Resonance

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Resonance is a high-performance real-time C# communication library with built-in support for several different transcoding and delivery methods. This library provides an intuitive API for asynchronous communication between machines and devices by exposing a set of easy to use, pluggable components.

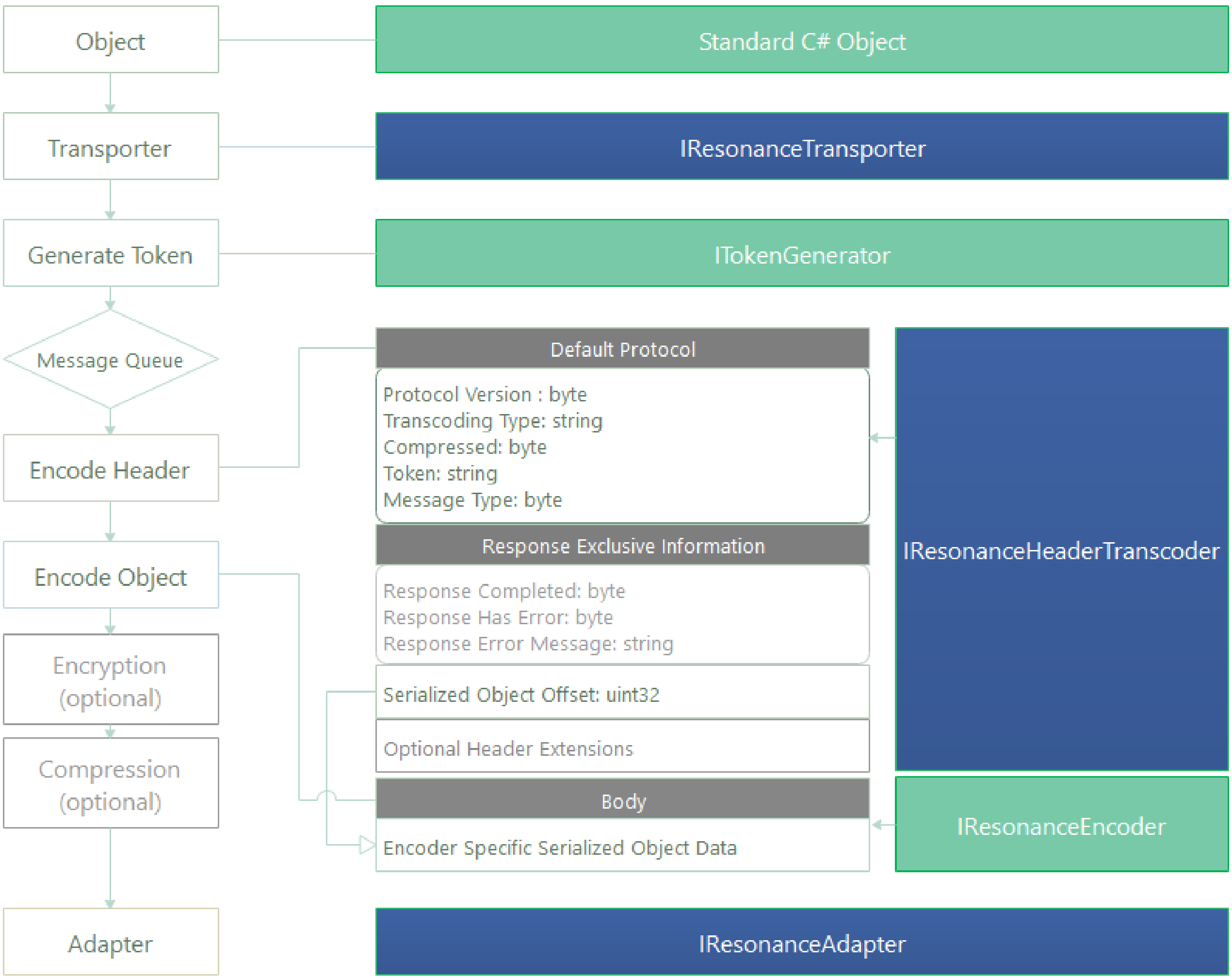
Module	Nuget	Description	Target Framework
Resonance	nuget v1.5.0	Core components	.NET Standard 2.0
Resonance.Protobuf	nuget v1.5.0	Protobuf Encoder & Decoder	.NET Standard 2.0
Resonance.MessagePack	nuget v1.5.0	MessagePack Encoder & Decoder	.NET Standard 2.0
Resonance.USB	nuget v1.5.0	USB Adapter support.	.NET 4.6.1, .NET 5
Resonance.SignalR	nuget v1.5.0	SignalR (core and legacy) Adapters and Hubs.	.NET 4.6.1, .NET 5

Resonance.WebRTC	nuget v1.5.0	WebRTC Adapter support.	.NET 4.6.1, .NET 5
Resonance.LZ4	nuget v1.5.0	LZ4 Compression support.	.NET Standard

Overview

Resonance is a request-response based communication framework. This means that for each request that is being sent, a matching response is expected. This is done by attaching a unique token to each request and expecting the same token from the response. Although the request-response pattern is the recommended approach, it is not enforced. Sending messages without expecting any response is possible.

The following diagram provides a basic overview of a message being sent.



The resonance library might be described by these 3 basic layers:

Transporting

A transporter responsibility is to provide the API for sending and receiving messages, managing those messages, and propagating the required information to other components.

Transcoding

Encoders and Decoders are components that can be plugged to a transporter, they determine how outgoing/incoming messages should be encoded and whether the data should be encrypted and/or compressed. The Following built-in transcoding methods are currently supported by the library:

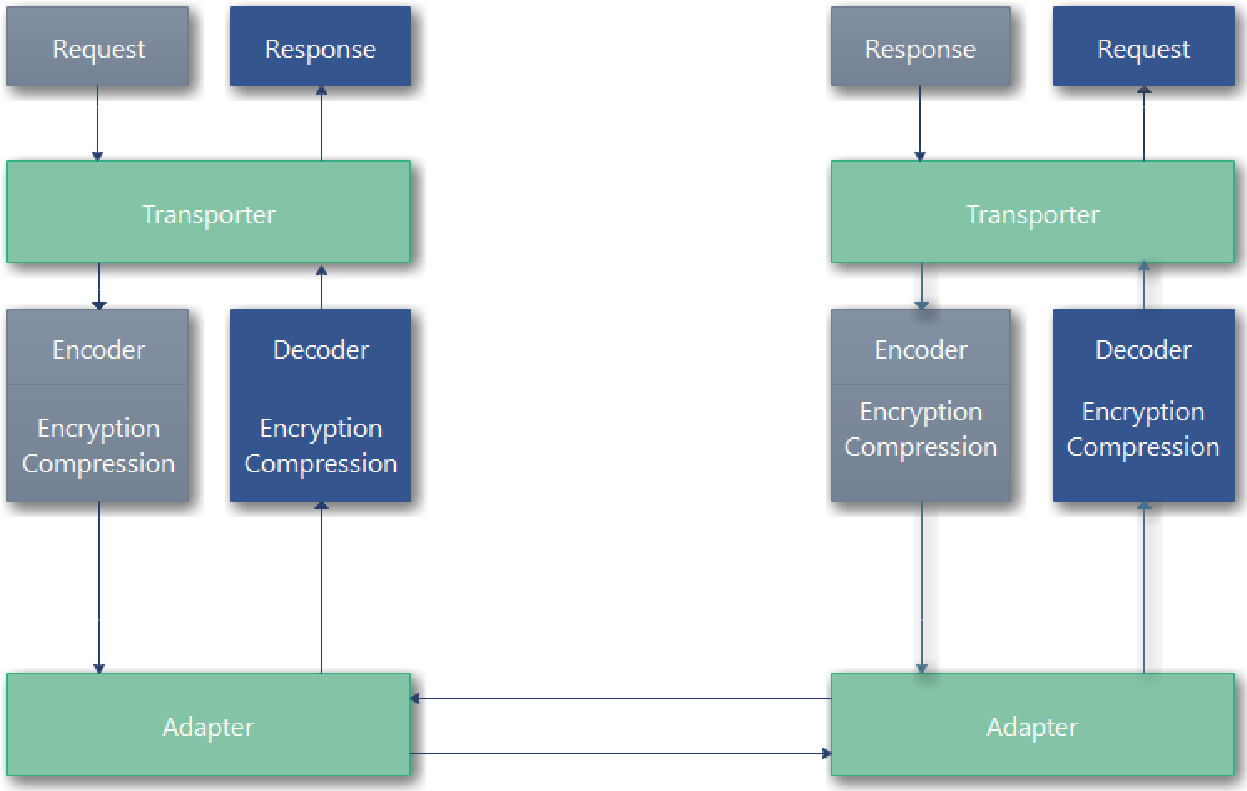
- Json
- Bson
- Protobuf
- MessagePack
- Xml

Adapters

Adapters can also be plugged to a transporter to determine how outgoing/incoming encoded data is going to be transmitted and where. The following built-in adapters are currently supported by the library:

- TCP
- UDP
- USB
- In-Memory
- SignalR
- WebRTC
- Named Pipes
- Shared Memory

The following diagram described a simple request-response scenario.



Getting Started

The first step is deciding about the communication and transcoding methods that we are going to use. For this demonstration, we are going to use JSON transcoding over TCP/IP as the means of communication between two Transporters.

Here is how we can create the first Transporter with JSON encoding/decoding and TCP/IP adapter.

```
public async void Init()
{
    IResonanceTransporter transporter = new ResonanceTransporter();

    transporter.Adapter = new TcpAdapter("127.0.0.1", 8888);
    transporter.Encoder = new JsonEncoder();
    transporter.Decoder = new JsonDecoder();

    await transporter.ConnectAsync();
}
```

A Transporter can also be instantiated using the fluent syntax builder.

```
public async void Init()
{
```

```
{
    IResonanceTransporter transporter = ResonanceTransporter.Builder
        .Create()
        .WithTcpAdapter()
        .WithAddress("127.0.0.1")
        .WithPort(8888)
        .WithJsonTranscoding()
        .Build();

    await transporter.ConnectAsync();
}
```

Now, since we are using TCP/IP as the means of communication, we need a TCP server/listener to accept incoming connections.
For that, we are going to use the built-in `ResonanceTcpServer` class. Although, you can use any other TCP/IP listener.

Here, we are going to create a new TCP server and wait for incoming connections.
Once a new connection is available, the `ConnectionRequest` event will be triggered.
The event arguments contains the `Accept` and `Decline` methods for accepting or declining the new connection.
The accept method returns an initialized `TcpAdapter` that can be used to create the "other side" second Transporter.

```
public async void Init_TcpServer()
{
    ResonanceTcpServer server = new ResonanceTcpServer(8888);
    server.ConnectionRequest += Server_ConnectionRequest;
    await server.StartAsync();
}

private async void Server_ConnectionRequest(object sender, ResonanceListeningServer
{
    IResonanceTransporter transporter2 = ResonanceTransporter.Builder
        .Create()
        .WithAdapter(e.Accept()) //Call the Accept method to get a new TcpAdapter.
        .WithJsonTranscoding()
        .Build();

    await transporter2.ConnectAsync();
}
```

Now that we have both transporters connected, we can start sending messages.
Let's define two simple request and response messages.

CalculateRequest:

```
public class CalculateRequest
{
    public double A { get; set; }
    public double B { get; set; }
}
```

CalculateResponse:

```
public class CalculateResponse
{
    public double Sum { get; set; }
}
```

Here is how we can send a `CalculateRequest` from the first Transporter, while expecting a `CalculateResponse` from the "other-side" second Transporter.

```
var response = await transporter1.SendRequestAsync<CalculateRequest, CalculateRespo
{
    A = 10,
    B = 5
});

Console.WriteLine(response.Sum);
```

Finally, we need to handle the incoming `CalculateRequest` on the second Transporter.

Handling incoming requests can be achieved using any of the following method:

- Registering a `RequestReceived` event handler.
- Registering a request handler using the `RegisterRequestHandler` method.
- Registering an `IResonanceService` using the `RegisterService` method.

We are going to cover each of the above methods.

Handling incoming requests using the `RequestReceived` event:

Let's go back to where we accepted the first Transporter connection and initialized the second one.

Here is how we would register for the `RequestReceived` event and respond to the `CalculateRequest` with a `CalculateResponse`.

```
private async void Server_ConnectionRequest(object sender, ResonanceListeningServer
{
    IResonanceTransporter transporter2 = ResonanceTransporter.Builder
        .Create()
        .WithAdapter(e.Accept())
        .WithJsonTranscoding()
        .Build();

    //Register an event handler..
    transporter2.RequestReceived += Transporter2_RequestReceived;

    await transporter2.ConnectAsync();
}

private async void Transporter2_RequestReceived(object sender, ResonanceRequestRece
{
    if (e.Message.Object is CalculateRequest calculateRequest)
    {
        if (calculateRequest.A > 0 && calculateRequest.B > 0)
        {
            await e.Transporter.SendResponseAsync(new CalculateResponse()
            {
                Sum = calculateRequest.A + calculateRequest.B
            }, e.Request.Token);
        }
        else
        {
            await e.Transporter.SendErrorResponseAsync("A & B must be greater than
        }
    }
}
```

Notice, when using this method, we need to explicitly call the Transporter `SendResponse` method while specifying the request token.
If there are any errors, we can trigger an exception on the other-side Transporter by calling the `SendErrorResponse` method.

Handling incoming request using a `Request Handler`:

A better and more intuitive approach is to register a request handler method that will require far less coding, filtering and error handling.

Let's go back again and see how we might register a request handler.

```
private async void Server_ConnectionRequest(object sender, ResonanceListeningServer
{
    IResonanceTransporter transporter2 = ResonanceTransporter.Builder
        .Create()
        .WithAdapter(e.Accept())
        .WithJsonTranscoding()
        .Build();

    //Register a request handler method...
    transporter2.RegisterRequestHandler<CalculateRequest, CalculateResponse>(Handle

    await transporter2.ConnectAsync();
}


private ResonanceActionResult<CalculateResponse> HandleCalculateRequest(CalculateRe
{
    if (request.A > 0 && request.B > 0)
    {
        return new CalculateResponse() { Sum = request.A + request.B };
    }
    else
    {
        throw new ArgumentException("A & B must be greater than zero");
    }
}
```

Notice, when using this method, we don't need to specify the request token, and, we are just returning a `CalculateResponse` as the result of the method. Also, we don't need to explicitly report any errors, we can just throw an exception. Actually, any exception that occurs while handling a request, will trigger an automatic error response.

Handling incoming requests using a Service:

The last approach for handling incoming requests is to register an instance of `IResonanceService` as a service.
A Service is basically just a class that contains methods that can handle requests, just like the previous request handler example.

Only methods that meets the below criteria will be registered as request handlers.

- Accepts only one argument with the request type.
- Returns:
  - `void`.
  - `Task`.

- `ResonanceActionResult<T>` where T is the type of the response.
- `Task<ResonanceActionResult<T>>` where T is the type of the response.

Let's create our Calculation Service class.

```
private class CalculationService : IResonanceService
{
    public ResonanceActionResult<CalculateResponse> Calculate(CalculateRequest requ
    {
        return new CalculateResponse() { Sum = request.A + request.B };
    }

    public void OnTransporterStateChanged(ResonanceComponentState state)
    {
        if (state == ResonanceComponentState.Failed)
        {
            //Connection lost
        }
    }
}
```

Let's go back again and see how we might register our service.

```
private async void Server_ConnectionRequest(object sender, ResonanceListeningServer
{
    IResonanceTransporter transporter2 = ResonanceTransporter.Builder
        .Create()
        .WithAdapter(e.Accept())
        .WithJsonTranscoding()
        .Build();

    //Register a service...
    transporter2.RegisterService(new CalculationService());

    await transporter2.ConnectAsync();
}
```

Congratulations! we have successfully completed a fully working request-response pattern.

You can continue reading if you want to explore some more advanced topics.

In-Memory Testing

Testing your communication is easier without initializing an actual known communication method. The library implements a special `InMemoryAdapter` which can be used for testing. All you need to do is assign each of the adapters the same address.

```
public async void Demo()
{
    IResonanceTransporter transporter1 = ResonanceTransporter.Builder
        .Create()
        .WithInMemoryAdapter()
        .WithAddress("TEST")
        .WithJsonTranscoding()
        .Build();

    IResonanceTransporter transporter2 = ResonanceTransporter.Builder
        .Create()
        .WithInMemoryAdapter()
        .WithAddress("TEST")
        .WithJsonTranscoding()
        .Build();

    await transporter1.ConnectAsync();
    await transporter2.ConnectAsync();
}
```

Continuous Response

The continuous response pattern is simply the concept of sending a single request and expecting multiple response messages.
We are basically opening a constant stream of response messages.
This pattern is useful if we want to track some state of a remote application.

In this example, we are going to track a simple made up progress.
The first Transporter will send a `ProgressRequest` using the `SendContinuousRequest` method.

Continuous request tracking is made using the Reactive programming style. Meaning, the request sender will need to `Subscribe` and provide `Next` , `Error` and `Completed` callbacks.

First, let's create our `ProgressRequest` and `ProgressResponse` messages.

ProgressRequest:

```
public class ProgressRequest
{
    public int Count { get; set; }
    public TimeSpan Interval { get; set; }
}
```

ProgressResponse:

```
public class ProgressResponse
{
    public int Value { get; set; }
}
```

Now, we are going to initialize two Transporters, send a continuous request from the first one, and respond with multiple response messages from the other.

```
public async void Send_Continuous_Request()
{
    IResonanceTransporter transporter1 = ResonanceTransporter.Builder
       .Create()
       .WithInMemoryAdapter()
       .WithAddress("TEST")
       .WithJsonTranscoding()
       .Build();

    IResonanceTransporter transporter2 = ResonanceTransporter.Builder
        .Create()
        .WithInMemoryAdapter()
        .WithAddress("TEST")
        .WithJsonTranscoding()
        .Build();

    await transporter1.ConnectAsync();
    await transporter2.ConnectAsync();

    transporter2.RegisterRequestHandler<ProgressRequest>(async (t, request) =>
    {
        for (int i = 0; i < request.Message.Count; i++)
        {
            await t.SendResponseAsync(new ProgressResponse() { Value = i }, request
            Thread.Sleep(request.Message.Interval);
        }
    });

    transporter1.SendContinuousRequest<ProgressRequest, ProgressResponse>(new Progr
```

```
    {
        Interval = TimeSpan.FromSeconds(1),
        Count = 10
    }).Subscribe((response) =>
    {
        Console.WriteLine(response.Value);
    }, (ex) =>
    {
        Console.WriteLine($"Error: {ex.Message}");
    }, () =>
    {
        Console.WriteLine($"Continuous Request Completed!");
    });
}
```

One-way Messages

In all previous examples we have seen how we can send a request and receive a response in various ways.
Actually, you can also send a message without expecting any response by using the `Send` method.

Here is how you might send a message with no response and handle it on the other side.

```
private async void Send_Example()
{
    IResonanceTransporter t1 = ResonanceTransporter.Builder
        .Create()
        .WithInMemoryAdapter()
        .WithAddress("TST")
        .WithJsonTranscoding()
        .Build();

    IResonanceTransporter t2 = ResonanceTransporter.Builder
        .Create()
        .WithInMemoryAdapter()
        .WithAddress("TST")
        .WithJsonTranscoding()
        .Build();

    t1.Connect();
    t2.Connect();

    t2.RegisterMessageHandler<SomeObject>((t, message) =>
    {
        Console.WriteLine(message.Object.SomeValue);
    });
```

```
    await t1.SendAsync(new SomeObject() { SomeValue = "some value"});
}
```

Notice, there is a distinct separation between requests and one-way messages methods, events and handling.

- One-way messages are sent using the `Send` method and not the `SendRequest` method.
- One-way messages are received using the `MessageReceived` event and not the `RequestReceived` event.
- One-way messages handlers are registered using the `RegisterMessageHandler` and not the `RegisterRequestHandler`.

By default, one-way message is sent with no acknowledgment, meaning, there is no certainty that it was received by the other side, but you can configure a one-way message to require an acknowledgment.
To do this, you need to set the message configuration `RequireACK` property to `true`.

```
await t1.SendAsync(new SomeObject() { SomeValue = "some value"}, new ResonanceMessa
{
     RequireACK = true
});
```

When setting `RequireACK = true`, the `SendAsync` will wait until an acknowledgment is received.

One-way message acknowledgment can also carry an error that might occur at the receiving side and throw an exception . To enable this functionality, you need to configure both transporters `MessageAcknowledgmentBehavior` property to `ResonanceMessageAckBehavior.ReportErrors`.

Here is an example:

```
private async void SendWithErrorExample()
{
    IResonanceTransporter t1 = ResonanceTransporter.Builder
        .Create()
        .WithInMemoryAdapter()
        .WithAddress("TST")
        .WithJsonTranscoding()
        .Build();
```

```
    IResonanceTransporter t2 = ResonanceTransporter.Builder
        .Create()
        .WithInMemoryAdapter()
        .WithAddress("TST")
        .WithJsonTranscoding()
        .Build();

    //Enable error reporting.
    t1.MessageAcknowledgmentBehavior = ResonanceMessageAckBehavior.ReportErrors;
    t2.MessageAcknowledgmentBehavior = ResonanceMessageAckBehavior.ReportErrors;

    t1.Connect();
    t2.Connect();

    t2.RegisterMessageHandler<SomeObject>((t, message) =>
    {
        throw new Exception("Test Error");
    });

    try
    {
        await t1.SendAsync(new SomeObject() { SomeValue = "some value" }, new Reson
        {
            RequireACK = true
        });
    }
    catch (Exception ex)
    {
        Console.WriteLine(ex.Message);
    }
}
```

Message Configuration

In all previous example we used the Transporter to send request and response messages by providing the request or response objects, but actually, we can specify additional configuration to each request or response message.

For example, by specifying a request configuration, we can change the default timeout for the request, or priority of the message.

Here is how you would specify the configuration of a simple request message.

```
var response = await transporter1.SendRequest<CalculateRequest, CalculateResponse>(
{
    A = 10,
    B = 5
```

```
}, new ResonanceRequestConfig()
{
    //After 5 seconds and no response, a TimeoutException will be thrown.
    Timeout = TimeSpan.FromSeconds(5),

    //This message has high priority in the message queue.
    Priority = Threading.QueuePriority.High,
});
```

A continuous request configuration also allows specifying the continuous timeout, meaning, the maximum time interval between each response.

Keep Alive

The Resonance library implements an automatic internal keep alive mechanism.
The keep alive mechanism helps detect lost connection between adapters.

We can enable/disable and control a Transporter's keep alive behavior by changing its `KeepAliveConfiguration` property.

Here is how we would change a Transporter's keep alive configuration.

```
IResonanceTransporter t = new ResonanceTransporter();

//Enable keep alive.
t.KeepAliveConfiguration.Enabled = true;

//Frequency of keep alive messages.
t.KeepAliveConfiguration.Interval = TimeSpan.FromSeconds(5);

//Maximum failed attempts.
t.KeepAliveConfiguration.Retries = 4;

//Respond to the other-side transporter keep alive messages.
t.KeepAliveConfiguration.EnableAutoResponse = true;

//Transporter state will change to 'Failed' when keep alive times out.
t.KeepAliveConfiguration.FailTransporterOnTimeout = true;
```

Here is how you can configure the keep alive using the Transporter fluent builder.

```
IResonanceTransporter transporter1 = ResonanceTransporter.Builder
    .Create()
    .WithTcpAdapter()
```

```
    .WithAddress("127.0.0.1")
    .WithPort(8888)
    .WithJsonTranscoding()
    .WithKeepAlive(interval: TimeSpan.FromSeconds(5), retries: 4)
    .Build();
```

Compression

The Resonance transcoding system provides the ability to compress messages and reduce network bandwidth.
Compression and decompression is performed by the Transporter's `Encoder` and `Decoder`. To enable the encoder compression, you can access the encoder's `CompressionConfiguration`.

```
IResonanceTransporter t = new ResonanceTransporter();
t.Encoder = new JsonEncoder();
t.Encoder.CompressionConfiguration.Enabled = true; //Enable compression.
```

Or, using the fluent builder...

```
IResonanceTransporter transporter1 = ResonanceTransporter.Builder
    .Create()
    .WithInMemoryAdapter()
    .WithAddress("TST")
    .WithJsonTranscoding()
    .NoKeepAlive()
    .NoEncryption()
    .WithCompression() //Enable compression
    .Build();
```

Once the Encoder is configured for compression, all sent messages will be compressed. There is no need to configure the receiving Decoder as it automatically detects the compression from the message header.

The base library uses GZip for compression, but you can use the faster LZ4 compression algorithm by installing the **Resonance.LZ4** nuget package and specifying it as the Encoder's compressor.

```
IResonanceTransporter transporter1 = ResonanceTransporter.Builder
    .Create()
    .WithInMemoryAdapter()
```

```
      .WithAddress("TST")
      .WithJsonTranscoding()
      .NoKeepAlive()
      .NoEncryption()
      .WithLZ4Compression() //Enable LZ4 compression.
      .Build();
```

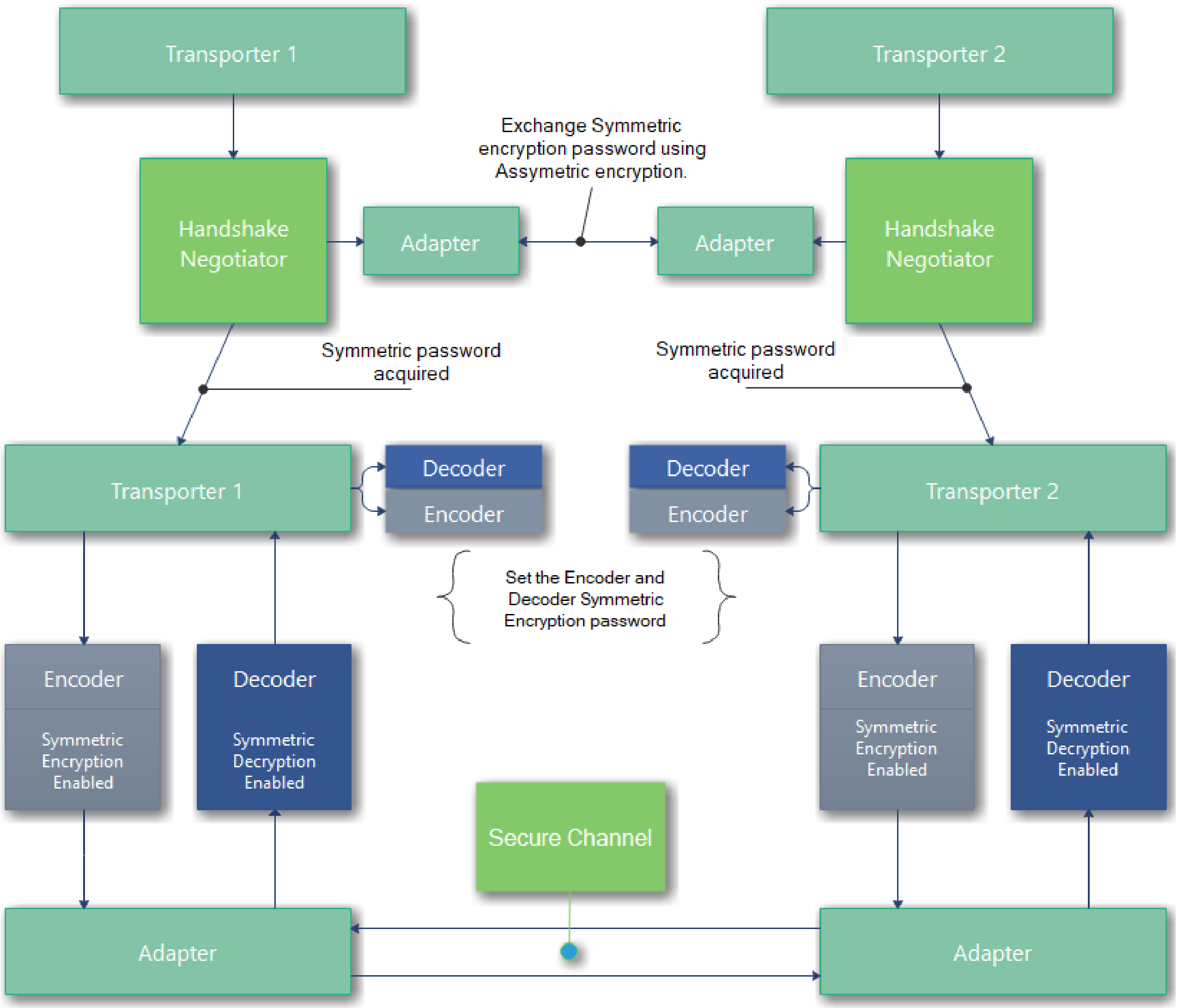
Encryption

The Resonance transcoding system also provides the ability to encrypt and decrypt outgoing and incoming messages.
Although some of the adapters already supports their internal encryption like the SignalR and WebRTC adapters, you might want to implement your own.

The Resonance library implements its own automatic SSL style encryption using a handshake that is initiated in order to exchange encryption information.
The handshake negotiation is done by the `IHandshakeNegotiator` interface.

In order to secure a communication channel, each participant needs to create an `Asymmetric` RSA private-public key pair, then share that public key with the remote peer.
Next, both participants needs to agree on a `Symmetric` encryption configuration based on a shared password.
The actual password is shared and encrypted using the initial RSA public key.

Once the password is acquired by both participants, they can start send and receive messages using the faster `Symmetric` encryption based on the shared password.



Due to Resonance being a client-client transporting library rather than a client-server communication protocol, there is no real "connection" point where one client tries to reach some server. That is why implementing the encryption handshake was a bit tricky.
Actually, the handshake does not occur once a Transporter tries to "Connect", but only before the first message sending attempt.
Since both transporters can start sending message at the exact same time, there is the issue of, who is the "manager" of the negotiation?, which side determines the Symmetric encryption password?
In order to determine who is the "manager" of the negotiation, each `HandshakeNegotiator` object generates a unique random number (ClientID) that is shared to the other side at the first step of the negotiation.
The one with the highest ClientID gets to decide about the Symmetric encryption password.

After we understand what happens behind the scenes, let's see how to configure a Transporter to encrypt messages.

```
IResonanceTransporter t = new ResonanceTransporter();
t.CryptographyConfiguration.Enabled = true; //Enable encryption.
```

You can also configure encryption using the fluent builder.

```
IResonanceTransporter transporter1 = ResonanceTransporter.Builder
    .Create().WithTcpAdapter()
    .WithAddress("127.0.0.1")
    .WithPort(8888)
    .WithJsonTranscoding()
    .WithKeepAlive()
    .WithEncryption() //Enable encryption.
    .Build();
```

In order to establish a secure communication, both Transporters `CryptographyConfiguration` must be enabled.

In case encryption is disabled on both transporters, no handshake will occur at all.

Logging

It is very important to be able to trace your communication through logs.
The Resonance library takes advantage of structured logs by attaching log properties that can later be used to trace and aggregate each request and response path.

Communication logs are delivered using Microsoft's Logging.Abstractions interfaces.
That makes it easy to hook up your favorite logging library to expose Resonance communication logs.

In order to route Resonance logging to your logging infrastructure, you need to provide an instance of `ILoggerFactory` .

Here is how you can hookup Resonance to **Serilog** logging library.

```
public void InitLogging()
{
    var loggerFactory = new LoggerFactory();
    var logger = new LoggerConfiguration()
        .MinimumLevel.Debug()
        .WriteTo.Console()
        .WriteTo.Seq("http://localhost:5341")
        .CreateLogger();
```

```
    loggerFactory.AddSerilog(logger);

    ResonanceGlobalSettings.Default.LoggerFactory = loggerFactory;
}
```

Once you have your logging configured, you can also specify each request logging mode through the `RequestConfig` object.

The logging mode of a request determines whether the request and its response should be logged and how.

- `None` (will not log the request)
- `Title` (logs the request and its response message name)
- `Content` (logs the request and its response message name along with the actual message content)

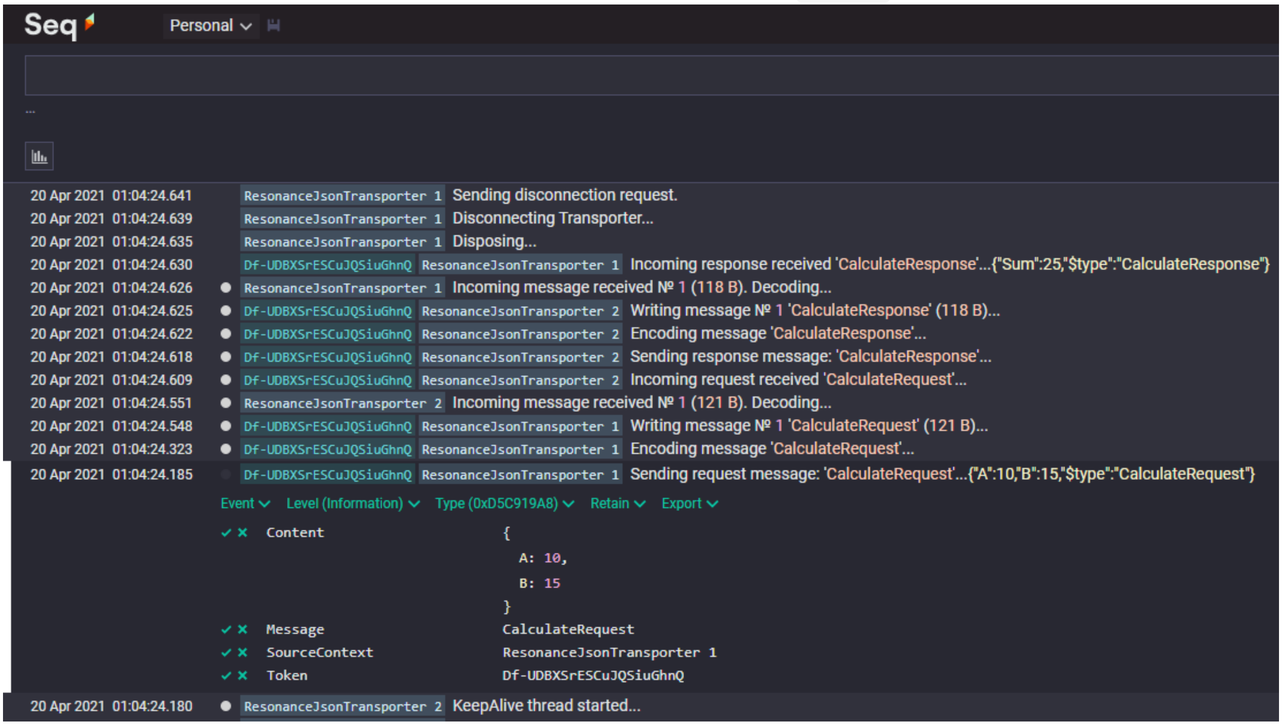
Note, when the minimum log level is "Debug" request and response messages will always be logged in `Title` mode, unless the `Content` logging mode was specified.

Here is how you would configure the logging mode of a request.

```
public async void Demo()
{
    IResonanceTransporter transporter1 = ResonanceTransporter.Builder
       .Create().WithTcpAdapter()
       .WithAddress("127.0.0.1")
       .WithPort(8888)
       .WithJsonTranscoding()
       .WithKeepAlive()
       .NoEncryption()
       .WithCompression()
       .Build();

    await transporter1.ConnectAsync();

    CalculateRequest request = new CalculateRequest() { A = 10, B = 5 };

    //Log request and response names
    var response = await transporter1.SendRequestAsync<CalculateRequest, CalculateR
        new ResonanceRequestConfig() { LoggingMode = ResonanceMessageLoggingMode.Ti

    //Log request and response names and content
    response = await transporter1.SendRequestAsync<CalculateRequest, CalculateRespo
        new ResonanceRequestConfig() { LoggingMode = ResonanceMessageLoggingMode.Co
}
```

The recommended way of viewing the Resonance communication logs is using Seq with the Serilog Seq sink.
The Seq logs viewer supports structured logs that fits nicely with Resonance logging implementation.

Here is a screenshot of a request being traced using its `Token` property through Seq.



Performance Benchmarks

> 1000 Roundtrips (request -> response), Intel Core i7-6700HQ CPU 2.60GHz (Skylake)

Transcoding

Method	Mean	Error	StdDev
Json	205.6 ms	4.09 ms	9.96 ms
Protobuf	180.3 ms	4.07 ms	3.81 ms

Encryption / Compression

Method	Mean	Error	StdDev
Normal	183.4 ms	2.87 ms	2.40 ms

Compressed	421.9 ms	8.25 ms	13.32 ms
Encrypted	260.9 ms	5.18 ms	12.41 ms
Compressed / Encrypted	517.2 ms	9.12 ms	8.08 ms