(Guid id, out MessageStream stream)
{
    stream = dispatcher.InputStream;
    return id == Options.ServerId;
}
```

In a common case (UDP) a client code should hold message streams (on UDP streams) to all the communicating nodes and return one of these streams by the specified unique ID.

2.2.4 Understanding Data Transfer Objects

There are two main problems when sending and receiving messages:

1. Messages in Protocol Buffers format are not self-describing. That means that in common case we cannot predict what type of message we should read as we doesn't know its structure.
2. `MessageDispatcher` should be able to send delivery notifications immediately after receiving of a message without knowing of its structure.

To resolve them the concept of DTOs where used. The DTO in Cloudy consists of:

Property	Type	Description
FromId	Guid	The unique identifier of a sender
TrackingId	Int32	The unique (within all existing DTOs) identifier of this DTO during transferring
Tag	Nullable<Int32>	User specified value that indicates a type of the message
Value	T	User-specific data (serialized as embedded message)

Actually, a developer can now nothing about DTOs in order to use Cloudy, because Cloudy hides using of them. If you simply know the type of an expected message, you can invoke the `MessageDispatcher.Receive<TResult>` method directly. Else, all you need is to receive a message:

```
int? tag;
Guid fromId;
ICastableValue dto = dispatcher.Receive(out fromId, out tag);
```

And extract needed data after analyzing of a message type:

```
if (tag == Tags.Says)
{
    Console.WriteLine("Server says: {0}", dto.Get<SaysValue>().Message);
}
```

Where `Message` is just a serializable property of the serializable `SaysValue` class.

`MessageStream` is able to read and write tagged messages via hidden usage of DTO's:

```
messageStream.Write(tags[i], new A { UIntValue = values[i]});
...
int? tag;
uint value = messageStream.Read(out tag).Get<A>().UIntValue;
```

2.3 Helper Classes – the Helpers namespace

2.3.1 UdpStream

Implements the Stream interface. That allows interacting with an UDP connection as if it was simply a Stream. This is useful in UDP-messaging via the Protobuf protocol.

Yes, there is the NetworkStream class, but unfortunately one can't use NetworkStream for UDP.

2.3.1.1 Example

```
UdpStream stream1 = new UdpStream(new UdpClient(new IPEndPoint(IPAddress.Any, 1234)));
UdpStream stream2 = new UdpStream(new UdpClient());
stream2.Client.Connect("localhost", 1234);
byte[] buffer = new byte[] { 0x01, 0x02, 0x03, 0x04 };
stream2.Write(buffer, 0, buffer.Length);
foreach (byte b in buffer)
{
    Assert.AreEqual(b, (byte)stream1.ReadByte());
}
```