Driving IT

From IL Weaving to Source Generators

the Realm story

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The context: “Code generation” in .NET

IL Weaving

.NET code is compiled to IL (*Intermediate Language*) first, then converted to machine code at runtime

IL is similar to Java bytecode, “high-level assembly”

IL can be modified with *Weaving*

Weaving happens **after** compilation

Possible to modify existing code in any way, “feels like magic”

Useful to generate repetitive or optimised code

Source code

```
public class Person
{
    public string Name { get; set; }
}
```

IL

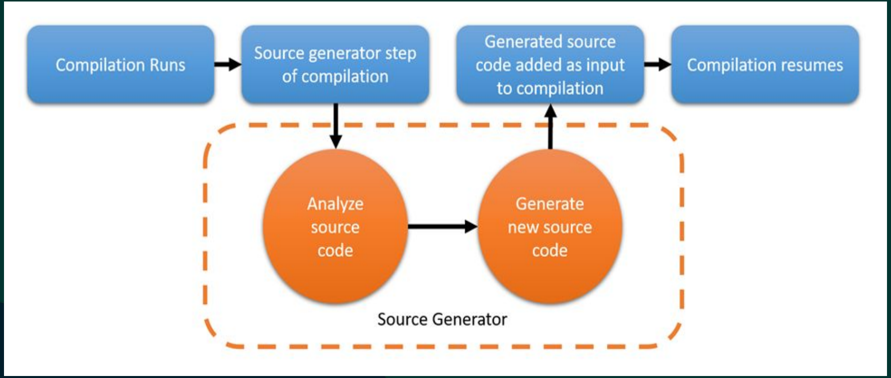
```
.method public hidebysig specialname
    instance string get_Name () cil managed
{
    .maxstack 8
    IL_0000: ldarg.0
    IL_0001: ldfld string Person::'<Name>k__BackingField'
    IL_0006: ret
} // end of method Person::get_Name

.method public hidebysig specialname
    instance void set_Name (string 'value') cil managed
{
    .maxstack 8
    IL_0000: ldarg.0
    IL_0001: ldarg.1
    IL_0002: stfld string Person::'<Name>k__BackingField'
    IL_0007: ret
} // end of method Person::set_Name
```

PropertyChanged.Fody

```csharp
public class Person : INotifyPropertyChanged
{
    public event PropertyChangedEventHandler PropertyChanged;

    public string GivenNames { get; set; }
    public string FamilyName { get; set; }
    public string FullName => $"{GivenNames} {FamilyName}";
}
```

```csharp
public class Person : INotifyPropertyChanged
{
    public event PropertyChangedEventHandler PropertyChanged;

    string givenNames;
    public string GivenNames
    {
        get => givenNames;
        set
        {
            if (value != givenNames)
            {
                givenNames = value;
                OnPropertyChanged("GivenNames");
                OnPropertyChanged("FullName");
            }
        }
    }

    string familyName;
    public string FamilyName
    {
        get => familyName;
        set
        {
            if (value != familyName)
            {
                familyName = value;
                OnPropertyChanged("FamilyName");
                OnPropertyChanged("FullName");
            }
        }
    }

    public string FullName => $"{GivenNames} {FamilyName}";

    protected void OnPropertyChanged(PropertyChangedEventArgs eventArgs)
    {
        PropertyChanged?.Invoke(this, eventArgs);
    }
}
```

Source Generators



Compiler feature introduced with .NET 5

“Plugs” into the compilation pipeline

Source Generators are passed a *compilation object* that can be analyzed

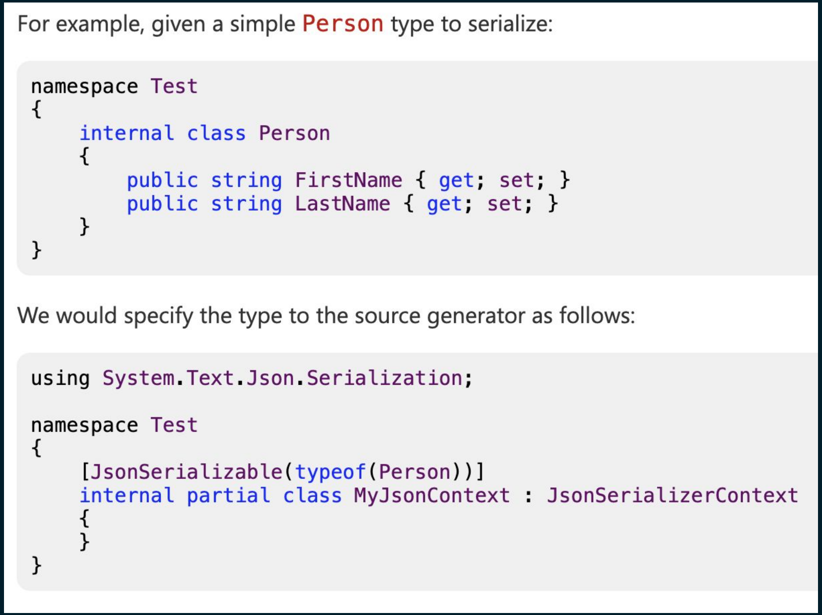
Source Generators emit source code

Source generation happen **during** compilation

Only additive

Useful to generate repetitive or optimised code

System.Text.Json

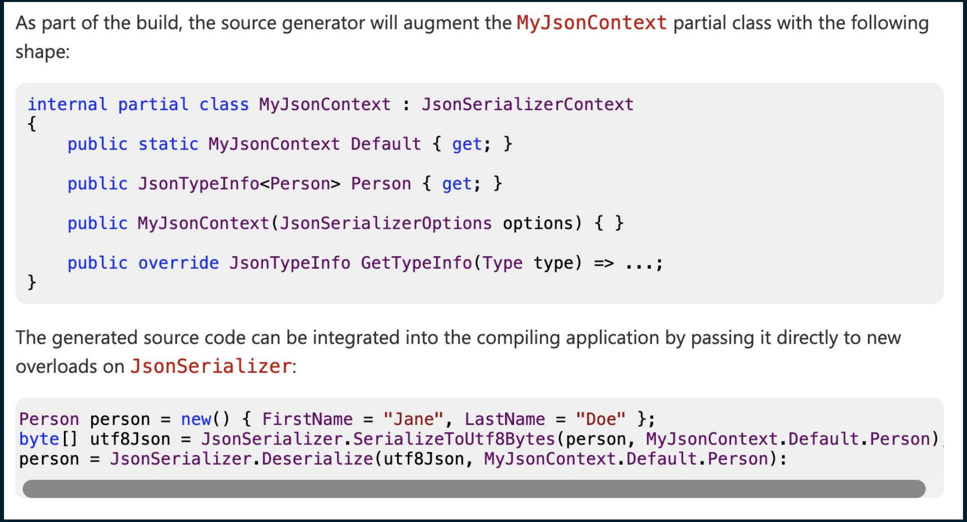


For example, given a simple `Person` type to serialize:

```
namespace Test
{
    internal class Person
    {
        public string FirstName { get; set; }
        public string LastName { get; set; }
    }
}
```

We would specify the type to the source generator as follows:

```
using System.Text.Json.Serialization;

namespace Test
{
    [JsonSerializable(typeof(Person))]
    internal partial class MyJsonContext : JsonSerializerContext
    {
    }
}
```



As part of the build, the source generator will augment the `MyJsonContext` partial class with the following shape:

```
internal partial class MyJsonContext : JsonSerializerContext
{
    public static MyJsonContext Default { get; }

    public JsonTypeInfo<Person> Person { get; }

    public MyJsonContext(JsonSerializerOptions options) { }

    public override JsonTypeInfo GetTypeInfo(Type type) => ...;
}
```

The generated source code can be integrated into the compiling application by passing it directly to new overloads on `JsonSerializer`:

```
Person person = new() { FirstName = "Jane", LastName = "Doe" };
byte[] utf8Json = JsonSerializer.SerializeToUtf8Bytes(person, MyJsonContext.Default.Person)
person = JsonSerializer.Deserialize(utf8Json, MyJsonContext.Default.Person);
```

Realm is an **object-oriented** and cross-platform database

The past
(IL Weaving)

Defined model

```
public class Person : RealmObject
{
    [PrimaryKey]
    public Guid Id { get; set; }

    public string Name { get; set; }

    public int Age { get; set; }

    public IList<Dog> Dogs { get; }
}
```

Compiled model

```
public class Person : RealmObject
{
    public string Name
    {
        //Simplified
        get => GetValue("Name");
        set => SetValue(“Name”, value);
    }
    //…
}
```

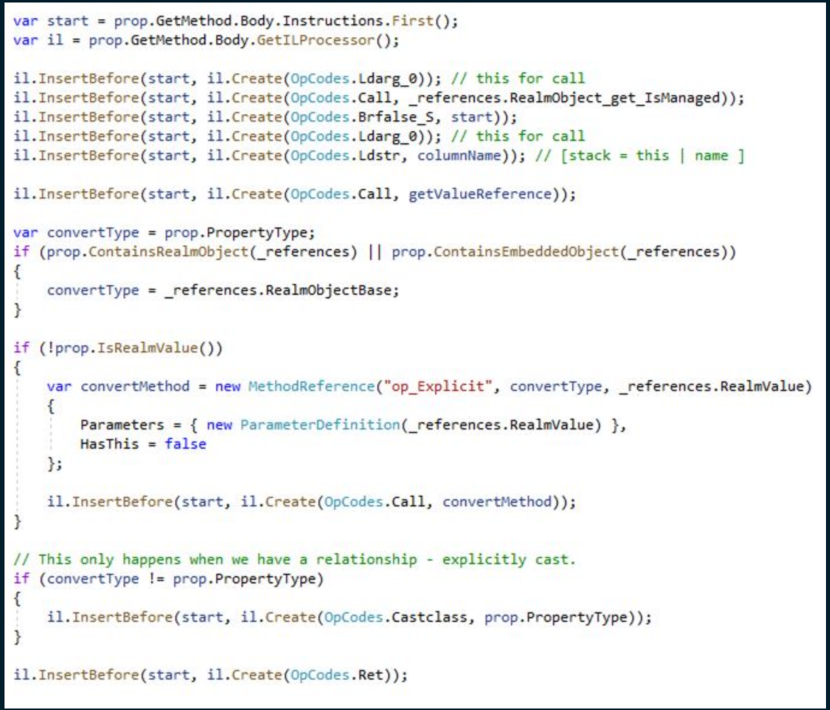
Defined model (IL)

```
.method public hidebysig specialname
    instance string get_Name () cil managed
{
    .maxstack 8
    IL_0000: ldarg.0
    IL_0001: ldfld string
Person::'<Name>k__BackingField'
    IL_0006: ret
} // end of method Person::get_Name
```

Weaved model (IL)

```
.method public hidebysig specialname
    instance string get_Name () cil managed
{
    .maxstack 8
    IL_0000: ldarg.0
    IL_0001: ldfld bool RealmObject::IsManaged
    IL_0006: brtrue.s IL_000f
    IL_0008: ldarg.0
    IL_0009: ldfld string Person2::_name
    IL_000e: ret
    IL_000f: ldarg.0
    IL_0010: ldstr "Name"
    IL_0015: call instance string
RealmObject::GetValue(string)
    IL_001a: ret
} // end of method Person::get_Name
```

IL Weaving drawbacks



```
var start = prop.GetMethod.Body.Instructions.First();
var il = prop.GetMethod.Body.GetILProcessor();

il.InsertBefore(start, il.Create(OpCodes.Ldarg_0)); // this for call
il.InsertBefore(start, il.Create(OpCodes.Call, _references.RealmObject_get_IsManaged));
il.InsertBefore(start, il.Create(OpCodes.Brfalse_S, start));
il.InsertBefore(start, il.Create(OpCodes.Ldarg_0)); // this for call
il.InsertBefore(start, il.Create(OpCodes.Ldstr, columnName)); // [stack = this | name ]

il.InsertBefore(start, il.Create(OpCodes.Call, getValueReference));

var convertType = prop.PropertyType;
if (prop.ContainsRealmObject(_references) || prop.ContainsEmbeddedObject(_references))
{
    convertType = _references.RealmObjectBase;
}

if (!prop.IsRealmValue())
{
    var convertMethod = new MethodReference("op_Explicit", convertType, _references.RealmValue)
    {
        Parameters = { new ParameterDefinition(_references.RealmValue) },
        HasThis = false
    };

    il.InsertBefore(start, il.Create(OpCodes.Call, convertMethod));
}

// This only happens when we have a relationship - explicitly cast.
if (convertType != prop.PropertyType)
{
    il.InsertBefore(start, il.Create(OpCodes.Castclass, prop.PropertyType));
}

il.InsertBefore(start, il.Create(OpCodes.Ret));
```

Not readable
IL code is difficult to read and to reason about

Difficult to extend
Weaver requires specific knowledge and a lot of trial and error

Black box
Changes to IL are “not visible” to final user

Not debuggable
It’s not possible to step into the weaved code

The future (Source Generators)

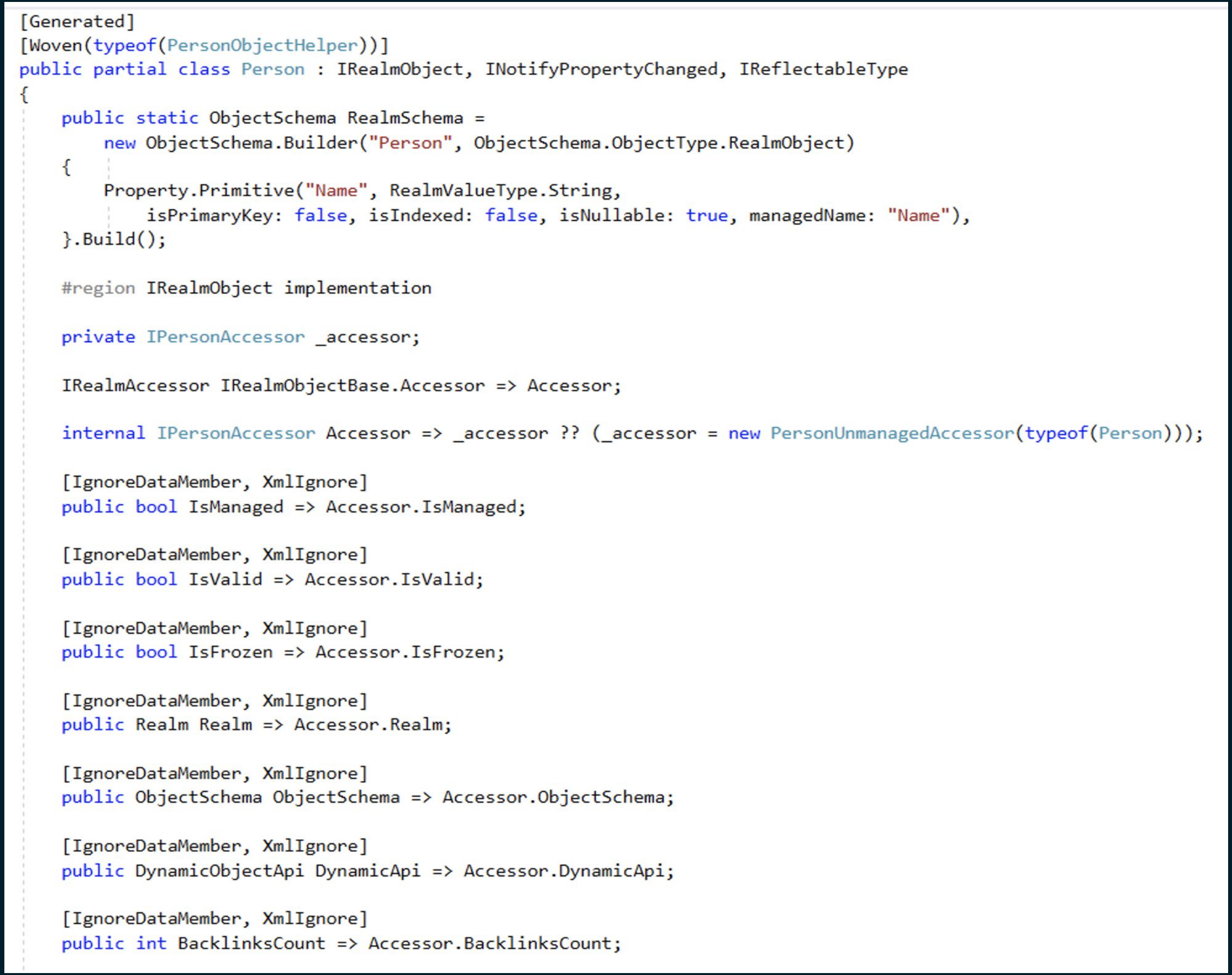
Broader re-think of the SDK associated with the move to Source Generators

Classic model

```
public class Person : RealmObject
{
    [PrimaryKey]
    public Guid Id { get; set; }

    public string Name { get; set; }

    public int Age { get; set; }

    public IList<Dog> Dogs { get; }
}
```

New model

```
public partial class Person : IRealmObject
{
    [PrimaryKey]
    public Guid Id { get; set; }

    public string Name { get; set; }

    public int Age { get; set; }

    public IList<Dog> Dogs { get; }
}
```



```csharp
[Generated]
[Woven(typeof(PersonObjectHelper))]
public partial class Person : IRealmObject, INotifyPropertyChanged, IReflectableType
{
    public static ObjectSchema RealmSchema =
        new ObjectSchema.Builder("Person", ObjectSchema.ObjectType.RealmObject)
    {
        Property.Primitive("Name", RealmValueType.String,
            isPrimaryKey: false, isIndexed: false, isNullable: true, managedName: "Name"),
    }.Build();

    #region IRealmObject implementation

    private IPersonAccessor _accessor;

    IRealmAccessor IRealmObjectBase.Accessor => Accessor;

    internal IPersonAccessor Accessor => _accessor ?? (_accessor = new PersonUnmanagedAccessor(typeof(Person)));

    [IgnoreDataMember, XmlIgnore]
    public bool IsManaged => Accessor.IsManaged;

    [IgnoreDataMember, XmlIgnore]
    public bool IsValid => Accessor.IsValid;

    [IgnoreDataMember, XmlIgnore]
    public bool IsFrozen => Accessor.IsFrozen;

    [IgnoreDataMember, XmlIgnore]
    public Realm Realm => Accessor.Realm;

    [IgnoreDataMember, XmlIgnore]
    public ObjectSchema ObjectSchema => Accessor.ObjectSchema;

    [IgnoreDataMember, XmlIgnore]
    public DynamicObjectApi DynamicApi => Accessor.DynamicApi;

    [IgnoreDataMember, XmlIgnore]
    public int BacklinksCount => Accessor.BacklinksCount;
```

The bright side

Readable and Debuggable
Generated code can be inspected and debugged

Easy to work with
The generated code is just “plain” code, easy to reason with

Extensible
Allow us to introduce support for new features much faster (nullability…)

The less bright side

Tooling
There are various tooling issues appearing while working with Source Generators

No central “knowledge base”
Lots of googling

Performance
Source generators can run multiple times, even with no changes

Only Additive
Existing code cannot be modified

IL Weaving is still there 😓

Weaving

```
class Person : RealmObject
{
    [PrimaryKey]
    public Guid Id { get; set; }

    public string Name { get; set; }

    public int Age { get; set; }

    public IList<Dog> Dogs { get; }
}
```

SG

```
partial class Person : IRealmObject
{
    [PrimaryKey]
    private Guid _id;

    private string _name;

    private int _age;

    private IList<Dog> _dogs;
}
```

SG + Weaving

```
partial class Person : IRealmObject
{
    [PrimaryKey]
    public Guid Id { get; set; }

    public string Name { get; set; }

    public int Age { get; set; }

    public IList<Dog> Dogs { get; }
}
```

New model

```
Public partial class Person : IRealmObject
{
    [PrimaryKey]
    public Guid Id { get; set; }

    public string Name { get; set; }

    public int Age { get; set; }

    public IList<Dog> Dogs { get; }
}
```

Compiled model

```
public partial class Person : IRealmObject
{
    public string Name
    {
        get => Accessor.Name;
        set => Accessor.Name = value;
    }
    //…
}
```

Status and Future Work

In the pipeline for about 6 months

`Realm.SourceGenerator` has just been published in beta

Planning to support nullability

Planning to add incremental generator

Completely remove IL Weaving (?)

Conclusion

Code generation is useful to hide complexity in the .NET Realm SDK

IL Weaving is powerful but difficult

Source Generators are a good alternative

They have their own quirks/limitations

The switch was worth it, it will allow to introduce new features in an easier way

Thank you for your time.