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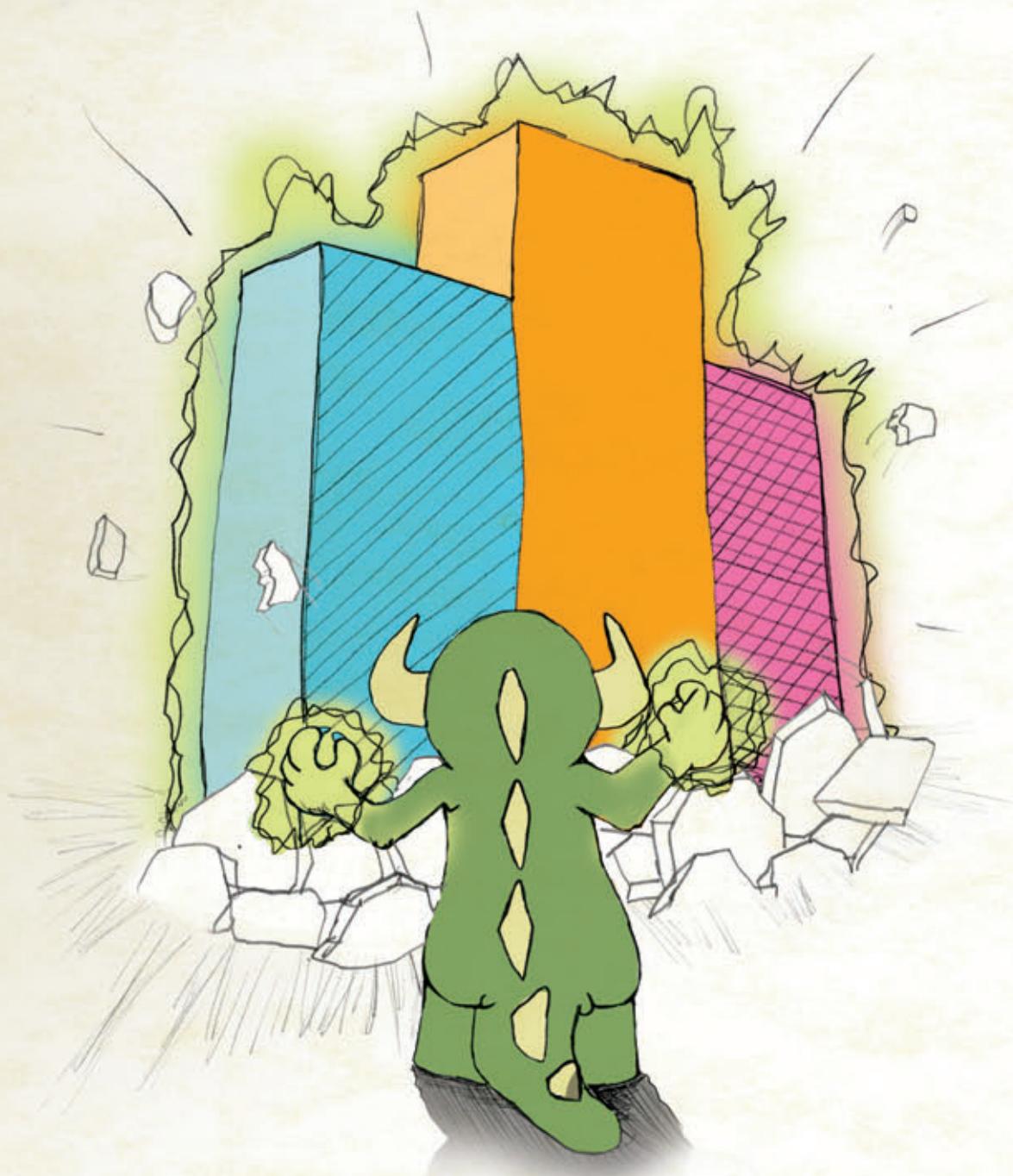
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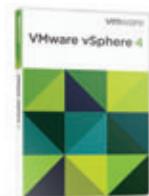
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## EDITOR'S NOTE

KEITH WARD

# A Few of My Favorite App Things

Windows Phone 7 will be out possibly as early as the month you read this—October—although no firm release date had been announced as of this writing. Obviously, Windows Phone 7 represents a lot of risk for Microsoft—and a lot of potential.

There's no getting around the fact that Microsoft is late to the smartphone game, with the iPhone and Android gobbling up market share. But, in my opinion, it's not too late—not by a long shot. Right now the aforementioned competitors are the main game in town: HP hasn't given any clues as to what will happen with the Palm Pre phone since it bought Palm, and the BlackBerry has no juice at all. That means there's absolutely room for another entry, and Microsoft is working hard to make sure Windows Phone 7 becomes that third major player.

To do that, it will all be about—say it with me (and skip a little bit, if you're feeling brave)—developers, developers, developers, developers! Previews of the UI are encouraging, and I love the fact that Microsoft hasn't copied what Apple and Google have done with their interfaces, coming up with something completely different.

But at the end of the day, folks buy smartphones because of the apps they can put on them. It will be crucial for the developer community to have a heaping helping of apps ready to go at launch, and many more soon after. If those apps aren't outstanding—and they need to be, given the competition's head start—it will make the hill that much higher to climb. So, putting on my consumer hat, here's what I think are the key features of any Windows Phone 7 app, in order of importance:

**1. Price.** Studies continue to show that the lowest-priced and free apps are the most popular. That's no revelation, but worth keeping on the front burner of your go-to-market strategy. It's tempting, when you've put in six months of development on something, to assume that customers will want to pony up for your brilliant app. The reality is, however, that you'll have more competition in your space—whatever your space is—than you've probably ever had before. That means making a calculation on whether a competitive price will bring in enough downloads to offset the lower price. I urge you to consider this point very, very

carefully; it may be the thing that makes or breaks your success in the Windows Phone 7 market.

**2. Stability.** No matter how entertaining your game is, how useful your password-management app is, or how revolutionary your guitar-tuner app, if it's buggy from the beginning, it's likely to be unused. And worse, the negative comments on the Microsoft app store (whatever form that store may take) could be fatal. Version 1 apps built with the attitude of "we'll fix it with version 2" may not make it to version 2.

I have a GPS app on my smartphone (the manufacturer shall remain anonymous—I'll be getting Windows Phone 7 as soon as it's out) that works about half the time. When it does work, it's awesome. But it's my least-favorite app, by a mile, because I never know if I'll be able to use it. Again, you'll probably have many competitors in your space; even if their apps are inferior to yours in terms of features, they'll get the sales because they just work.

**3. Complexity, or lack thereof.** Never, ever forget that these apps will be on tiny screens, with users pushing fingers around. A UI that tries to cram in too much is doomed. Simplicity wins the day here. Ask yourself if every menu bar, button and icon must be there. If not, be brutal and delete. You're not going to get—nor do users expect—the kind of UI choices and options available with a typical desktop app. In fact, they'll be expecting the opposite: a clean, spare, easy-to-navigate UI that involves as little reading as possible.

**4. Get it to market early.** You have an opportunity to get your app the kind of attention and publicity that's simply not available with apps from the "other guys." This is a brand-new market, and now's the time to plant your flag. I'm not saying to rush development and invalidate point No. 2, but instead to move resources around to give your Windows Phone 7 development team the ability to create a polished app that's ready to go when the phone launches. So get to work. I can't wait to see what you come up with.

Tell me about your app at

mmeditor@microsoft.com.

*Keith Ward*

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# Action Filters in ASP.NET MVC

The biggest challenge many software architects face today is how to design and implement an application that can meet all version 1 requirements plus all others that can show up afterward. Maintainability has been one of the fundamental attributes of software design since the first draft of the ISO/IEC 9126 paper, back in 1991. (The paper provides a formal description of software quality and breaks it down into a set of characteristics and sub-characteristics, one of which is maintainability. A PDF version of the paper can be obtained at [iso.org](http://iso.org).)

The ability to serve a customer's present and future needs certainly isn't a new requirement for any piece of software. However, what many Web applications require today is a subtle and short-term form of maintainability. Many times customers don't want new functions or a different implementation of an existing feature. They just want you to add, replace, configure or remove small pieces of functionality. A typical example is when Web sites with large audiences launch specific advertising campaigns. The overall behavior of the site doesn't change, but extra actions must be performed along with existing actions. Moreover, these changes usually aren't persistent. They must be removed after a few weeks to then be reincorporated a few months later, be configured differently and so forth. You need the ability to program any required functionality by composing small pieces together; you need to track dependencies without greatly impacting the source code; and you need to move toward an aspect-oriented design of software. These are some of the primary reasons behind the rapid adoption of Inversion of Control (IoC) frameworks in many enterprise projects.

So what's this article all about? It isn't meant to be a boring lecture on how software is changing today. Instead, it's an in-depth exploration of a powerful feature of ASP.NET MVC controllers that can notably help you in the building of aspect-oriented Web solutions: ASP.NET MVC action filters.

## What's an Action Filter, Anyway?

An action filter is an attribute that, when attached to a controller class or a controller method, provides a declarative means to attach some behavior to a requested action. By writing an action filter, you can hook up the execution pipeline of an action method and adapt it to your needs. In this way, you can also take out of the controller class any logic that doesn't strictly belong to the controller. In doing so, you make this particular behavior reusable and, more importantly, optional. Action filters are ideal for implementing crosscutting concerns that affect the life of your controllers.

ASP.NET MVC comes with a few predefined action filters such as HandleError, Authorize and OutputCache. You use HandleError to trap exceptions thrown during the execution of methods on the target controller class. The programming interface of the HandleError attribute lets you indicate the error view to associate with a given exception type.

The Authorize attribute blocks the execution of a method for unauthorized users. It doesn't distinguish, however, between users who just haven't logged in yet and logged users lacking enough permissions to perform a given action. In the configuration of the attribute, you can specify any roles required to execute a given action.

The OutputCache attribute caches the response of the controller's method for the specified duration and requested list of parameters.

An action filter class implements several interfaces. The full list of interfaces is presented in **Figure 1**.

In the most common scenarios, you're mostly concerned with IActionFilter and IResultFilter. Let's get to know them more closely. Here's the definition of the IActionFilter interface:

```
public interface IActionFilter
{
    void OnActionExecuted(ActionExecutedContext filterContext);
    void OnActionExecuting(ActionExecutingContext filterContext);
}
```

You implement the OnActionExecuting method to execute code before the controller's action executes; you implement OnActionExecuted to post-process the controller state a method has determined. The context objects provide a lot of runtime information. Here's the signature of ActionExecutingContext:

```
public class ActionExecutingContext : ControllerContext
{
    public ActionDescriptor ActionDescriptor { get; set; }
    public ActionResult Result { get; set; }
    public IDictionary<string, object> ActionParameters { get; set; }
}
```

The action descriptor, in particular, provides information about the action method, such as its name, controller, parameters, attributes and additional filters. The signature of ActionExecutedContext is only a bit different, as shown here:

```
public class ActionExecutedContext : ControllerContext
{
    public ActionDescriptor ActionDescriptor { get; set; }
    public ActionResult Result { get; set; }
    public bool Canceled { get; set; }
    public Exception Exception { get; set; }
    public bool ExceptionHandled { get; set; }
}
```

In addition to a reference to the action description and action result, the class supplies information about an exception that could've occurred and offers two Boolean flags that deserve more attention.

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**Figure 1 Interfaces for an Action Filter**

Filter Interfaces	Description
IActionFilter	Methods in the interface are invoked before and after the execution of the controller method.
IAuthorizationFilter	Methods in the interface are invoked before the controller method executes.
IExceptionFilter	Methods in the interface are invoked whenever an exception is thrown during the execution of the controller method.
IResultFilter	Methods in the interface are invoked before and after the processing of the action result.

The `ExceptionHandled` flag indicates that your action filter is given a chance to mark an occurred exception as handled. The `Canceled` flag concerns the `Result` property of the `ActionExecutingContext` class.

Note that the `Result` property on the `ActionExecutingContext` class exists only to move the burden of generating any action response from the controller method to the list of registered action filters. If any action filters assign a value to the `Result` property, the target method on the controller class will never be invoked. In doing this, you bypass the target method, moving the burden of producing a response entirely to action filters. However, if multiple action filters were registered for a controller method, then they'd share the action result. When a filter sets the action result, all subsequent filters in the chain will receive the `ActionExecuteContext` object with the property `Canceled` set to true. Whether you set `Canceled` programmatically in the action-executed step, or set the `Result` property in the action-executing step, the target method will never be run.

## Writing Action Filters

As mentioned, when it comes to writing custom filters, most of the time you're interested in filters that pre- and post-process the action result and filters that run before and after the execution of the regular controller method. Instead of implementing interfaces natively, an action filter class is commonly derived from `ActionFilterAttribute`:

```
public abstract class ActionFilterAttribute : 
    FilterAttribute, IActionFilter, IResultFilter
{
    public virtual void OnActionExecuted(
        ActionExecutedContext filterContext);
    public virtual void OnActionExecuting(
        ActionExecutingContext filterContext);
    public virtual void OnResultExecuted(
        ResultExecutedContext filterContext);
    public virtual void OnResultExecuting(
        ResultExecutingContext filterContext);
}
```

You override `OnActionExecuted` to add some custom code to the execution of the method. You override `OnActionExecuting` as a precondition to the execution of the target method. Finally, you override `OnResultExecuting` and `OnResultExecuted` to place your code around the internal step that governs the generation of the method response.

**Figure 2** shows a sample action filter that adds compression programmatically to the response of the method it's applied to.

In ASP.NET, compression is commonly achieved by registering an HTTP module that intercepts any requests and compresses their responses. In the alternative, you can also enable compression at the IIS level. ASP.NET MVC supports both scenarios well and also offers a third option: controlling compression on a per-method

basis. In this way, you can control the level of compression for a specific URL without the need of writing, registering and maintaining an HTTP module.

As you can see in **Figure 2**, the action filter overrides the `OnActionExecuting` method. This may sound a bit weird at first, as you might expect compression to be a crosscutting concern you take care of just before returning some response. Compression is implemented through the `Filter` property of the intrinsic `HttpResponse`. Any response being worked out by the runtime environment is returned to the client browser through the `HttpResponse` object. Subsequently, any custom streams mounted on the default output stream through the `Filter` property can alter the output being sent. Thus, in the course of the `OnActionExecuting` method, you just set up additional streams on top of the default output stream.

When it comes to HTTP compression, however, the most difficult part is taking into careful account the preferences of the browser. The browser sends its compression preferences through the `Accept-Encoding` header. The content of the header indicates that the browser is able to handle only certain encodings—usually gzip and deflate. To be a good citizen, your action filter must try to

**Figure 2 A Sample Action Filter for Compressing the Method Response**

```
public class CompressAttribute : ActionFilterAttribute
{
    public override void OnActionExecuting(
        ActionExecutingContext filterContext)
    {
        // Analyze the list of acceptable encodings
        var preferred = GetPreferredEncoding(
            filterContext.HttpContext.Request);

        // Compress the response accordingly
        var response = filterContext.HttpContext.Response;
        response.AppendHeader("Content-encoding", preferred.ToString());

        if (preferredEncoding == CompressionScheme.Gzip)
        {
            response.Filter = new GZipStream(
                response.Filter, CompressionMode.Compress);
        }

        if (preferredEncoding == CompressionScheme.Deflate)
        {
            response.Filter = new DeflateStream(
                response.Filter, CompressionMode.Compress);
        }
        return;
    }

    static CompressionScheme GetPreferredEncoding(
        HttpRequestBase request)
    {
        var acceptableEncoding = request.Headers["Accept-Encoding"];
        acceptableEncoding = SortEncodings(acceptableEncoding);

        // Get the preferred encoding format
        if (acceptableEncoding.Contains("gzip"))
            return CompressionScheme.Gzip;
        if (acceptableEncoding.Contains("deflate"))
            return CompressionScheme.Deflate;

        return CompressionScheme.Identity;
    }

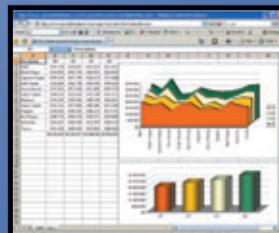
    static String SortEncodings(string header)
    {
        // Omitted for brevity
    }
}
```

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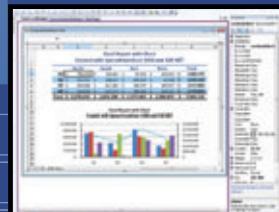
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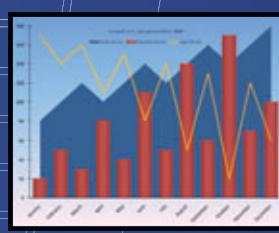
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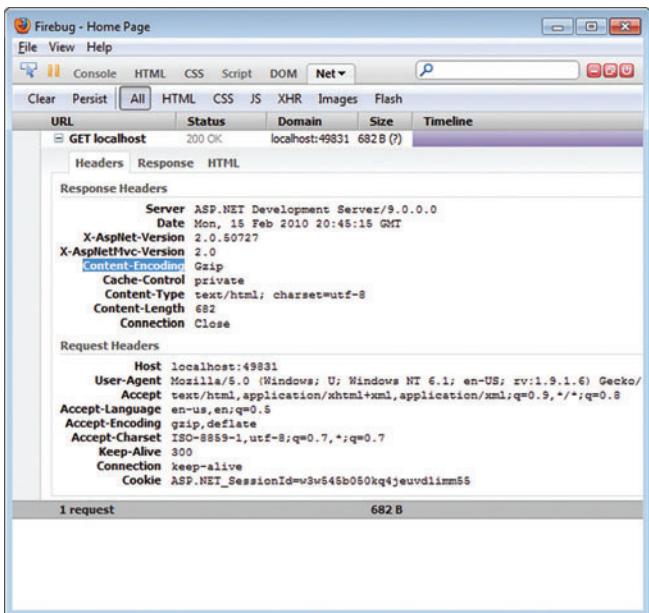
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**Figure 3 A Compressed Response Obtained via the Compress Attribute**

figure out exactly what the browser can handle. This can be a tricky task. The role of the Accept-Encoding header is fully explained in RFC 2616 (see [w3.org/Protocols/rfc2616/rfc2616-sec14.html](http://w3.org/Protocols/rfc2616/rfc2616-sec14.html)). In brief, the content of the Accept-Encoding header can contain a *q* parameter that's meant to assign a priority to an acceptable value. For example, consider that all the following strings are acceptable values for an encoding, but even though gzip is apparently the first choice in all of them, only in the first one is it the favorite choice:

```
gzip, deflate
gzip;q=.7,deflate
gzip;q=.5,deflate;q=.5,identity
```

A compression filter should take this into account, like the filter in **Figure 2** does. These details should reinforce the idea that when you write an action filter, you're interfering with the handling of the request. Subsequently, anything you do should be consistent with the expectation of the client browser.

## Applying an Action Filter

As mentioned, an action filter is just an attribute that can be applied to individual methods as well as to the whole parent class. Here's how you would set it up:

```
[Compress]
public ActionResult List()
{
    // Some code here
    ...
}
```

If the attribute class contains some public properties, you can assign values to them declaratively using the familiar notation of attributes:

```
[Compress(Level=1)]
public ActionResult List()
{
    ...
}
```

**Figure 3** shows the compressed response as reported by Firebug.

An attribute is still a static way of configuring a method. This means that you need a second compile step to apply further changes.

However, action filters expressed in the form of attributes provide a key benefit: They keep crosscutting concerns out of the core action method.

## A Broader Look at Action Filters

To measure the real power of action filters, think of applications that need a lot of customization work over time and applications that require adaptation when installed for different customers.

Imagine, for example, a Web site that at some point launches an advertising campaign based on reward points a registered user may gain if he performs some standard action within a site (buying goods, answering questions, chatting, blogging and so on). As a developer, you probably need some code that runs after the regular method of executing a transaction, posting a comment or starting a chat has run. Unfortunately, this code is come-and-go and should hardly be part of the original implementation of the core action method. With action filters, you can create distinct components for each required scenario and, for example, arrange an action filter for adding reward points. Next, you attach the reward filter to any methods where the post action is required; then you recompile and go.

```
[Reward(Points=100)]
public ActionResult Post(String post)
{
    // Core logic for posting to a blog
    ...
}
```

As mentioned, attributes are static and require an additional compile step. While this may not be desirable in all cases (say, in sites with highly volatile features), it's much better than nothing. At the minimum, you gain the ability to update Web solutions quickly and with a low impact on existing features, which is always good to keep regression failures under strict control.

## Dynamic Loading

This article demonstrated action filters in the context of controller action methods. I demonstrated the canonical approach of writing filters as attributes that you use to decorate action methods statically. There's an underlying question, however: Can you load action filters dynamically?

The ASP.NET MVC framework is a well-written (and large) piece of code, so it exposes a number of interfaces and overridable methods with which you can customize nearly every aspect of it. Happily, this trend is going to be reinforced by the upcoming Model-View-Controller (MVC) 3. According to the public roadmap, one of the team's objectives for MVC 3 is enabling dependency injection at all levels. The answer to the previous question about dynamic loading, therefore, lies in the dependency-injection abilities of the MVC framework. A possible winning strategy is customizing the action invoker to gain access to the list of filters before the execution of a method. Because the list of filters looks like a plain read/write collection object, it shouldn't be that hard to populate it dynamically. But this is good fodder for a new column. ■

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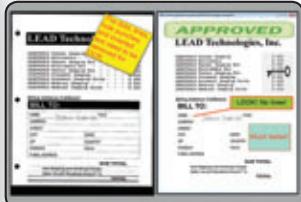
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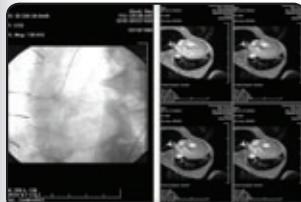
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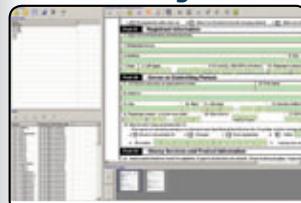
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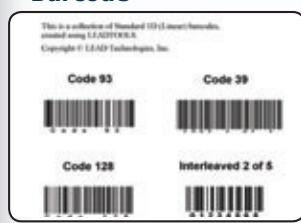
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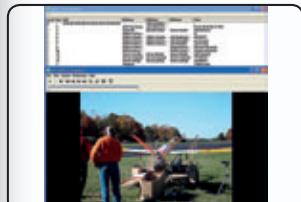
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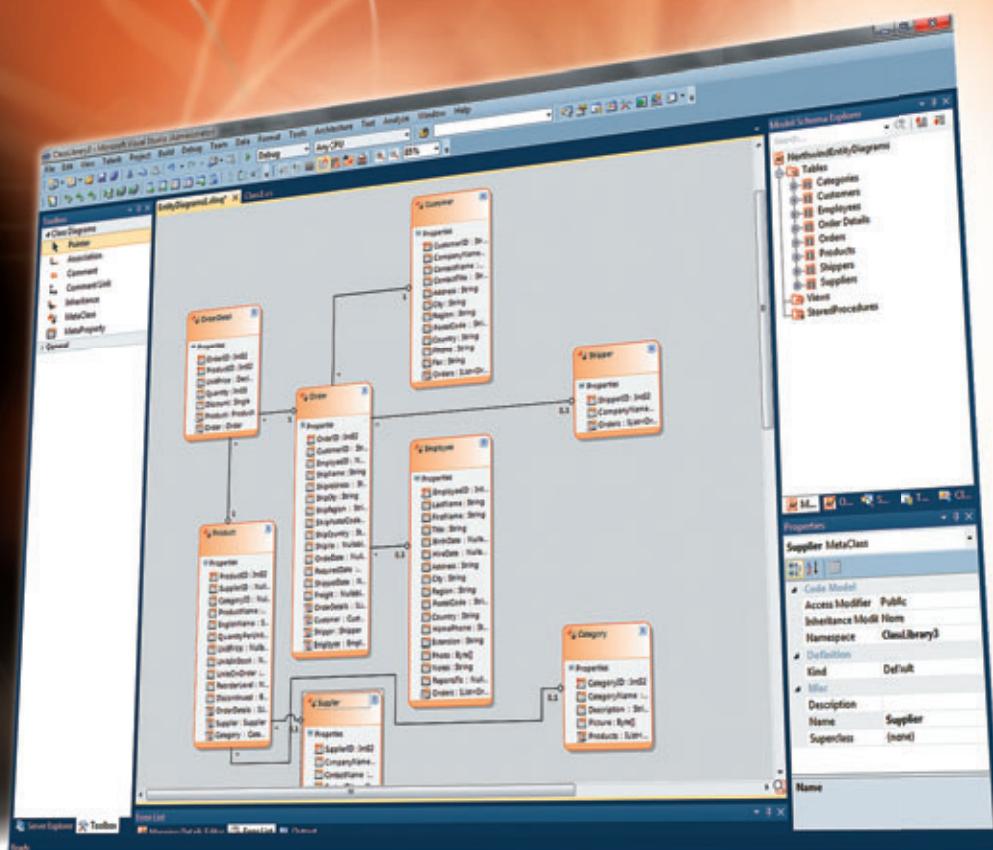
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# Entity Framework Preview: Code First, ObjectSet and DbContext

While the Entity Framework (EF) 4 was still in beta, the development team began work on another way to use it. We had the database-first way of creating a model (by reverse engineering a database into an Entity Data Model) and the new EF 4 model-first feature (define an Entity Data Model, then create the database from it). In addition, the team decided to create something called “code first.”

With code first you begin with code—not the database and not the model. In fact, with code first there’s no visual model and no XML describing that model. You simply create the classes for your application domain and code first will enable them to participate in the EF. You can use a context, write and execute LINQ to Entities queries and take advantage of EF change-tracking. But there’s no need to deal with a model in a designer. When you aren’t building highly architected apps, you can almost forget that the EF is even there, handling all of your database interaction and change-tracking for you.

An ObjectSet is a generic collection-like representation of a set of entity types.

Domain-driven development (DDD) fans seem to love code first. In fact, it was a number of DDD gurus who helped the EF team understand what code first could do for DDD programmers. Check out Danny Simmons’ blog post about the Data Programmability Advisory Council for more about that ([blogs.msdn.com/b/dsimmons/archive/2008/06/03/dp-advisory-council.aspx](http://blogs.msdn.com/b/dsimmons/archive/2008/06/03/dp-advisory-council.aspx)).

But code first wasn’t ready for inclusion in the Microsoft .NET Framework 4 and Visual Studio 2010. In fact, it’s still evolving and Microsoft is providing developers access to the bits to play with and provide feedback through the Entity Framework Feature CTP (EF Feature CTP). The fourth iteration of this community technology preview (CTP4) was released in mid-July 2010. The changes in this iteration were significant.

In addition to including the code-first assembly in the CTP4, Microsoft has been working on some great new ideas for the next iteration of the EF. Those are also included in CTP4 so that people can play with them and, again, provide feedback. More importantly, code first takes advantage of some of these new features.

You can find a number of detailed walkthroughs on this CTP in blog posts by the EF team ([tinyurl.com/297xm3j](http://tinyurl.com/297xm3j)), Scott Guthrie ([tinyurl.com/29r3qkb](http://tinyurl.com/29r3qkb)) and Scott Hanselman ([tinyurl.com/253dl2g](http://tinyurl.com/253dl2g)).

In this column, I want to focus on some of the particular features and improvements in the CTP4 that have generated an incredible amount of buzz around the EF because they simplify developing with the EF—and the .NET Framework in general—so dramatically.

## Improvements to Core API

One of the noteworthy improvements that the CTP4 adds to the EF runtime is a lightweight version of two workhorse classes, `ObjectContext` and `ObjectSet`. `ObjectContext` enables querying, change-tracking and saving back to the database. `ObjectSet` encapsulates sets of like objects.

The new classes, `DbContext` and `DbSet`, have the same essential functions, but don’t expose you to the entire feature set of `ObjectContext` and `ObjectSet`. Not every coding scenario demands access to all of the features in the more robust classes. `DbContext` and `DbSet` are not derived from `ObjectContext` and `ObjectSet`, but `DbContext` provides easy access to the full-featured version through a property: `DbContext.ObjectContext`.

## ObjectSet Basics and the Simplified DbSet

An `ObjectSet` is a generic collection-like representation of a set of entity types. For example, you can have an `ObjectSet<Customer>` called `Customers` that’s a property of a context class. LINQ to Entities queries are written against `ObjectSets`. Here’s a query against the `Customers` `ObjectSet`:

```
from customer in context.Customers  
where customer.LastName=="Lerman"  
select customer
```

`ObjectSet` has an internal constructor and does not have a parameterless constructor. The way to create an `ObjectSet` is through the `ObjectContext.CreateObjectSet` method. In a typical context class, the `Customers` property would be defined as:

```
public ObjectSet< Customer> Customers {  
    get {  
        return _customers?? (_customers =  
            CreateObjectSet< Customer >(" Customers"));  
    }  
}  
  
private ObjectSet< Customer > _customers;
```

This article discusses a prerelease version of the Entity Framework.  
All information is subject to change.

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Now you can write queries against Customers and manipulate the set, adding, attaching and deleting objects as necessary.

DbSet is much simpler to work with. DbSet isn't publicly constructible (similar to ObjectSet) but it will auto-create DbSets and assign them to any properties (with public setters) you declare on your derived DbContext.

The ObjectSet collection methods are geared toward the EF terminology—AddObject, Attach and DeleteObject:

```
context.Customers.AddObject(myCust)
```

DbSet simply uses Add, Attach and Remove, which is more in line with other collection method names, so you don't have to spend time figuring out "how to say that in the EF" like so:

```
context.Customers.Add(MyCust)
```

## My favorite feature of DbSet is that it lets you work more easily with derived types.

The use of the Remove method instead of DeleteObject also more clearly describes what the method is doing. It removes an item from a collection. DeleteObject suggests that the data will be deleted from the database, which has caused confusion for many developers.

By far my favorite feature of DbSet is that it lets you work more easily with derived types. ObjectSet wraps base types and all of the types that inherit from it. If you have a base entity, Contact and a Customer entity that derives from it, every time you want to work with customers, you'll have to start with the Contacts ObjectSet. For example, to query for customers, you write context.Contacts.OfType<Customer>. That's not only confusing, it's also definitely not easily discoverable. DbSet lets you wrap the derived types, so now you can create a property Customers that returns DbSet<Customer> and enables interaction with that directly rather than through the Contacts set.

### DbContext—a Streamlined Context

DbContext exposes the most commonly used features of the ObjectContext and provides some additional ones that are truly beneficial. My two favorite features so far of DbContext are the generic Set property and the OnModelCreating method.

All of those ObjectSets I've referred to so far are explicit properties of an ObjectContext instance. For example, say you have a model called PatientHistory that has three entities in it: Patient, Address and OfficeVisit. You'll have a class, PatientHistoryEntities, which inherits ObjectContext. This class contains a Patients property that's an ObjectSet<Patient> as well as an Addresses property and an OfficeVisits property. If you want to write dynamic code using generics, you must call context.CreateObjectSet<T> where T is one of your entity types. Again, this is just not discoverable.

DbContext has a simpler method called Set that lets you simply call context.Set<T>, which will return a DbSet<T>. It may only look like 12 less letters, but to my coding brain, using the property feels right, whereas calling a factory method doesn't. You can also use derived entities with this property.

Another DbContext member is OnModelCreating, which is useful in code first. Any additional configurations you want to apply to your domain model can be defined in OnModelCreating just before the EF builds the in-memory metadata based on the domain classes. This is a big improvement over the previous versions of code first. You'll see more about this further on.

### Code First Gets Smarter and Easier

Code first was first presented to developers as part of the EF Feature CTP1 in June 2009 with the name "code only." The basic premise behind this variation of using the EF was that developers simply want to define their domain classes and not bother with a physical model. However, the EF runtime depends on that model's XML to coerce queries against the model into database queries and then the query results from the database back into objects that are described by the model. Without that metadata, the EF can't do its job. But the metadata does not need to be in a physical file. The EF reads those XML files once during the application process, creates strongly typed metadata objects based on that XML, and then does all of that interaction with the in-memory XML.

Code first creates in-memory metadata objects, too. But instead of creating it by reading XML files, it infers the metadata from the domain classes (see **Figure 1**). It uses convention to do this and then provides a means by which you can add additional configurations to further refine the model.

The new code first ModelBuilder class builds the in-memory model.

Another important job of code first is to use the metadata to create a database schema and even the database itself. Code first has provided these features since its earliest public version.

Here's an example of where you'd need a configuration to overcome some invalid assumptions. I have a class called ConferenceTrack with an identity property called TrackId. Code-first convention looks for "Id" or class name + "Id" as an identity property to be used for an entity's EntityKey and a database table's primary key. But TrackId doesn't fit this pattern, so I have to tell the EF that this is my identity key.

The new code first ModelBuilder class builds the in-memory model based on the classes described earlier. You can further define configurations using ModelBuilder. I'm able to specify that the

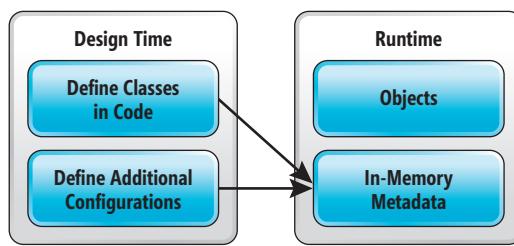


Figure 1 Code First Builds the Entity Data Model Metadata at Run Time

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ConferenceTrack entity should use its TrackId property as its key with the following ModelBuilder configuration:

```
modelBuilder.Entity<ConferenceTrack>().HasKey(  
    ct => ct.TrackId);
```

ModelBuilder will now take this additional information into account as it's creating the in-memory model and working out the database schema.

## Applying Configurations More Logically

This is where DbContext.OnModelCreating comes in so nicely. You can place the configurations in this method so that they'll be applied as the model is being created by the DbContext:

```
protected override void OnModelCreating(  
    ModelBuilder modelBuilder) {  
    modelBuilder.Entity<ConferenceTrack>().HasKey(  
        ct => ct.TrackId);  
}
```

Another new feature added in the CTP4 is an alternative way to apply configurations through attributes in the classes. This technique is called data annotations. The same configuration can be achieved by applying the Key annotation directly to the TrackId property in the ConferenceTrack class:

```
[Key]  
public int TrackId { get; set; }
```

Definitely simpler, however, my personal preference is to use the programmatic configurations so that the classes don't have to have any EF-specific knowledge in them.

Using this approach also means DbContext will take care of caching the model so constructing further DbContexts doesn't incur model discovery cost again.

## Relationships Get Easier

One of the most noteworthy improvements to code first is it's much smarter about making assumptions from the classes. While there are many improvements to these conventions, I find the enhanced relationship conventions to have affected my code the most.

Code first can correctly interpret the intent of most relationships defined in classes.

Even though relationships are defined in your classes, in previous CTPs it was necessary to provide configuration information to define these relationships in the model. In addition, the configurations were neither pretty nor logical. Now code first can correctly interpret the intent of most relationships defined in classes. In cases where you need to tweak the model with some configurations, the syntax is much simpler.

My domain classes have a number of relationships defined through properties. ConferenceTrack for example, has this one-to-many relationship:

```
public ICollection<Session> Sessions { get; set; }
```

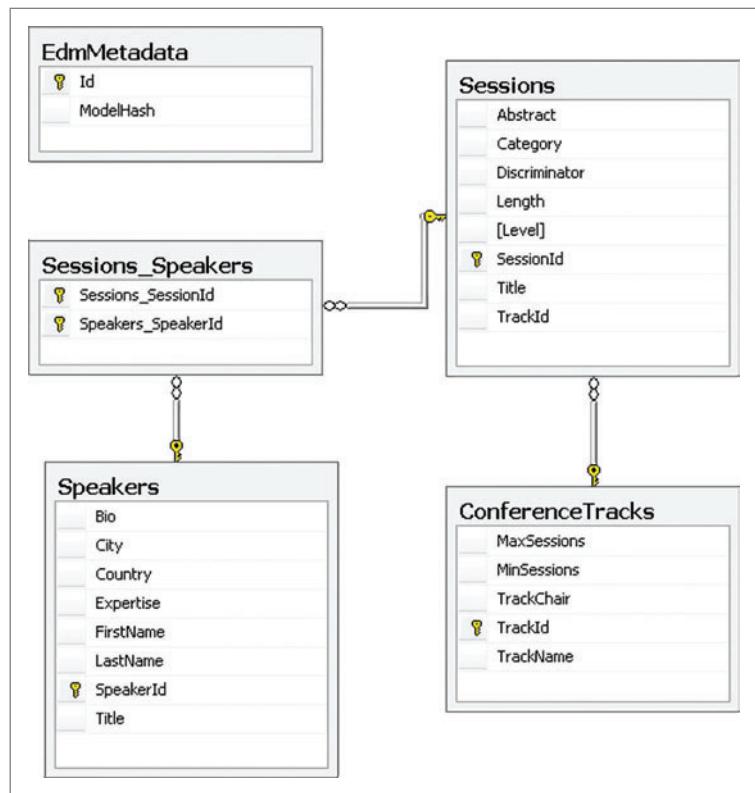


Figure 2 Model Building-Created Database Structure

Session has the converse relationship as well as a many-to-many:

```
public ConferenceTrack ConferenceTrack { get; set; }  
public ICollection<Speaker> Speakers { get; set; }
```

Using my classes and a single configuration (to define the TrackId as the key for conferences), the model builder created the database with all of the relationships and inheritances shown in Figure 2.

Notice the Sessions\_Speakers table created for the many-to-many relationship. My domain has a Workshop class that inherits from Session. By default, code first assumes Table Per Hierarchy inheritance, so it created a discriminator column in the Sessions table. I can use a configuration to change its name to IsWorkshop or even to specify that it should create a Table per Type inheritance instead.

## Planning Ahead for These New Features

These compelling new features that you have early access to in CTP4 might be a source of frustration for developers who are saying "I want it now!" It's true that this is just a preview and you can't put it in production today, but certainly play with these bits if you're able to and provide your feedback to the EF team to help make it even better. You can begin planning ahead for how you'll use code first and the other new EF features in your upcoming applications. ■

---

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# New Features and Improved Performance in Silverlight 4

One of the biggest changes in Silverlight 4 was moving to a new version of the CLR for the core execution engine. Every release of the .NET Framework has used the same CLR as its core, from the Microsoft .NET Framework 2.0 through the .NET Framework 3.5 SP1. The .NET Framework 4 made some changes—even some very large changes, such as factoring out the easy-to-download Client Profile and decreasing startup time by optimizing layout of native binaries—but we've always been restricted by the high compatibility bar imposed by being an in-place update.

With the .NET Framework 4 release, we were able to make major changes to the CLR itself, while still remaining highly compatible with previous versions. Silverlight 4 uses the new CLR as the basis for its CoreCLR and brings all of its improvements from the desktop to the Web. Some of the most notable runtime improvements are a change in the default garbage collector (GC) behavior and the fact that we no longer just-in-time (JIT) compile Silverlight Framework binaries every time a Silverlight program executes. In the base classes we've made improvements throughout, including enhancements to isolated storage and changes in System.IO that enable direct access to the file system from Silverlight applications running with elevated permissions.

Let's start with a little background on how the CoreCLR GC works.

## Generational GC

CoreCLR uses the same GC as the desktop CLR. It's a generational GC, which means that its operations are based upon the heuristic that the most recently allocated objects are the most likely to be garbage at the next collection time. This heuristic is apparent in small scopes: Function locals are not program-reachable immediately after the function returns. This heuristic is generally applicable for larger scopes as well: Programs usually hold some global state in objects that live the length of the program's execution.

Objects are usually allocated in the youngest generation—what we refer to as Generation 0—and are promoted during garbage collections (if they survive the collection) to older generations until they reach the maximum generation (Generation 2 in the current CLR GC implementation).

We have another generation in the CLR GC called the Large Object Heap (LOH). Large objects—currently defined as objects greater than 85,000 bytes—are allocated directly into the LOH. This heap is collected at the same time as Generation 2.

Without a generational GC, the GC needs to inspect the entire heap in order to know what memory is reachable and what memory is

garbage before collecting the unused memory. With a generational GC we don't need to look at the whole heap for every collection. Because the duration of a collection is directly related to the size of the generations being collected, the GC is optimized to only collect Generation 2 (and the LOH) less frequently. Collections are almost instant on small heaps and take longer as the heaps grow—Generation 0 collections can take as little as tens of microseconds.

## CoreCLR uses the same garbage collector as the desktop CLR.

For most programs, Generation 2 and the LOH are much larger than Generation 0 and Generation 1, so inspecting all the memory on these heaps takes longer. Keep in mind that the GC always collects Generation 0 when it collects Generation 1, and collects all of the heaps when it collects Generation 2. This is why a Generation 2 collection is called a *full* collection. For more details on the performance of the different heap collections, see the October 2009 CLR Inside Out column at [msdn.microsoft.com/magazine/ee309515](http://msdn.microsoft.com/magazine/ee309515).

## Concurrent GC

The straightforward algorithm to perform a garbage collection is to have the execution engine pause all program threads while the GC does its work. We refer to this kind of a collection as a *blocking* collection. These allow the GC to move non-pinned memory around—for example, to move it from one generation to the next or to compact sparse memory segments—without the program knowing that anything has changed. If memory were to move while program threads are executing, it would look to the program like memory had been corrupted.

But some of the work of a garbage collection doesn't change memory. Since the first version of the CLR, we've provided a GC mode that does *concurrent* collections. These are collections that do most of the work of a full GC without having to pause program threads for the whole duration of that collection.

There are a number of things the GC can do without changing any state that's visible to the program, for example, the GC can find all program-reachable memory. Program threads can continue to execute while the GC inspects the heaps. Before doing the actual collection, the GC just needs to discover what has changed while

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it was inspecting memory—for example, if the program allocated a new object, it needs to be marked as reachable. At the end of this, the GC asks the execution engine to block all threads—just as in a non-concurrent GC—and proceeds to finish all the reachable memory at that point.

## The impact of background GC on program latency is significant.

### Background GC

Concurrent GC has always provided a great experience in most scenarios, but there's one scenario that we improved greatly. Remember that memory is allocated in the youngest generation or on the LOH. Generations 0 and 1 are located on a single segment—we call it the *ephemeral* segment because it holds short-lived objects. When the ephemeral segment fills up, the program can no longer create new objects because there's no room for them on the ephemeral segment. The GC needs to do a collection on the ephemeral segment to free some space and allow allocation to continue.

The problem with concurrent GC is that it can't do either of these things while a concurrent collection is taking place. The GC thread can't move any memory around while program threads are running (so it can't promote older objects to Generation 2) and because there's already a GC in progress it can't start an ephemeral collection. But the GC needs to free some memory on the ephemeral segment before the program can continue. It's pretty much stuck; the program threads have to be paused, not because concurrent GC is changing program-visible state, but because the program can't allocate. If a concurrent collection finds that the ephemeral segment is full once it's found all reachable memory, it will pause all threads and do a blocking compaction.

This problem explains the motivation behind the development of background GC. It works like the concurrent GC in that the GC always does most of the work of a full collection on its own thread in the background. The main difference is that it allows an ephemeral collection to take place while the full collection gathers data. This means programs can continue to execute when the ephemeral segment fills. The GC just does an ephemeral collection and everything goes on as expected.

The impact of background GC on program latency is significant. When running the background GC, we observed far fewer pauses in program execution and those that remained were shorter in duration.

Background GC is the default mode for Silverlight 4 and is only enabled on Windows platforms because OS X lacks some of the OS support the GC needs to run in background or concurrent mode.

### NGen Performance Improvements

The compilers for managed languages such as C# and Visual Basic don't directly produce code that can be executed on the user's

machine. These compilers produce an intermediate language called MSIL that's compiled to executable code at program execution using a JIT compiler.

Using MSIL has a lot of benefits, ranging from security to portability, but there are two tradeoffs with JIT-compiled code. First, a lot of .NET Framework code has to be compiled before your program's Main function can be compiled and executed. This means your user has to wait for the JIT before the program starts running. Second, any .NET Framework code that gets used has to be compiled for every Silverlight program executing on the user's machine.

NGen helps with both of these issues. NGen compiles the .NET Framework code at install time so that it's already compiled when your program starts executing. Code that's been compiled with NGen can often be shared across multiple programs so the working set on the user's machine is reduced when running two or more Silverlight programs. If you want to know more about how NGen improves startup time and working set, see the May 2006 CLR Inside Out column at [msdn.microsoft.com/magazine/cc163610](http://msdn.microsoft.com/magazine/cc163610).

Code from the .NET Framework makes up a large portion of Silverlight programs, so not having NGen available in Silverlight 2 and 3 made a noticeable difference in startup time. The JIT compiler was taking far too long to optimize and compile the library code on the startup path of every program.

Our solution to this problem was to not have the JIT compiler optimize code generation in Silverlight 2 and 3. The code still needed to be compiled, but because the JIT compiler was producing simple code, it didn't take very long to compile. Compared to traditional desktop applications, most programs written for rich Internet application Web scenarios are small and don't run for very long. Even more importantly, they're usually interactive programs, meaning they spend most of their time waiting for the user's input. In the scenarios targeted by Silverlight 2 and 3, having quick startup time was far more important than generating optimized code.

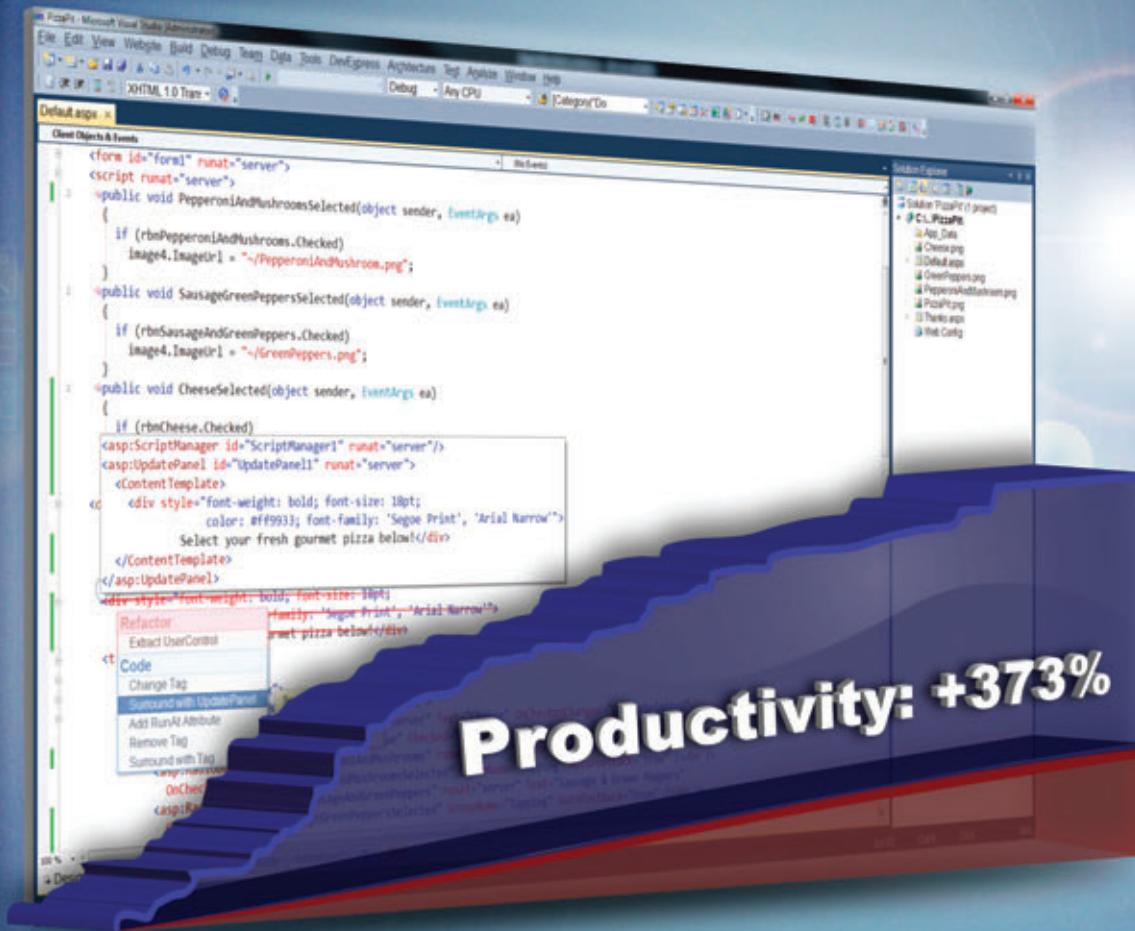
## Silverlight 4 gives you both startup performance and optimized code.

As Silverlight Web apps have evolved, we've made changes to keep the experience positive. For example, we added support for installing and running Silverlight applications from the desktop in Silverlight 3. Normally, these applications are larger and do more work than the small, interactive applications found in the classic Web scenario. Silverlight itself has added a lot of computationally intensive functionality, such as support for touch input under Windows 7 and rich photo manipulation as you see on the Bing Maps Web site. All of these scenarios require that the code be optimized to perform efficiently.

Silverlight 4 gives you startup performance and optimized code. The JIT compiler now uses the same optimizations in Silverlight

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as it does for desktop .NET applications. We're able to do the optimizations because we've enabled NGen for the Silverlight .NET Framework assemblies. When you install Silverlight, we automatically compile all of the managed code that comes in the Silverlight runtime and save it on your hard disk. When a user executes your Silverlight program, it starts executing without having to wait for any of the framework code to compile. Just as importantly, we now optimize the code in your Silverlight program so that your programs run faster, and we can share the framework code between multiple Silverlight programs executing on the user's machine.

## Isolated storage is a virtual file system that Silverlight applications can use.

Silverlight 4 creates native images for the .NET Framework assemblies during installation. There are some applications where startup performance is the only performance that matters. Think of Notepad as an example: it's important that it starts quickly, but once you start typing it doesn't matter how fast Notepad runs (provided it runs faster than you type). For this class of programs, the time it takes to JIT compile the application startup code may cause a performance decrease. Most applications will start up 400 ms to 700 ms more quickly in Silverlight 4 and will see up to a 60 percent performance improvement during execution.

The Base Class Library (BCL) is at the core of the managed APIs that are now supported by NGen in Silverlight 4. Let's take a look at what's new in the BCL.

### New BCL Functionality

Many of the new BCL enhancements in Silverlight 4 are also new in the .NET Framework 4 and have already been written about in that context. I'll give you a brief overview of what we've included in Silverlight 4.

Code contracts provide a built-in way to express pre-conditions, post-conditions and object invariants in your Silverlight code. Code contracts can be used to better express assumptions in your code and can help find bugs early. There are many additional benefits to using code contracts. You can learn more in Melitta Andersen's August 2009 CLR Inside Out column at [msdn.microsoft.com/magazine/ee236408](http://msdn.microsoft.com/magazine/ee236408), on the Code Contracts DevLabs site at [msdn.microsoft.com/devlabs/dd491992](http://msdn.microsoft.com/devlabs/dd491992), and on the BCL team blog at [blogs.msdn.com/bclteam](http://blogs.msdn.com/bclteam).

Tuples are most often used to return multiple values from a method. They're often used in functional languages such as F# and dynamic languages like IronPython, but are just as easy to use from Visual Basic and C#. You can learn more about the design of tuples in Matt Ellis' July 2009 CLR Inside Out column at [msdn.microsoft.com/magazine/dd942829](http://msdn.microsoft.com/magazine/dd942829).

Lazy<T> provides an easy way to lazily initialize objects. Lazy initialization is a technique that applications can use to defer loading or initializing data until it's first needed.

The new BigInteger and Complex numeric data types are available in the Silverlight 4 SDK in System.Numerics.dll. BigInteger represents an arbitrary-precision integer and Complex represents a complex number with real and imaginary components.

Enum, Guid and Version now support TryParse like many of the other BCL data types, providing a more efficient way to create an instance from a string that doesn't throw exceptions on errors.

Enum.HasFlag is a new convenience method that can be used to easily check whether or not a flag is set on a Flags enum, without having to remember how to use the bitwise operators.

String.IsNullOrWhiteSpace is a convenience method that checks whether or not a string is null, empty or contains only white space.

String.Concat and Join overloads now take an IEnumerable<T> parameter. These new overloads to String.Concat and Join enable concatenating any collection that implements IEnumerable<T> without the need to first convert the collection to an array.

Stream.CopyTo makes it easy to read from one stream and write the contents to another stream in one line of code.

In addition to these new features, we've also made some enhancements to isolated storage and enabled trusted Silverlight applications to directly access parts of the file system through System.IO.

### Isolated Storage Enhancements

Isolated storage is a virtual file system that Silverlight applications can use to store data on the client. To learn more about isolated storage in Silverlight, refer to the March 2009 CLR Inside Out column at [msdn.microsoft.com/magazine/dd458794](http://msdn.microsoft.com/magazine/dd458794).

The most notable improvement to isolated storage in Silverlight 4 is in the area of performance. Since the release of Silverlight 2, we've received a lot of feedback from developers regarding the performance of isolated storage. In Silverlight 3, we made some changes that significantly improved the performance of reading data out of isolated storage. In Silverlight 4, we've gone a step further and addressed the performance bottlenecks that developers were seeing when writing data to isolated storage. Overall, the performance of isolated storage is much improved in Silverlight 4.

We also heard from developers that there was no easy way to rename or copy files within isolated storage. In order to rename a file, you had to manually read from the original file, create and write to a new file, and then delete the original file. Renaming a directory could be accomplished in a similar manner, but requires even more lines of code, especially when the directory you want to rename contains subdirectories. This works, but is more code than you should have to write and isn't as efficient as telling the OS to simply rename the file or directory on disk.

In Silverlight 4, we've added new methods to the IsolatedStorageFile class that you can call to efficiently perform these operations in single line of code: CopyFile, MoveFile and MoveDirectory. We also added new methods that provide additional information about the files and directories within isolated storage: GetCreationTime, GetLastAccessTime and GetLastWriteTime.

Another new API we added in Silverlight 4 is IsolatedStorageFile.IsEnabled. Previously, the only way to determine whether isolated storage was enabled was to try using it and then catching the subsequent IsolatedStorageException, which is thrown if isolated

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storage is disabled. The new static `IsEnabled` property can be used to more easily determine whether or not isolated storage is enabled.

Many browsers such as Internet Explorer, Firefox, Chrome and Safari now support a private browsing mode where browsing history, cookies and other data aren't persisted. Silverlight 4 respects private browsing settings, preventing apps from accessing isolated storage and storing information on your local machine when the browser is in private mode. In such circumstances, the `IsEnabled` property will return false and any attempt to use isolated storage will result in an `IsolatedStorageException`, the same behavior as if isolated storage had been explicitly disabled by the user.

## File System Access

Silverlight applications run in a partial-trust security sandbox. The security sandbox restricts access to the local machine and places a number of constraints on the application, preventing malicious code from causing harm. For example, partial-trust Silverlight applications cannot directly access the file system. If an app needs to store data on the client, its only option is to store data within isolated storage. Access to the broader file system can only be accomplished through the `OpenFileDialog` or `SaveFileDialog`.

Silverlight 4 allows out-of-browser applications to configure themselves to run in elevated trust.

Silverlight 3 added the ability to install and run apps out-of-browser. This enables some interesting offline scenarios, but such apps still run within the same sandbox as apps running inside the browser. Silverlight 4 allows out-of-browser applications to configure themselves to run in elevated trust. Such trusted applications are able to bypass some of the restrictions of the sandbox after installation. For example, trusted applications can access user files, use networking without cross-domain access restrictions, bypass user consent and initiation requirements, and access native OS functionality.

When a user installs an application that requires elevated trust, the normal installation prompt is replaced with a warning that tells users that the application can access user data and should only be installed from trusted Web sites.

Trusted applications can use the APIs in `System.IO` to directly access the following user directories on the file system: `MyDocuments`, `MyMusic`, `MyPictures` and `MyVideos`. File operations outside of these directories are currently not allowed and will result in a `SecurityException`. Within these directories, all file operations are allowed, including reading and writing. For example, a trusted photo album application can directly access all files within the `MyPictures` directory. A trusted video-editing app can save a movie to the `MyVideos` directory.

It's important not to hardcode file system paths to these directories in your applications as the paths will be different depending on the underlying OS. File system paths are absolutely different between Windows and Mac OS X, but paths can also be different between versions of Windows. To work correctly across all platforms, `System.Environment.GetFolderPath` should be used to get the file system paths for these directories. The following code uses `Environment.GetFolderPath` to get the file system path to the `MyPictures` directory, finds all files within `MyPictures` (and subdirectories) that end with `.jpg` using the `System.Directory.EnumerateFiles` method, and adds each file path to a `ListBox`:

```
if (Application.Current.HasElevatedPermissions) {
    string myPictures = Environment.GetFolderPath(
        Environment.SpecialFolder.MyPictures);
    IEnumerable<string> files =
        Directory.EnumerateFiles(myPictures, "*.jpg",
            SearchOption.AllDirectories);
    foreach (string file in files) {
        listBox1.Items.Add(file);
    }
}
```

This code shows how to create a text file in the user's `MyDocuments` directory from a trusted application:

```
if (Application.Current.HasElevatedPermissions) {
    string myDocuments = Environment.GetFolderPath(
        Environment.SpecialFolder.MyDocuments);
    string filename = "Hello.txt";
    string file = Path.Combine(myDocuments, filename);

    try {
        File.WriteAllText(file, "Hello World!");
    }
    catch {
        MessageBox.Show("An error occurred.");
    }
}
```

`System.IO.Path.Combine` is used to combine the path to `MyDocuments` with the name of the file, which will insert the appropriate directory separator character for the underlying platform between the two (Windows uses \, while Mac uses /). `File.WriteAllText` is used to create the file (or overwrite it if it already exists) and write the text "Hello World!" to the file.

## Better Performance and More Capabilities

As you've seen, the new CLR in Silverlight 4 includes improvements in both the runtime and base classes. The new GC behavior, the fact that we now NGen the Silverlight Framework assemblies, and the isolated storage performance improvements mean your apps will start faster and run better on Silverlight 4. Enhancements to the BCL enable apps to do more with less code, and new capabilities, such as the ability for trusted applications to access the file system, facilitate compelling new app scenarios. ■

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**THANKS** to the following technical experts for reviewing this article:  
Surupa Biswas, Vance Morrison and Maoni Stephens

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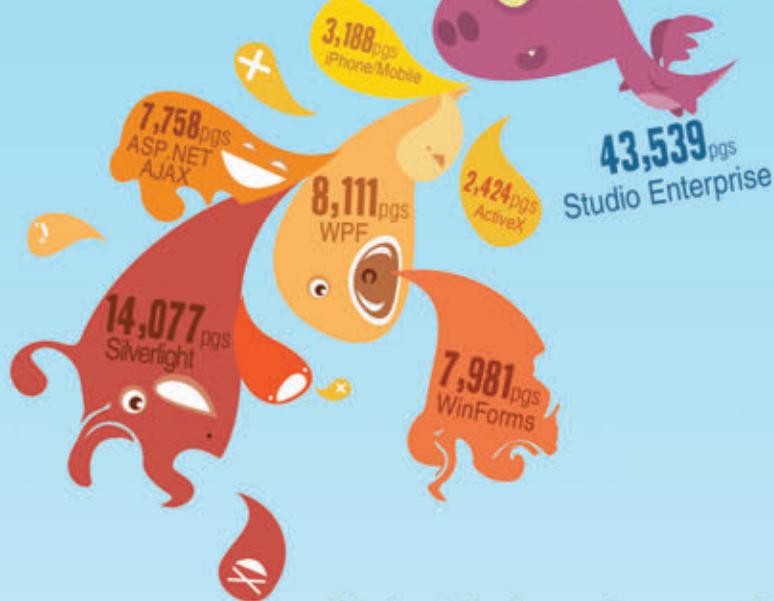
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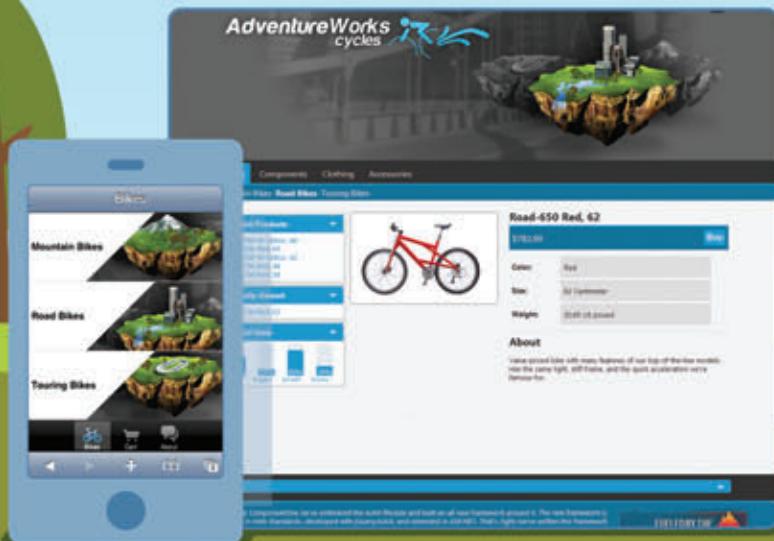
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# AppFabric Service Bus Discovery

Juval Lowy

In my January 2010 article, “Discover a New WCF with Discovery” ([msdn.microsoft.com/magazine/ee335779](http://msdn.microsoft.com/magazine/ee335779)), I presented the valuable discovery facility of Windows Communication Foundation (WCF) 4. WCF Discovery is fundamentally an intranet-oriented technique, as there’s no way to broadcast address information across the Internet.

Yet the benefits of dynamic addresses and decoupling clients and services on the address axis would apply just as well to services that rely on the service bus to receive client calls.

Fortunately, you can use events relay binding to substitute User Datagram Protocol (UDP) multicast requests and provide for discovery and announcements. This enables you to combine

the benefit of easy deployment of discoverable services with the unhindered connectivity of the service bus. This article walks through a small framework I wrote to support discovery over the service bus—bringing it on par with the built-in support for discovery in WCF—along with my set of helper classes. It also serves as an example of rolling your own discovery mechanism.

## AppFabric Service Bus Background

If you’re unfamiliar with the AppFabric Service Bus, you can read these past articles:

- “Working With the .NET Service Bus,” April 2009  
[msdn.microsoft.com/magazine/dd569756](http://msdn.microsoft.com/magazine/dd569756)
- “Service Bus Buffers,” May 2010  
[msdn.microsoft.com/magazine/ee336313](http://msdn.microsoft.com/magazine/ee336313)

## Solution Architecture

For the built-in discovery of WCF, there are standard contracts for the discovery exchange. Unfortunately, these contracts are defined as internal. The first step in a custom discovery mechanism is to define the contracts used for discovery request and callbacks. I defined the `IServiceBusDiscovery` contract as follows:

```
[ServiceContract]
public interface IServiceBusDiscovery
{
    [OperationContract(IsOneWay = true)]
    void OnDiscoveryRequest(string contractName, string contractNamespace,
                           Uri[] scopesToMatch, Uri replayAddress);
}
```

### This article discusses:

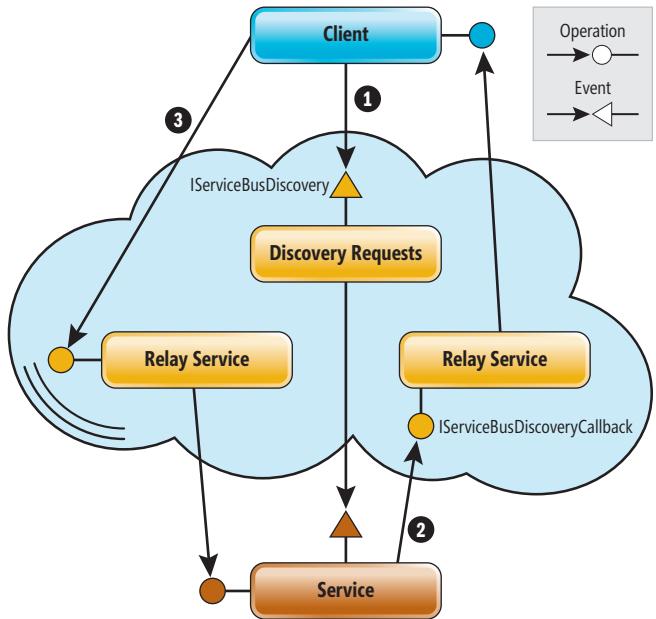
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- The discovery host
- The discovery client
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Windows Communication Foundation, AppFabric Service Bus

### Code download available at:

[code.msdn.microsoft.com/mag201010Discovery](http://code.msdn.microsoft.com/mag201010Discovery)



**Figure 1** Discovery over the Service Bus

The single-operation `IServiceBusDiscovery` is supported by the discovery endpoint. `OnDiscoveryRequest` allows the clients to discover service endpoints that support a particular contract, as with regular WCF. The clients can also pass in an optional set of scopes to match.

Services should support the discovery endpoint over the events relay binding. A client fires requests at services that support the discovery endpoint, requesting the services call back to the client's provided reply address.

The services call back to the client using the `IServiceBusDiscoveryCallback`, defined as:

```
[ServiceContract]
public interface IServiceBusDiscoveryCallback
{
    [OperationContract(IsOneWay = true)]
    void DiscoveryResponse(Uri address, string contractName,
        string contractNamespace, Uri[] scopes);
}
```

The client provides an endpoint supporting `IServiceBusDiscoveryCallback` whose address is the `replyAddress` parameter of `OnDiscoveryRequest`. The binding used should be the one-way relay binding to approximate unicast as much as possible. **Figure 1** depicts the discovery sequence.

The first step in **Figure 1** is a client firing an event of discovery request at the discovery endpoint supporting `IServiceBusDiscovery`. Thanks to the events binding, this event is received by all discoverable services. If a service supports the requested contract, it calls back to the client through the service bus (step 2 in **Figure 1**). Once the client receives the service endpoint (or endpoints) addresses, it proceeds to call the service as with a regular service bus call (step 3 in **Figure 1**).

## Discoverable Host

Obviously a lot of work is involved in supporting such a discovery mechanism, especially for the service. I was able to encapsulate that with my `DiscoverableServiceHost`, defined as:

```
public class DiscoverableServiceHost : ServiceHost, ...
{
    public const string DiscoveryPath = "DiscoveryRequests";
    protected string Namespace {get;}
    public Uri DiscoveryAddress {get;set;}
    public NetEventRelayBinding DiscoveryRequestBinding {get;set;}
    public NetOneWayRelayBinding DiscoveryResponseBinding {get;set;}
    public DiscoverableServiceHost(object singletonInstance,
        params Uri[] baseAddresses);
    public DiscoverableServiceHost(Type serviceType,
        params Uri[] baseAddresses);
}
```

Besides discovery, `DiscoverableServiceHost` always publishes the service endpoints to the service bus registry. To enable discovery, just as with regular WCF discovery, you must add a discovery behavior and a WCF discovery endpoint. This is deliberate, so as to both avoid adding yet another control switch and to have in one place a single consistent configuration where you turn on or off all modes of discovery.

You use `DiscoverableServiceHost` like any other service relying on the service bus:

```
Uri baseAddress =
    new Uri("sb://MyServiceNamespace.servicebus.windows.net/MyService/");

ServiceHost host = new DiscoverableServiceHost(typeof(MyService),baseAddress);

// Address is dynamic
host.AddServiceEndpoint(typeof(IMyContract),new NetTcpRelayBinding(),
    Guid.NewGuid().ToString());

// A host extension method to pass creds to behavior
host.SetServiceBusCredentials(...);

host.Open();
```

Note that when using discovery, the service address can be completely dynamic.

**Figure 2** provides the partial implementation of pertinent elements of `DiscoverableServiceHost`.

The helper property `IsDiscoverable` of `DiscoverableServiceHost` returns true only if the service has a discovery behavior and at least one discovery endpoint. `DiscoverableServiceHost` overrides the `OnOpening` method of `ServiceHost`. If the service is to be discoverable, `OnOpening` calls the `EnableDiscovery` method.

`EnableDiscovery` is the heart of `DiscoverableServiceHost`. It creates an internal host for a private singleton class called `DiscoveryRequestService` (see **Figure 3**).

The constructor of `DiscoveryRequestService` accepts the service endpoints for which it needs to monitor discovery requests (these are basically the endpoints of `DiscoverableServiceHost`).

`EnableDiscovery` then adds to the host an endpoint implementing `IServiceBusDiscovery`, because `DiscoveryRequestService` actually responds to the discovery requests from the clients. The address of the discovery endpoint defaults to the URI "DiscoveryRequests" under the service namespace. However, you can change that before opening `DiscoverableServiceHost` to any other URI using the `DiscoveryAddress` property. Closing `DiscoverableServiceHost` also closes the host for the discovery endpoint.

**Figure 3** lists the implementation of `DiscoveryRequestService`.

`OnDiscoveryRequest` first creates a proxy to call back the discovering client. The binding used is a plain `NetOneWayRelayBinding`, but you can control that by setting the `DiscoveryRe-`

sponseBinding property. Note that DiscoverableServiceHost has a corresponding property just for that purpose. OnDiscoveryRequest then iterates over the collection of endpoints provided to the constructor. For each endpoint, it checks that the contract matches the requested contract in the discovery request. If the contract matches, OnDiscoveryRequest looks up the scopes associated with the endpoint and verifies that those scopes match the optional scopes in the discovery request. Finally, OnDiscoveryRequest calls back the client with the address, contract and scope of the endpoint.

## Discovery Client

For the client, I wrote the helper class ServiceBusDiscoveryClient, defined as:

```
public class ServiceBusDiscoveryClient : ClientBase<IServiceBusDiscovery>,...  
{  
    protected Uri ResponseAddress  
    {get;}  
  
    public ServiceBusDiscoveryClient(string serviceNamespace, string secret);  
  
    public ServiceBusDiscoveryClient(string endpointName);  
    public ServiceBusDiscoveryClient(NetOneWayRelayBinding binding,  
        EndpointAddress address);  
  
    public FindResponse Find(FindCriteria criteria);  
}
```

**Figure 2 Implementing DiscoverableServiceHost (Partial)**

```
public class DiscoverableServiceHost : ServiceHost,...  
{  
    Uri m_DiscoveryAddress;  
    ServiceHost m_DiscoveryHost;  
  
    // Extracts the service namespace out of the endpoints or base addresses  
    protected string Namespace  
    {  
        get  
        {...}  
    }  
  
    bool IsDiscoverable  
    {  
        get  
        {  
            if (Description.Behaviors.Find<ServiceDiscoveryBehavior>() != null)  
            {  
                return Description.Endpoints.Any(endpoint =>  
                    endpoint is DiscoveryEndpoint);  
            }  
            return false;  
        }  
    }  
  
    public Uri DiscoveryAddress  
    {  
        get  
        {  
            if (m_DiscoveryAddress == null)  
            {  
                m_DiscoveryAddress =  
                    ServiceBusEnvironment.CreateServiceUri("sb", Namespace, DiscoveryPath);  
            }  
            return m_DiscoveryAddress;  
        }  
        set  
        {  
            m_DiscoveryAddress = value;  
        }  
    }  
  
    public DiscoverableServiceHost(Type serviceType, params Uri[]  
        baseAddresses) : base(serviceType, baseAddresses)  
    {}
```

I modeled ServiceBusDiscoveryClient after the WCF DiscoveryClient, and it's used much the same way, as shown in **Figure 4**.

ServiceBusDiscoveryClient is a proxy for the IServiceBusDiscovery discovery events endpoint. Clients use it to fire the discovery request at the discoverable services. The discovery endpoint address defaults to "DiscoveryRequests," but you can specify a different address using any of the constructors that take an endpoint name or an endpoint address. It will use a plain instance of NetOneWayRelayBinding for the discovery endpoint, but you can specify a different binding using any of the constructors that take an endpoint name or a binding instance. ServiceBusDiscoveryClient supports cardinality and discovery timeouts, just like DiscoveryClient.

**Figure 5** shows partial implementation of ServiceBusDiscoveryClient.

The Find method needs to have a way of receiving callbacks from the discovered services. To that end, every time it's called, Find opens and closes a host for an internal synchronized singleton class called DiscoveryResponseCallback. Find adds to the host an endpoint supporting IServiceBusDiscoveryCallback. The constructor of DiscoveryResponseCallback accepts a delegate of the type Action<Uri, Uri[]>. Every time a service responds back, the implementation of DiscoveryResponse invokes that delegate,

```
void EnableDiscovery()  
{  
    // Launch the service to monitor discovery requests  
    DiscoveryRequestService discoveryService =  
        new DiscoveryRequestService(Description.Endpoints.ToArray());  
  
    discoveryService.DiscoveryResponseBinding = DiscoveryResponseBinding;  
  
    m_DiscoveryHost = new ServiceHost(discoveryService);  
  
    m_DiscoveryHost.AddServiceEndpoint(typeof(IServiceBusDiscovery),  
        DiscoveryRequestBinding, DiscoveryAddress.AbsoluteUri);  
  
    m_DiscoveryHost.Open();  
}  
  
protected override void OnOpening()  
{  
    if (IsDiscoverable)  
    {  
        EnableDiscovery();  
    }  
  
    base.OnOpening();  
}  
protected override void OnClosed()  
{  
    if (m_DiscoveryHost != null)  
    {  
        m_DiscoveryHost.Close();  
    }  
  
    base.OnClosed();  
}  
  
[ServiceBehavior(InstanceContextMode = InstanceContextMode.Single,...]  
class DiscoveryRequestService : IServiceBusDiscovery  
{  
    public DiscoveryRequestService(ServiceEndpoint[] endpoints);  
  
    public NetOneWayRelayBinding DiscoveryResponseBinding  
    {get;set;}  
}
```

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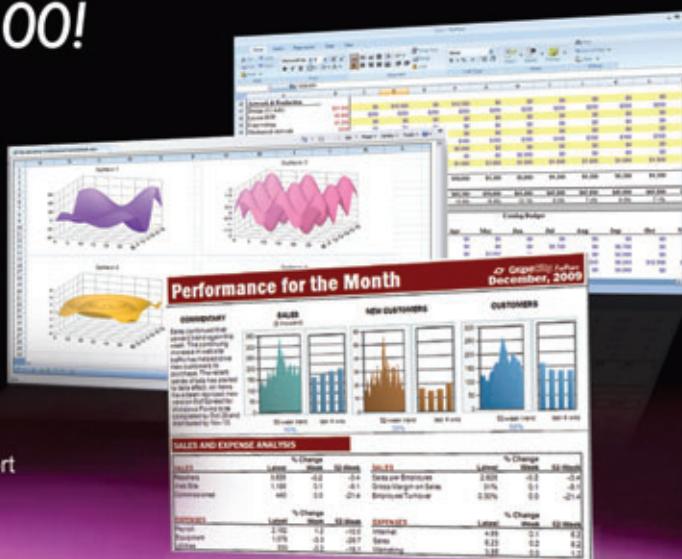
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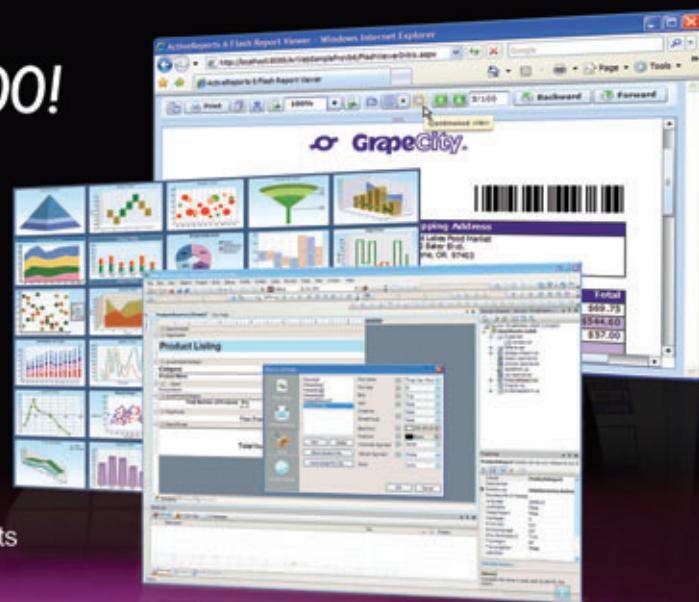
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Figure 3 The DiscoveryRequestService Class (Partial)

```

public class DiscoverableServiceHost : ServiceHost
{
    [ServiceBehavior(InstanceContextMode = InstanceContextMode.Single,
        UseSynchronizationContext = false)]
    class DiscoveryRequestService : IServiceProviderDiscovery
    {
        readonly ServiceEndpoint[] Endpoints;

        public NetOneWayRelayBinding DiscoveryResponseBinding
        {get;set;}

        public DiscoveryRequestService(ServiceEndpoint[] endpoints)
        {
            Endpoints = endpoints;
        }

        void IServiceProviderDiscovery.OnDiscoveryRequest(string contractName,
            string contractNamespace, Uri[] scopesToMatch, Uri responseAddress)
        {
            ChannelFactory<IServiceProviderDiscoveryCallback> factory =
                new ChannelFactory<IServiceProviderDiscoveryCallback>(
                    DiscoveryResponseBinding, new EndpointAddress(responseAddress));

            IServiceProviderDiscoveryCallback callback = factory.CreateChannel();

            foreach(ServiceEndpoint endpoint in Endpoints)
            {
                if(endpoint.Contract.Name == contractName &&
                    endpoint.Contract.Namespace == contractNamespace)
                {
                    Uri[] scopes = DiscoveryHelper.LookupScopes(endpoint);

                    if(scopesToMatch != null)
                    {
                        bool scopesMatched = true;
                        foreach(Uri scope in scopesToMatch)
                        {
                            if(scopes.Any(uri => uri.AbsoluteUri == scope.AbsoluteUri)
                                == false)
                            {
                                scopesMatched = false;
                                break;
                            }
                        }
                        if(scopesMatched == false)
                        {
                            continue;
                        }
                    }
                    callback.DiscoveryResponse(endpoint.Address.Uri, contractName,
                        contractNamespace, scopes);
                }
            }
            (callback as ICommunicationObject).Close();
        }
    }

    public static class DiscoveryHelper
    {
        static Uri[] LookupScopes(ServiceEndpoint endpoint)
        {
            Uri[] scopes = new Uri[0];
            EndpointDiscoveryBehavior behavior =
                endpoint.Behaviors.Find<EndpointDiscoveryBehavior>();
            if(behavior != null)
            {
                if(behavior.Scopes.Count > 0)
                {
                    scopes = behavior.Scopes.ToArray();
                }
            }
            return scopes;
        }
        // More members
    }
}

```

providing it with the discovered address and scope. The Find method uses a lambda expression to aggregate the responses in an instance of FindResponse. Unfortunately, there's no public constructor for FindResponse, so Find uses the CreateFindResponse method of DiscoveryHelper, which in turn uses reflection to instantiate it. Find also creates a waitable event handle. The lambda expression signals that handle when the cardinality is met. After calling DiscoveryRequest, Find waits for the handle to be signaled, or for the discovery duration to expire, and then it aborts the host to stop processing any discovery responses in progress.

## More Client-Side Helper Classes

Although I wrote ServiceBusDiscoveryClient to be functionally identical to DiscoveryClient, it would benefit from a streamlined discovery experience offered by my ServiceBusDiscoveryHelper:

```

public static class ServiceBusDiscoveryHelper
{
    public static EndpointAddress DiscoverAddress<T>(
        string serviceNamespace, string secret, Uri scope = null);

    public static EndpointAddress[] DiscoverAddresses<T>(
        string serviceNamespace, string secret, Uri scope = null);

    public static Binding DiscoverBinding<T>(
        string serviceNamespace, string secret, Uri scope = null);
}

```

DiscoverAddress<T> discovers a service with a cardinality of one, DiscoverAddresses<T> discovers all available service endpoints (cardinality of all) and DiscoverBinding<T> uses the service metadata endpoint to discover the endpoint binding.

Much the same way, I defined the class ServiceBusDiscoveryFactory:

```

public static class ServiceBusDiscoveryFactory
{
    public static T CreateChannel<T>(string serviceNamespace, string secret,
        Uri scope = null) where T : class;

    public static T[] CreateChannels<T>(string serviceNamespace, string secret,
        Uri scope = null) where T : class;
}

```

CreateChannel<T> assumes cardinality of one, and it uses the metadata endpoint to obtain the service's address and binding used to create the proxy. CreateChannels<T> creates proxies to all discovered services, using all discovered metadata endpoints.

Figure 4 Using ServiceBusDiscoveryClient

```

string serviceNamespace = "...";
string secret = "...";

ServiceBusDiscoveryClient discoveryClient =
    new ServiceBusDiscoveryClient(serviceNamespace, secret);

FindCriteria criteria = new FindCriteria(typeof(IMyContract));
FindResponse discovered = discoveryClient.Find(criteria);
discoveryClient.Close();

EndpointAddress address = discovered.Endpoints[0].Address;
Binding binding = new NetTcpRelayBinding();
ChannelFactory<IMyContract> factory =
    new ChannelFactory<IMyContract>(binding, address);
// A channel factory extension method to pass creds to behavior
factory.SetServiceBusCredentials(secret);

IMyContract proxy = factory.CreateChannel();
proxy.MyMethod();
(proxy as ICommunicationObject).Close();

```

Figure 5 Implementing ServiceBusDiscoveryClient (Partial)

```

public class ServiceBusDiscoveryClient : ClientBase<IServiceBusDiscovery>
{
    protected Uri ResponseAddress
    {get;private set;}

    public ServiceBusDiscoveryClient(string endpointName) : base(endpointName)
    {
        string serviceNamespace =
            ServiceBusHelper.ExtractNamespace(Endpoint.Address.Uri);
        ResponseAddress = ServiceBusEnvironment.CreateServiceUri(
            "sb",serviceNamespace,"DiscoveryResponses/"+Guid.NewGuid());
    }

    public FindResponse Find(FindCriteria criteria)
    {
        string contractName = criteria.ContractTypeNames[0].Name;
        string contractNamespace = criteria.ContractTypeNames[0].Namespace;

        FindResponse response = DiscoveryHelper.CreateFindResponse();

        ManualResetEvent handle = new ManualResetEvent(false);

        Action<Uri,Uri[]> addEndpoint = (address,scopes)=>
        {
            EndpointDiscoveryMetadata metadata = new EndpointDiscoveryMetadata();
            metadata.Address = new EndpointAddress(address);
            if(scopes != null)
            {
                foreach(Uri scope in scopes)
                {
                    metadata.Scopes.Add(scope);
                }
            }
            response.Endpoints.Add(metadata);

            if(response.Endpoints.Count >= criteria.MaxResults)
            {
                handle.Set();
            }
        };
        DiscoveryResponseCallback callback =
            new DiscoveryResponseCallback(addEndpoint);

        ServiceHost host = new ServiceHost(callback);

        host.AddServiceEndpoint(typeof(IServiceBusDiscoveryCallback),
            Endpoint.Binding,ResponseAddress.AbsoluteUri);

        host.Open();
        try
        {
            DiscoveryRequest(criteria.ContractTypeNames[0].Name,
                criteria.ContractTypeNames[0].Namespace,
                criteria.Scopes.ToArray(),ResponseAddress);

            handle.WaitOne(criteria.Duration);
        }
        catch
        {}
        finally
        {
            host.Abort();
        }
        return response;
    }

    void DiscoveryRequest(string contractName,string contractNamespace,
        Uri[] scopesToMatch,Uri replayAddress)
    {
        Channel.OnDiscoveryRequest(contractName,contractNamespace,
            scopesToMatch, replayAddress);
    }

    [ServiceBehavior(InstanceContextMode = InstanceContextMode.Single,
        UseSynchronizationContext = false)]
    class DiscoveryResponseCallback : IServiceBusDiscoveryCallback
    {
        readonly Action<Uri,Uri[]> Action;

        public DiscoveryResponseCallback(Action<Uri,Uri[]> action)
        {
            Action = action;
        }

        public void DiscoveryResponse(Uri address,string contractName,
            string contractNamespace,Uri[] scopes)
        {
            Action(address,scopes);
        }
    }

    public static class DiscoveryHelper
    {
        internal static FindResponse CreateFindResponse()
        {
            Type type = typeof(FindResponse);

            ConstructorInfo constructor =
                type.GetConstructors(BindingFlags.Instance|BindingFlags.NonPublic)[0];

            return constructor.Invoke(null) as FindResponse;
        }
        // More members
    }
}

```

## Announcements

To support announcements, you can again use the events relay binding to substitute UDP multicast. First, I defined the IServiceBusAnnouncements announcement contract:

```

[ServiceContract]
public interface IServiceBusAnnouncements
{
    [OperationContract(IsOneWay = true)]
    void OnHello(Uri address, string contractName,
        string contractNamespace, Uri[] scopes);

    [OperationContract(IsOneWay = true)]
    void OnBye(Uri address, string contractName,
        string contractNamespace, Uri[] scopes);
}

```

As shown in **Figure 6**, this time, it's up to the clients to expose an event binding endpoint and monitor the announcements.

The services will announce their availability (over the one-way relay binding) providing their address (step 1 in **Figure 6**), and the clients will proceed to invoke them (step 2 in **Figure 6**).

## Service-Side Announcements

My DiscoveryRequestService supports announcements:

```

public class DiscoverableServiceHost : ServiceHost, ...
{
    public const string AnnouncementsPath = "AvailabilityAnnouncements";

    public Uri AnnouncementsAddress
    {get;set;}

    public NetOneWayRelayBinding AnnouncementsBinding
    {get;set;}

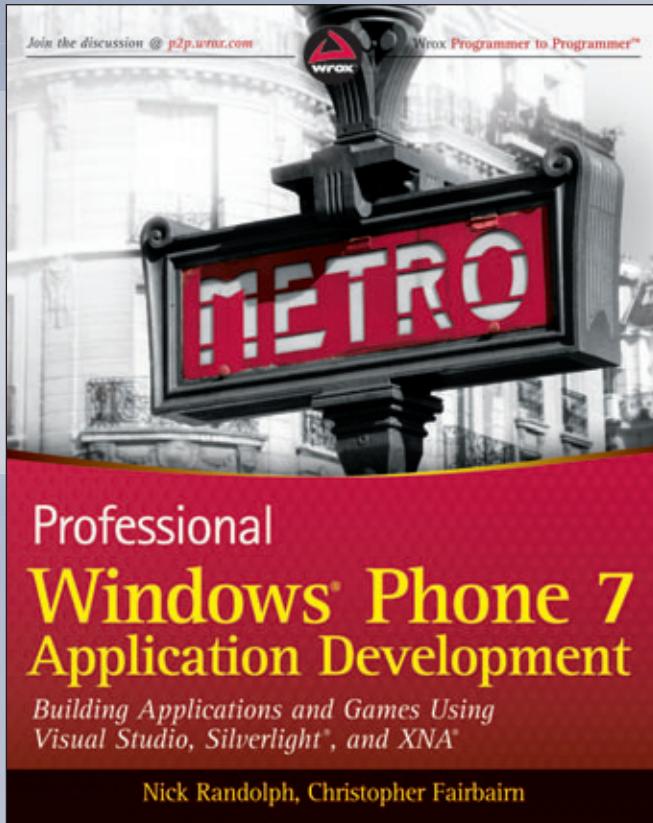
    // More members
}

```

However, on par with the built-in WCF announcements, by default it won't announce its availability. To enable announcements, you need to configure an announcement endpoint with the discovery behavior. In most cases, this is all you'll need to do. DiscoveryRequestService will fire its availability events on the "AvailabilityAnnouncements" URI under the service namespace.

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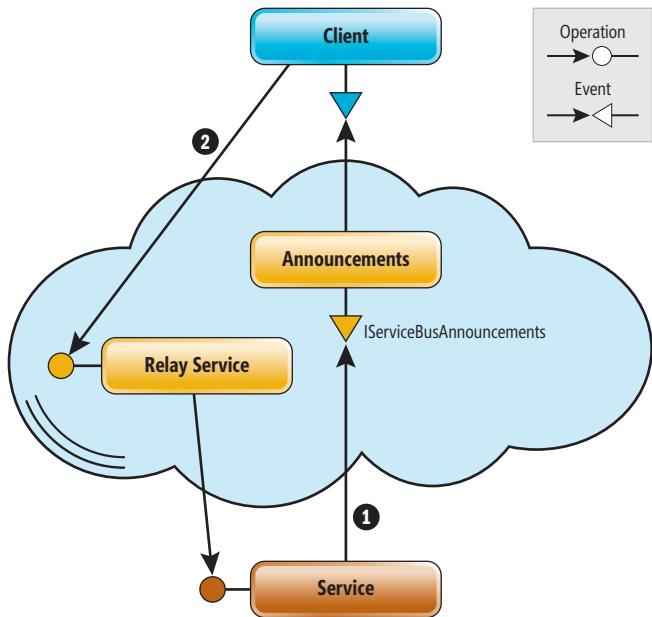


Figure 6 Availability Announcements over the Service Bus

Figure 7 Supporting Announcements with DiscoveryRequestService

```

public class DiscoverableServiceHost : ServiceHost, ...
{
    Uri m_AnnouncementsAddress;

    bool IsAnnouncing
    {
        get
        {
            ServiceDiscoveryBehavior behavior =
                Description.Behaviors.Find<ServiceDiscoveryBehavior>();
            if(behavior != null)
            {
                return behavior.AnnouncementEndpoints.Any();
            }
            return false;
        }
    }

    public Uri AnnouncementsAddress
    {
        get
        {
            if(m_AnnouncementsAddress == null)
            {
                m_AnnouncementsAddress = ServiceBusEnvironment.
                    CreateServiceUri("sb", Namespace, AnnouncementsPath);
            }
            return m_AnnouncementsAddress;
        }
        set
        {
            m_AnnouncementsAddress = value;
        }
    }

    IServiceBusAnnouncements CreateAvailabilityAnnouncementsClient()
    {
        ChannelFactory<IServiceBusAnnouncements> factory =
            new ChannelFactory<IServiceBusAnnouncements>(
                AnnouncementsBinding, new EndpointAddress(AnnouncementsAddress));

        return factory.CreateChannel();
    }

    protected override void OnOpened()
    {
        base.OnOpened();
    }

    if(IsAnnouncing)
    {
        IServiceBusAnnouncements proxy =
            CreateAvailabilityAnnouncementsClient();
        PublishAvailabilityEvent(proxy.OnHello);
    }
}

protected override void OnClosed()
{
    if(IsAnnouncing)
    {
        IServiceBusAnnouncements proxy =
            CreateAvailabilityAnnouncementsClient();
        PublishAvailabilityEvent(proxy.OnBye);
    }
    ...
}

void PublishAvailabilityEvent(Action<Uri, string, string, Uri[]> notification)
{
    foreach(ServiceEndpoint endpoint in Description.Endpoints)
    {
        if(endpoint is DiscoveryEndpoint || endpoint is
            ServiceMetadataEndpoint)
        {
            continue;
        }
        Uri[] scopes = LookupScopes(endpoint);

        AsyncCallback fire = delegate
        {
            try
            {
                notification(endpoint.Address.Uri, endpoint.Contract.Name,
                    endpoint.Contract.Namespace, scopes);
                (notification.Target as ICommunicationObject).Close();
            }
            catch
            {}
        };
        ThreadPool.QueueUserWorkItem(fire);
    }
}

```

You can change that default by setting the AnnouncementsAddress property before opening the host. The events will be fired by default using a plain one-way relay binding, but you can provide an alternative using the AnnouncementsBinding property before opening the host. DiscoveryRequestService will fire its availability events asynchronously to avoid blocking operations during opening and closing of the host. **Figure 7** shows the announcement-support elements of DiscoveryRequestService.

The CreateAvailabilityAnnouncementsClient helper method uses a channel factory to create a proxy to the IServiceBusAnnouncements announcements events endpoint. After opening and before closing DiscoveryRequestService, it fires the notifications. DiscoveryRequestService overrides both the OnOpened and OnClosed methods of ServiceHost. If the host is configured to announce, OnOpened and OnClosed call CreateAvailabilityAnnouncementsClient to create a proxy and pass it to the PublishAvailabilityEvent method to fire the event asynchronously. Because the act of firing the event is identical for both the hello and bye announcements, and the only difference is which method of IServiceBusAnnouncements to call, PublishAvailabilityEvent accepts a delegate for the target method. For each endpoint of DiscoveryRequestService,

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Figure 8 Receiving Announcements

```
class MyClient
{
    AddressesContainer<IMyContract> m_Addresses;

    public MyClient()
    {
        string serviceNamespace = "...";
        string secret = "...";

        m_Addresses = new ServiceBusAnnouncementSink<IMyContract>(
            serviceNamespace,secret);

        m_Addresses.Open();

        ...
    }

    public void OnCallService()
    {
        EndpointAddress address = m_Addresses[0];

        IMyContract proxy = ChannelFactory<IMyContract>.CreateChannel(
            new NetTcpRelayBinding(),address);
        proxy.MyMethod();
        (proxy as ICommunicationObject).Close();
    }

    ...
}
```

PublishAvailabilityEvent looks up the scopes associated with that endpoint and queues up the announcement to the Microsoft .NET Framework thread pool using a WaitCallback anonymous method. The anonymous method invokes the provided delegate and then closes the underlying target proxy.

The events will be fired by default using a plain one-way relay binding.

## Receiving Announcements

I could have mimicked the WCF-provided AnnouncementService, as described in my January article, but there's a long list of things I've improved upon with my AnnouncementSink<T>, and I didn't see a case where you would prefer to use AnnouncementService in favor of AnnouncementSink<T>. I also wanted to leverage and reuse the behavior of AnnouncementSink<T> and its base class.

Figure 9 Implementing ServiceBusAnnouncementSink<T> (Partial)

```
[ServiceBehavior(UseSynchronizationContext = false,
    InstanceContextMode = InstanceContextMode.Single)]
public class ServiceBusAnnouncementSink<T> : AnnouncementSink<T>,
    IServiceBusAnnouncements
{
    Uri m_AnnouncementsAddress;

    readonly ServiceHost Host;
    readonly string ServiceNamespace;
    readonly string Owner;
    readonly string Secret;

    public ServiceBusAnnouncementSink(string serviceNamespace,
        string owner,string secret)
    {
        Host = new ServiceHost(this);
        ServiceNamespace = serviceNamespace;
        Owner = owner;
        Secret = secret;
    }

    public Uri AnnouncementsAddress
    {
        get
        {
            if(m_AnnouncementsAddress == null)
            {
                m_AnnouncementsAddress =
                    ServiceBusEnvironment.CreateServiceUri(
                        "sb",ServiceNamespace,
                        DiscoverableServiceHost.AnnouncementsPath);
            }
            return m_AnnouncementsAddress;
        }
        set
        {
            m_AnnouncementsAddress = value;
        }
    }

    public override void Open()
    {
        base.Open();

        Host.AddServiceEndpoint(typeof(IServiceBusAnnouncements),
            AnnouncementsBinding, AnnouncementsAddress.AbsoluteUri);
        Host.SetServiceBusCredentials(Owner,Secret);
        Host.Open();
    }
}
```

```
public override void Close()
{
    Host.Close();

    base.Close();
}

void IServiceBusAnnouncements.OnHello(Uri address,string contractName,
    string contractNamespace,Uri[] scopes)
{
    AnnouncementEventArgs args =
        DiscoveryHelper.CreateAnnouncementArgs(
            address,contractName,contractNamespace,scopes);
    OnHello(this,args); //In the base class AnnouncementSink<T>
}

void IServiceBusAnnouncements.OnBye(Uri address,string contractName,
    string contractNamespace,Uri[] scopes)
{
    AnnouncementEventArgs args = DiscoveryHelper.CreateAnnouncementArgs(
        address,contractName,contractNamespace,scopes);
    OnBye(this,args); //In the base class AnnouncementSink<T>
}

public static class DiscoveryHelper
{
    static AnnouncementEventArgs CreateAnnouncementArgs(Uri address,
        string contractName, string contractNamespace, Uri[] scopes)
    {
        Type type = typeof(AnnouncementEventArgs);
        ConstructorInfo constructor =
            type.GetConstructors(BindingFlags.Instance|BindingFlags.NonPublic)[0];

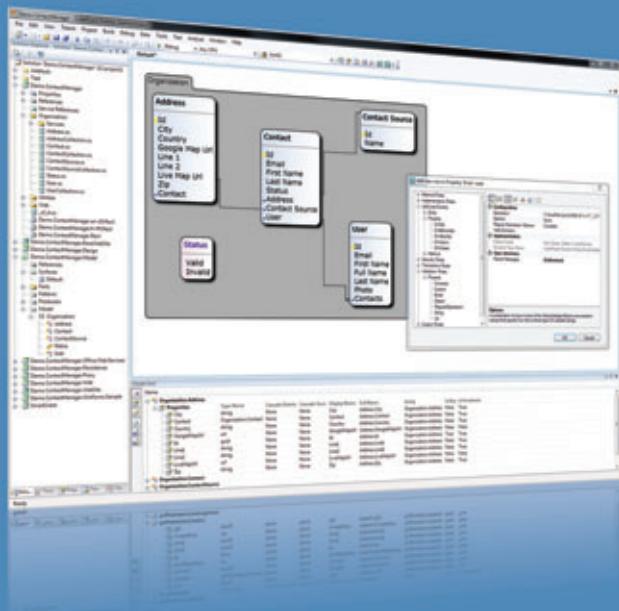
        ContractDescription contract =
            new ContractDescription(contractName,contractNamespace);

        ServiceEndpoint endpoint =
            new ServiceEndpoint(contract,null,new EndpointAddress(address));
        EndpointDiscoveryMetadata metadata =
            EndpointDiscoveryMetadata.FromServiceEndpoint(endpoint);

        return constructor.Invoke(
            new object[]{null,metadata}) as AnnouncementEventArgs;
    }
    // More members
}
```



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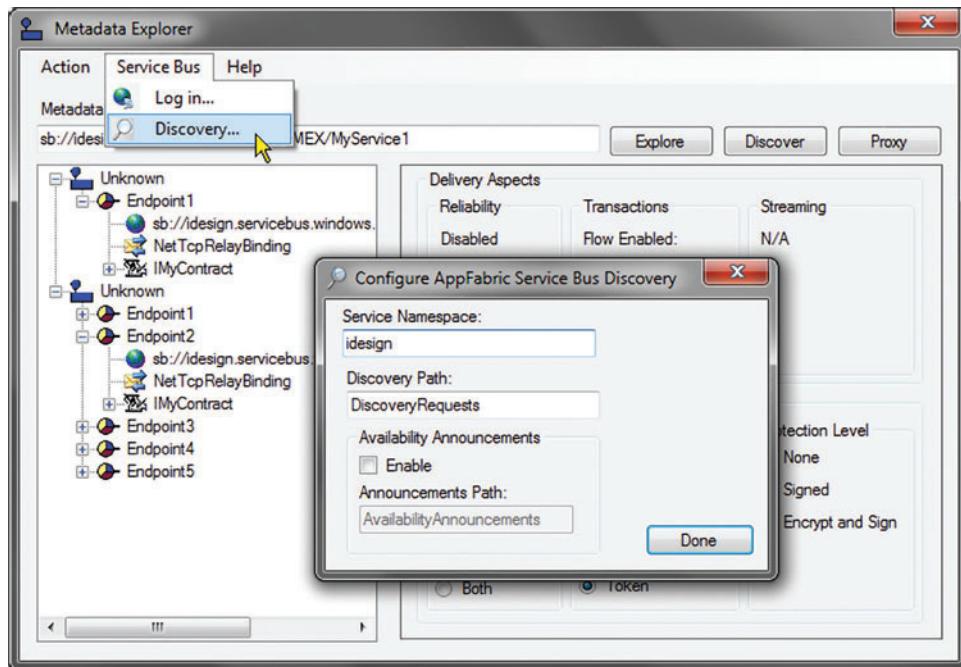


Figure 10 Configuring Discovery over the Service Bus

Therefore, for the client, I wrote `ServiceBusAnnouncementSink<T>`, defined as:

```
[ServiceBehavior(UseSynchronizationContext = false,
    InstanceContextMode = InstanceContextMode.Single)]
public class ServiceBusAnnouncementSink<T> : AnnouncementSink<T>,
    IServiceProvider, where T : class
{
    public ServiceBusAnnouncementSink(string serviceNamespace, string secret);

    public ServiceBusAnnouncementSink(string serviceNamespace, string owner,
        string secret);
    public Uri AnnouncementsAddress { get; set; }

    public NetEventRelayBinding AnnouncementsBinding { get; set; }
}
```

The constructors of `ServiceBusAnnouncementSink<T>` require the service namespace.

`ServiceBusAnnouncementSink<T>` supports `IServiceBusAnnouncements` as a self-hosted singleton. `ServiceBusAnnouncementSink<T>` also publishes itself to the service bus registry. `ServiceBusAnnouncementSink<T>` subscribes by default to the availability announcements on the “`AvailabilityAnnouncements`” URI under the service namespace. You can change that (before opening it) by setting the `AnnouncementsAddress` property. `ServiceBusAnnouncementSink<T>` uses (by default) a plain `NetEventRelayBinding` to receive the notifications, but you can change that by setting the `AnnouncementsBinding` before opening `ServiceBusAnnouncementSink<T>`. The clients of `ServiceBusAnnouncementSink<T>` can subscribe to the delegates of `AnnouncementSink<T>` to receive the announcements, or they can just access the address in the base address container. For an example, see **Figure 8**.

**Figure 9** shows the partial implementation of `ServiceBusAnnouncementSink<T>` without some of the error handling.

The constructor of `ServiceBusAnnouncementSink<T>` hosts itself as a singleton and saves the service namespace. When you open

`ServiceBusAnnouncementSink<T>`, it adds to its own host an endpoint supporting `IServiceBusAnnouncements`. The implementation of the event handling methods of `IServiceBusAnnouncements` creates an `AnnouncementEventArgs` instance, populating it with the announced service address, contract and scopes, and then calls the base class implementation of the respective announcement methods, as if it was called using regular WCF discovery. This both populates the base class of the `AnnouncementsContainer<T>` and fires the appropriate events of `AnnouncementSink<T>`. Note that to create an instance of `AnnouncementEventArgs`, you must use reflection due to the lack of a public constructor.

## The Metadata Explorer

Using my support for discovery for the service bus, I extended the discovery feature of the Metadata Explorer tool (presented in previous articles) to support the service bus. If you click the Discover button (see **Figure 10**), for every service namespace you have already provided credentials for, the Metadata Explorer will try to discover metadata exchange endpoints of discoverable services and display the discovered endpoints in the tree.

The Metadata Explorer will default to using the URI “`DiscoveryRequests`” under the service namespace. You can change that path by selecting Service Bus from the menu, then Discovery, to bring up the Configure AppFabric Service Bus Discovery dialog (see **Figure 10**).

For each service namespace of interest, the dialog lets you configure the desired relative path of the discovery events endpoint in the Discovery Path text box.

The Metadata Explorer also supports announcements of service bus metadata exchange endpoints. To enable receiving the availability notification, bring up the discovery configuration dialog box and check the `Enable` checkbox under `Availability Announcements`. The Metadata Explorer will default to using the “`AvailabilityAnnouncements`” URI under the specified service namespace, but you can configure for each service namespace any other desired path for the announcements endpoint.

The support in the Metadata Explorer for announcements makes it a simple, practical and useful service bus monitoring tool. ■

---

**JUVAL LOWY** is a software architect with iDesign providing .NET and architecture training and consulting. This article contains excerpts from his recent book, “Programming WCF Services 3rd Edition” (O’Reilly, 2010). He’s also the Microsoft regional director for the Silicon Valley. Contact Lowy at [idesign.net](http://idesign.net).

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# Runtime Data Sharing Through an Enterprise Distributed Cache

Iqbal Khan

**Many organizations use a** combination of Microsoft .NET Framework and Java applications, especially midsize to large organizations that can't commit to only one technology for various reasons. Often, they employ Web applications, service-oriented architecture (SOA) Web services and other server applications that process lots of transactions.

Many of these applications need to share data with one another at run time. Often, they're all working on common business data that's stored in a database. They typically deal with continuous streams of data (for example, financial trading applications), and they need to process it and share results with other applications, again all at run time.

Although the database should be the master data store for permanent storage, it's not well-suited for runtime data sharing. One

reason for this is that performance isn't always great when reading data from the database. Furthermore, the database may not scale nicely in terms of handling transactions, so it may quickly become a bottleneck and slow down all the applications relying on it.

Moreover, you can't effectively share data in real time. Real-time data sharing requires that as soon as one application updates some data, all other applications interested in that data should be informed. Similarly, some applications may be waiting for certain types of data to be created and made available, and when this happens, they should be notified immediately.

These problems are common whether the applications needing to share data are all based on the .NET Framework or whether some are .NET and others Java. In fact, if the applications are a mix of .NET and Java, the problems are compounded because there's no automatic way for these applications to share data at the app-to-app level in a native fashion.

## The Solution: Enterprise Distributed Cache

Luckily, the enterprise distributed cache can resolve these problems. This in-memory store spans multiple servers, pooling the memory of the servers so that memory storage capacity is scalable. Transaction capacity also becomes scalable, so the more servers you add, the greater the transaction load you can handle.

Enterprise distributed caches also provide event notification mechanisms, allowing applications to alert one another when they have updated data. Hence, you can have an asynchronous event notification mechanism where one application produces some data and others may consume it, creating a producer/consumer

### This article discusses:

- How .NET and Java apps communicate via a cache
- Item-based event notifications
- App-generated custom event notifications
- Continuous query-based event notifications
- Read-through and write-through handlers
- Database synchronization
- High availability via a self-healing dynamic cluster
- Scalability via cache partitioning and replication

### Technologies discussed:

Microsoft .NET Framework, Java

**Figure 1 A .NET App Using an Enterprise Distributed Cache**

```
using System;
...
using Alachisoft.NCache.Web.Caching;

namespace Client
{
    class Program
    {
        static string _sCacheName = "myAppCache";
        static Cache _sCache = NCache.InitializeCache(_sCacheName);

        static void Main(string[] args)
        {
            string employeeId = "1000";
            string key = "Employee:EmployeeId:" + employeeId;

            // First check the cache for this employee
            Employee emp = _sCache.Get(key);

            // If cache doesn't have it then make database call
            if (emp == null)
            {
                emp = LoadEmployeeFromDb(employeeId);

                // Now add it to the cache for next time
                _sCache.Insert(key, emp);
            }
        }
    }
}
```

model or publish/subscribe model. Multiple applications subscribe to certain types of data and are notified when it's published.

There's also a read-through/write-through mechanism, which means the enterprise distributed cache itself can read considerable data from the data source and the applications. Regardless of whether those applications are Java or .NET, their code becomes much simpler because they read the data from the enterprise distributed cache. They don't need to have all that database access

code built into them. See **Figure 1** for a simple example of a .NET Framework app using an enterprise distributed cache.

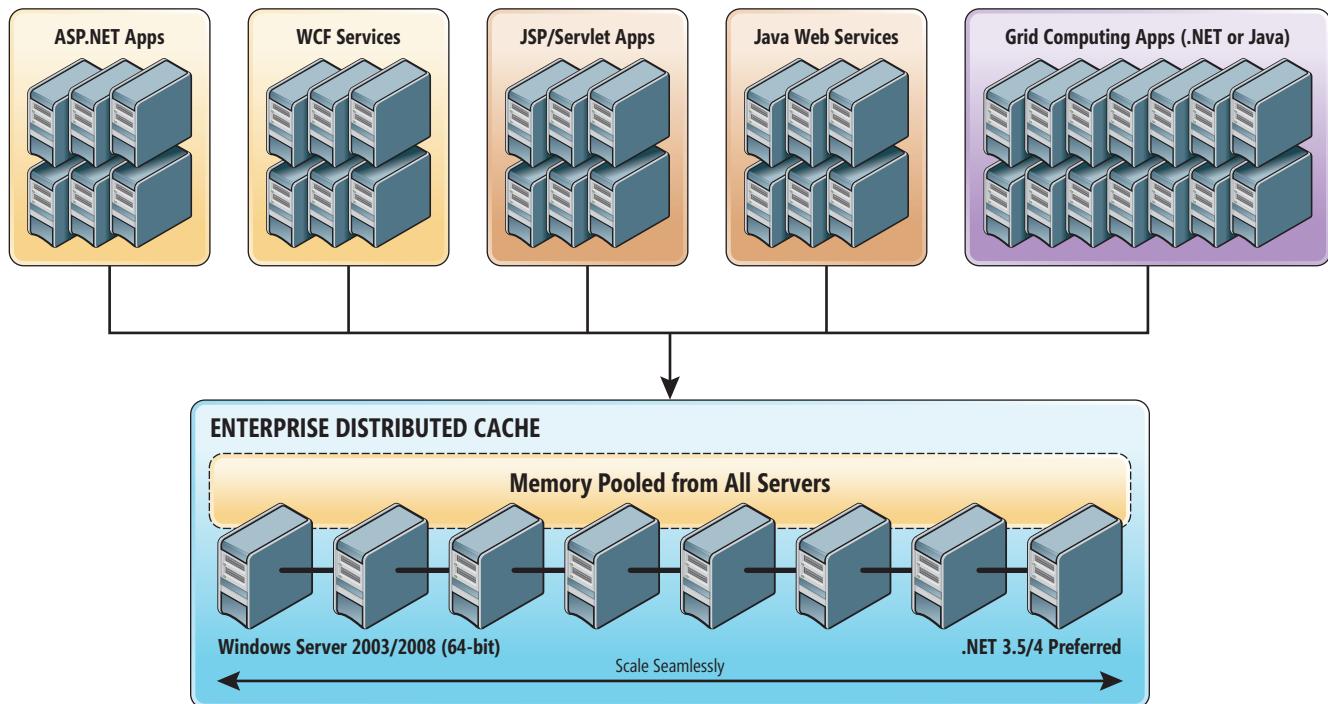
Moreover, an enterprise distributed cache can synchronize itself with any data changes in the database made by other third-party applications. It has a connection with the database, allowing the database to notify it whenever a certain type of data changes in the database. **Figure 2** illustrates how .NET and Java applications can share data with one another at run time through an enterprise distributed cache.

## .NET and Java Apps Sharing Data

With an enterprise distributed cache, multiple applications—both .NET and Java—can access the same cache and share data through it. If it were only .NET applications (or only Java applications) sharing data through a distributed cache, they could store the objects in a native binary form and serialize/deserialize them. But when both types try to share data with each other, they need a portable data format in which to store the data in the distributed cache.

That's because when a .NET application stores an object in the distributed cache, it actually transforms the object into an XML document and stores that XML. On the other side, when a Java application reads that data from the distributed cache, it transforms the XML into a Java object. In effect, the XML is used as a portable data storage mechanism as a .NET object is transformed into XML and then from XML into Java and vice versa.

A number of open source libraries can help you transform your .NET or Java objects into XML and then back into the object form. You can develop your own, of course, but I recommend you pick an open source library. I personally like Web Objects in XML (WOX), developed by Carlos Jaimez and Simon Lucas



**Figure 2 .NET and Java Apps Sharing Data Through a Distributed Cache**

**Figure 3 Student and Course Classes in Java and C#**

```
// Java classes
public class Student
{
    private String name;
    private int registrationNumber;
    private Course[] courses;
}

public class Course
{
    private int code;
    private String name;
    private int term;
}

// ****
// .NET classes in C#
public class Student
{
    private String name;
    private Int32 registrationNumber;
    private Course[] courses;
}

public class Course
{
    private Int32 code;
    private String name;
    private Int32 term;
}
```

(woxserializer.sourceforge.net). I'll use examples of Java-to-.NET transformation from their Web site in this article (with their permission). **Figure 3** shows Student and Course classes defined both in Java and C#.

If we use .NET and Java apps to store these Student and Course objects in an enterprise distributed cache, we can then use the WOX library to transform them into XML. Then, when an application wants to read these objects from the enterprise distributed cache, it reads the WOX library again to transform the XML back into the Java or .NET object form. **Figure 4** shows both Student and Course classes transformed into XML.

Within your application, you should call WOX from your caching layer or the data access layer.

**Figure 4 Java and .NET Classes Transformed into XML**

```
<object type="Student" id="0">
    <field name="name" type="string" value="Carlos Jaimez"/>
    <field name="registrationNumber" type="int" value="76453"/>
    <field name="courses">
        <object type="array" elementType="Course" length="3" id="1">
            <object type="Course" id="2">
                <field name="code" type="int" value="6756"/>
                <field name="name" type="string"
                    value="XML and Related Technologies"/>
                <field name="term" type="int" value="2"/>
            </object>
            <object type="Course" id="3">
                <field name="code" type="int" value="9865"/>
                <field name="name" type="string"
                    value="Object Oriented Programming"/>
                <field name="term" type="int" value="2"/>
            </object>
            <object type="Course" id="4">
                <field name="code" type="int" value="1134"/>
                <field name="name" type="string" value="E-Commerce Programming"/>
                <field name="term" type="int" value="3"/>
            </object>
        </object>
    </field>
</object>
```

## Item-Based Event Notifications

Event notifications are a powerful mechanism that allows multiple applications (both .NET and Java) to coordinate data sharing asynchronously. This mechanism helps avoid the expensive polling of the database that applications would have to do if they didn't have such a facility. It's shared among .NET and Java applications, so they can notify one another seamlessly.

When a .NET application stores an object in the distributed cache, it actually transforms the object into an XML document and stores that XML.

One common type of event notification is item-based notification. In this type, applications register interest in various cached item keys (that may or may not exist in the cache yet), and they're notified separately whenever that item is added, updated or removed from the distributed cache by anybody for any reason. For example, even if an item is removed due to expiration or eviction, the item-remove event notification is fired.

Both .NET and Java applications can register interest for the same cached items and be notified about them. The notification usually includes the affected cached item as well, which, as we saw in the previous section, is transformed into either .NET or Java, depending on the type of application.

## App-Generated Custom Event Notifications

An enterprise distributed cache is also a powerful event propagation platform for both .NET and Java applications. Any applications connected to an enterprise distributed cache can fire custom events into the cache, and then all other applications that have registered interest in those custom events will be notified by the cache, regardless of where those applications are located. This by itself provides a powerful language- and platform-independent event propagation mechanism in an enterprise distributed cache.

This feature allows applications to collaborate in data sharing asynchronously. For example, if one application puts some data in the distributed cache, it can then fire a custom event so other applications that are supposed to consume or process this data further are notified immediately.

## Continuous Query-Based Event Notifications

Item-based event notification is powerful but requires the application to know the key of the cached item. If you combine item-based event notification with other grouping features commonly provided in an enterprise distributed cache (such as tags, groups/subgroups and more), you can pretty much handle most



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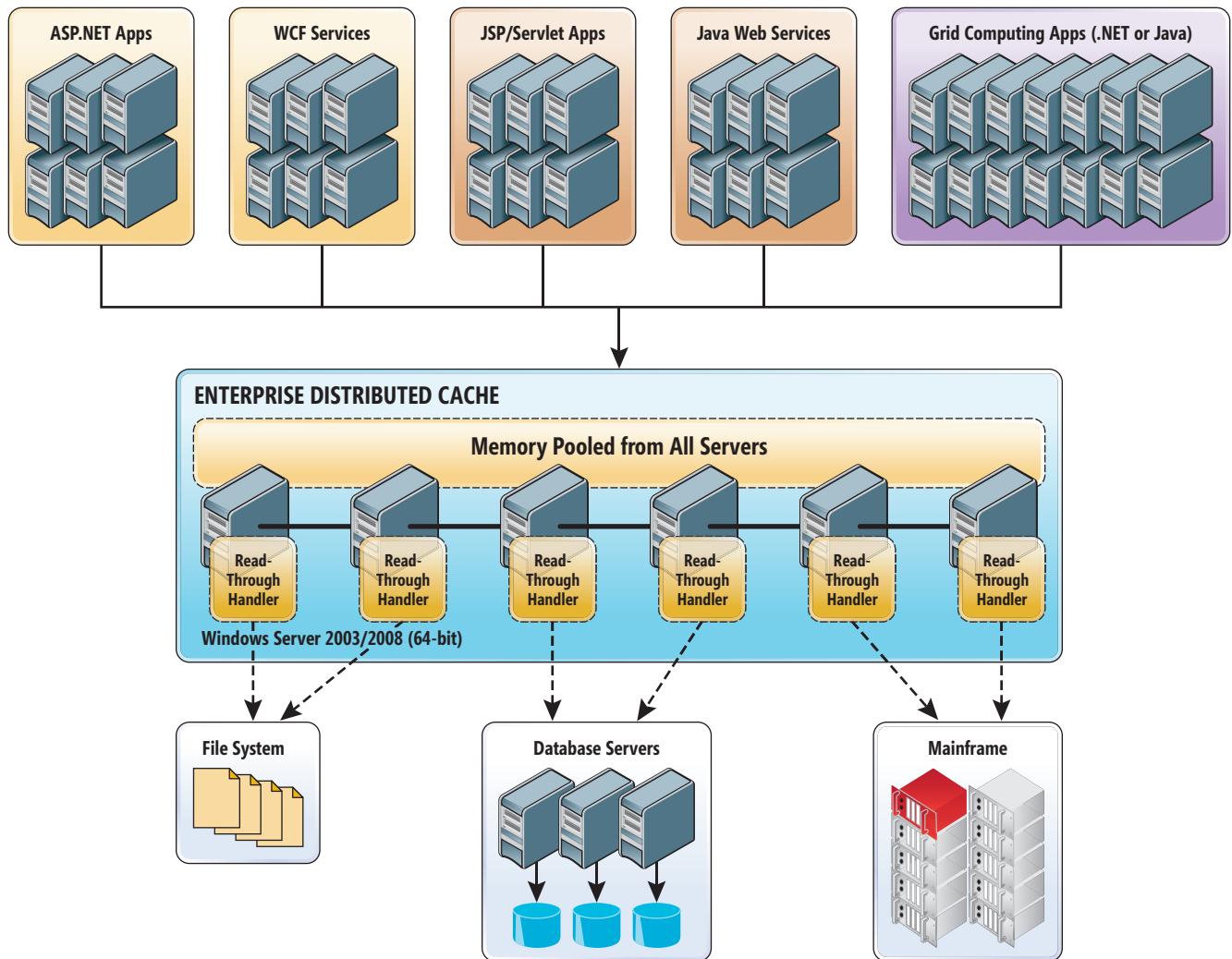
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**Figure 5 How Read-Through/Write-Through Is Used**

of the cases where applications need to be notified based on what happens to various cached items.

However, there are two limitations with item-based events. First, as noted, the application has to know all the keys of cached items about which it wants to be notified. Second, it will be notified no matter what change is made to these items. The application can't put more detailed criteria in place, so it's notified only when specific changes are made to the data.

To handle such cases, an enterprise distributed cache provides a continuous query—a SQL-like query that captures an application's business rules about data in which it's interested. A continuous query isn't a search query but rather a "criteria" the enterprise distributed cache keeps; anytime something is added or updated in the distributed cache, the operation is compared to the continuous query criteria. If the criteria match, an event is fired and the application issuing the continuous query criteria is notified.

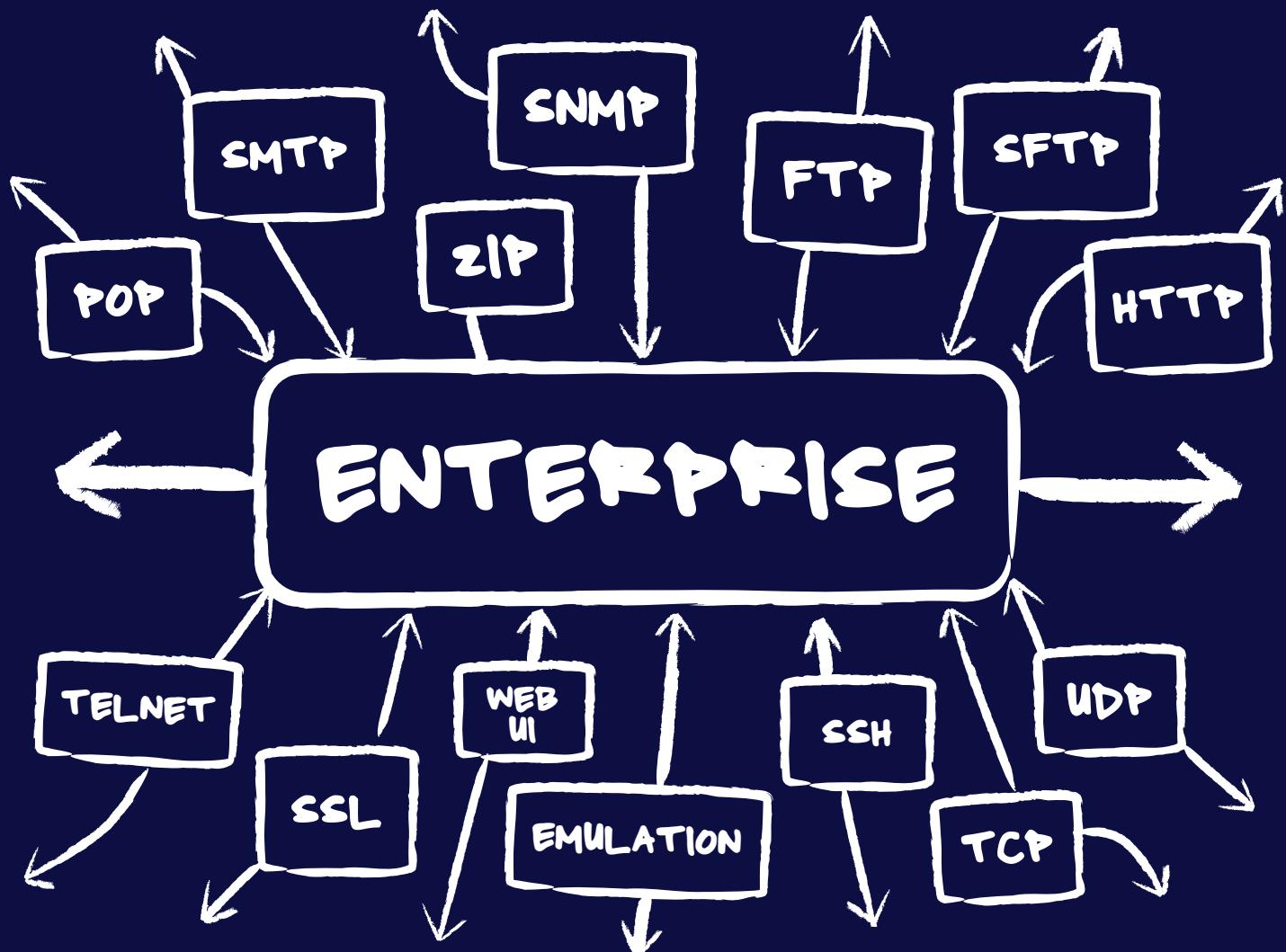
Continuous query allows applications to watch for more complex and sophisticated changes and be notified only when those changes happen.

## Read-Through and Write-Through Handlers

Many times, applications try to read data that doesn't exist in the enterprise distributed cache and must be read from a database. In these situations, applications could go directly to the database and read that data, but that would mean that all applications end up having the same data access code duplicated (especially in both .NET and Java). Or, they can ask the enterprise distributed cache to read the data from the database for them when they need it.

The read-through/write-through feature allows an enterprise distributed cache to read data directly from the data source. The applications can simplify their code so they don't have to go to the database. They can just ask the enterprise distributed cache to give them the data, and if the cache doesn't have the data, it will go and read it from the data source. **Figure 5** shows how read-through and write-through fit into an enterprise distributed cache.

I want to mention one point of caution here. Although there's great benefit in having the distributed cache read the data from the database for you, many types of data are best read directly from the database by the application. If you're reading collections of data that involve complex joins, it's best to read it yourself and then put it in the distributed cache.



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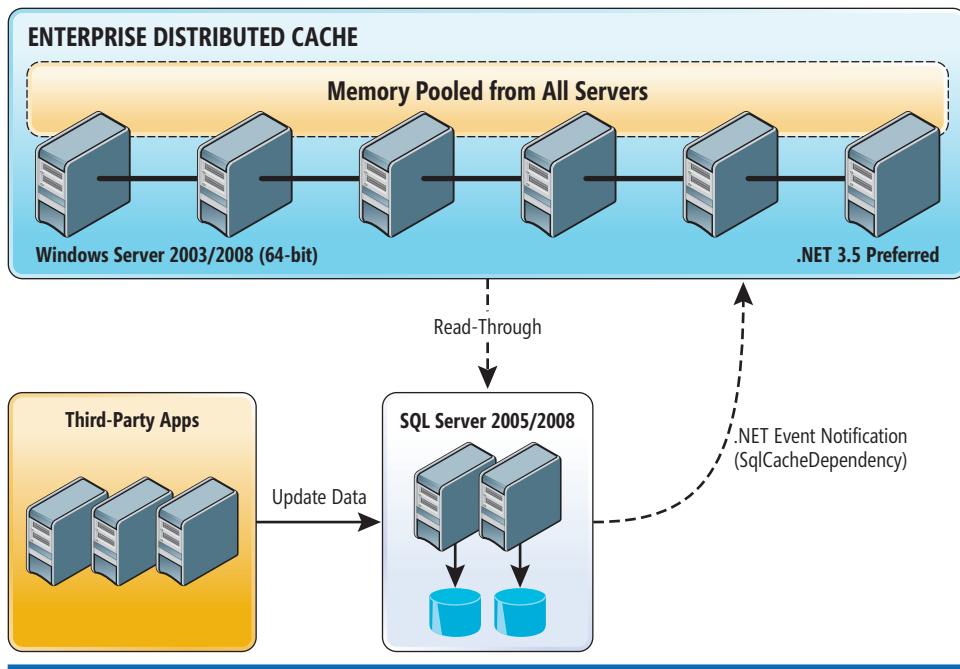


Figure 6 Database Synchronization in Distributed Cache

## Database Synchronization

Because a lot of data is being put in the enterprise distributed cache, it only makes sense to make sure this data is kept synchronized with the master data source, usually a relational database. An enterprise distributed cache provides such a feature.

This database synchronization feature allows applications to specify a relationship (a dependency) between cached items and rows in database tables. Whenever data in the database changes, the database server fires a .NET event if it's a SQL Server 2005/2008 database and notifies the enterprise distributed cache of such a change. For other databases that don't support .NET events, an enterprise distributed cache also provides configurable polling, where it can poll the database (say, once every 15 seconds) and synchronize if data has changed there.

The distributed cache then either removes that data from the cache or reads a fresh copy of it if you've configured the read-through feature. **Figure 6** shows how an enterprise distributed cache synchronizes with SQL Server.

## High Availability: Self-Healing Dynamic Cluster

An enterprise distributed cache is used as a runtime data sharing platform among multiple applications (.NET to .NET, .NET to Java, and Java to Java). In many cases, these applications are mission-critical for your business.

This means an enterprise distributed cache must be highly available, because so many

mission-critical applications depend on it. The enterprise distributed cache can't go down or stop working, and it should require virtually no downtime for maintenance or other normal operations.

An enterprise distributed cache achieves high availability by having a self-healing, dynamic cluster of cache servers. Self-healing here means the cluster is aware of all its members and adjusts dynamically if a member leaves or joins. It also ensures that data is replicated for reliability, and if a cluster member leaves, its backup data is made available to the applications automatically. All of this must be done quickly and without causing any interruptions in the applications using the enterprise distributed cache.

## Scalability: Cache Partitioning and Replication

Many applications using an enterprise distributed cache are high-transaction apps. Therefore, the load on the cache cluster can grow rapidly; however, if the response time of the enterprise distributed cache drops, it loses its value. In fact, this is an area where an enterprise distributed cache is superior to relational databases; it can handle a lot more transactions per second because it can keep

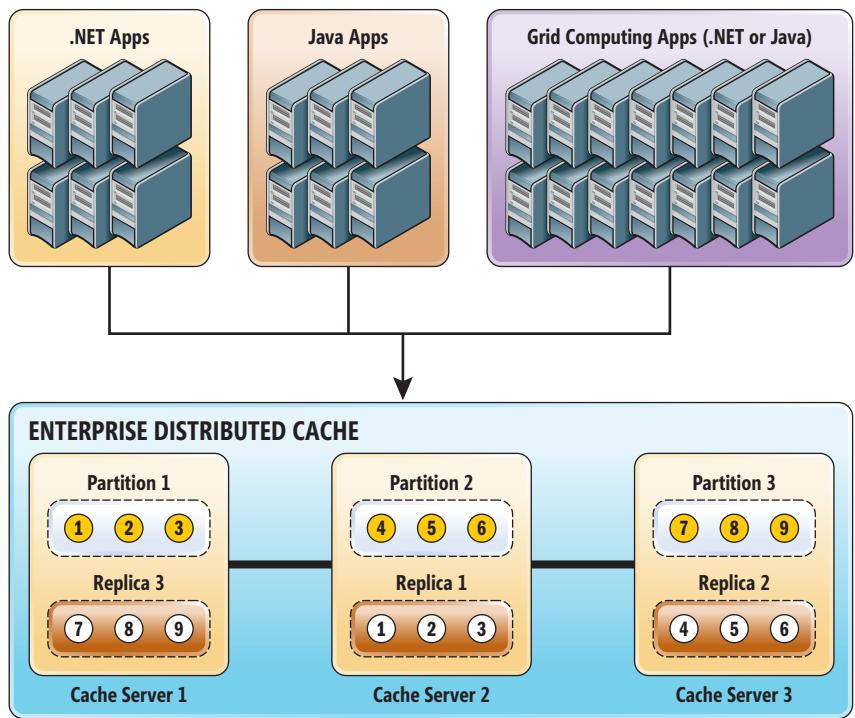


Figure 7 Partitioned-Replication Topology for Reliable Scalability

adding more servers to the dynamic cluster. But scalability can't be achieved unless data in the distributed cache is stored intelligently. This is accomplished through data partitioning, with each partition replicated for reliability.

Thanks to the enterprise distributed cache, you're allowed to exploit the benefits of a partitioned topology for scalability. **Figure 7** shows a partitioned-replication topology.

An enterprise distributed cache automatically partitions all data you're storing in the cache. Every partition is stored on a different server, and a backup for this partition is created and stored on yet another server. This ensures that if any server goes down, no data is lost.

An enterprise distributed cache is extremely fast and scalable by design.

So, to summarize, partitioning allows you to keep adding more cache servers to the dynamic cluster to grow storage capacity, and it also increases the transaction-per-second capacity as you add more servers. And replication ensures reliability of data because no data loss occurs if a server goes down.

### Capable and Collaborative

Wrapping up, an enterprise distributed cache is an ideal way for high-transaction .NET and Java applications to share data with other apps. It ensures that data sharing is done in real time because of its powerful event propagation mechanisms, including item-based event notification, application-generated custom event notifications and continuous query-based event notifications.

An enterprise distributed cache is extremely fast and scalable by design. It's fast because it's in-memory. It's scalable because it can grow into multiple servers. It partitions the actual storage and stores each partition on a different server, and it stores a backup of that partition onto yet another server, like a RAID disk.

Today's applications need to be much more capable than in the past. They need to work in a more collaborative fashion to share data and interact with one another. They need to be exceedingly fast while meeting the needs of extremely high loads to avoid compromising performance and scalability. Moreover, they must perform across different platforms so

.NET applications can transparently and effectively work with Java apps. An enterprise distributed cache helps meet all these goals. ■

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Stefan Schackow



The banner for the Microsoft Dynamics AX Technical Conference 2011 features the Microsoft Dynamics AX logo at the top left. The main title "TECHNICAL CONFERENCE 2011" is prominently displayed in large white letters. Below the title is a photograph of two men in a conference setting, one in a blue shirt and glasses, the other in a red shirt and glasses, both looking towards the right. A blue banner across the middle of the photo contains the words "Learn | Inspire | Innovate". At the bottom of the banner, the dates "January 17 - 20, 2011 • Redmond, WA" are displayed. To the right of the banner, a text block reads: "The Microsoft Dynamics AX team has been hard at work developing our most innovative release to date. We are inviting our partners and customers to Redmond to experience the product pre-release." Below this, another text block states: "Microsoft Dynamics AX provides industry solutions for customers by bringing together a breadth of Microsoft products and technologies, including:" followed by logos for Office, SharePoint Server 2010, Visual Studio 2010, Windows Server 2008 R2, Microsoft SQL Server 2008 R2, and Microsoft .NET. A call-to-action section at the bottom right encourages attendees to "Experience How. Get Involved." with links to the conference website and email address.

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# Building a Real-Time Transit Application Using the Bing Map App SDK

Luan Nguyen

During the Tech•Ed 2010 conference in June, Microsoft announced the availability of the free Bing Map App SDK, which enables developers to write map-centric applications on top of the Bing Maps explore site located at [bing.com/maps/explore/](http://bing.com/maps/explore/).

This presents ample opportunities for organizations, businesses or hobbyists to create their own mapping experiences within Bing Maps. Businesses can write apps to advertise their products or to complement their online services. For example, [bestparking.com](http://bestparking.com) developed a “Parking finder” app, which helps you find all parking facilities in your city using their database.

#### This article discusses:

- Downloading the Bing Map App SDK
- The One Bus Away API
- Defining a map entity
- Writing a plug-in
- Using a layer to show content and pushpins
- Testing, debugging and submitting a map app

#### Technologies discussed:

The Bing Map App SDK

#### Code download available at:

[code.msdn.microsoft.com/mag201010BingMap](http://code.msdn.microsoft.com/mag201010BingMap)

To see what a map app looks like, go to the Bing Maps explore site and click on the MAP APPS button located near the bottom left corner of the page. The Map apps gallery will open, showing the available apps. There are already many apps featured in the gallery, and it continues to grow.

In this article, I'll describe what it takes to write a map app using the Bing Map App SDK. I'll walk you through the development of a sample app that shows real-time bus arrival information around King County in Washington state. This app is inspired by the popular One Bus Away app.

#### The Final Product

Before I delve into code, let's take a look at what the final map app will look like. When activated, if the map is zoomed into the King County area, my map app will show in the left panel the list of all bus stops within the map viewport (see **Figure 1**).

Each bus stop has information about all buses serving that stop. Clicking on the “Arrival times” hyperlink for each stop will bring up the second panel, which displays upcoming arrival times (see **Figure 2**).

The app also places a visually appealing pushpin (marked with the letter B) at every bus stop on the map. You can interact with the pushpins to activate a pop-up, from which you can invoke common commands for a particular bus stop, such as getting driving or walking directions to or from it (see **Figure 3**).

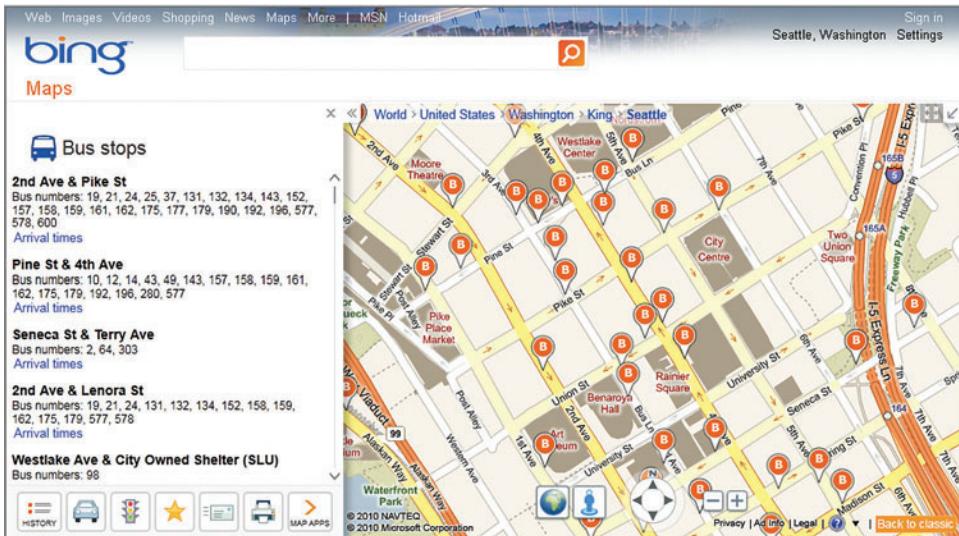


Figure 1 The OBA App Shows Bus Information on the Left Panel and Pushpins on the Map

## Download the Bing Map App SDK

Before starting to write your first map app, you need to install the Bing Map App SDK at [connect.microsoft.com/bingmapapps](http://connect.microsoft.com/bingmapapps). The SDK provides the reference assemblies, one sample project and offline documentation. In addition, because the SDK is based on Silverlight 4, you also need to install the Silverlight 4 Tools for Visual Studio 2010, available at [silverlight.net/getstarted/](http://silverlight.net/getstarted/).

## Map App Basics

The Bing Maps explore site was built with extensibility as one of the top priorities. The Bing Maps team wanted to enable developers around the world to easily add functionality that they would find useful and that would be potentially useful to others. In that sense, a *map app* is a concrete feature that makes use of the building block services provided by the core of Bing Maps. If you look at the default Bing Maps site, the driving directions, business search and location search features are all built from the same building blocks.

With that goal in mind, the Bing Maps team decided to build an extensible framework to support the concept of map apps. When written on top of the framework, map apps take advantage of a dependency injection-style approach to provide access to functionality, similar to that found in the Managed Extensibility Framework (MEF).

At the core of the framework is the concept of plug-ins. A plug-in is a unit of extensibility that allows developers to add features in a maintainable, decoupled way. It can be thought of as the equivalent of a composable part in MEF terminology. Through attributes, a plug-

in declares the imports it needs as well as exports it wants to share. At run time, the framework will resolve dependencies among plug-ins and match the imports with the exports of the same contract.

To write a map app, you create a Silverlight 4 class library that contains exactly one subclass of the base *Plugin* class. In order to do anything useful, your plug-in will likely import a number of built-in contracts that allow you to access various core services. The SDK documentation has a section listing all of the built-in contracts exported by the framework.

To reference the *Plugin* class and all built-in contract types, your project will need to reference the provided assemblies from the SDK. **Figure 4** briefly describes these four assemblies.

## Access the One Bus Away API

To obtain real-time bus arrival information, I'll be making use of the publicly available One Bus Away REST API (simply referred to as Oba API for the rest of this article). You'll find details about the Oba API at [code.google.com/p/onebusaway/wiki/OneBusAwayRestApi](http://code.google.com/p/onebusaway/wiki/OneBusAwayRestApi). (Note that the API is currently free for noncommercial use, but you're required to register for an application key before you can access it. In the downloadable code for this article, I've removed the key assigned to me, so if you want to compile and try the app yourself, you need to replace it with your own key.)

When a Silverlight application tries to access a Web service on a different domain, the Silverlight runtime mandates that the service must explicitly opt in to allow cross-domain access. A service indicates its consent by placing either a *clientaccesspolicy.xml* or *crossdomain.xml* file at the root of the domain where the service is hosted. More details regarding the schemas of these two files are documented at [msdn.microsoft.com/library/cc197955%28VS.95%29](http://msdn.microsoft.com/library/cc197955%28VS.95%29). Luckily, the Oba API provides the *crossdomain.xml* file, which allows my map app to call it in Silverlight code.

In the downloadable solution, you'll see two library projects, *ObaApp* and *ObaLib*. *ObaApp* is the main project, which contains the map app plug-in, and it references

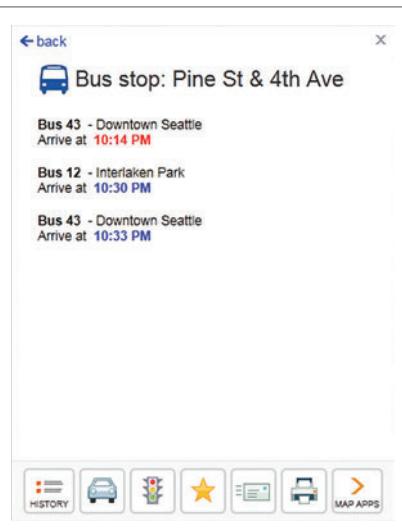


Figure 2 Bus Arrival Times for a Particular Bus Stop



Figure 3 Clicking on a Pushpin Shows a Pop-Up UI with Extra Information

Figure 4 Reference Assemblies for a Map App Project

Assembly Name	Description
Microsoft.Maps.Plugins.dll	Contains the base Plugin class and related Import/Export attribute classes.
Microsoft.Maps.Core.dll	Contains all the contract types that Bing Maps provides.
Microsoft.Maps.MapControl.Types.dll	Contains the types required for working with the map control.
Microsoft.Maps.Extended.dll	Contains the types to interact with the StreetSide map mode.

ObaLib. ObaLib is another class library project that encapsulates all helper classes to communicate with the Oba API. I made it a separate library so I can easily reuse it in different projects if I need to. I won't go into the details of every class in this library, but you're encouraged to examine the source code to learn more about the classes in there.

The most important class to know is the ObaSearchHelper class, which provides convenient methods and events to make queries to the Oba API:

```
public sealed class ObaSearchHelper
{
    public void SearchArrivalTimesForStop(string stopId);
    public event EventHandler<BusTripsEventArgs>
        SearchArrivalTimesForStopCompleted;

    public void SearchStopsByLocation(double latitude, double longitude,
        double radius, int maxResultCount);
    public event EventHandler<BusStopsEventArgs>
        SearchStopsByLocationCompleted;

    // more method/event pairs
    // ...
}
```

It's easy to spot the pattern used in this class. For every REST endpoint of the Oba API, there's one method to trigger the search and one corresponding event to signal the completion of that

Figure 5 The BusStopEntity Class

```
public class BusStopEntity : Entity
{
    private readonly DependencyProperty NamePropertyKey =
        Entity.RetrieveProperty("Name", typeof(string));

    private BusStop _busStop;

    // Short name of this bus stop
    public string Name
    {
        get { return _busStop.Name; }
    }

    // Unique id of this bus stop
    public string StopId
    {
        get { return _busStop.Id; }
    }

    public BusStopEntity(BusStop busStop,
        PushpinFactoryContract pushpinFactory)
    {
        _busStop = busStop;

        // Set the location of this Entity
        Location location =
            new Location(_busStop.Latitude, _busStop.Longitude);
        this.Primitive = pushpinFactory.CreateStandardPushpin(location, "B");

        // Set the name of this Entity
        this.SetValue(NamePropertyKey, _busStop.Name);
    }
}
```

search. Subscribers of the events can obtain the results from event argument objects.

With this handy class ready, let's dissect the main classes in the ObaApp project.

You can interact with the pushpins to activate a pop-up, from which you can invoke common commands for a particular bus stop, such as getting driving or walking directions to or from it.

## Define the Map Entity

The first thing you need to do when writing a map app is to define your map entity. Here's the definition of entity from the SDK documentation: "An Entity is a geo-associated item on the map. A map entity can be a point, a polyline, a polygon or an image overlay." The simple rule of thumb is that if you want to place *something* on the map, you need an instance of Entity to represent it. Usually, you want to create a subclass of Entity to add extra properties and custom logic for your entities. In my app, because I want to show the locations of bus stops, I wrote a BusStopEntity class to represent a bus stop. **Figure 5** shows the BusStopEntity class.

My BusStopEntity class exposes two properties, Name and StopId, which I'll later use to data-bind to UI controls. These values come from the underlying BusStop instance. Defined in the ObaLib project, the BusStop class encapsulates data of a bus stop, which it gets from the Oba API.

In the constructor, I also set the Primitive and the Name properties. The Primitive property represents the type (for example, point, polygon or polyline) and location of my entity. I set the location to the longitude and latitude values of the BusStop instance. In addition, setting the Primitive property to the returned value of PushpinFactoryContract.CreateStandardPushpin gives my entity the look and feel of the standard Bing Maps pushpins. The PushpinFactoryContract type provides handy methods for creating common pushpin UI elements. You don't have to use it if you want to create your own custom pushpin shapes. Here I just simply put a letter B (for bus) inside the pushpin, but you can use an image or any UIElement.

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**Figure 6 Imports Declared in ObaPlugin Class**

```
public class ObaPlugin : Plugin
{
    #region Imports

    [ImportSingle("Microsoft/LayerManagerContract", ImportLoadPolicy.Synchronous)]
    public LayerManagerContract LayerManager { get; set; }

    [ImportSingle("Microsoft/PopupContract", ImportLoadPolicy.Synchronous)]
    public PopupContract PopupContract { get; set; }

    [ImportSingle("Microsoft/ConfigurationContract",
        ImportLoadPolicy.Synchronous)]
    public ConfigurationContract ConfigurationContract { get; set; }

    [ImportSingle("Microsoft/MapContract", ImportLoadPolicy.Synchronous)]
    public MapContract Map { get; set; }

    [ImportSingle("Microsoft/PushpinFactoryContract",
        ImportLoadPolicy.Synchronous)]
    public PushpinFactoryContract PushpinFactory { get; set; }

    [ImportSingle("Microsoft/ContributorHelperContract",
        ImportLoadPolicy.Synchronous)]
    public ContributorHelperContract ContributorHelper { get; set; }

    #endregion
```

Although I define the Name property in my subclass, it won't be recognized by other types in the SDK—those types simply have no knowledge of my property. Therefore, I also set the same value to the Name dependency property, which I retrieve via the call Entity.RetrieveProperty("Name", typeof(string)). By doing this, I enable other features to retrieve the name of a bus stop entity.

## Write the Main Plug-in

As explained earlier, you need a Plugin-derived class to represent your map app. **Figure 6** shows mine, which is aptly named ObaPlugin. My plug-in imports a total of six contracts. Notice that all contracts provided by Bing Maps follow the naming convention of Microsoft/\*. The SDK documentation provides detailed descriptions of all contracts that can be imported, shown in **Figure 7**.

**Figure 7 Contracts Imported by the ObaPlugin**

Contract Type	Description
LayerManagerContract	Allows a plug-in to add or remove map layers.
PopupContract	Allows a plug-in to show the pop-up UI when user hovers or clicks on the entities/pushpins.
ConfigurationContract	Allows a plug-in to dynamically load configuration values from the configuration file at run time.
MapContract	Allows a plug-in to control the map.
PushpinFactoryContract	Allows a plug-in to render standard pushpins for its entities.
ContributorHelperContract	Allows a plug-in to create asynchronous or demand-load contributors. (I'll use this helper to add "Driving directions" and "StreetSide" contributor links to my pop-up later.)

After declaring the imports, I override the virtual Initialize method:

```
public override void Initialize()
{
    // Obtain the application key from configuration file
    IDictionary<string, object> configs =
        ConfigurationContract.GetDictionary(this.Token);
    string appKey = (string) configs["ApplicationKey"];
    _searchHelper = new ObaSearchHelper(appKey);
    _searchHelper.SearchStopsByLocationCompleted +=
        OnSearchBusStopsCompleted;
    _searchHelper.SearchArrivalTimesForStopCompleted +=
        OnSearchArrivalTimesComplete;

    // Update the bus stop every time map view changes
    Map.TargetViewChangedThrottled += (s, e) => RefreshBusStops();
}
```

The Bing Maps explore site was built with extensibility being one of the top priorities.

This method is called exactly once after the plug-in instance is constructed and all the declared imports are satisfied. This is the perfect place to do any initialization work that depends on the imported contracts. If your plug-in has any exports, you also have to make sure all the exported properties are fully instantiated by the time Initialize returns.

I first obtain the application key from the configuration file via the imported ConfigurationContract instance and pass it to the ObaSearchHelper constructor. By putting the application key in the configuration file, I can easily change it at any time without recompiling my project.

The second thing I do is hook up the event TargetViewChangedThrottled from the MapContract instance. This event is raised every time the map's view is about to change, either programmatically or through user interaction. As the name suggests, the event is throttled internally so that it doesn't fire too many times within a short duration. Therefore, it's a perfect event to consider if you want to keep your entities in sync with the map view. In my case, I call the RefreshBusStops method to refresh the list of bus stops. Here's the definition of RefreshBusStops:

```
internal void RefreshBusStops()
{
    if (Map.ZoomLevel >= 14)
    {
        // Search within the radius of 1km, maximum 150 results
        _searchHelper.SearchStopsByLocation(
            Map.Center.Latitude, Map.Center.Longitude, radius: 1000, 150);
    }
    else
    {
        // Clear all bus stops
        ClearBusStops();
    }
}
```

Here, I check that the current map zoom level is at least 14, then I issue a call to the SearchStopsByLocation method, which will return the list of all bus stops within a specified radius around the map center. Otherwise, if the zoom level is less than 14, meaning the map is not zoomed in close enough to the city level, I clear out all bus stops.



VISUAL STUDIO PARTNER PROFILE

# A Visual Studio 2010 Q&A with Pamela Szabo of Stone Bond Technologies

## **Q** What is Enterprise Enabler®?

**A** Enterprise Enabler is our established agile integration software platform that automates complex bi-directional data aggregation, transformation and migration of entities among multiple line of business applications.

## **Q** What makes Enterprise Enabler® different?

**A** I think it is the holistic view in Enterprise Enabler of all the different aspects of integration. It is designed to cover the full range of needs and possibilities in a single environment. Our grass roots transformation engine that we built from the ground up, is not an off the shelf XSLT engine, which we have as well, but ours is far more flexible. It gives us the capability with our AppComm [Not Adapter] technology, to reach out to applications live and "talk" among the different applications that we're connecting. We do both: reading or writing and can align the data, so in the end we've got virtual relationships without having to stage data anywhere.

## **Q** You call Enterprise Enabler "Agile Integration Software", what is that?

**A** That is really the end result of this holistic approach, characterized by 10 key points:

1. Off-the-shelf
2. Can create virtual relationships
3. Has embedded code editors and compilers
4. Has Design Time Validation
5. Has a transformation engine that is not limited to XML formats
6. A Single environment for development, testing, deployment and monitoring
7. Data Workflow logic
8. Secure, Auditable environment
9. Embeddable in software applications
10. Integration infrastructure change management



Pamela Szabo

Executive Vice President & CTO  
Stone Bond Technologies

[www.agileintegrationsoftware.blogspot.com](http://www.agileintegrationsoftware.blogspot.com)

## **Q** What is different for programmers?

**A** We don't want them to have to keep doing the same thing over and over again, so we have automated most every repeatable task, allowing the programmers to be innovative and do other things. Our Users love that they don't have to keep doing the same tedious tasks. Instead of wasting time, they can enhance the tools or extend it or drop in their own code, it becomes one with them in their environment. So it becomes their tool to do whatever they want with. Everything from building composite applications, to ecommerce and so forth. They even create their own reusable components they can drop into compilers right from the User Interface they are already working in.

## **Q** What systems and applications can Enterprise Enabler extend connectivity for?

**A** Enterprise Enabler can be embedded in applications like ADO.Net, WSS, SharePoint 2010 and connect with systems like SAP, SalesForce, SQL, Oracle DB2, EDI. You name it, the product can codelessly connect!

## **Q** What business value does Enterprise Enabler bring to an organization?

**A** There are so many benefits with Enterprise Enabler. For example, it eliminates the need for staging databases by providing real-time access to data aligned and merged from multiple sources. It also improves business decision-making by enhancing the capability of dashboards, business intelligence, analytics and SharePoint. The bottom line is a huge savings in resources and time to generate complex integration.

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**Figure 8 Handler for the SearchBusStopsCompleted Event**

```
private int _searchCount;
private Dictionary<BusStop, int> _busStopCache =
    new Dictionary<BusStop, int>();
private ObaLayer _layer;

private void OnSearchBusStopsCompleted(object sender, BusStopsEventArgs e)
{
    _searchCount++;

    // Contains new bus stops not present in the current view
    Collection<BusStopEntity> addedEntities =
        new Collection<BusStopEntity>();
    foreach (BusStop stop in e.BusStops)
    {
        // If this bus stop is not in the cache, it is a new one
        if (!_busStopCache.ContainsKey(stop))
        {
            addedEntities.Add(new BusStopEntity(stop, PushpinFactory));
        }

        // Marks this bus stop as being in the current search
        _busStopCache[stop] = _searchCount;
    }

    // Contains the old bus stops
    // that should be removed from the current view
    Collection<BusStopEntity> removedEntities =
        new Collection<BusStopEntity>();
    foreach (BusStopEntity bse in _layer.Entities)
    {
        // This bus stop belongs to the previous search,
        // add it to removed list
        if (_busStopCache[bse.BusStop] < _searchCount)
        {
            removedEntities.Add(bse);
            _busStopCache.Remove(bse.BusStop);
        }
    }

    // Tells the layer to add new in-view entities
    // and remove out-of-view ones
    _layer.RefreshEntities(addedEntities, removedEntities);
}
```

When the `SearchStopsByLocation` method completes (asynchronously), it raises the `SearchStopsByLocationCompleted` event, shown in **Figure 8**, which I subscribed to earlier in the `Initialize` method.

Note the object of type `ObaLayer`, which I'll explain in the next section. For now, suffice it to say that this object is responsible for managing the left panel's content and entities on the map.

Notice that I use a `Dictionary<BusStop, int>` object to help me keep track of the current list of displayed bus stops. With the help of this dictionary, every time I get a brand-new set of bus stops from the service call, I can quickly determine the new stops that aren't already shown, as well as the old stops that are now out of view due to the map view change.

You may wonder why I don't just clear out all current bus stops and show the new set of bus stops altogether. Well, the reason is performance. If I did so, I'd force all the pushpin controls to be re-created even if many of them were at the same location in both the old and new map views. Even worse, users would see a short flash when the pushpins were removed and quickly added back. My approach eliminates both of these shortcomings.

## Show Content and Pushpins with a Layer

The Plugin class represents your map app, but if you want to show UI representations of it, you need to create *layers*. A layer is

an abstract concept that allows you to place entities on the map as pushpins (or polylines, or polygons) and to show custom UI content on the left panel. Optionally, it can also place an arbitrary UI overlay on top of the map, but I don't need that for my app. Most apps have only one layer.

If you've used Photoshop, you'll find the concept very similar to Photoshop layers. The History button (located at the bottom left corner of the page) shows the list of all currently loaded layers. You can choose to show or hide any layer, or you can set a layer to become active. When a layer becomes active, its `Panel` UI element is shown in the left panel and all of its entities are brought forward in the z-index stack.

In code, a layer is a subclass of the abstract `Layer` class. As shown in **Figure 9**, `ObaPlugin` creates and manages an instance of the `ObaLayer` class, which derives from `Layer`.

A plug-in is a unit of extensibility  
that allows developers to add  
functionalities in a maintainable,  
decoupled way.

In the constructor of `ObaLayer`, I set the title of my layer, which will show at the top of the left panel. I also set the `Panel` property to an instance of the `BusStopsPanel` user control, which will occupy the entire left panel region if my layer becomes active. The user control's `DataContext` property is set to an instance of `ObservableCollection<Entity>`.

So how does the layer get displayed? That's done by `ObaPlugin` as shown in **Figure 10**.

The override `Activate` method is called every time my map app is activated through the Map apps gallery. To show my layer, I refer to the `LayerManagerContract` type I imported earlier. The `LayerManagerContract` class defines methods to work with layers. If my

**Figure 9 ObaLayer Class**

```
internal class ObaLayer : Layer
{
    private ObaPlugin _parent;
    private BusStopsPanel _resultPanel;
    private ObservableCollection<BusStopEntity> _busStopEntities;

    public ObaLayer(ObaPlug-in parent) : base(parent.Token)
    {
        _parent = parent;

        // Contains the set of active bus stop entities
        // for data binding purpose
        _busStopEntities = new ObservableCollection<BusStopEntity>();
        _resultPanel = new BusStopsPanel(parent, this);
        _resultPanel.DataContext = _busStopEntities;

        this.Title = "Bus stops";
        this.Panel = _resultPanel;
    }
    ...
}
```

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**Figure 10 ShowResultLayer Method Shows the ObaLayer Instance to the User**

```
public override void Activate(IDictionary<string, string>
activationParameters)
{
    ShowResultLayer();
    RefreshBusStops();
}

private void ShowResultLayer()
{
    if (_layer == null)
    {
        _layer = new ObaLayer(this);
    }

    if (LayerManager.ContainsLayer(_layer))
    {
        LayerManager.BringToFront(_layer);
    }
    else
    {
        LayerManager.AddLayer(_layer);
    }
}
```

layer is already added, I set it to active by calling the BringToFront method. Attempting to add the same layer twice results in an exception.

In [Figure 8](#), I called the ObaLayer.RefreshEntities method to update the bus stops. [Figure 11](#) shows its definition.

To add or remove an entity on the map, I use the Layer.Entities collection property. And for every new BusStopEntity, I call the PopupContract.Register method to register for the pop-up UI on my bus stop pushpin. The Register method accepts the entity and a callback method that gets invoked whenever the pop-up control changes state on the entity (see [Figure 12](#)).

Inside the pop-up callback, the method argument of PopupStateChangeContext type gives me access to the current state of the pop-up and the entity currently under pop-up. Based on those, I set the pop-up title with the bus stop name and the pop-up content with the BusStopEntity.BusRoutesAsString property, which returns a comma-separated list of bus routes serving this particular bus stop.

If the pop-up is in Normal state, I also add three contributor links to the pop-up via the Contributors collection property—the “Arrival times” contributor shows the arrival times for this bus stop, the Directions contributor invokes the driving directions feature and the Streetside contributor switches to street-level map mode.

A contributor is represented by a hyperlink at the bottom of the pop-up control. It allows map apps to invoke a certain core feature of Bing Maps. To generate contributors, you call one of the two methods of the ContributorHelperContract type: CreateAsyncContributor or CreateDemandLoadContributor. Both methods return a proxy contributor synchronously and defer the loading of the real contributor instance. The only difference is that the CreateAsyncContributor loads the real contributor as soon as it returns, whereas CreateDemandLoadContributor only does so when the proxy contributor link is invoked the first time.

## BusStopsPanel UserControl

BusStopsPanel is a UserControl, which is responsible for showing the list of in-view bus stops in the left panel (as shown in [Figure 1](#)). It contains an ItemsControl instance with the ItemTemplate

property set to a custom DataTemplate (see [Figure 13](#)). Notice that I turn on UI virtualization mode for my ItemsControl by setting the ItemsPanel property to use a VirtualizingStackPanel. Generally, it's a good practice to apply UI virtualization to ItemsControl if your app may load hundreds of items into it.

Inside the bus stop DataTemplate I added a HyperlinkButton control, which, when clicked, will trigger the search for the arrival times of the corresponding bus stop:

```
private void OnBusStopClick(object sender, RoutedEventArgs e)
{
    FrameworkElement element = (FrameworkElement)sender;
    BusStopEntity entity = (BusStopEntity)element.DataContext;
    _plugin.SearchArrivalTimes(entity);
}
```

Notice that its Style property is set to an object from the StaticResource collection, with the key as “App.P2.Hyperlink.” Bing Maps provides a default set of UI resources, such as Styles and ControlTemplates of common controls, as well as standard Colors and Brushes used by Bing Maps itself. Map app authors are encouraged to apply these resources to their UI elements so they have the same look and feel as native UI elements. Refer to the documentation for all the resources provided by Bing Maps.

SearchArrivalTimes is an internal method of the ObaPlugin class. It calls the ObaSearchHelper.SearchArrivalTimesForStop method to retrieve arrival times for the specified bus stop:

```
internal void SearchArrivalTimes(BusStopEntity _entity)
{
    _searchHelper.SearchArrivalTimesForStop(_entity.StopId, _entity);
}
```

When the search completes, the plug-in will instruct ObaLayer to show the arrival times in the left panel. ObaLayer does so by dynamically changing its Title and Panel properties.

## Testing and Debugging the Map App

When you're done coding, you'll want to test your app. The Bing Maps site has a developer mode that's enabled by appending a “developer=1” query parameter to the URL, like this: <http://www.bing.com/maps/explore/?developer=1>. When in developer mode, you test your map app with the “Map app test tool,” which can be activated via the

**Figure 11 The ObaLayer.RefreshEntities Method Definition**

```
public void RefreshEntities(
    ICollection<BusStopEntity> addedEntities,
    ICollection<BusStopEntity> removedEntities)
{
    foreach (BusStopEntity entity in removedEntities)
    {
        // Remove this pushpin from the map
        this.Entities.Remove(entity);
        // Remove this bus stop entry from the panel
        _busStopEntities.Remove(entity);
    }

    foreach (BusStopEntity entity in addedEntities)
    {
        // Add this pushpin to the map
        this.Entities.Add(entity);
        // Add this bus stop entry to the panel
        _busStopEntities.Add(entity);

        // Register this entity to have popup behavior
        _parent.PopupContract.Register(entity, OnPopupStateChanged);
    }
}
```

same Map apps gallery. The Map app test tool allows you to select the plug-in assemblies from your local hard drive. It then loads your plug-in into the site just as it does with all native plug-ins. To debug

Figure 12 Changing the State of a Pop-Up Control

```
private void OnPopupStateChangeHandler(PopupStateChangeContext context)
{
    if (context.State == PopupState.Closed)
    {
        return;
    }

    BusStopEntity entity = (BusStopEntity)context.Entity;
    context.Title = entity.Name;
    context.Content = "Bus numbers: " + entity.BusRoutesAsString;

    // Only shows contributors link in the normal state of popup
    if (context.State == PopUpState.Normal)
    {
        // Add Arrival times contributor
        context.Contributors.Add(new BusStopContributor(_parent, entity));

        Dictionary<string, object> parameter = new Dictionary<string, object>
        {
            {"Entity", entity}
        };
        var contributorHelper = _parent.ContributorHelper;

        // Add Directions contributor
        context.Contributors.Add(contributorHelper.
            CreateDemandLoadContributor(
            "Microsoft/DirectionsContributorFactoryContract",
            parameter, "Directions"));

        // Add Streetside contributor
        context.Contributors.Add(contributorHelper.CreateAsyncContributor(
            "Microsoft/StreetsideContributorFactoryContract", parameter));
    }
}
```

Figure 13 The BusStopsPanel UserControl

```
<UserControl.Resources>
<DataTemplate x:Key="BusStopTemplate">
    <Border Margin="2,0,2,12">
        <StackPanel>
            <TextBlock Text="{Binding Name}" FontSize="14" FontWeight="Bold"
                TextWrapping="Wrap" />
            <TextBlock Text="{Binding BusRoutesAsString, StringFormat='Bus numbers:
                {0}'}" FontSize="12" TextWrapping="Wrap" />
            <HyperlinkButton Content="Arrival times" Click="OnBusStopClick"
                Style="{StaticResource App.P2.Hyperlink}"
                HorizontalAlignment="Left" />
        </StackPanel>
    </Border>
</DataTemplate>

<ControlTemplate x:Key="ScrollableItemsControl">
    <TargetType="ItemsControl">
        <ScrollViewer Style="{StaticResource App.ScrollViewer}">
            <VerticalScrollBarVisibility="Auto" />
            <ItemsPresenter />
        </ScrollViewer>
    </ControlTemplate>
</UserControl.Resources>

<ItemsControl
    ItemsSource="{Binding}"
    VirtualizingStackPanel.VirtualizationMode="Recycling"
    ItemTemplate="{StaticResource BusStopTemplate}"
    Template="{StaticResource ScrollableItemsControl}">
    <ItemsControl.ItemsPanel>
        <ItemsPanelTemplate>
            <VirtualizingStackPanel />
        </ItemsPanelTemplate>
    </ItemsControl.ItemsPanel>
</ItemsControl>
```

your code, attach VS.NET to your browser while your app is loaded. Make sure you set the debug code type to Silverlight.

## Submitting Your Map App

Finally, when you're satisfied with your code, you can submit your app to be published officially onto the Bing Maps site. You can submit a new app and view the status of previous submissions at the Bing Maps Account Center ([bingmapsportal.com](http://bingmapsportal.com)). The SDK documentation has detailed instructions on submitting your app, and it lists the requirements your apps must meet in order to be approved.

## Call to Action

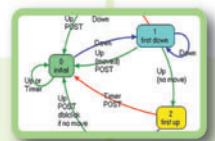
So there you have it: a full-fledged, real-time transit application that didn't require a lot of code. The SDK supplies the building blocks that make writing map-centric applications an enjoyable and rewarding experience. I encourage you to download the SDK today, learn it, and start writing your own map apps. ■

**LUAN NGUYEN** worked as a developer on the Bing Maps team (formerly known as Microsoft Virtual Earth) for almost four years. He was a member of the Shell feature team, which was responsible for the framework shell of the Bing Maps site and the Bing Map App SDK. He has recently switched to the ASP.NET team.

**THANKS** to the following technical experts for reviewing this article:  
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# Connected Devices Using the .NET Micro Framework

Colin Miller

Today, we see a proliferation of applications that include connected devices. In fact, the “Internet of Things” (devices connected over the Internet) is already estimated to be larger than the World Wide Web in terms of endpoints and is projected to grow to an order of magnitude larger in the next few years.

In the near future, we’ll be interacting with more intelligent devices instead of recognizable computers. Just look around your house. The things that can be usefully connected include your appliances (for energy management, software updates and maintenance); your

car (for coordination on recharging your new electric vehicle with the grid, automatic testing and maintenance and software updates); your irrigation system (for scheduling based on weather reports and water management); your pets (to determine their location and configure invisible fencing); your thermostat (for remote control); and much more.

These devices are connected to one another, to smart controllers, to the router and to the cloud. What does this mean for Microsoft .NET Framework developers? Right now, .NET developers can produce applications for all parts of the system to which small devices connect. And with the .NET Micro Framework, .NET developers can develop the full system right down to the small devices.

The .NET Micro Framework is an implementation of the .NET Framework specifically targeting the smallest devices possible with extensions for embedded programming needs. It runs directly on the hardware without an underlying OS in order to minimize its footprint. General information is available at [microsoft.com/netmf](http://microsoft.com/netmf) and the project’s open source community site: [netmf.com](http://netmf.com).

Several months ago, I started a series of articles on the .NET Micro Framework blog ([blogs.msdn.com/b/netmftteam](http://blogs.msdn.com/b/netmftteam)) that describes the process of building one of these small devices—a bicycle computer—from the ground up using only the .NET Micro Framework, Visual Studio and a minimal amount of electronics. I wanted to demonstrate how .NET Framework developers can build rich applications on small devices. (The first article in this series can be found at: [tinyurl.com/2dpy6rx](http://tinyurl.com/2dpy6rx).) **Figure 1** shows the actual computer. I picked a bicycle computer because everyone is a domain expert when it

## This article discusses:

- The NETMF bicycle computer open source project
- Using the Web services model to connect devices
- The Devices Profile for Web Services
- Configuring a Wi-Fi radio
- Setting up a service connection
- Using WDSL to define the service
- Generating code with MFSvcUtil.exe
- Uploading bicycle ride data

## Technologies discussed:

.NET Micro Framework

## Code download available at:

[code.msdn.microsoft.com/mag201010Micro](http://code.msdn.microsoft.com/mag201010Micro)

comes to bicycles. The application includes a gesture-based UI, supports a number of sensors and addresses issues like managing the battery power supply.

The blog discusses each feature's implementation, and the code for the project is available on CodePlex at [netmfbikecomputer.codeplex.com/](http://netmfbikecomputer.codeplex.com/). However, I saved the best for last—in this article, I'm going to connect this device to a Microsoft Windows Azure-hosted Web service over Wi-Fi. Here's the scenario: you've just finished your ride and brought your bike into the garage. Your computer contains data it collected during your ride: distance, speed, cadence, incline, time and so on. You flip over to the data view and press the Upload button. The data for your ride is uploaded to the cloud, where it can be aggregated with all your other rides and shared with your friends.

In this article, I'll focus on making the connection and uploading the data rather than discussing the form of the cloud service to which you might connect. Check out examples like [bikejournal.com](http://bikejournal.com) and [cyclistats.com](http://cyclistats.com) to see what the possibilities are for tracking your bicycling progress and competing with your friends. I'll discuss how easy it is to make that connection.

## First, a Little Background

The Web services model is great for connecting devices because it supports a full range of device and service interactions that may not be fully known at the time we create an application. On the device side, we use a subset of the full Web service infrastructure called Devices Profile for Web Services (DPWS)—see [en.wikipedia.org/wiki/Devices\\_Profile\\_for\\_Web\\_Services](http://en.wikipedia.org/wiki/Devices_Profile_for_Web_Services) to learn more about it. DPWS is described as Universal Plug and Play (UPNP) for networked devices. In the .NET Micro Framework, DPWS supports the WS-Addressing, WS-Discovery, WS-MetaDataExchange and WS-Eventing interfaces, and is built on the underlying technologies of SOAP, XML, HTTP, MTOM and Base64 encoding.

With DPWS, you can connect to devices that are clients (devices that consume services from others), or servers (devices that provide services for others) or both. You can negotiate what you provide and what you can consume through the metadata, and you can publish and subscribe to notifications of changes in other entities. **Figure 2** shows the DPWS stack.

The implementation in the .NET Micro Framework supports DPWS version 1.0—which is compatible with Windows 7—and DPWS version 1.1—which is compatible with Windows Communication Foundation (WCF) 4. You can specify the binding you use for your connection: for example, SOAP over HTTP (ws2007HttpBinding) or a custom binding that you want to support.



Figure 1 The NETMF Bicycle Computer

Our application for the bicycle computer is really pretty simple—we'll just be uploading data to the cloud. DPWS can actually do so much more. For example, let's say my utility company installs a smart service meter that limits the resources I can use at any specific time. Along with that, I install a local energy management service that gives me control over how I use those limited resources. I can set priorities and heuristics that allow the system to make decisions about how to limit consumption—for example, hot water for showers has a high priority.

Now I go out and buy a new dishwasher. I bring it home and plug it in. In the background, the dishwasher finds the local network and “discovers” the management service. It informs the service of its power consumption in various states and rules for

how it can be used. Later, when the dishwasher is running, I jump in the shower and the hot water heater comes on. But once I start the dishwasher, I don't want it to just turn off and have the food harden on the plates. To cut total consumption, the management service tells the dishwasher to just rinse the dishes every 15 minutes to keep them from drying out, and to resume where it left off in the washing cycle when I'm done with the shower. As you can see, this entire scenario can support an arbitrary set of endpoints with the functionality defined in DPWS.

## Enough Background—Let's Make It Work

Configuring the Wi-Fi radio is easy enough. There are two ways to do this—one uses the MFDDeploy.exe utility, and the other is a programmatic interface supported by the GHI SDK (from GHI Electronics). Let's start with MFDDeploy.exe, which is a tool that comes with the .NET Micro Framework and can be found in the tools section of the SDK installation. In the Target | Configuration | Network Configuration dialog box (see **Figure 3**), I enable DHCP,

select the security mechanism and enter the pass phrase and other configuration aspects of my home network.

DHCP will take care of filling in the Gateway and DNS field of the network settings. This information is available to the managed application through the NetworkInterface type and its child Wireless80211. The HTTP stack will implicitly use this information when sending and receiving bytes, but it might need an additional piece of information to enable using a proxy—something your network might require. To help the HTTP stack use the proxy correctly, it's advisable to add the following to a program as a further hint as to where to connect:

```
WebRequest.DefaultWebProxy =  
    new WebProxy("<router IP Address>");
```

If there's no explicit proxy role in your network, you can usually default to using the Gateway

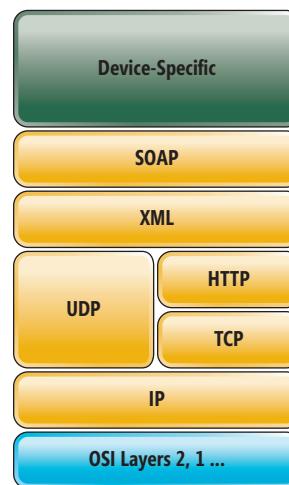


Figure 2 The DPWS Stack

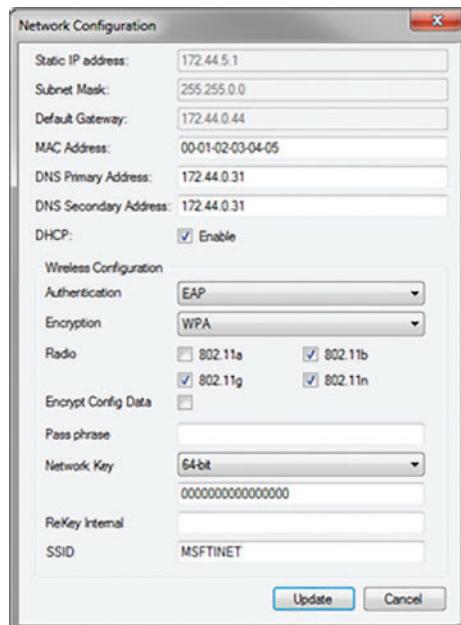
address. With the GHI programmatic interface, you use some derivative of the code shown in **Figure 4**.

The **Figure 4** example assumes that you're using WPA or WPA2 security. WEP is also supported. The first thing you do is identify the SPI port and control lines used by the radio. This configuration represents the connections for the hardware, a FEZ Cobra board from GHI. All that's required is to set up the WiFiSettings, save the configuration and call EnableDHCP. Notice that some of these calls are blocking, and this can take some time, so you'll need to ensure that the user knows what's happening. Also, there's no way in this programmatic interface to enumerate the available networks so you can select from them. I hard-coded the network information in the **Figure 4** example.

For a commercial implementation of the bicycle computer, I need to write an integrated Wi-Fi configuration UI that exposes the information entered into the dialog shown in **Figure 3**, and an onscreen keyboard to enter it. I may have time to write this up in another blog article before this article is published. I'm working on a Time Service article that shows how to use the Wi-Fi connection to get the date and time when I start up the computer so that I don't have to keep the device running to maintain that information or have the user (me) enter it on startup.

## Setting up the Service Connection

All that remains is the DPWS implementation. As a reminder, I'm going to focus on the device side. The Windows Azure service I'm using provides a simple "Hello World" template. I start with this and



**Figure 3** The MFDeploy Network Configuration Dialog

extend the contract by adding the fields that I need to store and the operations by writing the UpLoad and Get operations. This creates a service that can accept my data, store it and give me back the last data stored. Obviously, a full service requires much more work, but that's another article. Let's look briefly at the contract created for this service. The ServiceContract contains the two operations and the DataContract contains the fields (see **Figure 5**).

The actual implementation of the contract is minimal to support the bicycle computer example (see **Figure 6**).

## The WSDL Defines the Service

From the contract and schema that I created, the Windows Azure service auto-generates a Web Service Definition Language (WSDL) file. It contains the Service Modeling Language (SML) definition of the service. The W3C specification for the WSDL document can be found at [w3.org/](http://w3.org/TR/wsdl)

TR/wsdl. It defines the operations and messages that the service supports. The WSDL is stored as an XML description on a Web site, where it's accessible to anyone connecting to the service. Ours can be found at [netmfbikecomputerservice.cloudapp.net/BikeComputerService.svc?wsdl](http://netmfbikecomputerservice.cloudapp.net/BikeComputerService.svc?wsdl). **Figure 7** shows a small snapshot of the WSDL file so you can see what it looks like, but remember that this file is auto-generated and is only consumed by other programs. You don't need to ever write this complex and touchy XML.

You can see that the WSDL includes the definitions for messages for data input and output and operations for getting and uploading data. Now that we have our simple interface to the service defined and published, how do I program to that? That's pretty easy as well.

**Figure 4** Wi-Fi Configuration with the GHI Programmatic Interface

```
// -- Set up the network connection -- //
WiFi.Enable(SPI.SPI_module.SPI2, (Cpu.Pin)2, (Cpu.Pin)26);

NetworkInterface[] networks = NetworkInterface.GetAllNetworkInterfaces();
Wireless80211 WiFiSettings = null;

for (int index = 0; index < networks.Length; ++index)
{
    if (networks[index] is Wireless80211)
    {
        WiFiSettings = (Wireless80211)networks[index];
        Debug.Print("Found network: " + WiFiSettings.Ssid.ToString());
    }
}

WiFiSettings.Ssid = "yourSSID";
WiFiSettings.PassPhrase = "yourPassphrase";
WiFiSettings.Encryption = Wireless80211.EncryptionType.WPA;
Wireless80211.SaveConfiguration(
    new Wireless80211[] { WiFiSettings }, false);

_networkAvailabilityBlocking = new ManualResetEvent(false);

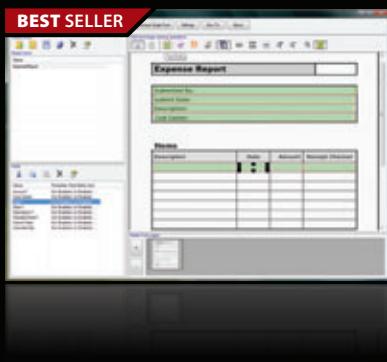
if (!WiFi.IsLinkConnected)
{
    _networkAvailabilityBlocking.Reset();
    while (!_networkAvailabilityBlocking.WaitOne(5000, false))
    {
        if (!WiFi.IsLinkConnected)
        {
            Debug.Print("Waiting for Network");
        }
        else
            break;
    }
    Debug.Print("Enable DHCP");
    try
    {
        if (!WiFiSettings.IsDhcpEnabled)
            WiFiSettings.EnableDhcp(); // This function is blocking
        else
        {
            WiFiSettings.RenewDhcpLease(); // This function is blocking
        }
    }
    catch
    {
        Debug.Print("DHCP Failed");
    }
}
```



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## Generating Code with MFSvcUtil.exe

On the desktop, there's a utility called the ServiceModel Metadata Utility Tool (SvcUtil.exe) that can generate service model code from metadata documents (like our WSDL) and vice versa. The .NET Micro Framework has a similar utility called MFSvcUtil.exe. This is a command-line tool that's best run in the project directory. So, we run it by pointing it at the published WSDL specification:

```
<SDK_TOOLS_PATH>\MFSvcUtil.exe http://netfbikecomputerservice.cloudapp.net/BikeComputerService.svc?wsdl
```

The tool generates three files (see **Figure 8**).

Remember that devices can be clients, servers or both.

The BikeComputerService.cs file contains the definition of the data in the messages, the classes defining the operations supported by the service (because our device is a client) and a number of helper functions for serializing and de-serializing the data (see **Figure 9**).

The BikeComputerClientProxy.cs file contains the proxy interfaces for the Web service:

```
namespace BikeComputer.org
{
    public class IBikeComputerServiceClientProxy : DpwsClient
    {
        private IRequestChannel m_requestChannel = null;

        public IBikeComputerServiceClientProxy(Binding binding,
            ProtocolVersion version) : base(binding, version)...

        public virtual GetLastComputerDataResponse
            GetLastComputerData(GetLastComputerData req) ...

        public virtual UploadBikeComputerDataResponse
            UploadBikeComputerData(UploadBikeComputerData req) ...
    }
}
```

The third file that MFSvcUtil.exe creates is the BikeComputerServiceHostedService.cs file; this contains the interface logic that runs on the service side of the interface. In our case, the WSDL was generated from the service and data contracts that were created, so this file is a "throw away" for us. It's generated to cover scenarios where you get a published WSDL and you want to replicate a service from it or where you want to run a service on another device. Remember that devices can be clients, servers or both. The option to have devices provide services for other devices enables some interesting applications. This is what BikeComputerServiceHostedService contains:

```
namespace BikeComputer.org
{
    public class IBikeComputerServiceClientProxy : DpwsHostedService
    {
        private IIIBikeComputerService m_service;

        public IIIBikeComputerService(IIIBikeComputerService service,
            ProtocolVersion version) : base(version) ...

        public IIIBikeComputerService(IIIBikeComputerService service) :
            this(service, new ProtocolVersion10())...

        public virtual WsMessage GetLastComputerData(WsMessage request) ...

        public virtual WSMesssage UploadBikeComputerData(WsMessage request) ...
    }
}
```

Figure 5 The Service Contract

```
[ServiceContract]
public interface IBikeComputerService
{
    [OperationContract]
    BikeComputerData GetLastComputerData();

    [OperationContract]
    void UploadBikeComputerData(BikeComputerData rideData);
}

// Use a data contract as illustrated in the sample below
// to add composite types to service operations.
[DataContract]
public class BikeComputerData
{
    DateTime _Date;
    TimeSpan _StartTime;
    TimeSpan _TotalTime;
    TimeSpan _RidingTime;
    float _Distance;
    float _AverageSpeed;
    float _AverageCadence;
    float _AverageIncline;
    float _AverageTemperature;
    bool _TempIsCelcius;

    [DataMember]
    public DateTime Date...

    [DataMember]
    public TimeSpan StartTime...

    [DataMember]
    public TimeSpan TotalTime...

    [DataMember]
    public TimeSpan RidingTime...

    [DataMember]
    public float Distance...

    [DataMember]
    public float AverageSpeed...

    [DataMember]
    public float AverageCadence...

    [DataMember]
    public float AverageIncline...

    [DataMember]
    public float AverageTemperature...

    [DataMember]
    public bool TemperatureIsInCelcius...
}
```

Figure 6 The Contract Implementation

```
public class BikeComputerService : IBikeComputerService
{
    static BikeComputerData _lastData = null;

    public BikeComputerData GetLastComputerData()
    {
        if (_lastData != null)
        {
            return _lastData;
        }
        return new BikeComputerData();
    }

    public void UploadBikeComputerData(BikeComputerData rideData)
    {
        _lastData = rideData;
    }
}
```

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```

<?xml version="1.0" encoding="utf-8" ?>
<wsdl:definitions name="BikeComputerService" targetNamespace="http://BikeComputer.org/" xmlns:wsdl="http://schemas.xmlsoap.org/wsdl/">
  xmlns:wsx="http://schemas.xmlsoap.org/ws/2004/09/mex" xmlns:wsa10="http://www.w3.org/2005/08/addressing"
  xmlns:tns="http://BikeComputer.org/" xmlns:soap12="http://schemas.xmlsoap.org/wsdl/soap12/" xmlns:wsu="http://docs.oasis-open.org/wss/2004/01/oasis-200401-wss-wssecurity-utility-1.0.xsd" xmlns:wsip="http://schemas.xmlsoap.org/ws/2004/09/policy"
  xmlns:wsap="http://schemas.xmlsoap.org/ws/2004/08/addressing/policy" xmlns:msc="http://schemas.microsoft.com/ws/2005/12/wsdl/contract"
  xmlns:wsaw="http://schemas.xmlsoap.org/ws/2004/08/addressing/wsdl" xmlns:wsam="http://www.w3.org/2007/05/addressing/metadata"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema" xmlns:soapenc="http://schemas.xmlsoap.org/soap/encoding/"/>
  wsip:Policy wsu:Id="WSHttpBinding_BikeComputerService_policy">
    wsip:ExactlyOne>
    wsip:All>
    wsaw:UsingAddressing />
  </wsip:All>
  </wsip:ExactlyOne>
  </wsip:Policy>
  wsdl:types>
    xsd:schema targetNamespace="http://BikeComputer.org/Imports">
      xsd:import schemaLocation="http://netmfbikecomputerservice.cloudapp.net/BikeComputerService.svc?xsd=xsd0" namespace="http://BikeComputer.org/"/>
      xsd:import schemaLocation="http://netmfbikecomputerservice.cloudapp.net/BikeComputerService.svc?xsd=xsd1" namespace="http://schemas.microsoft.com/2003/10/Serialization/"/>
      xsd:import schemaLocation="http://netmfbikecomputerservice.cloudapp.net/BikeComputerService.svc?xsd=xsd2" namespace="http://schemas.datacontract.org/2004/07/BikeComputerServiceWebRole/"/>
    </xsd:schema>
  </wsdl:types>
  wsdl:message name="IBikeComputerService_GetLastComputerData_InputMessage">
    wsdl:part name="parameters" element="tns:GetLastComputerData" />
  </wsdl:message>
  wsdl:message name="IBikeComputerService_GetLastComputerData_OutputMessage">
    wsdl:part name="parameters" element="tns:GetLastComputerDataResponse" />
  </wsdl:message>
  wsdl:message name="IBikeComputerService_UploadBikeComputerData_InputMessage">
    wsdl:part name="parameters" element="tns:UploadBikeComputerData" />
  </wsdl:message>
  wsdl:message name="IBikeComputerService_UploadBikeComputerData_OutputMessage">
    wsdl:part name="parameters" element="tns:UploadBikeComputerDataResponse" />
  </wsdl:message>
  wsdl:portType name="IBikeComputerService">
    wsdl:operation name="GetLastComputerData">
      wsdl:input wsaw:Action="http://BikeComputer.org/IBikeComputerService/GetLastComputerData"
      message="tns:BikeComputerService_GetLastComputerData_InputMessage" />
      wsdl:output wsaw:Action="http://BikeComputer.org/IBikeComputerService/GetLastComputerDataResponse"
      message="tns:BikeComputerService_GetLastComputerData_OutputMessage" />
    </wsdl:operation>
    wsdl:operation name="UploadBikeComputerData">
      wsdl:input wsaw:Action="http://BikeComputer.org/IBikeComputerService/UploadBikeComputerData"
      message="tns:BikeComputerService_UploadBikeComputerData_InputMessage" />
      wsdl:output wsaw:Action="http://BikeComputer.org/IBikeComputerService/UploadBikeComputerDataResponse"
      message="tns:BikeComputerService_UploadBikeComputerData_OutputMessage" />
    </wsdl:operation>
  </wsdl:portType>
</wsdl:definitions>

```

Figure 7 The WSDL File

## Uploading the Data

As you've seen, all the device application code so far has been auto-generated from the WSDL. What code do you actually have to write on the client to connect to the service and post your data and read it back just to be sure that it's been received? Just a few lines of code are required. Here's what I did in the bicycle computer project.

In the RideDataModel class, I added the following to the constructor to set up the DPWS connection:

```

public RideDataModel()
{
  _currentRideData = new CurrentRideData();
  _summaryRideData = new SummaryRideData();
  _today = DateTime.Now; //change this to the time service later.

  //--Setup the Web Service Connection
  WS2007HttpBinding binding = new WS2007HttpBinding(
    new HttpTransportBindingConfig(new Uri
      ("http://netmfbikecomputerservice.cloudapp.net/BikeComputerService.svc"))

```

```

  ));;

  m_proxy = new
    IBikeComputerServiceClientProxy(
      binding, new ProtocolVersion11());

  _upload = new
    UploadBikeComputerData();

  _upload.rideData = new
    schemas.datacontract.org.
    BikeComputerServiceWebRole.
    BikeComputerData();
}

```

Next, I created a method in that class for uploading the data to the Web service. This routine puts my summary data from the ride into the fields for the Web service schema (referenced in the WSDL and reflected in BikeComputerService.cs), which is designed to match that data. Then I invoke the proxy's UploadBikeComputerData method with the upload data and retrieve the date of the last ride on the Web service to validate that my data was received (see Figure 10).

This assumes that you take only one ride a day, so if you do take

more rides, you need to change that comparison logic. I expect to use the "Pause" feature on the bicycle computer and treat all the rides in a day as one set of data. I already have the ability to store the data in a file on an SD card on the bike as I described in a

## Navigate to the Save Your Data screen with a simple gesture.

previous article on the blog. I'll add the ability to track which sets of ride data have been posted to the Web service and post any that are missing. This allows me to be out of range of my wireless connection for some time and still be able to update the Web service

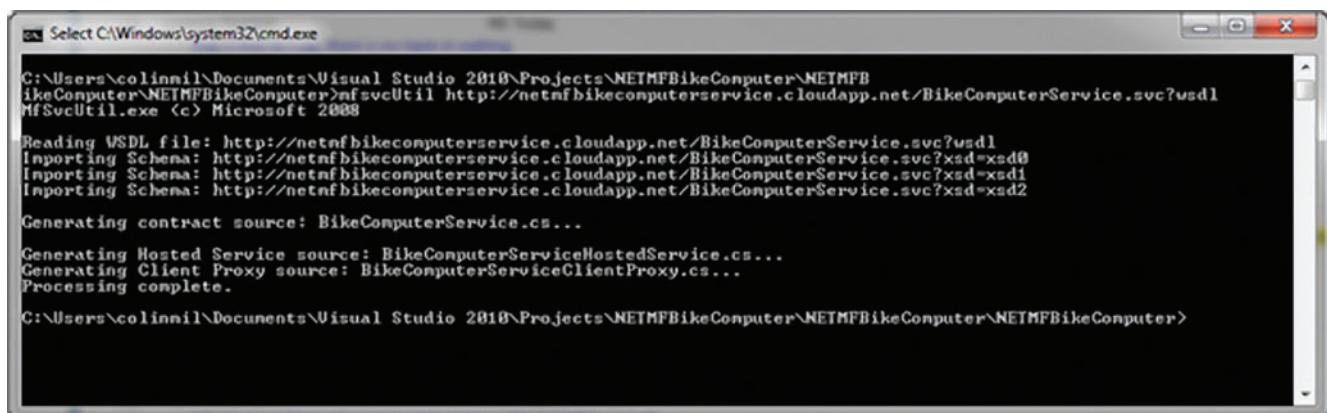
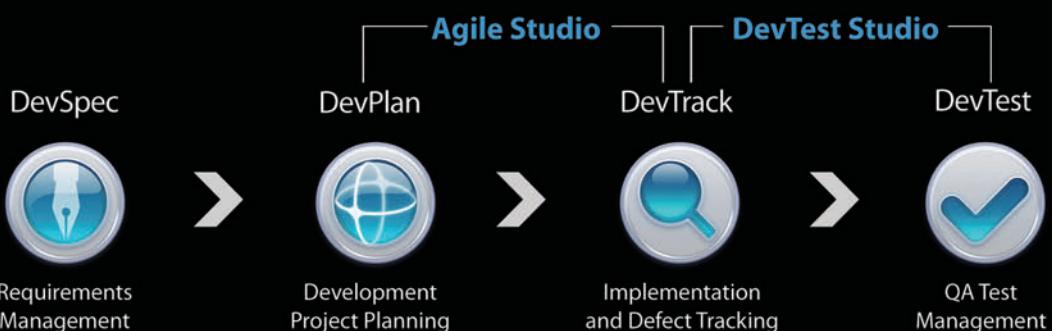


Figure 8 Executing the MFSvcUtil.exe Command

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Figure 9 The BikeComputerService.cs File

```
namespace BikeComputer.org
{
    [DataContract(Namespace="http://tempuri.org/")]
    public class GetLastComputerData ...

    public class GetLastComputerDataContractSerializer : DataContractSerializer...
        [DataContract(Namespace="http://tempuri.org/")]
        public class GetLastComputerDataResponse ...

        public class GetLastComputerDataContractSerializer : DataContractSerializer...
            [DataContract(Namespace="http://tempuri.org/")]
            public class UploadBikeComputerData ...

            public class UploadBikeComputerDataContractSerializer : DataContractSerializer...
                [ServiceContract(Namespace="http://tempuri.org/")]
                [PolicyAssertion(Namespace="http://schemas.xmlsoap.org/ws/2004/09/policy",
                    Name="ExactlyOne",
                    PolicyID="WSHttpBinding_IBikeComputerService_policy")]
                public interface IBikeComputerService ...
            }
        namespace schemas.datacontract.org.BikeComputerServiceWebRole...
```

later. Another enhancement is to enable connecting to a PC as an intermediary when my home network isn't available.

So, 17 lines of code that I wrote in the application (most of it mapping the summary data into the service schema fields) and I'm uploading data to a service and doing validity checks. Not bad.

## Now We End Our Ride Connected

At the end of a ride, as I come into my garage, I can navigate to the Save Your Data screen with a simple gesture and post my data up to the cloud.

Figure 10 Uploading Data to the Web Service

```
public bool postDataToWS()
{
    //-- Load the ride summary data into the upload fields --//

    _upload.rideData.AverageCadence = _summaryRideData.averageCadence;
    _upload.rideData.AverageIncline = _summaryRideData.averageIncline;
    _upload.rideData.AverageSpeed = _summaryRideData.averageSpeed;
    _upload.rideData.AverageTemperature =
        _summaryRideData.averageTemperature;
    _upload.rideData.Date = _summaryRideData.rideDate;
    _upload.rideData.Distance = _summaryRideData.distance;
    _upload.rideData.RidingTime = _summaryRideData.ridingTime;
    _upload.rideData.StartTime = _summaryRideData.startTime;

    //-- Upload the data --//
    m_proxy.UploadBikeComputerData(_upload);

    //-- Validate the upload by retrieving the data and comparing --//

    GetLastComputerData req = new GetLastComputerData();
    GetLastComputerDataResponse back = m_proxy.GetLastComputerData(req);

    if (back.GetLastComputerDataResult.Date == _upload.rideData.Date)
    {
        return false;
    }

    return true;
}
```

There's still some work to do at that end to make the data more useful, but that's another story.

Embedded devices have been islands of specialized technology where ease of programming and flexibility were traded off for small footprint/low-cost and high-performance requirements. More and more frequently, we're seeing small devices connected to other devices and to networks to create compelling solutions. At the same time, the price of processors and memory continues to go down to the point where we no longer have to give up the productivity of desktop tools and languages to be able to make rich and price-competitive devices. The result is that .NET programmers find themselves with both the skills and the opportunities to work on small devices.

.NET Framework  
programmers can now add  
“Embedded Programmer”  
to their business cards.

The Web services model provides a strong option for connecting these small devices, because discovering remote services, subscribing to remote events and exchanging information about services through metadata enables the flexible connection of a number of devices. The cost is that the connection—using SOAP and XML—is verbose, so it may not be appropriate in all cases.

The bicycle computer project demonstrates that .NET Framework programming skills enable you to write compelling UIs for small devices, write drivers for a variety of sensors and connect those devices with the cloud. As I showed you, the work involves defining the Web service, and the majority of the code that runs on the device is auto-generated by MFSvcUtil.exe. Just a few lines of additional code were required to upload the data. Other applications may require probing for the Web service (WS\_Discovery), or subscribing to events on other endpoints (WS\_Eventing), or dealing with devices and services of varying capabilities (WS\_MetaDataExchange). All of these can be added to the basic data exchange model as needed.

As a friend of mine once commented, .NET Framework programmers can now add “Embedded Programmer” to their business cards. We'd love to hear about the devices that you build with .NET on the Discussions at [netmf.com](http://netmf.com), where I can also answer any questions that you have on this article or on the blog site.

Happy riding!

---

**COLIN MILLER** started his affair with computing as a scientific programmer, building 8- and 16-bit experimental control systems. He strayed from small devices, working for 25 years (including 15 at Microsoft) on PC software including databases, desktop publishing, consumer products, Word, Internet Explorer, Passport (LiveID) and online services. As the product unit manager of the .NET Micro Framework, he has finally (and happily) been able to merge these disparate parts of his career.

---

**THANKS** to the following technical experts for reviewing this article:  
Jane Lawrence and Patrick Butler Monterde

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# Getting Started with Windows Phone Development Tools

Joshua Partlow

**Like many of you,** I've spent the past year or so inundated by a slew of post-apocalyptic, Terminator-esque ads telling me what Droid Does. I've hummed along with the T-Mobile My Touch commercials. I've read articles about how many apps Apple has sold for the iPhone.

Unlike many of you, I've also spent the past year repeatedly telling friends and family that, yes, I do in fact work on a mobile phone, but no, none of those are the phone that I work on.

So it's fair to say that I was rather excited when Steve Ballmer and Joe Belfiore announced Windows Phone 7 at Mobile World Congress (MWC) in Barcelona, Spain. It was 6 a.m. Redmond time on Feb. 15, 2010, but I was sitting in a Microsoft conference room with a few hundred coworkers, some still in pajamas, anxiously waiting to watch a live feed of Belfiore demoing our new vision for the phone ([microsoft.com/presspass/press/2010/feb10/02-15mwc10pr.mspx](http://microsoft.com/presspass/press/2010/feb10/02-15mwc10pr.mspx)). I'll probably watch many more products launched in the years to come, but I'm

sure this will remain one of the highlights. It was certainly the most exciting moment I've had at Microsoft to date.

In an attempt to get you equally excited about the potential for Windows Mobile app development, over the course of this article I'm going to introduce you to the Windows Phone 7 application platform. Specifically, I'll talk about the basic components of the application platform, give you an overview of the Windows Phone Developer Tools, and walk you through the creation of a Windows Phone application that accesses a Web service.

## A Break from the Past

With Windows Phone 7, Microsoft acknowledged that there's been a change in the mobile landscape. There's a new expectation that, beyond just allowing you to read e-mail and documents, a phone should also be an integral part of your life. Allowing you to do things like listen to music, share pictures and videos, and keep in touch with friends. Apparently, business users enjoy Facebook, too, and teenagers enjoy browsing the Web. It's not that shocking, I know, but it really does represent an evolution of the role a phone is expected to play in our lives.

As potential customers, I hope you saw Belfiore's demo and walked away ready to buy a phone. More importantly, as developers, I hope you came away curious about the application story. After all, creating a new OS is only part of competing in the crowded mobile market. If our premise is that users want a phone that enables them to merge their work and personal lives in new and exciting ways, then it's going to be a combination of the OS and an ecosystem of awesome applications that makes that possible.

I won't spend time describing the phone, because I'm sure you can find breakdowns on your favorite blog, but rather get to what I imagine are two bigger questions for you as developers: What's the Microsoft application platform for Windows Phone 7, and how do you get started building apps?

This article discusses a prerelease version of Windows Phone Developer Tools. All information is subject to change.

### This article discusses:

- Windows Phone 7 application platform architecture
- Using Windows Phone Developer Tools
- Creating a Windows Phone application project
- Formatting the application bar
- Implementing auto-generated event handlers for the application bar buttons

### Technologies discussed:

Windows Phone 7, Silverlight, XNA Framework, Visual Studio 2010 Express for Windows Phone

### Code download available at:

[code.msdn.microsoft.com/mag201010Phone](http://code.msdn.microsoft.com/mag201010Phone)

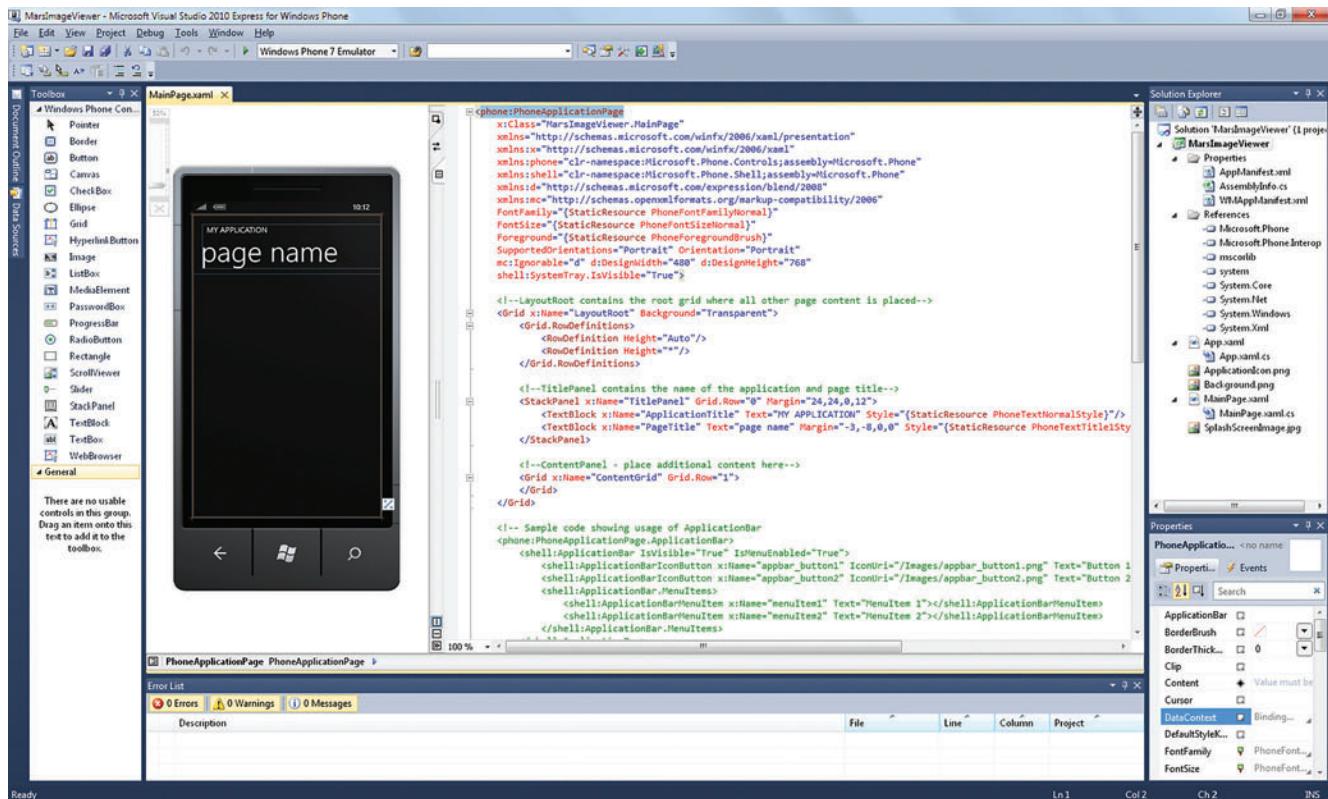


Figure 1 Your Initial Windows Phone Project in Visual Studio

## A New World for Developers

Well, if MWC started the revelation of Windows Phone 7, then the Game Developers Conference (GDC) and MIX10 completed the story. At GDC and MIX, Microsoft announced that the Windows Phone 7 application platform is based on Silverlight and the XNA Framework. If you've developed for Windows Mobile in the past, then you know that this marks a fundamental divergence from previous versions of the OS.

So why change things up? Well, my opinion is that the strength of Microsoft lies in its broad suite of products, and that it's never more successful than when it ties them together. Prior to Windows Phone 7, the mobile development story might have leveraged some Microsoft assets, but not nearly to the extent you'll see now.

The XNA Framework was designed to allow developers to create complex and powerful 2D and 3D games that could span desktop, console and mobile spaces. It was designed around a broad set of hardware, from the graphics capabilities of the Xbox console to the sensor and touch capabilities of the Zune HD. What's more, it was also designed with networked gameplay in mind.

Silverlight is the Microsoft desktop platform for Web-based media and productivity applications. Here's a platform that, when combined with Expression Blend, is designed to enable the creation of compelling UIs that can work well standing alone or tied into Web services.

Both the XNA Framework and Silverlight are strong platforms in their own right. But when combined on the phone, they take things to a whole new level, allowing for the development of applications with beautiful UIs and stunning graphics that can easily leverage the capabilities of a mobile device.

As I experimented with Silverlight and XNA applications early in the Windows Phone 7 development cycle, I was quickly convinced that it was a good direction. I was new to both platforms, as well as to managed code, and the speed with which I could develop visually cool applications impressed me.

Another notable feature of the new application platform is the standardization of hardware and your programmatic access to it. Specifically, another announcement that came out of MIX was that Windows Phones would support a core set of hardware that developers could access in a consistent and reliable manner. Why is that important? Historically, it has been difficult to develop applications to run on multiple phones because you ended up having to create device-specific versions of your application. Some phones wouldn't run your application without significant rework, or wouldn't work at all because they didn't support features needed by your app.

With Windows Phone 7, there won't be a question of whether the phone your app is running on has support for location services—all of them will. There won't be a question of whether the phone has an accelerometer and whether you can access it—all of them will, and the access will be consistent. There won't be a question of whether your phone is touch-enabled—all of them will be, and again the access will be consistent. The list goes on, but I hope you get the idea.

With the Windows Phone 7 application platform, you'll be able to develop a single application and know that what you test on your phone will work on all of them. There will still be differentiation of hardware on Windows Phones, but there will also be a core foundation of hardware that your applications will be able to rely upon.

For more details on the Windows Phone hardware and the architecture of the application platform, you can refer to the application platform and hardware overviews on MSDN at [msdn.microsoft.com/library/ff402531\(v=VS.92\)](http://msdn.microsoft.com/library/ff402531(v=VS.92).aspx) and [msdn.microsoft.com/library/ff637514\(v=VS.92\)](http://msdn.microsoft.com/library/ff637514(v=VS.92).aspx).

## Getting Started

OK, now that we've talked briefly about the application platform, let's talk about how you develop on it. Currently in beta, the Windows Phone Developer Tools are available for download from the Windows Phone Developer Portal ([developer.windowsphone.com](http://developer.windowsphone.com)). If you don't have Visual Studio, the Developer Tools come with Visual Studio 2010 Express for Windows Phone. If you have Visual Studio 2010, the tools will integrate directly with it. Either way, you'll have everything you need to develop for Windows Phone 7.

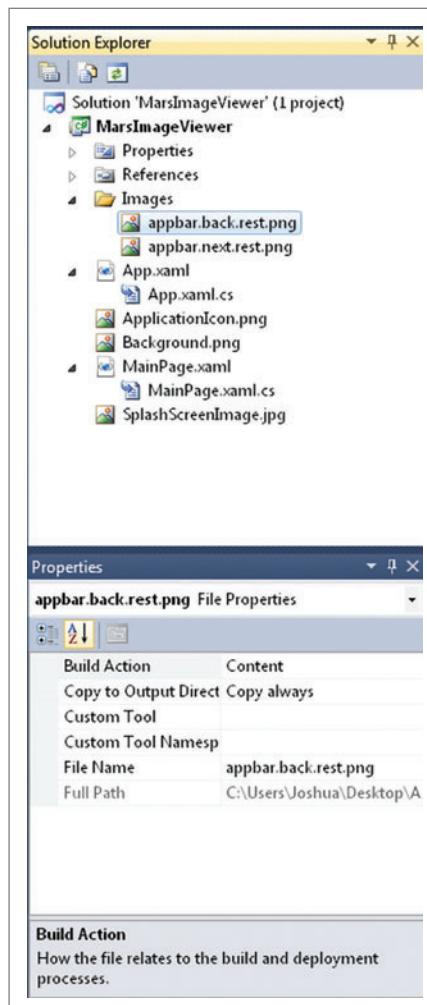
The Developer Tools include a Windows Phone Emulator and Microsoft Expression Blend for Windows Phone. While not final, the beta is a good indication of what you'll have at launch. It's possible you might need to make some modifications to your code between the beta and final version of the tools, but those changes should be minor or at least well-documented.

I've installed the beta version of the tools, using Visual Studio 2010 Express for Windows Phone, and it's what I'll be using for my example. If you want a slightly simpler tutorial to start with, you can check out the Windows Phone Getting Started Guide on MSDN at [msdn.microsoft.com/library/ff402529\(v=VS.92\)](http://msdn.microsoft.com/library/ff402529(v=VS.92).aspx).

So, what to create? Rather than do a general "hello world" or "make that flashlight" app I know you're dying to see, I thought I'd share a portion of a fun little project I've been working on.

At MIX I happened to attend a session on a Windows Azure project: Microsoft Codename "Dallas" ([microsoft.com/windowsazure/dallas](http://microsoft.com/windowsazure/dallas)). Dallas is basically a marketplace for developers interested in getting data for their applications from Web services looking to sell it. Currently in its second community technology preview (CTP), you can utilize both the online portal and a number of free data sources provided as a trial to experiment with what the service has to offer. While the current list of providers isn't huge, there's still a bunch of stuff to play with. I personally found the image data provided by NASA on the Mars missions interesting and decided it would be cool to create a Windows Phone application that could browse through Mars rover pictures.

As a warning, the code included here and available for download is a working sample, but if you want to run it you'll need to register for the Dallas CTP to get an account key and user ID, which I've left blank in my code ([microsoft.com/windowsazure/developers/dallas](http://microsoft.com/windowsazure/developers/dallas)).



**Figure 2 Adding Image Resources to the Project**

## Creating Your Project

The first step to creating the Mars rover image viewer is to create a Windows Phone application project. Launching the express version of Visual Studio 2010 for Windows Phone, you're presented with a standard Visual Studio Start Page. From there, you can select New Project, which will allow you to choose from a number of different project templates. If you've only installed the Windows Phone Developer Tools, your list will be limited to Silverlight for Windows Phone and XNA Game Studio 4.0.

I selected a Windows Phone app from the Silverlight templates and named my project MarsImageViewer. From there, Visual Studio does its magic and generates a project for you.

If you've worked with Windows Presentation Foundation (WPF) or Silverlight before, you shouldn't be all that surprised by what you get. You'll see that you're provided a design surface with a cool phone skin, a toolbox with some basic controls and a number of XAML files with their associated C# code-behind files (see **Figure 1**). If you care to learn about the exact differences between Silverlight and XNA on Windows and Silverlight and XNA on Windows Phone, you can reference the Windows Phone framework overview on MSDN at [msdn.microsoft.com/library/ff402528\(v=VS.92\)](http://msdn.microsoft.com/library/ff402528(v=VS.92).aspx).

## Understanding the XAML

As with Silverlight, the Windows Phone application template provides an App.xaml file and a MainPage.xaml file, which are the heart of your application. I won't spend time going over these in detail because they function in basically the same manner as their Silverlight counterparts, but I would like to point out two key differences before moving on to creating the application.

**Figure 3 Configuring the App Bar**

```
<phone:PhoneApplicationPage.ApplicationBar>
<shell:ApplicationBar
  IsVisible="True" IsMenuEnabled="False">
  <shell:ApplicationBarIconButton
    x:Name="appbar_BackButton"
    IconUri="/Images/appbar.back.rest.png"
    Text="Back"
    Click="appbar_BackButton_Click">
  </shell:ApplicationBarIconButton>
  <shell:ApplicationBarIconButton
    x:Name="appbar_ForwardButton"
    IconUri="/Images/appbar.next.rest.png"
    Text="Next"
    Click="appbar_ForwardButton_Click">
  </shell:ApplicationBarIconButton>
</shell:ApplicationBar>
</phone:PhoneApplicationPage.ApplicationBar>
```

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**Figure 4 MainPage.xaml**

```
<!--TitlePanel contains the name of the application and page title-->
<StackPanel x:Name="TitlePanel" Grid.Row="0" Margin="24,24,0,12">
    <TextBlock x:Name="ApplicationTitle"
        Text="MarsImageViewer"
        Style="{StaticResource PhoneTextNormalStyle}"/>
    <TextBlock x:Name="PageTitle"
        Text="Images"
        Margin="-3,-8,0,0"
        Style="{StaticResource PhoneTextTitle1Style}"/>
</StackPanel>

<!--ContentPanel - place additional content here-->
<Grid x:Name="ContentGrid" Grid.Row="1">
    <Image Height="300"
        HorizontalAlignment="Left"
        Margin="36,104,0,0"
        Name="MarsImage"
        Stretch="Fill"
        VerticalAlignment="Top"
        Width="400" />
</Grid>
```

The first point of interest is in the default App.xaml file. You'll notice that while the majority of the auto-generated code is the same as you'd see in a desktop Silverlight project, there's an additional section that contains a PhoneApplicationService object:

```
<shell:PhoneApplicationService
    Launching="Application_Launching" Closing="Application_Closing"
    Activated="Application_Activated" Deactivated="Application_Deactivated"/>
```

With the Windows Phone Developer Tools beta, there's a new execution model that dictates the behavior of applications; this section of markup, combined with the code-behind in App.xaml.cs, is one place where that model surfaces. If you'd like to better understand the behavior of Windows Phone applications and this object, you can refer to the topic Execution Model for Windows Phone on MSDN at [msdn.microsoft.com/library/ff769557\(VS.92\).](http://msdn.microsoft.com/library/ff769557(VS.92).)

The second point of interest is in the MainPage.xaml file, and actually where I'll start creating the application. If you look closely, much of the file is similar to Silverlight, but there's a commented-out XAML section for an application bar. The application bar is a system control you can use to expose buttons and menu items. Not only does it save you the trouble of creating your own, its use lends consistency to the phone, as it appears and behaves exactly like the one used in the core phone applications. While I'll modify this template markup to create my application bar, you can also create one for a page using C# (see [msdn.microsoft.com/library/ff431786\(VS.92\)](http://msdn.microsoft.com/library/ff431786(VS.92).) for details).

## Steal My App Bar

The first step to creating the application bar is to find the icons you want to use. You can create your own, or you can use some of the ones included with the developer tools. By default, the included icons can be found at C:\Program Files (x86)\Microsoft SDKs\Windows Phone\v7.0\Icons\ for 64-bit Windows and C:\Program Files\Microsoft SDKs\Windows Phone\v7.0\Icons\ for 32-bit Windows. They're definitely worth checking out because they match the look and feel of the phone.

Once you've picked the images you want, create an Images folder in your project and add the icons

to it. Then set the properties for each icon: Build Action should be "Content" and Copy to Output Directory should be "Copy always," as shown in **Figure 2**.

The next step is to uncomment the application bar markup and modify it for your application. In this case, that entails creating two buttons and their associated event handlers. Specifically, I created a button for retrieving the next photo and a button for retrieving the previous photo. I also added click events to the XAML and allowed Visual Studio to generate the event handlers. The application bar XAML should now look like the code in **Figure 3**.

Before moving to the code-behind, I also took the time to specify an application title and page name and to add an image control to the root grid of MainPage.xaml, as shown in **Figure 4**. This should leave the design surface looking like **Figure 5**, where you'll notice a blank app bar of four circles.

With the application interface defined, it's time to get some Mars rover images. The Dallas portal is designed to be user-friendly and allows you to experiment with queries. It also gives you the appropriate Web service URL, shows you how to add parameters and provides the appropriate header information for your queries.

What I discovered through the portal is that the NASA Web service allows queries for image information based on parameters or the retrieval of a specific JPEG image through an image ID. What that implies for this program is that two operations are required. The first is to query for image information, which includes the image ID. The second is to parse the returned XML for the image IDs, which can then be used to retrieve a specific image.

## Calling Houston ... I mean, Dallas

So let's get started. In the default MainPage.xaml.cs file, I added using statements for three namespaces:

```
using System.Xml.Linq;
using System.IO;
using System.Windows.Media.Imaging;
```

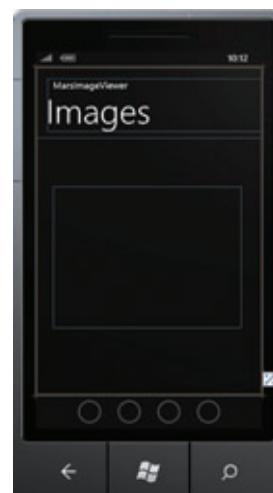
Then I added a reference to the System.Xml.Linq DLL by right-clicking References in Solution Explorer, selecting Add Reference, selecting System.Xml.Linq and then clicking OK. System.Xml.Linq provides access to classes that aid in loading XML from streams and then querying that XML through LINQ. Don't worry if you're not familiar with LINQ; this example uses a minimal amount of LINQ to XML and you can always refer to MSDN for more information.

I also created two private variables for the page. An IEnumerable of XElement objects called entries to store the result of a LINQ to XML query, and an integer index to keep track of the picture I'm on. I then modified the MainPage constructor to initialize the index to 0 and call a getImageIDs function:

```
private IEnumerable< XElement> entries;
private int index;

// Constructor
public MainPage() {
    InitializeComponent();

    index = 0;
    getImageIDs();
}
```



**Figure 5 The Configured Design Surface**

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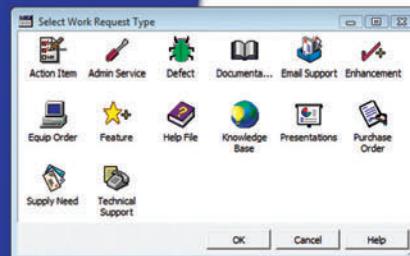
Ticket No.	Subject	Priority	Ticket Status	Open Date
SD-026554	Test of new ticket	C - Low	Open	Thu Nov 20 14:30:01 EST 2008
SD-026701	I need help setting up Team-Web	B - Moderate	Open	Fri Oct 17 09:24:32 EDT 2008
SD-026592	Custom sorts do not apply immediately in Team-Web	B - Moderate	Open	Wed Sep 24 16:24:47 EDT 2008
SD-026584	Another demo	A - High	Re-Open	Wed Sep 24 11:44:01 EDT 2008
SD-026578	Second sample ticket with a longer subject	C - Low	Resolved	Tue Sep 23 15:28:23 EDT 2008



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Figure 6 Retrieving the Image

```
private void getImage(string ID) {
    Uri serviceUri = new Uri(
        "https://api.sqlazureservices.com/NasaService.svc/MER/Images/" +
        ID + "?format=raw");
    WebClient imgDownloader = new WebClient();
    imgDownloader.Headers["$accountKey"] = "<Your account key>";
    imgDownloader.Headers["$uniqueUserID"] = "<Your user ID>";
    imgDownloader.OpenReadCompleted +=
        new OpenReadCompletedEventHandler(imgDownloader_OpenReadCompleted);
    imgDownloader.OpenReadAsync(serviceUri);
}

private void imgDownloader_OpenReadCompleted(
    object sender, OpenReadCompletedEventArgs e) {
    if (e.Error == null) {
        Stream imageStream = e.Result;
        BitmapImage imgsrc = new BitmapImage();
        imgsrc.SetSource(imageStream);
        MarsImage.Source = imgsrc;
    }
}
```

The `getImageIDs` function is designed to start the retrieval of image information from the Web service. The function uses the Web service URL and a `WebClient` to start an asynchronous request for the image information:

```
private void getImageIDs() {
    Uri serviceUri = new Uri("https://api.sqlazureservices.com/
NasaService.svc/MER/Images?missionId=1&format=raw");
    WebClient recDownloader = new WebClient();
    recDownloader.Headers["$accountKey"] = "<Your account key>";
    recDownloader.Headers["$uniqueUserID"] = "<Your user ID>";
    recDownloader.OpenReadCompleted +=
        new OpenReadCompletedEventHandler(recDownloader_OpenReadCompleted);
    recDownloader.OpenReadAsync(serviceUri);
}
```

You'll notice that, for simplicity, I've hardcoded the `missionId` parameter to 1, which in this case represents the Opportunity mission. Ideally, this parameter and others would be dynamically defined by the user.

With any asynchronous request, you need a handler. This handler is called when the request for data completes. It then uses the returned stream along with some basic LINQ to XML to access all the “entry” tags in the returned XML; “entry” being the opening tag for each image record:

```
private void recDownloader_OpenReadCompleted(
    object sender, OpenReadCompletedEventArgs e) {
    if (e.Error == null) {
        Stream responseStream = e.Result;
        XNamespace ns = "http://www.w3.org/2005/Atom";
        XElement marsStuff = XElement.Load(responseStream);
        entries = marsStuff.Elements(ns + "entry");
        string imageID =
            (string)entries.ElementAt< XElement >(index).Element(
                ns + "title").Value;
        getImage(imageID);
    }
}
```

The resulting collection is stored to the `IEnumerable` of `XElement` objects (`entries`), which I declared earlier. With a final bit of LINQ to XML, the handler then retrieves the value of the `title` tag for the first `XElement` in `entries`. The value of the `title` tag in this XML schema happens to correspond to the image ID, which is then passed into a `getImage` function.

The `getImage` function is similar to the `getImageIDs` function. The only difference is the Web service URL that's used. This function asynchronously retrieves a stream to the image identified by the

`ID` parameter. Its handler then uses that stream to set the source of the picture control I defined in `MainPage.xaml` (see Figure 6).

## Buttoning up Buttons

At this point, the rest of the application is pretty simple, with only the auto-generated event handlers for the application bar buttons remaining to be implemented. These are the buttons that will be used to advance forward and backward through the Mars rover pictures. As you can see, I basically just reused the `getImage` function and added some logic to handle changing the index of the current record in the `entries` collection. Here's the handler for the back button:

```
private void appBar_BackButton_Click(
    object sender, EventArgs e) {
    if (index > 0) {
        index--;
        XNamespace ns = "http://www.w3.org/2005/Atom";
        string imageID = (string)entries.ElementAt<
            XElement >(index).Element(ns + "title").Value;
        getImage(imageID);
    }
}
```

The forward button handler is pretty much the same, except for its indexing:

```
if ((index + 1) < entries.Count< XElement >()) {
    index++;
    ...
}
```

You can now run the program by using the included Windows emulator. Select Windows Phone 7 Emulator from the target device menu on the Standard toolbar. Press F5 and the program is built and deployed to the emulator (see Figure 7).

## Ready for Launch

This sample was relatively simple, but I hope it's given you a rough idea of what the developer tools look like and how easy it is to pull together an application on Windows Phone. There are a lot of possibilities with Windows Phone 7, and you should take the time to explore them more.

What you've seen here is only a small introductory glimpse of what the application platform has to offer. As proof of that, consider the simple application I laid out. With one more button and roughly 12 lines of code, you could use the `MediaLibrary` class in the `Microsoft.Xna.Framework.Media` namespace to save a given photo to the media library (see [msdn.microsoft.com/library/ff769549\(v=VS.92\)](http://msdn.microsoft.com/library/ff769549(v=VS.92).)).

Yes, that's right—you can use XNA APIs from within your Windows Phone Silverlight-based applications. Unfortunately, discussions about the interweaving of Silverlight and XNA APIs in apps, along with much more, will have to wait for a later date. So watch out for some deeper, more-targeted articles and check out the documentation and samples on MSDN at [msdn.microsoft.com/library/ff402535\(v=VS.92\)](http://msdn.microsoft.com/library/ff402535(v=VS.92).). ■



Figure 7 Running the App in the Emulator

**JOSHUA PARTLOW** is a programming writer on the Windows Phone 7 team. He works on documenting the phone bring-up process, device driver development and application development for OEMs creating Windows Phones.

**THANKS** to the following technical expert for reviewing this article: Windows Phone 7 Team

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# Scalable Multithreaded Programming with Thread Pools

Ron Fosner

**Programming is getting** more challenging, particularly if you're working in a field that requires you to tune your application for the fastest possible throughput. One contributing factor is that the last few years have seen a change in the way PCs are evolving. Instead of relying on the ever-increasing speed of a single processor, the computational power of PCs is now being distributed across multiple cores. This is a good thing. Hefty increases in latent processing power are now available at relatively low cost, and often with much lower power consumption and cooling needs.

But there's a downside to the increasing prevalence of multiple-core systems. To use multiple processors, you need to delve into the world of parallel processing. That means it takes more work—and sometimes a significant learning curve—for programmers to take advantage of that latent processing power. It's possible to throw a few compiler hints into your project and get the compiler to write some multithreaded code for you. However, to take advantage of the full power of multicore PCs, you'll need to make some changes in the way that you program large jobs.

#### This article discusses:

- Multithreading basics
- Using OpenMP
- Using thread pools
- Measuring core utilization

#### Technologies discussed:

Visual Studio 2010

#### Code download available at:

[code.msdn.microsoft.com/mag201010Thread](http://code.msdn.microsoft.com/mag201010Thread)

There are many different ways to distribute your work across multiple cores. One of the easiest and most robust is called task-based programming. Tasks allow you to take your application's work and spread it across some or all of the CPU cores that are available. With a bit of thoughtful programming, you can minimize or even eliminate any data-dependency or time-synchronization constraints. To achieve this state of multicore bliss, you'll have to reexamine some of your preconceptions of how to attack a programming problem and rethink them in terms of task-based programming.

To show you how this can work, I'll walk you through the steps—and the missteps—I took in converting a single-threaded application to one that can scale up to using all of the CPUs available in a computer. In this article, I'll present some of the concepts of multithreaded programming and show you some simple ways to introduce threaded execution into your code with OpenMP and thread pools. You'll also see how to use Visual Studio 2010 to measure the improvement in performance you gained from these techniques. In a future article, I'll build on that foundation to show you more sophisticated multithreaded executing with tasks.

#### From Threads to Tasks

The major challenge with making a program scale to the number of CPU cores is that you can't just decide to throw some jobs onto their own threads and let them run. In fact, this is what a lot of folks do, but it only scales well to the number of cores for which the app was designed. It doesn't scale well with fewer or more than the number of cores that were targeted, and it totally overlooks the built-in obsolescence that such an approach engenders.

A better way to make sure that your application scales well with a varying number of cores is to break larger jobs into smaller, thread-friendly sub-jobs called tasks. The most challenging part of

converting a monolithic single-threaded program or a program that has a few dedicated threads into a task-based job system is actually breaking your jobs into tasks.

There are a few guidelines to keep in mind when converting a large single-threaded job into multithreaded tasks:

- The large job can be arbitrarily divided into 1 to  $n$  tasks.
- The tasks should be able to run in any order.
- The tasks should be independent of each other.
- The tasks must have associated context data.

If all these were easy, you'd have no problem making your applications run on any number of cores. Unfortunately not all problems can be broken so neatly into tasks that meet these guidelines.

These guidelines are important because, if followed, they enable you to run each task independently on a thread, with no dependence between tasks. Ideally tasks should be able to be run in any order, so eliminating or reducing interdependencies is paramount to getting a task-based system up and running.

Most real-world programs will go through various stages of processing, with each stage required to complete prior to starting the next stage. These synchronization points are often unavoidable, but with a task-based system the goal is to make sure you take advantage of whatever CPU power is immediately available. With some judicious breaking of large jobs into smaller ones, it's often possible to start intermingling some completed task results with their next stage of processing while some of the initial tasks are still running.

## Simple Multithreading with OpenMP

Before converting your entire application to use tasks, you should be aware of other ways to get some of the benefits of multithreading without going through the rigorous exercise of making everything a task. There are numerous ways to incorporate multithreading into your application—many that require little actual effort—but that allow you to benefit from adding multithreading to your code.

OpenMP is one of the simplest ways to add parallel processing to your programs and has been supported by the Visual Studio C++ compiler since 2005. You enable OpenMP by adding pragmas to your code that indicate where and what kind of parallelism you'd like to add. For example, you can add parallelism to a simple Hello World program:

```
#include <omp.h> // You need this or it won't work
#include <stdio.h>
int main (int argc, char *argv[]) {
    #pragma omp parallel
    printf("Hello World from thread %d on processor %d\n",
        ::GetCurrentThreadId(),
        ::GetCurrentProcessorNumber());
    return 0;
}
```

The OpenMP pragma parallelizes the next block of code—in this case it's just the printf—and runs it simultaneously across all hardware threads. The number of threads will depend on how many hardware threads are available on the machine. The output is a printf statement running on each hardware thread.

To get any OpenMP program to parallelize (and not silently ignore your OpenMP pragmas), you need to enable OpenMP for your program. First, you have to include the /openmp compiler option (Properties | C/C++ | Language | Open MP Support). Second, you need to include the omp.h header file.

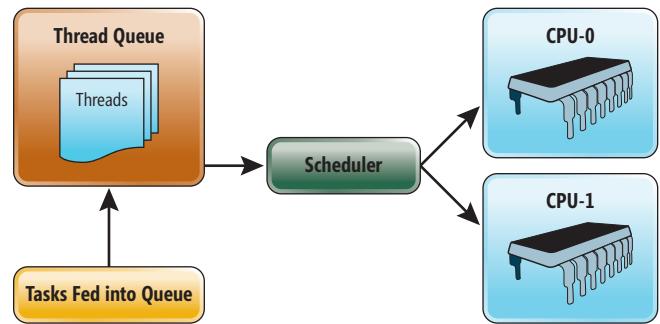


Figure 1 A Thread Pool

Where OpenMP really shines is when your application spends most of its time looping over functions or data and you want to add multiprocessor support. For example, if you have a for loop that takes a while to execute, you can use OpenMP to easily parallelize the loop. Here's an example that automatically breaks up array calculations and distributes them across the number of cores that are currently available:

```
#pragma omp parallel for
for (int i = 0; i < 50000; i++)
    array[i] = i * i;
```

OpenMP has other constructs that give you more control over the number of threads created, whether the distributed work needs to finish before the next block of code is executed, creating thread-local data, synchronization points, critical sections and so on.

As you can see, OpenMP is an easy way to gently introduce parallelism into an existing code base. However, while the simplicity of OpenMP is attractive, there are times you need more control over what your application is doing, such as when you want the program to dynamically adjust what it's doing or you need to make sure that a thread stays on a particular core. OpenMP is designed to easily

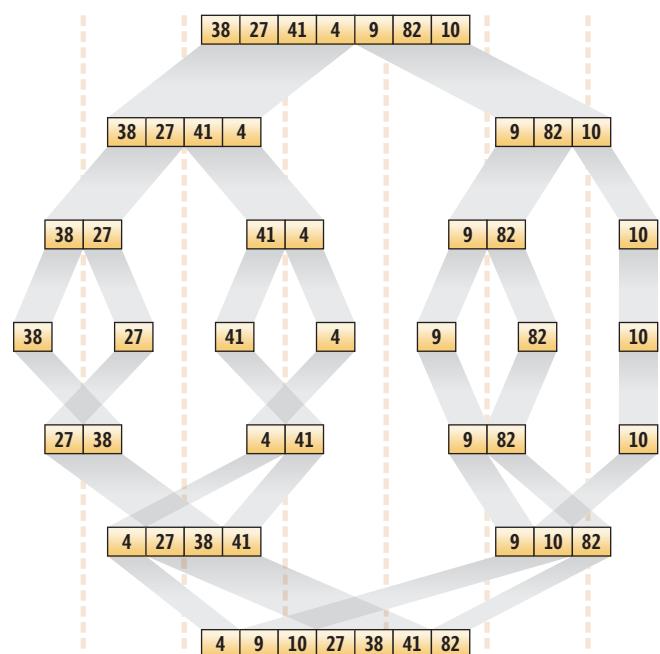


Figure 2 Sorting a String of Random Integers

Figure 3 Quick Sort

```
using System;
using System.Threading;
using System.Threading.Tasks;
using System.Diagnostics;

namespace ParallelSort {
    class Program {
        // For small arrays, use Insertion Sort
        private static void InsertionSort(
            int[] list, int left, int right) {

            for (int i = left; i < right; i++) {
                int temp = list[i];
                int j = i;

                while ((j > 0) && (list[j - 1] > temp)) {
                    list[j] = list[j - 1];
                    j = j - 1;
                }
                list[j] = temp;
            }
        }

        private static int Partition(
            int[] array, int i, int j) {

            int pivot = array[i];

            while (i < j) {
                while (array[j] >= pivot && i < j) {
                    j--;
                }

                if (i < j) {
                    array[i++] = array[j];
                }

                while (array[i] <= pivot && i < j) {
                    i++;
                }

                if (i < j) {
                    array[j--] = array[i];
                }
            }

            array[i] = pivot;
            return i;
        }

        static void QuickSort(
            int[] array, int left, int right) {

            // Single or 0 elements are already sorted
            if (left >= right)
                return;

            // For small arrays, use a faster serial routine
            if (right - left <= 32) {
                InsertionSort(array, left, right);
                return;
            }

            // Select a pivot, then quicksort each sub-array
            int pivot = Partition(array, left, right);

            QuickSort(array, left, pivot - 1);
            QuickSort(array, pivot + 1, right);
        }

        static void Main(string[] args) {
            const int ArraySize = 50000000;

            for (int iters = 0; iters < 1; iters++) {
                int[] array;
                Stopwatch stopwatch;

                array = new int[ArraySize];
                Random random1 = new Random(5);

                for (int i = 0; i < array.Length; ++i) {
                    array[i] = random1.Next();
                }

                stopwatch = Stopwatch.StartNew();
                QuickSort(array, 0, array.Length - 1);
                stopwatch.Stop();

                // Verify it is sorted
                for (int i = 1; i < array.Length; ++i)
                    if (array[i - 1] > array[i - 1])
                        throw new ApplicationException("Sort Failed");

                Console.WriteLine("Serialized: {0} ms",
                    stopwatch.ElapsedMilliseconds);
            }
        }
    }
}
```

integrate some aspects of multithreaded programming into your program, but it lacks some of the advanced features you'll find you require to get optimal use of out multiple cores. This is where tasks and thread pools come in.

## Using the Thread Pool

Threads require a lot of bookkeeping by the OS, so it's not a good idea to wantonly create and destroy them. There are not-insignificant costs associated with creating and destroying a thread, so if you do this constantly, it's easy to lose any advantage you gain by multithreading.

Instead, it's best to use an existing set of threads, recycled as needed, for all of your threaded activity. This design is called a thread pool, and Windows provides one for you to use. Using this thread pool relieves you of having to deal with thread creation, destruction, and management, all of which is handled for you by the thread pool. OpenMP uses a thread pool to distribute work with threads, and both Windows Vista and Windows 7 provide optimized versions of the thread pool for you to use directly.

While it's entirely possible to create your own thread pool—which you might need to do if you've got some unusual scheduling requirements—you're much better off using one provided by the OS or the Microsoft .NET Framework.

At this point I need to clarify some terminology. When most people talk about a thread, they're referring to the flow of execution through a single CPU core—in other words, a software thread. On a CPU, the flow of execution (the actual execution of instructions) occurs on hardware threads. The number of hardware threads is limited by the hardware your application is running on. In the old days, this used to be a single-threaded CPU, but now it's common to find systems that have at least dual-core processors. A four-core CPU will have the ability to run four hardware threads, or eight if it's hyperthreaded. High-end desktop systems boast as much as 16 hardware threads, and some server configurations have more than 100!

While a hardware thread actually runs the instructions, a software thread refers to the entire context—register values, handles, security attributes and so on—required to actually execute the job on a hard-

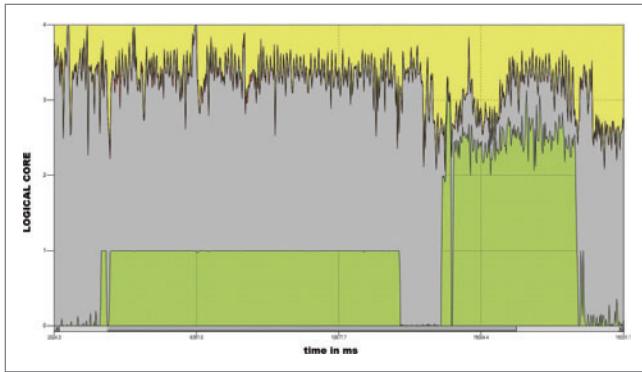


Figure 4 Core Utilization

ware thread. It's important to note that you can have many more software threads than hardware threads, and this is the underlying basis of a thread pool. It allows you to queue up tasks with software threads and then schedule them to execute on the actual hardware threads.

The advantage of using a thread pool instead of creating your own threads is that the OS will take care of scheduling tasks for you—your job will be to keep feeding tasks into the thread pool so that the OS will be able to keep all of the hardware threads busy. This is illustrated in **Figure 1**. Everything in the box makes up the thread pool and is out of the realm of the programmer. It's up to the application to feed tasks into the thread pool, where they are placed into the thread queue and eventually scheduled to run on a hardware thread.

Now you get to the hard part: What's the best way to structure jobs to keep the cores busy and the CPU utilization at its maximum? This depends on what your application needs to do.

I frequently work with video game companies and these are some of the most challenging types of applications to work with because there's a lot of work to be done—usually some in a particular serial order—and it's sensitive to delays. There's usually a certain frame rate at which the program updates, so if the frame rates start to fall behind, the game experience suffers. As a result, there's a lot of incentive to maximize use of the hardware.

On the other hand, if your application does one large thing at a time, it's a little more obvious what you need to do, but it's still challenging to try to distribute a single job across multiple cores.

## Multithreaded Sorting

First let's take a look at a monolithic job that's frequently found in applications and see how you can go about transforming it into a more multithread-friendly form. I'm thinking, of course, about sorting. Sorting is a particularly good example because it's got

one major obstacle: How do you sort something and spread out the sorting across multiple cores so that the sorting on one core is independent from what's being sorted on another core?

A naïve approach frequently seen is to lock access to any data that can be accessed by multiple cores using something like a mutex, semaphore or critical section. This will work. However, if it's used as a panacea for not correctly scheduling access to shared data, at best you'll end up killing any gains you might have achieved by blocking other threads from executing. At worst, you might introduce some subtle race condition that will be excruciatingly difficult to track down.

Luckily, you can design the application to eliminate most of the shared access to the data across threads by choosing the appropriate sorting algorithm.

A better approach is to give each core a subsection of the array to sort. This divide-and-conquer method is an easy way to distribute work on the same data set across multiple cores. Algorithms such as merge sort and quick sort work from a divide-and-conquer strategy and are straightforward to implement in a way that takes advantage of a multicore system.

Let's look at how merge sort works on the string of random integers shown in **Figure 2**. The first step is to choose a midpoint in the array and divide it into two sublists. Keep dividing until you have lists that are zero or one element long.

In most implementations, there's actually a list size limit below which you have an efficient algorithm designed for small lists, but it also works if you just keep dividing until you can't divide any more. The important thing to note is that once you divide a list into two sublists, the lists are independent. This is illustrated by the dashed red lines in **Figure 2**. Once you divide the list into sublists, each sublist is independent and you can give each one to a CPU to manipulate as it likes without having to lock anything.

To make the sorting as efficient as possible, choose an algorithm that will take each sublist and sort it in place. This is important not only to prevent unnecessary copying of the data, but also to keep the data warm in the CPU's L2 cache. As you strive to write more and more efficient parallel code, you eventually have to be aware of how data gets swapped into and out of the L2 cache, which is generally about 256KB in most modern processors.

There are many sorting algorithms that lend themselves to parallelization. Quick sort, selection sort, merge sort, and radix sort are all algorithms that subdivide the data and operate on it independently. So let's take a look at a serial implementation of a sorting routine and convert it into a parallel one.

In theory, once you keep subdividing an array recursively you will eventually end up with a single element. At this point, there's



Figure 5 Thread Work

nothing to sort, so the algorithm moves onto the next step, which is merging sorted sublists together. The individual elements are merged into larger, sorted lists. These sorted sublists are then merged into even larger sorted lists until you have the original array in a sorted order. As mentioned previously, it's usually faster to switch to an algorithm that's optimized to sort small lists when the list size reaches a certain threshold.

There are many ways to write a sorting algorithm, and I've chosen to write a simple quick sort routine in C#, as shown in **Figure 3**. This program fills a large array with the same sequence of random numbers and then sorts them using a quick sort routine, reporting how long it took.

If you look at the QuicSort function, you'll see that it recursively divides the array in two until a threshold is reached, at which point it sorts the list without further subdivision. If you change this to a parallel version, all you have to do is change these two lines:

```
QuickSort( array, lo, pivot - 1);
QuickSort( array, pivot + 1, hi);
```

The parallelized version is:

```
Parallel.Invoke(
    delegate { QuickSort(array, left, pivot - 1); },
    delegate { QuickSort(array, pivot + 1, right); }
);
```

The Parallel.Invoke interface is part of the Systems.Threading.Tasks namespace found in the .NET Task Parallel Library. It allows you to specify a function to be run asynchronously. In this case, I tell it that I want to run each sorting function on a separate thread.

While it would be more efficient to spawn only one new thread and to use the current thread of execution to sort the other sublist, I wanted to maintain symmetry and illustrate how easy it is to convert a serial program into a parallel program.

## Core Utilization

The next obvious question is: Has this parallelization improved performance at all?

Visual Studio 2010 includes several tools to help you understand where your program is spending its time and how it behaves as a multithreaded application. There's a great introduction to using these tools for measuring the performance of your multithreaded app with Visual Studio 2010 in the September 2009 *MSDN Magazine* article "Debugging Task-Based Parallel Applications in Visual Studio 2010" by Stephen Toub and Daniel Moth ([msdn.microsoft.com/magazine/ee410778](http://msdn.microsoft.com/magazine/ee410778)), plus there's a good video introduction by Daniel Moth on Channel 9 ([channel9.msdn.com/posts/DanielMoth/Parallel-Tasks-new-Visual-Studio-2010-debugger-window/](http://channel9.msdn.com/posts/DanielMoth/Parallel-Tasks-new-Visual-Studio-2010-debugger-window/)).

Parallel programming requires you to actually make measurements to verify that you've truly improved performance and are utilizing all the hardware. To learn more about how parallelization was being used in my example application, let's use these tools to measure the sorting routines in action. I launched the Visual Studio 2010 Performance Wizard to take concurrency measurements of my sorting application while it runs.

The first thing you want to look at is core utilization, which shows how the application made use of the CPU cycles available. My test program runs the serial sort, sleeps for a second, then runs the parallel version of the sort. On my 4-core machine I get the graph of core utilization shown in **Figure 4**. The green is my application, yellow

is the OS and other programs, and gray is idle. The flat line at the 1-core level shows that I totally saturate the processing on a single core when I'm running the serial version, and that I get about 2.25 out of four cores when running the parallel version. Not too surprisingly, the time to execute the parallel sort is about 45 percent of the time required for the serial sort. Not too shabby for changing two lines of code.

Now, let's switch from looking at the CPU utilization chart to the thread display shown in **Figure 5**, which shows how the application utilized threads that were available. Notice that there is a single thread for the majority of the execution time. It's not until you start spawning off tasks that more threads are created. In this display the salmon color indicates a thread that's been blocked by another thread.

In fact, the thread display shows that while I did get a significant increase in execution speed, I didn't do it very efficiently. It's perfectly OK to have a thread block, waiting for other threads as the main thread is waiting for the tasks to complete. However, what you really want to see is solid green on as many tasks as you have CPU cores. So even though the CPU utilization chart shows improved utilization of the CPU cores, when you take a closer look at how tasks were spread throughout the thread pool, you see room for further optimization.

In fact, you should always measure your code for performance after you've done some multithreading work—even work as simple as I've done here. For small jobs, you don't want to multithread because the overhead will overwhelm any threading performance. For larger jobs, you'd want to break the job up onto as many CPU cores as are available to you so as not to oversubscribe the thread pool.

## What Next?

There are a number of ways to squeeze even better performance out of the code, but that's not the objective of this initial article. But you did see how to get 80 percent CPU utilization by making just a few changes to the code that make it thread-friendly. Rather than optimizing this code further, however, we're going to focus on getting maximum performance out of the CPUs on a system by architecting jobs a bit differently.

Sorting in the manner I've demonstrated here is particularly amenable to multithreading. You can calculate how far you're going to divide the job and then give each sub-job to a thread. However, while I did get a performance boost, I did leave some performance behind.

But in real applications you might run into a situation where you either have many jobs giving you groups of unique tasks, or possibly not knowing how long any particular task is going to run and having to schedule tasks around this uncertainty. It's a particularly challenging problem. In my next article, I'm going to take a look at an architecture that takes a holistic approach to threading, allowing you to distribute multiple, perhaps dissimilar jobs. I'll show you how to architect an application to make it multicore-aware from the start through the use of tasks and thread pools.

---

**RON FOSNER** has been optimizing high-performance applications and games on Windows for 20 years and is starting to get the hang of it. He's a graphics and optimization expert at Intel and is happiest when he sees all CPU cores running flat out. You can reach him at [Ron@directx.com](mailto:Ron@directx.com).

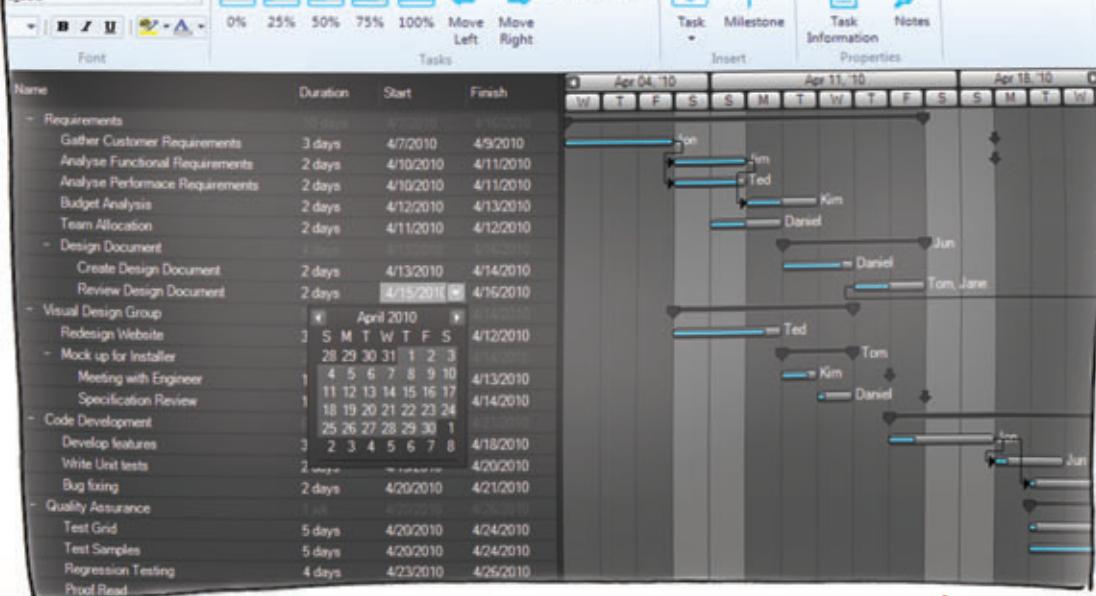
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**THANKS** to the following technical expert for reviewing this article:  
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# Performance-Based Scaling in Windows Azure

Without a doubt, cloud computing is gaining lots of mindshare, and its practical use is building momentum across technology platforms and throughout the industry. Cloud computing isn't a new or revolutionary concept; indeed, it has been around for years in the form of shared hosting and other such services. Now, however, advances in technology and years of experience running servers and services have made cloud computing not only technically practical, but increasingly interesting to both consumers and providers.

Progress in cloud computing will reach beyond IT and touch every part of your company—from the people managing hardware and services, to the developers and architects, to the executives who will approve the budget and pay the bills. You'd better be prepared for it.

In this column I'll focus primarily on the developers and architects who need to understand and leverage cloud computing in their work. I'll supply some guidance on how to accomplish a given task, including notes on architecture considerations and their impact on cost and performance. Please tell me what you think of the topics I cover and, even more importantly, about topics that are of particular interest in cloud computing.

## Seeding the Cloud

One of the first benefits people focus on in cloud computing is the idea that application owners don't have to worry about infrastructure setup, configuration or maintenance. Let's be honest: that's pretty compelling.

However, I think it's more important to focus on the ability to scale up or down to serve the needs of the application owner, thereby creating a more efficient cost model without sacrificing performance or wasting resources. In my experience, demand elasticity is something that comes up in any conversation about the cloud, regardless of the platform being discussed.

In this installment I'll demonstrate how to use performance counter data from running roles to automate the process of shrinking or growing the number of instances of a particular Web Role. To do this, I'll take a look at a broad cross-section of Windows Azure features and functionality, including Windows Azure Compute, Windows Azure Storage and the REST Management API.

The concept is quite simple: test collected performance data against a threshold and then scale the number of instances up or down accordingly. I won't go into detail about collecting diagnostic data—I'll leave that to you or to a future installment. Instead, I'll examine performance counter data that has been dumped to a table in Windows Azure Storage, as well as the code and setup

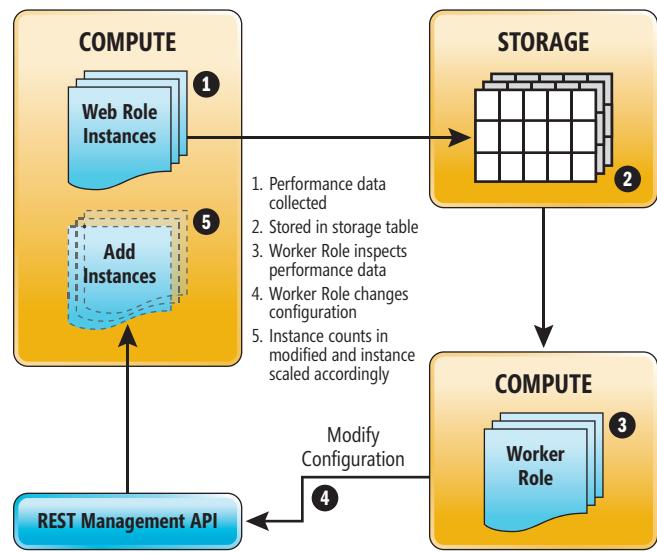


Figure 1 Performance-Based Scaling

required to execute the REST call to change the instance count in the configuration. Moreover, the downloadable code sample will contain a simple page that will make REST management calls to force the instance count to change based on user input. The scenario is something like the drawing in Figure 1.

## Project Setup

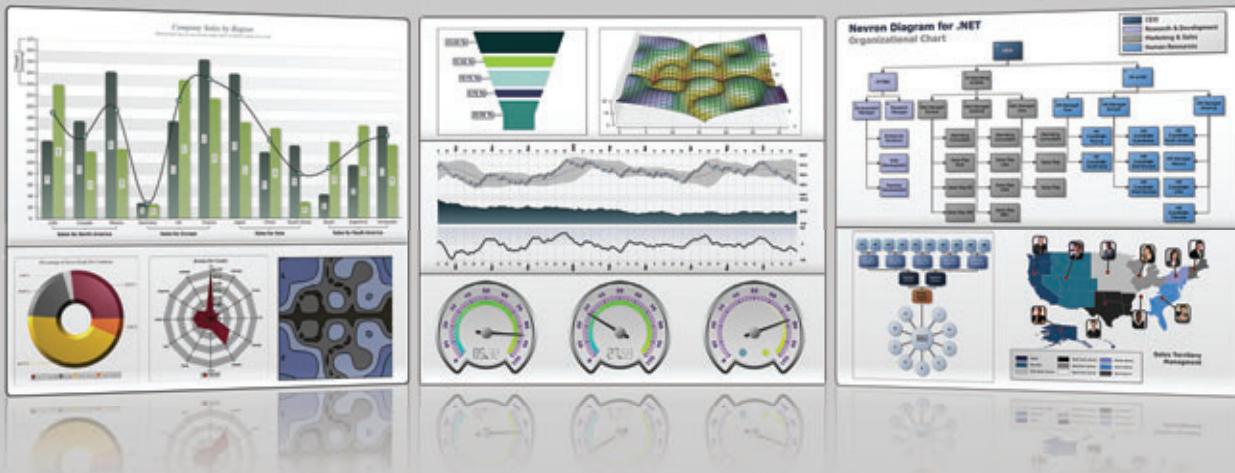
To get things started, I created a Windows Azure Cloud Service project that contains one Worker Role and one Web Role. I configured the Web Role to publish performance counter data, specifically % Processor Time, from the role and push it to storage every 20 seconds. The code to get that going lives inside of the WebRole:OnStart method and looks something like this:

```
var performanceConfiguration =  
    new PerformanceCounterConfiguration();  
performanceConfiguration.CounterSpecifier =  
    @"\Processor(_Total)\% Processor Time";  
performanceConfiguration.SampleRate =  
    System.TimeSpan.FromSeconds(1.0);  
  
// Add the new performance counter to the configuration  
config.PerformanceCounters.DataSources.Add(  
    performanceConfiguration);  
config.PerformanceCounters.ScheduledTransferPeriod =  
    System.TimeSpan.FromSeconds(20.0);
```

Code download available at [code.msdn.microsoft.com/mag2010Cloudy](http://code.msdn.microsoft.com/mag2010Cloudy).

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The screenshot shows the 'Import Certificate' step in the Azure Test portal. It has fields for 'Upload Certificate' (Browse... and Upload buttons), 'Type the password for the private key:' (password field), 'Confirm password:' (password field), and a table titled 'Installed Certificates' showing one entry: CN=JOFULTZHPW7.northamerica.corp.microsoft.com, Thumbprint: 49C340B3099E1822B1CB67A5C824E7B539693FC, with a Delete button.

**Figure 2 Importing Certificates**

This code registers the performance counter, sets the collection interval for data and then pushes the data to storage. The values I used for intervals work well for this sample, but are not representative of values I'd use in a production system. In a production system, the collection interval would be much longer as I'd be concerned with 24/7 operations. Also, the interval to push to storage would be longer in order to reduce the number of transactions against Windows Azure Storage.

## If the instances are running too hot, I can add instances.

Next I create a self-signed certificate that I can use to make the Azure REST Management API calls. Every request will have to be authenticated and the certificate is the means to accomplish this. I followed the instructions for creating a self-signed certificate in the TechNet Library article "Create a Self-Signed Server Certificate in IIS 7" ([technet.microsoft.com/library/cc753127\(WS.10\)](http://technet.microsoft.com/library/cc753127(WS.10).)). I exported both a .cer file and a .pfx file. The .cer file will be used to sign the requests I send to the management API and the .pfx file will be imported into the compute role via the management interface (see **Figure 2**).

I'll come back later and grab the thumbprint to put it in the settings of both the Web Roles and Worker Roles that I'm creating so they can access the certificate store and retrieve the certificate.

Finally, to get this working in Windows Azure, I need a compute project where I can publish the two roles and a storage project to which I can transfer the performance data. With these elements in place, I can move on to the meat of the work.

## Is It Running Hot or Cold?

Now that I've got the Web Role configured and code added to publish the performance counter data, the next step is to fetch that data and compare it to a threshold value. I'll create a `TestPerfData` method in which I retrieve the data from the table and test the values. I'll write a LINQ statement similar to the following:

```
double AvgCPU = (
    from d in selectedData
    where d.CounterName ==
        @"\Processor(_Total)\% Processor Time"
    select d.CounterValue).Average();
```

By comparing the average utilization, I can determine the current application performance. If the instances are running too hot, I can add instances. If they're running cold and I'm wasting resources—meaning money—by having running instances I don't need, I can reduce the number of instances.

You'll find in-depth coverage of the code and setup needed to access the performance counter table data in a blog post I wrote at [blogs.msdn.com/b/joseph\\_fultz/archive/2010/06/30/querying-azure-performance-counter-data-with-linq.aspx](http://blogs.msdn.com/b/joseph_fultz/archive/2010/06/30/querying-azure-performance-counter-data-with-linq.aspx).

I use a simple if-then-else block to assess the state and determine the desired action. I'll cover the details after I've created the functions needed to change the running service configuration.

## Using the REST Management API

Before I can finish the `TestPerfData` method, I have a little more work to do. I need a few methods to help me discover the number of instances of a given role, create a new valid service configuration for that role with an adjusted instance count, and, finally, allow me to update the configuration.

To this end I've added a class file to my project and created the six static methods shown in **Figure 3**.

The calls that interact with the REST Management API must include a certificate. To accomplish this, the certificate is added to the hosted service and the thumbprint is added to the role configuration and used to fetch the certificate at run time. Once the service and role are configured properly, I use the following code to grab the certificate from the Certificate Store:

```
string Thumbprint =
    RoleEnvironment.GetConfigurationSettingValue(
        ThumbprintSettingName);
X509Store certificateStore =
    new X509Store(StoreName.My, StoreLocation.LocalMachine);
certificateStore.Open(OpenFlags.ReadOnly);
X509Certificate2Collection certs =
    certificateStore.Certificates.Find(
        X509FindType.FindByThumbprint, Thumbprint, false);
```

**Figure 3 Configuration Methods**

Method	Description
GetDeploymentInfo	Retrieves the deployment configuration, including the encoded service configuration.
GetServiceConfig	Retrieves and decodes the service configuration from the deployment info.
GetInstanceCount	Fetches the instance count for a specified role.
ChangeInstanceCount	Updates the service configuration and returns the complete XML.
ChangeConfigFile	Updates the service configuration with the service configuration provided to the function.
LookupCertificate	Passes in the environment setting containing the thumbprint and retrieves the certificate from the certificate store.

Figure 4 The Less-Than-85-Percent Block

```
else if (AvgCPU < 85.0) {
    Trace.TraceInformation("in the AvgCPU < 25 test.");
    string deploymentInfo =
        AzureRESTMgmtHelper.GetDeploymentInfo();
    string svcconfig =
        AzureRESTMgmtHelper.GetServiceConfig(deploymentInfo);
    int InstanceCount =
        System.Convert.ToInt32(
            AzureRESTMgmtHelper.GetInstanceCount(
                svcconfig, "WebRole1"));
    if (InstanceCount > 1) {
        InstanceCount--;
        string UpdatedSvCConfig =
            AzureRESTMgmtHelper.ChangeInstanceCount(
                svcconfig, "WebRole1", InstanceCount.ToString());
        AzureRESTMgmtHelper.ChangeConfigFile(UpdatedSvCConfig);
    }
}
```

This is the main code of the LookUpCertificate method and it's called in the methods where I want to interact with the REST API. I'll review the GetDeploymentInfo function as an example of how calls are constructed. For this example, I've hardcoded some of the variables needed to access the REST API:

```
string x_ms_version = "2009-10-01";
string SubscriptionID = "[your subscription ID]";
string ServiceName = "[your service name]";
string DeploymentSlot = "Production";
```

## A simple conditional statement tests whether utilization is higher or lower than 85 percent.

I need to create a `HttpWebRequest` with the proper URI, set the request headers and add my certificate to it. Here I build the URI string and create a new `HttpWebRequest` object using it:

```
string RequestUri = "https://management.core.windows.net/" +
    SubscriptionID + "/services/hostedservices/" +
    ServiceName + "/deploymentslots/" + DeploymentSlot;

HttpWebRequest RestRequest =
    (HttpWebRequest)HttpWebRequest.Create(RequestUri);
```

For the call to be valid, it must include the version in the header. Thus, I create a name-value collection, add the version key and data, and add that to the request headers collection:

```
NameValuePairCollection RequestHeaders =
    new NameValueCollection();
RequestHeaders.Add("x-ms-version", x_ms_version);
if (RequestHeaders != null) {
    RestRequest.Headers.Add(RequestHeaders);
}
```

The last thing to do to prepare this particular request is to add the certificate to the request:

```
X509Certificate cert = LookupCertificate("RESTMgmtCert");
RestRequest.ClientCertificates.Add(cert);
```

Finally, I execute the request and read the response:

```
RestResponse = RestRequest.GetResponse();
using (StreamReader RestResponseStream = new StreamReader(RestResponse.
GetResponseStream(), true)) {
    ResponseBody = RestResponseStream.ReadToEnd();
    RestResponseStream.Close();
}
```

That's the general pattern I used to construct requests made to the REST Management API. The `GetServiceConfig` function extracts the Service Configuration out of the deployment configuration, using LINQ to XML statements like the following:

```
XElement DeploymentInfo = XElement.Parse(DeploymentInfoXML);
string EncodedServiceConfig =
    (from element in DeploymentInfo.Elements()
    where element.Name.LocalName.Trim().ToLower() == "configuration"
    select (string)element.Value).Single();
```

In my code, the return of the `GetServiceConfig` is passed on to the `GetInstanceCount` or `ChangeInstance` count functions (or both) to extract the information or update it. The return from the `ChangeInstance` function is an updated Service Configuration, which is passed to `ChangeConfigFile`. In turn, `ChangeConfigFile` pushes the update to the service by constructing a request similar to the previous one used to fetch the deployment information, with these important differences:

1. `/?comp=config` is added to the end of the URI
2. The PUT verb is used instead of GET
3. The updated configuration is streamed as the request body

## Putting It All Together

With the functions in place to look up and change the service configuration, and having done the other preparatory work such as setting up counters, configuring the connection string settings for Storage, and installing certificates, it's time to implement the CPU threshold test.

The Visual Studio template produces a Worker Role that wakes up every 10 seconds to execute code. To keep things simple, I'm leaving that but adding a single timer that will run every five minutes. In the timer, a simple conditional statement tests whether utilization is higher or lower than 85 percent, and I'll create two instances of the Web Role. By doing this I guarantee that the number of instances will definitely decrease from the initial two instances to a single instance.

Inside the Worker Role I have a `Run` method that declares and instantiates the timer. Inside of the timer-elapsed handler I add a call to the `TestPerfData` function I created earlier. For this sample,

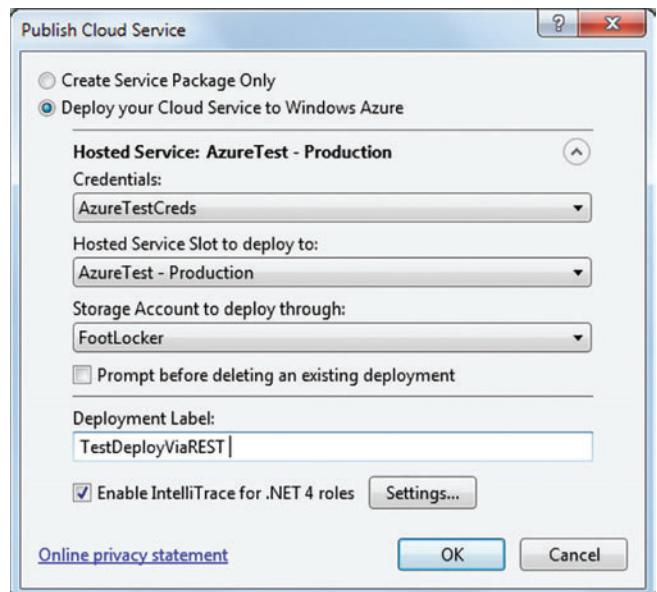


Figure 5 Publishing the Project

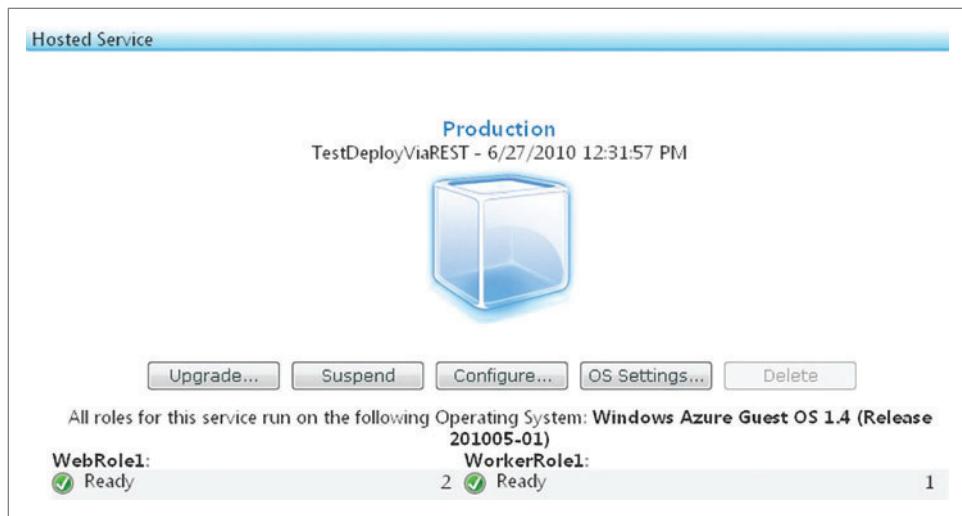


Figure 6 Two Web Roles and One Worker Role

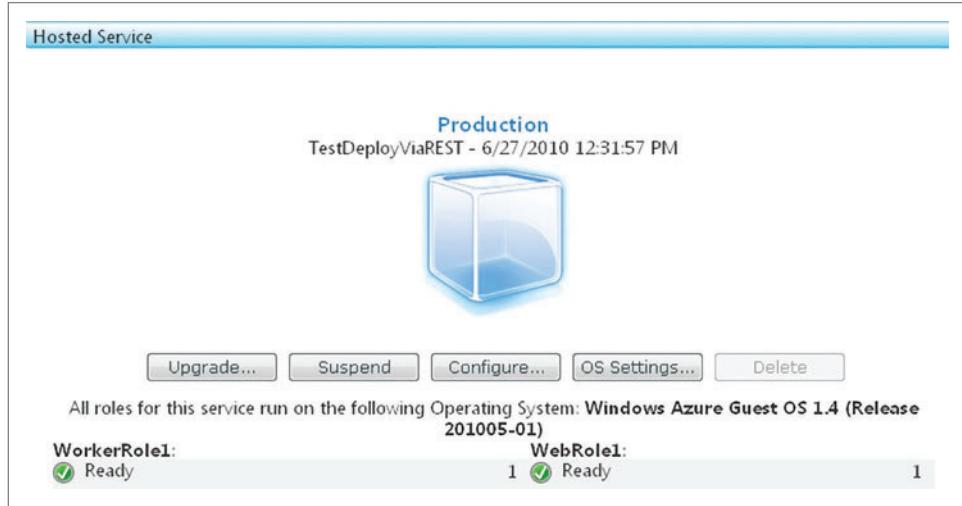


Figure 7 Now One Web Role and One Worker Role

I'm skipping the implementation of the greater-than condition because I know that the CPU utilization will not be that high. I set the less-than condition to be less than 85 percent as I'm sure the counter average will be lower than that. Setting these contrived conditions will allow me to see the change via the Web management console or via Server Explorer in Visual Studio.

In the less-than-85-percent block I check the instance count, modify the service configuration and update the running service configuration, as shown in **Figure 4**.

I make sure to check the instance count before adjusting down, because I don't want it to go to zero, as this is not a valid configuration and would fail.

## Running the Sample

I'm now ready to execute the example and demonstrate elasticity in Windows Azure. Knowing that my code is *always* right the first time—ahem—I right-click on the Cloud Service Project and click Publish. The dialog gives you the option to configure your credentials, which I've already done (see **Figure 5**).

I click OK and just have to wait for the package to be copied up and deployed. When deployment is complete, I switch to the Web management console and see two Web Roles and one Worker Role running, as shown in **Figure 6**.

I wait for the timer event to fire, executing the code that will determine that the average CPU utilization is less than 85 percent, and decrement the WebRole1 instance count. Once this happens, the management page will refresh to reflect an update to the deployment.

Because I'm using small VMs, changing the count by only one, and the application is lightweight (one.aspx page), the update doesn't take long and I see the final, auto-shrunk deployment as shown in **Figure 7**.

## Blue Skies

I want to share few final thoughts about the sample in the context of considering a real implementation. There are a few important points to think about.

First, the test is trivial and contrived. In a real implementation you'd need to evaluate more than simple CPU utilization and you'll need to take into account the quantum over which the collection occurred.

In addition, you need to evaluate the costs of using Windows Azure Storage. Depending on the solution, it might be advisable to scrub the records in the table for only ones that are of interest. You can decrease the upload interval to lower transaction costs, or you may want to move the data to SQL Azure to minimize that cost.

You also need to consider what happens during an update. A direct update will cause users to lose connectivity. It may be better to bring the new instances up in staging and then switch the virtual IP address. In either case, however, you'll have session and viewstate problems. A better solution is to go stateless and disable the test during scale adjustments.

That's it for my implementation of elasticity in Windows Azure. Download the code sample and start playing with it today. ■

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THANKS to the following technical expert for reviewing this article: Suraj Puri



# Multiparadigmatic .NET, Part 2

In my previous article ([msdn.microsoft.com/magazine/ff955611](http://msdn.microsoft.com/magazine/ff955611)), the first of this series, I mentioned that the two languages central to the Microsoft .NET Framework—C# and Visual Basic—are multiparadigm languages, just like C++, their syntactic (in the case of C#) or conceptual (in the case of Visual Basic) predecessor. Using a multiparadigmatic language can be confusing and difficult, particularly when the purposes of the different paradigms aren't clear.

## Commonality and Variability

But before we can start taking apart the different paradigms in these languages, a bigger question comes to mind: What, precisely, are we trying to do when we design a software system? Forget the “end result” goals—modularity, extensibility, simplicity and all that jazz—for a moment, and focus more on the “how” of the language. How, exactly, are we trying to create all those “end result” goals?

James O. Coplien—from his “Multi-Paradigm Design for C++” (Addison-Wesley Professional, 1998)—has an answer for us:

*When we think abstractly, we emphasize what is common while suppressing detail. A good software abstraction requires that we understand the problem well enough in all of its breadth to know what is common across related items of interest and to know what details vary from item to item. The items of interest are collectively called a family, and families—rather than individual applications—are the scope of architecture and design. We can use the commonality/variability model regardless of whether family members are modules, classes, functions, processes or types; it works for any paradigm. Commonality and variability are at the heart of most design techniques.*

Think about the traditional object paradigm for a moment. As object-oriented developers, we're taught from early on to “identify the nouns” in the system and look for the things that make up a particular entity—to find all the things that pertain to being a “teacher” within the system, for example, and put them into a class called Teacher. But if several “nouns” have overlapping and related behavior—such as a “student” having some data and operations overlapping with a “person” but with some marked differences—then we're taught that rather than replicate the common code, we should elevate the commonality into a base class, and relate the types to one another through inheritance. In other words, commonality is gathered together within a class, and variability is captured by extending from that class and introducing the variations. Finding the commonalities and variabilities within a system, and expressing them, forms the heart of design.

Commonalities are often the parts that are difficult to explicitly identify, not because we don't recognize them, but because they're so easily and intuitively recognizable it's tough to spot them. For example, if I say, “Vehicle,” what image pops into your head? If we do this exercise with a group of people, each will have a different image, yet there will be vast commonality among them all. However, if we start listing the various vehicles imagined, the different kinds of variabilities begin to emerge and categorize themselves (we hope), such that we can still have some set of commonalities among the vehicles.

## Positive and Negative Variability

Variability can come in two basic forms, one of which is easy to recognize and the other much more difficult. Positive variability is when the variability occurs in the form of adding to the basic commonality. For example, imagine the abstraction desired is that of a message, such as a SOAP message or e-mail. If we decide that a Message type has a header and body, and leave different kinds of messages to use that as the commonality, then a positive variability on this is a message that carries a particular value in its header, perhaps the date/time it was sent. This is usually easily captured in language constructs—in the object-oriented paradigm, for example, it's relatively trivial to create a Message subclass that adds the support for date/time sent.

Negative variability, however, is much trickier. As might be inferred, a negative variability removes or contradicts some facet of the commonality—a Message that has a header but no body (such as an acknowledgement message used by the messaging infrastructure) is a form of negative variability. And, as you can probably already guess, capturing this in a language construct is problematic—neither C# nor Visual Basic has a facility to remove a member declared in a base class. The best we could do in this case is return null or nothing from the Body member, which will clearly play havoc with any code that expects a Body to be present, such as verification routines that run a CRC on the Body to ensure it was transmitted correctly.

(Interestingly, XML Schema types offer negative variability in their schema-validation definitions, something that no mainstream programming language yet offers, which is one of the ways that the XML Schema Definition can mismatch against programming languages. Whether this will become a forthcoming feature in some as-yet-unwritten programming language, and whether it would be a Good Thing To Have, is an interesting discussion best had over beer.)

**Figure 1 Partial Implementation of a Point Class**

```
Public Class Point
    Public Sub New(ByVal XX As Integer, ByVal YY As Integer)
        Me.X = XX
        Me.y = YY
    End Sub

    Public Property X() As Integer
    Public Property y() As Integer

    Public Function Distance(ByVal other As Point) As Double
        Dim XDiff = Me.X - other.X
        Dim YDiff = Me.y - other.y
        Return System.Math.Sqrt((XDiff * XDiff) + (YDiff * YDiff))
    End Function

    Public Overrides Function Equals(ByVal obj As Object) As Boolean
        ' Are these the same type?
        If Me.GetType() = obj.GetType() Then
            Dim other As Point = obj
            Return other.X = Me.X And other.y = Me.y
        End If
        Return False
    End Function

    Public Overrides Function ToString() As String
        Return String.Format("({0},{1}", Me.X, Me.y)
    End Function
End Class
```

In many systems, negative variability is often handled using explicit code constructs at the client level—meaning, it's up to the users of the Message type to do some kind of if/else test to see what kind of Message it is before examining the Body, which renders the work put into the Message family all but irrelevant. Too much negative variability escaping the design is usually the underlying cause of calls from developers to “pitch it all and start over.”

## Binding Commonality and Variability

The actual moment that commonality and variability are set varies with each paradigm, and in general, the closer to run time that we

**Figure 2 A New Point Class with Floating-Point Members**

```
Public Class PointD
    Public Sub New(ByVal XX As Double, ByVal YY As Double)
        Me.X = XX
        Me.y = YY
    End Sub

    Public Property X() As Double
    Public Property y() As Double

    Public Function Distance(ByVal other As Point) As Double
        Dim XDiff = Me.X - other.X
        Dim YDiff = Me.y - other.y
        Return System.Math.Sqrt((XDiff * XDiff) + (YDiff * YDiff))
    End Function

    Public Overrides Function Equals(ByVal obj As Object) As Boolean
        ' Are these the same type?
        If Me.GetType() = obj.GetType() Then
            Dim other As PointD = obj
            Return other.X = Me.X And other.y = Me.y
        End If
        Return False
    End Function

    Public Overrides Function ToString() As String
        Return String.Format("({0},{1}", Me.X, Me.y)
    End Function
End Class
```

can bind those decisions, the more control we give customers and users over the system's evolution and as a whole. When discussing a particular paradigm or technique within a paradigm, it's important to recognize in which of these four “bind times” the variability kicks in:

- Source time.** This is the time before the compiler fires up, when the developer (or some other entity) is creating the source files that will eventually be fed into the compiler. Code-generative techniques, such as the T4 template engine—and to a lesser degree the ASP.NET system—operate at a source-time binding.
- Compile time.** As its name implies, this binding occurs during the compiler's pass over the source code to render it into compiled bytecode or executable CPU instructions. A great deal of decision making is finalized here, though not all of it, as we'll see.
- Link/load time.** At the time the program loads and runs, an additional point of variability kicks in, based on the specific modules (assemblies, in the case of .NET DLLs, in the case of native Windows code) that are loaded. This is commonly referred to as a plug-in- or add-in-style architecture when it's applied at a whole-scale program level.
- Run time.** During the program's execution, certain variabilities may be captured based on user input and decision making, and potentially different code executed (or even generated) based on those decisions/input.

In some cases, the design process will want to start from these “bind times” and work backward to figure out what language constructs can support the requirement; for example, a user may want to have the ability to add/remove/modify variability at run time (so that we don't have to go back through a compile cycle or reload code), which means that whatever paradigm the designer uses, it must support a runtime variability binding.

## Challenge

In my previous article, I left readers with a question:

*As an exercise, consider this: The .NET Framework 2.0 introduced generics (parameterized types). Why? From a design perspective, what purpose do they serve? (And for the record, answers of “It lets us have type-safe collections” are missing the point—Windows Communication Foundation uses generics extensively, clearly in ways that aren't just about type-safe collections.)*

Taking this a little further, look at the (partial) implementation of a Point class in **Figure 1**, representing a Cartesian X/Y point, like pixel coordinates on a screen, or a more classical graph.

In and of itself, it's not really all that exciting. The rest of the implementation is left to the reader's imagination, because it's not central to the discussion.

Notice that this Point implementation has made a few assumptions about the way Points are supposed to be utilized. For example, the X and Y elements of the Point are integers, meaning that this Point class can't represent fractional Points, such as Points at (0.5,0.5). Initially, this may be an acceptable decision, but inevitably, a request will come up asking to be able to represent “fractional Points” (for whatever reason). Now, the developer has an interesting problem: How to represent this new requirement?

Starting from the basics, let's do the "Oh Lord don't do that" thing and simply create a new Point class that uses floating-point members instead of integral members, and see what emerges (see Figure 2; note that PointD is short for "Point-Double," meaning it uses Doubles). As is pretty clear, there's a lot of conceptual overlap here between the two Point types. According to the commonality/variability theory of design, that means we need to somehow capture the common parts and allow for variability. Classic object-orientation would have us do it through inheritance, elevating the commonality into a base class or interface (Point), then implementing that in subclasses (PointI and PointD, perhaps).

Interesting problems emerge from attempting this, however. First, the X and Y properties need a type associated with them, but the variability in the two different subclasses concerns how the X and Y coordinates are stored, and thus represented, to users. The designer could always simply opt for the largest/widest/most comprehensive representation, which in this case would be a Double, but doing so means having a Point that can only have Integer values is now lost as an option, and it undoes all of the work the inheritance was intended to permit. Also, because they're related by inheritance now, the two Point-inheriting implementations are now supposedly interchangeable, so we should be able to pass a PointD into a PointI Distance method, which may or may not be desirable. And is a PointD of (0.0, 0.0) equivalent (as in Equals) to a PointI of (0,0)? All these issues have to be considered.

Even if these problems are somehow fixed or made tractable, other problems emerge. Later, we might want a Point that accepts values larger than can be held in an Integer. Or only absolute-positive values (meaning the origin is in the lower-left corner) are deemed acceptable. Each of these different requirements will mean new subclasses of Point must be created.

Stepping back for a moment, the original desire was to reuse the commonality of the implementation of Point but allow for variability in the type/representation of the values that make up the

**Figure 3 A Generic Constraint on Type**

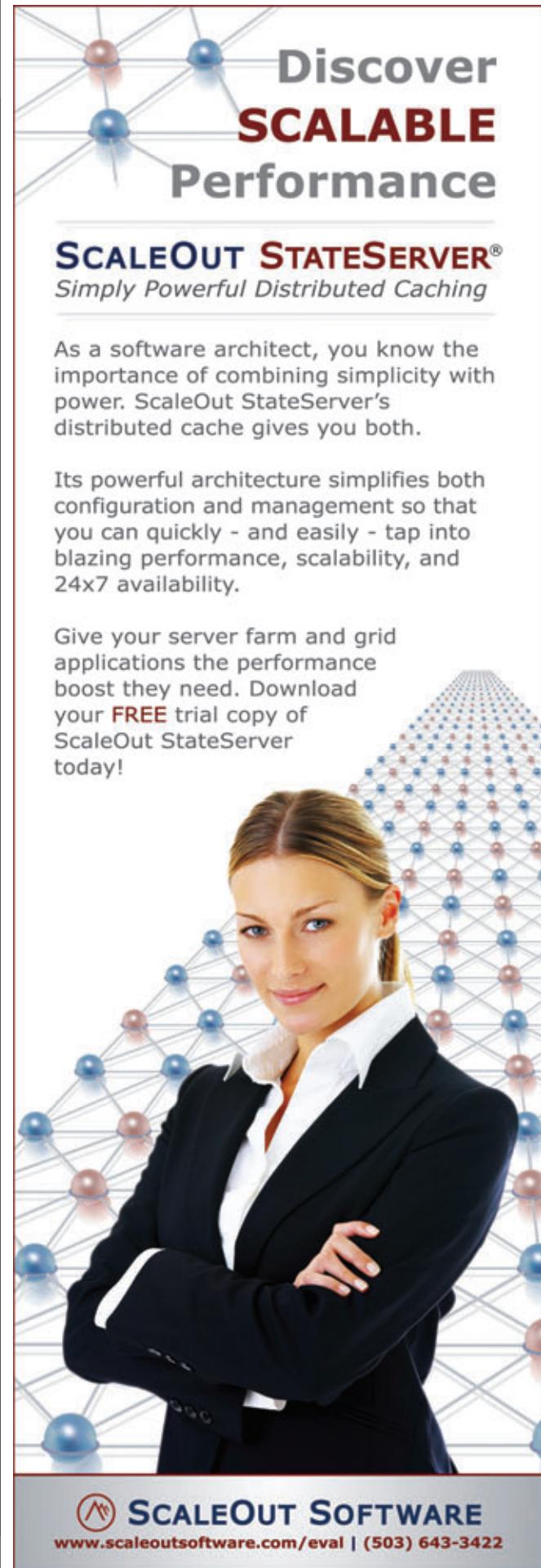
```
Public Class GPoint(Of Rep As {IComparable, IConvertible})
    Public Sub New(ByVal XX As Rep, ByVal YY As Rep)
        Me.X = XX
        Me.Y = YY
    End Sub

    Public Property X() As Rep
    Public Property Y() As Rep

    Public Function Distance(ByVal other As GPoint(Of Rep)) As Double
        Dim XDiff = (Me.X.ToDouble(Nothing)) - (other.X.ToDouble(Nothing))
        Dim YDiff = (Me.Y.ToDouble(Nothing)) - (other.Y.ToDouble(Nothing))
        Return System.Math.Sqrt((XDiff * XDiff) + (YDiff * YDiff))
    End Function

    Public Overrides Function Equals(ByVal obj As Object) As Boolean
        ' Are these the same type?
        If Me.GetType() = obj.GetType() Then
            Dim other As GPoint(Of Rep) = obj
            Return (other.X.CompareTo(Me.X) = 0) And (other.Y.CompareTo(Me.Y) = 0)
        End If
        Return False
    End Function

    Public Overrides Function ToString() As String
        Return String.Format("({0},{1}", Me.X, Me.Y)
    End Function
End Class
```



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Point. In the ideal, depending on the kind of graph we're working with, we should be able to choose the representation at the time the Point is created, and it would represent itself as an entirely distinct and different type, which is precisely what generics do.

Doing this, however, represents a problem: The compiler insists that "Rep" types won't necessarily have "+" and "-" operators defined for it, because it thinks we want to put any possible type here—Integers, Longs, Strings, Buttons, DatabaseConnections or whatever else comes to mind—and that's clearly a little too variable. So, once again, we need to express some commonality to the type that can be used here, in the form of a generic constraint on what types "Rep" can be (see **Figure 3**).

In this case, two constraints are imposed: one to ensure that any "Rep" type can be converted to double values (to calculate the distance between the two points), and the other to ensure that the constituent X and Y values can be compared to see if they're greater-than/equal-to/less-than one another.

And now the reason for generics becomes clearer: they support a different "axis" of variability for design, one that's drastically different from the traditional inheritance-based axis. It allows the designer to render the implementation as commonalities, and the types being operated upon by the implementation to be variabilities.

Note that this implementation assumes that the variability is occurring at compile time, rather than at link/load time or run time—if the user wants or needs to specify the type of the X/Y members of the Point at run time, then a different solution is needed.

## Not Dead (or Done) Yet!

If all of software design is a giant exercise in commonality and variability, then the need to understand multiparadigmatic design becomes clear: Each of the different paradigms offers different ways to achieve this commonality/variability, and mixing the paradigms creates confusion and leads to calls for a complete rewrite. Just as the human brain starts to get confused when we try to map three-dimensional constructs in our head into four and five dimensions, too many dimensions of variability in software cause confusion.

In the next half-dozen or so articles, I'll be looking at the different ways that each paradigm supported by C# and Visual Basic—the structural, object-oriented, metaprogramming, functional and dynamic paradigms being the principals—provide functionality to capture commonality and allows for variability. When we're through all of that, we'll examine how some of them can be combined in interesting ways to make your designs more modular, extensible, maintainable and all that other stuff.

Happy coding! ■

---

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---

**THANKS** to the following technical expert for reviewing this article:  
Anthony Green



The image shows a fortune cookie against a blue background. A white ribbon is tied around the cookie, with the text "Today Is Your Lucky Day." printed on it.

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# Multi-Touch and Inertia

UIs on computers seem to be most appealing when they mask the digital nature of the underlying technology, and instead mimic the analog feel of the real world. This trend began when graphical interfaces started replacing command lines, and then continued with the increased use of photographs, sound and other media.

The incorporation of multi-touch into video displays has given an extra boost to the process of making user controls more lifelike and intuitive. I think you've only begun to glimpse the potential of the touch revolution to revamp your relationship with the computer screen.

Perhaps someday we will even eliminate one of the ugliest vestiges of digital technology known to man: the push-button volume control. The basic dial that controlled volume (and other settings) on radios and televisions was delightfully simple, but has been replaced with awkward push buttons on remote controls and the appliances themselves.

Computer interfaces often offer sliders for volume control. These are almost as good as dials. But push-button volume controls are still persistent. Even the multi-touch screen of the Zune HD wants you to press plus and minus signs to increase and decrease volume. More preferable would be a dial that responds to touch.

I like the dial for multi-touch. Perhaps that's why I focused on simulating dials in my article, "Finger Style: Exploring Multi-Touch Support in Silverlight," in the March 2010 issue of *MSDN Magazine* ([msdn.microsoft.com/magazine/ee336026](http://msdn.microsoft.com/magazine/ee336026)), and why I'm returning to dials to talk about handling multi-touch inertia in the Windows Presentation Foundation (WPF).

## The Inertia Event

One of the ways in which a multi-touch interface attempts to mimic the real world is by introducing inertia—the tendency for objects to maintain the same velocity unless acted upon by other forces, such as friction. In multi-touch interfaces, inertia can keep a visual object moving when the fingers have left the screen. The most common application of touch inertia is in navigating lists, and inertia is already built into the WPF `ListBox`.

Among the downloadable code for this article is a little program called `IntertialListBoxDemo` that simply fills a WPF `ListBox` with a bunch of items so you can test it out on your multi-touch display.

In your own WPF controls, you'll need to decide how much inertia you want, if any. Handling inertia is easiest if you just want inertia to cause the same response from your program as direct manipulation. The hard part is getting a good understanding of the numeric values involved.

As you've seen in previous articles, a WPF element is informed of the onset of multi-touch manipulation with two events: `ManipulationStarting` (which is a good opportunity for performing some initialization) and `ManipulationStarted`. These two events are then followed by potentially very many `ManipulationDelta` events, which consolidate the action of one, two or more fingers into translation, scaling and rotation information.

You've only begun to  
glimpse the potential of the  
touch revolution.

When all the fingers have lifted from the element being manipulated, a `ManipulationInertiaStarting` event occurs. This is your program's opportunity to specify how much inertia you want. (I'll discuss how, shortly.) The effect of inertia takes the form of additional `ManipulationDelta` events until the object "runs down" and a `ManipulationCompleted` event signals the end. If you don't do anything with `ManipulationInertiaStarting`, it's followed immediately by `ManipulationCompleted`.

The use of the `ManipulationDelta` event to indicate both direct manipulations and inertia makes this whole scheme extremely easy to use. Basically, you can implement inertia with a single statement in the `ManipulationInertiaStarting` event. If necessary, you can discern the difference between direct manipulation and inertia by the `IsInertial` property of `ManipulationDeltaEventArgs`.

As you'll see, you specify how much inertia you want in one of two different ways, but they both involve deceleration—a decrease in velocity over a period of time until the velocity reaches zero and the object stops moving. This involves some concepts in physics that most programmers don't encounter often, so perhaps a little refresher course might help.

## A Refresher on Acceleration

If something is moving, it is said to have a *speed* or *velocity* that can be expressed in units of distance-per-time. If the velocity is itself changing over the course of time, then the object has *acceleration*.

Code download available at [code.msdn.microsoft.com/mag2010UIFrontiers](http://code.msdn.microsoft.com/mag2010UIFrontiers).

A negative acceleration (indicating decreasing velocity) is often called *deceleration*.

Throughout this discussion, let's assume that the acceleration or deceleration itself is constant. A constant acceleration means that velocity changes linearly—an equal amount per unit of time. If acceleration is 0, the velocity remains constant.

For example, automobile manufacturers sometimes advertise their cars as being able to accelerate from 0 to 60 mph in a certain number of seconds, let's say, 8 seconds. The car is initially at rest but by the end of 8 seconds, it's going at 60 mph, as shown in **Figure 1**.

Notice that the velocity increases by the same amount every second. The acceleration is expressed as the change in velocity during a particular period of time, or in this case, 7.5 mph per second.

That acceleration value is a little awkward because there are two units of time involved: hours and seconds. Let's get rid of hours and just use seconds. Because 60 mph is 88 feet per second, the car could equivalently be said to go from 0 to 88 feet per second in 8 seconds. The acceleration is 11 feet per second per second, or (as it's often phrased) 11 feet per second squared.

We can go back to miles and hours, but the units get ridiculous as the acceleration is calculated as 27,000 mph squared. This implies that at the end of the hour, the car is traveling 27,000 mph. Of course it doesn't do that. In real life, as soon as the car gets up to 60 mph or thereabouts, the velocity levels off and the acceleration goes down to 0. That's a change in acceleration, which in engineering circles is referred to as a *jerk*.

## You specify how much inertia you want in one of two different ways.

But for this exercise we're assuming constant acceleration. Starting at a velocity of 0, as a result of acceleration  $a$ , the distance  $x$  traveled during time  $t$  is:

$$x = \frac{1}{2}at^2$$

The  $\frac{1}{2}$  and square are necessary because the velocity  $v$  is calculated as the first derivative of the distance with respect to time:

$$v = \frac{dx}{dt} = at$$

If  $a$  is 11 feet per second squared, then at  $t$  equal to 1 second, the velocity is 11 feet per second, but the car has only traveled 5.5 feet. At  $t$  equal to 2 seconds, the velocity is 22 feet per second, and the car has traveled a total of 22 feet. During each second, the car travels a distance based on the average velocity during that second. At  $t$  equal to 8 seconds, the velocity is 88 feet per second, and the car has traveled a total of 352 feet.

Multi-touch inertia is like watching the car in reverse: At the time the fingers lift from the screen, the object has a certain velocity. The application specifies a deceleration that causes the velocity of the object to decrease linearly down to 0. The higher the deceleration, the quicker the object stops. A deceleration of 0 causes the object to continue moving at the same velocity forever.

Let's focus on rotational inertia first, because it's an effect familiar from the real world.

### Two Ways to Decelerate

The ManipulationDelta event arguments include a Velocities property of type ManipulationVelocities, which itself has three properties corresponding to the three types of manipulation:

- LinearVelocity of type Vector
- ExpansionVelocity of type Vector
- AngularVelocity of type double

The first two properties are expressed as device-independent units per millisecond; the third is in angles (in degrees) per millisecond. Of course, the millisecond is not an intuitively comprehensible period of time, so if you need to look at these values and get a sense of what they mean, you'll want to multiply them by 1,000 to convert to seconds.

Applications don't often make use of these Velocity properties, but they provide initial velocities for inertia. When the user's fingers leave the screen, a ManipulationInertiaStarting event occurs. The event arguments include these three properties that let you specify inertia separately for those same three types of manipulation:

- TranslationBehavior of type InertiaTranslationBehavior
- ExpansionBehavior of type InertiaExpansionBehavior
- RotationBehavior of type InertiaRotationBehavior

Each of those classes has an InitialVelocity property, a DesiredDeceleration property, and a third property named DesiredDisplacement, DesiredExpansion or DesiredRotation, depending on the class.

For translation and rotation, all the Desired properties have default values of Double.NaN, that special bit configuration that indicates "not a number." For expansion, the Desired properties are of type Vector with X and Y values of Double.NaN, but the concept is the same.

Let's focus on rotational inertia first, because it's an effect familiar from the real world (such as a playground roundabout), and you don't have to worry about objects flying off the screen.

By the time you get a ManipulationInertiaStarting event, the InertiaRotationBehavior object has been created, and the InitialVelocity value has been set from the previous ManipulationDelta event. If the InitialVelocity is 1.08, for example, that's 1.08 degrees per millisecond, or 1,080 degrees per second, or three revolutions per second, or 180 rpm.

**Figure 1 Acceleration**

Seconds	Velocity
0	0 mph
1	7.5
2	15
3	22.5
4	30
5	37.5
6	45
7	52.5
8	60

# Are you kidding?



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To keep the object spinning, you set either DesiredRotation or DesiredDeceleration but not both. If you try to set both, the last one you set will be valid and the other will be Double.NaN.

The first option is to set DesiredRotation to a value in degrees. This is the number of degrees the object will spin before it stops. If you set DesiredRotation to 360, for example, the spinning object will make just one additional revolution, slowing down and stopping in the process. The advantage is that you get the same amount of inertial activity regardless of the initial speed, so it's easy to predict what will happen. The disadvantage is that it's not entirely natural.

The alternative is to set DesiredDeceleration to a value in units of degrees per millisecond squared, and here's where it becomes a bit slippery because it's hard to guess at a good value.

If InitialVelocity is 1.08 degrees per millisecond and you set DesiredDeceleration to 0.01 degrees per millisecond squared, then the velocity will decrease by 0.01 degrees every millisecond: to 1.07 degrees per millisecond at the end of the first millisecond, 1.06 degrees per millisecond at the end of the second millisecond, and so forth linearly until the velocity gets down to 0. That whole process will take 108 ms, or a little more than one-tenth of a second.

You probably want to set DesiredDeceleration to something less than that, perhaps 0.001 degrees per millisecond squared, which will cause the object to continue spinning for 1.08 seconds.

When your finger is rotating the dial, the meter shows the current angular velocity.

Watch out if you want to convert the deceleration units to something a little easier for the human mind to contemplate. A velocity of 1.08 degrees per millisecond is the same as 1,080 degrees per second, but a deceleration of 0.001 degrees per millisecond squared is 1,000 degrees per second squared. To convert deceleration to seconds you need to multiply by 1,000 *twice* because time is squared.

If you combine the two formulas shown earlier and eliminate  $t$ , you get:

$$a = \frac{v^2}{2x}$$

This implies that the two methods for setting deceleration are equivalent and can be converted from one to the other. If the InitialVelocity is 1.08 degrees per millisecond, and you set the DesiredDeceleration to 0.001 degrees per millisecond squared, that's equivalent to setting DesiredRotation to 583.2 degrees. In either case, rotation stops after 1,080 ms.

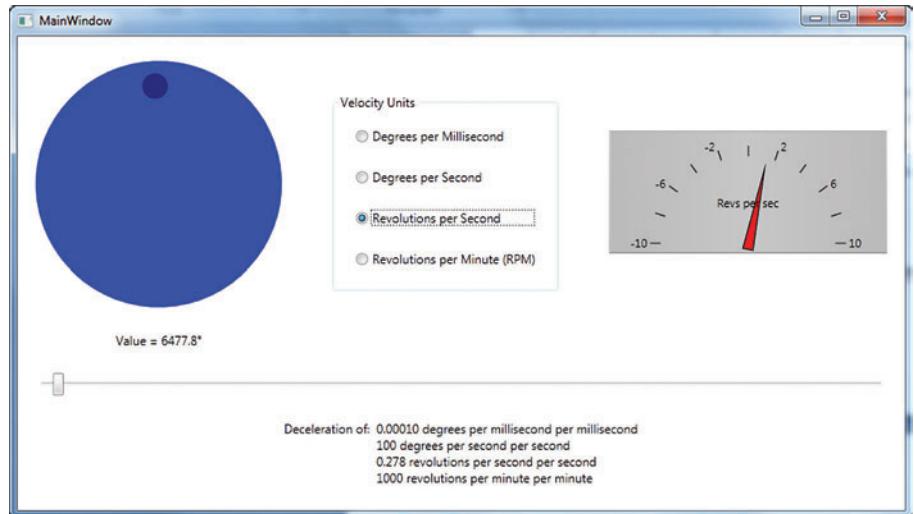


Figure 2 RotationalInertiaDemo Program in Action

## Experimentation

To get a feel for rotational inertia, I built the RotationalInertiaDemo program shown in **Figure 2**.

The wheel on the left is what you turn with your finger, either clockwise or counter-clockwise. It's very simple: just a UserControl derivative with two Ellipse elements in a Grid with all the Manipulation events handled in MainWindow.

The ManipulationStarting event performs initialization by restricting the manipulation to rotation only, allowing single-finger rotation, and setting the center of rotation:

```
args.IsSingleTouchEnabled = true;
args.Mode = ManipulationModes.Rotate;
args.Pivot = new ManipulationPivot(
    new Point(ctrl.ActualWidth / 2,
        ctrl.ActualHeight / 2), 50);
```

The speedometer at the right is a class called ValueMeter, and shows the current velocity of the wheel. If it looks vaguely familiar, it's only because it's an enhanced version of a ProgressBar template from an article I wrote for this magazine more than three years ago. The enhancements involved some flexibility with the labels so I could use it to show velocity in four different units. The GroupBox in the middle of the window let you select those units.

When your finger is rotating the dial, the meter shows the current angular velocity available from the Velocities.AngularVelocity sub-property of the ManipulationDelta event arguments. But I found it wasn't possible to funnel the velocity of the dial directly to ValueMeter. The result was too jittery. I had to write a little ValueSmoothen class to perform a weighted average of all the values from the past quarter second. The ManipulationDelta event handler also sets a RotateTransform object that actually rotates the dial:

```
rotate.Angle += args.DeltaManipulation.Rotation;
```

Finally, the Slider at the bottom lets you select a deceleration value. The value of the Slider is only read when the finger leaves the dial and a ManipulationInertiaStarted event is fired:

```
args.RotationBehavior.DesiredDeceleration = slider.Value;
```

That's the entire body of the ManipulationInertiaStarted event handler. During the inertial phase of the manipulation, the velocity

Figure 3 The OnManipulationDelta Event in BoundaryDemo

```
protected override void OnManipulationDelta(  
    ManipulationEventArgs args) {  
  
    FrameworkElement element =  
        args.Source as FrameworkElement;  
    MatrixTransform xform =  
        element.RenderTransform as MatrixTransform;  
    Matrix matx = xform.Matrix;  
    Vector totalTranslate =  
        args.DeltaManipulation.Translation;  
    Vector usableTranslate = totalTranslate;  
  
    if (args.IsInertial) {  
        double xAttenuation = 0, yAttenuation = 0, attenuation = 0;  
  
        if (matx.OffsetX < 0)  
            xAttenuation = -matx.OffsetX;  
        else  
            xAttenuation = matx.OffsetX +  
                element.ActualWidth - mainGrid.ActualWidth;  
  
        if (matx.OffsetY < 0)  
            yAttenuation = -matx.OffsetY;  
        else  
            yAttenuation = matx.OffsetY +  
                element.ActualHeight - mainGrid.ActualHeight;  
  
        xAttenuation = Math.Max(0, Math.Min(  
            1, xAttenuation / (element.ActualWidth / 2)));  
        yAttenuation = Math.Max(0, Math.Min(  
            1, yAttenuation / (element.ActualHeight / 2)));  
        attenuation = Math.Max(xAttenuation, yAttenuation);  
  
        if (attenuation > 0) {  
            usableTranslate.X =  
                (1 - attenuation) * totalTranslate.X;  
            usableTranslate.Y =  
                (1 - attenuation) * totalTranslate.Y;  
  
            if (totalTranslate != usableTranslate)  
                args.ReportBoundaryFeedback(  
                    new ManipulationDelta(totalTranslate -  
                        usableTranslate, 0, new Vector(), new Vector()));  
  
            if (attenuation > 0.99)  
                args.Complete();  
        }  
        matx.Translate(usableTranslate.X, usableTranslate.Y);  
        xform.Matrix = matx;  
    }  
    args.Handled = true;  
    base.OnManipulationDelta(args);  
}
```

values are much more regular and don't have to be smoothed, so the ManipulationDelta handler uses the IsInertial property to determine when to pass velocity values directly to the meter.

## Boundaries and Bounce Back

The most common use of inertia with multi-touch is in moving objects around the screen, such as scrolling through a long list or flicking elements to the side. The big problem is that it's very easy to cause an element to go flying right off the screen!

But in the process of handling that little problem, you'll discover that WPF has a built-in feature that makes manipulation inertia even more realistic. You may have noticed earlier in the ListBoxDemo program that when you let inertia scroll to the end or beginning of the list, the entire window bounces a bit when the ListBox reaches the end. That's also an effect you can get in your own applications (if you want it).

It's very easy to cause an element to go flying right off the screen!

The BoundaryDemo program consists of just one ellipse with an identity MatrixTransform set to its RenderTransform property sitting in a Grid named mainGrid. Only translation is enabled during the OnManipulationStarting override. The OnManipulationInertiaStarting method sets inertia deceleration like so:

```
args.TranslationBehavior.DesiredDeceleration = 0.0001;
```

That's 0.0001 device-independent units per millisecond squared, or 100 device-independent units per second squared, or about 1 inch per second squared.

The OnManipulationDelta override is shown in **Figure 3**. Notice the special handling when the IsInertial is true. The idea behind the

code is that the translation factors should be attenuated when the ellipse has drifted partially off the screen. The attenuation factor is 0 if the ellipse is within mainGrid, and goes up to 1 when the ellipse is halfway beyond the boundary of mainGrid. The attenuation factor is then applied to the translation vector delivered to the method (called totalTranslate) to calculate usableTranslate, which provides the values actually applied to the transform matrix.

The resulting effect is that the ellipse doesn't stop immediately when it hits the boundary, but slows down dramatically as if encountering some thick sludge.

The OnManipulationDelta override also calls the ReportBoundaryFeedback method, passing to it the unused portion of the translation vector, which is the vector totalTranslate minus usableTranslate. By default, this is processed to make the window bounce a bit as the ellipse slows down, demonstrating the physics principle that for every action there's an opposite and equal reaction.

This effect works best when the velocity on impact is fairly large. If the ellipse has slowed down appreciably, there's a vibration effect that's less satisfactory, but it's something you might want to control in more detail. If you don't want the effect at all (or only want it in some cases), you can simply avoid calling ReportBoundaryFeedback. Or you can handle the ManipulationBoundaryFeedback event yourself. You can inhibit default processing by setting the Handled property of the event arguments to true, or you can choose another approach. I've left an empty OnManipulationBoundaryFeedback method in the program for your experimentation. ■

**CHARLES PETZOLD** is a longtime contributing editor to MSDN Magazine. He's currently writing "Programming Windows Phone 7" (Microsoft Press), which will be published as a free downloadable e-book in the fall of 2010. A preview edition is currently available through his Web site [charlespetzold.com](http://charlespetzold.com).

**THANKS** to the following technical experts for reviewing this article:  
Doug Kramer and Robert Levy



# Devs and Designers Should Be Friends

Developers and designers don't usually get along well, and they need to. I first encountered this antipathy at Tech-Ed 2007 in Barcelona, Spain—the first time I'd seen a whole track of talks aimed at designers. The attendees hated this track, panning it so badly that management had to cancel it after the second day. I observed a few of these talks and found their quality decent. I didn't see any of the usual causes of terrible evaluations, such as demos not working or the speaker being more hungover than usual. Instead, I think that, at that time, the developer community was not willing to hear the fundamental message of the track: that these newfangled Windows Presentation Foundation (WPF) and Silverlight graphical environments required the services of new team members, with different skills but with status equal to the developers.

## Developers and designers hold different worldviews.

Their attitude toward each other hasn't improved much. My keynote talk at Dev Days in Amsterdam, Netherlands, in 2008 pleased both communities, but then the designers went off into their own world and didn't rejoin the developers until evening, when the beer started flowing (funny how that works). The same thing happened with my keynote at ReMix in Milan in 2009, except that in Italy they served wine.

Developers and designers hold different worldviews, as do physicians and surgeons. Both pairs make different, incompatible uses of similar environments; both take different, incompatible approaches to similar problems. And both developers and designers are now necessary to any successful client program, as both physicians and surgeons are necessary to any successful medical practice.

The antipathy between developers and designers reminds me of the conflict between cowboys and farmers in "Oklahoma!"—the 1943 Rodgers and Hammerstein stage musical (exclamation point abuse didn't start with Yahoo!). In the song "The Farmer and the Cowman Should Be Friends," Aunt Eller has to pull a gun to force the two groups to mingle at a dance (you can see a YouTube clip at [tinyurl.com/pvu93l](http://tinyurl.com/pvu93l) for an excellent performance).

I'd like to encourage better cooperation between the developer and designer communities—ideally not requiring coercion with firearms. Perhaps I'd update the lyrics:

*Oh, the devs and the designers should be friends,  
Oh, the devs and the designers should be friends.  
One just bangs out code all day  
The other wears a cool beret  
But that's no reason why they can't be friends.*

*Software folks should stick together,  
Software folks should all be friends.  
Some get down with Visual C#  
Others get high on Expression Blend.*

*Oh, the devs and the designers should be friends,  
Oh, the devs and the designers should be friends.  
One of them grinds his tooth enamel  
The other knows how to think in XAML  
But that's no reason why they can't be friends.*

When I teach WPF or Silverlight at a company, I insist that each class contain both developers and designers. And when I consult with companies on UI projects, I insist that the design team contain both. Usually the designer figures out what would make the user happy and the developer figures out how to implement those ideas efficiently, but a surprising amount of cross-fertilization runs both ways.

For example, at a recent session with a European client, I proposed a classic dialog box for looking up a customer, with a text box for government ID and a calendar control for date of birth, with labels identifying each. The designer said, "Fine, but this operation happens so frequently, how about a search box on the toolbar like Google? The user types in whatever information she has, and we'll take it from there, like a search engine." "Yes, I can parse out all the possible inputs," said the developer, "I have some good reusable classes, it won't take long." (It did, but *sic semper cum geeks*.) "And we can put a prompt string inside the text box, so the user knows what it's for," I added. And—zing!—we had a prototype in front of users for testing in just a few days.

That's what we can accomplish when developers and designers work together, assisted by a designated curmudgeon who keeps the pot stirred. Now start doing it, or I'll butcher that song again. ■

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**DAVID S. PLATT** teaches Programming .NET at Harvard University Extension School and at companies all over the world. He is the author of 11 programming books, including "Why Software Sucks" (Addison-Wesley Professional, 2006) and "Introducing Microsoft .NET" (Microsoft Press, 2002). Microsoft named him a Software Legend in 2002. He wonders whether he should tape down two of his daughter's fingers so she learns how to count in octal. Contact him at [rollthunder.com](http://rollthunder.com).

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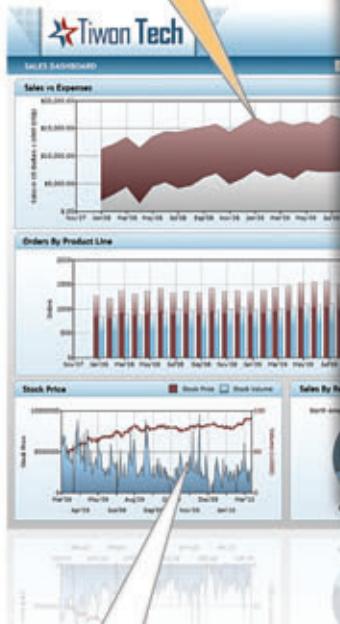
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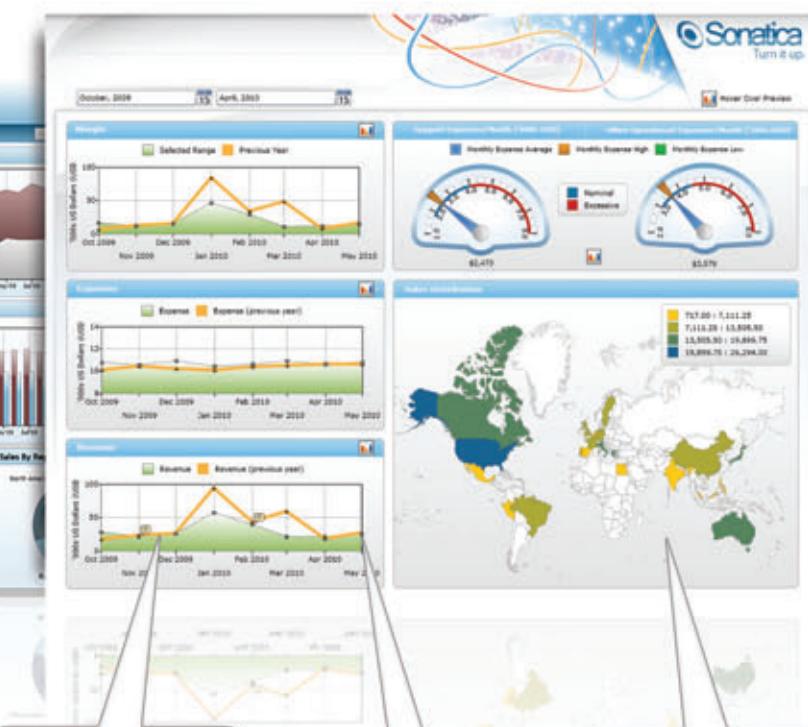
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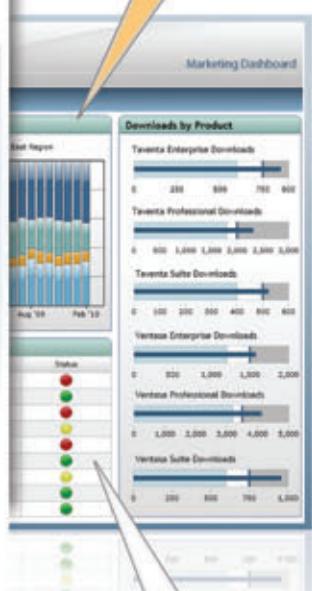


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