Optimization Services (OS) Framework

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Outline

Optimization Services (OS)

Service Oriented Architectures and Web Services

Optimization As a Web Service

OS Protocols
- OSProtocols: Representation
- OSProtocols: Communication
- OSProtocols: Registry

Solver Service – An OS Implementation

Client Service – An OS Implementation

Summary

Optimization Services (OS)

Software as a service! In industry, CRM (customer relationship software), tax preparation, Office Live, etc. are all becoming services. All of the major players in software are promising software as a service. There clearly is a trend away from the fat client loaded with lots of heavyweight applications.

So why not Optimization Services?

What is Optimization Services?

Short Answer: *A service oriented architecture for optimization based on Web services.*

Optimization Services (OS)

Optimization Services Long Answer:

- *A set of standards to facilitate communication between modeling languages, solvers, problem analyzers, simulation engines, and registry and discovery services in a distributed computing environment.*

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Optimization Services (OS)

Optimization Services Long Answer:

- *A set of standards to facilitate communication between modeling languages, solvers, problem analyzers, simulation engines, and registry and discovery services in a distributed computing environment.*
- *These standards should be programming language, operating system, and hardware independent.*
- *These standards should be open and available for everyone in the OR community to use free of charge.*

Optimization Services

Optimization services is needed because there are:

- Numerous modeling languages each with their own format for storing the underlying model.
- Numerous solvers each with their own application program interface (API). There is no standard API.
- Numerous operating system, hardware, and programming language combination. It is difficult for software vendors to support every platform.
- No standard for representing problem instances, especially nonlinear optimization instances.
- No real standard for registry and discovery services.

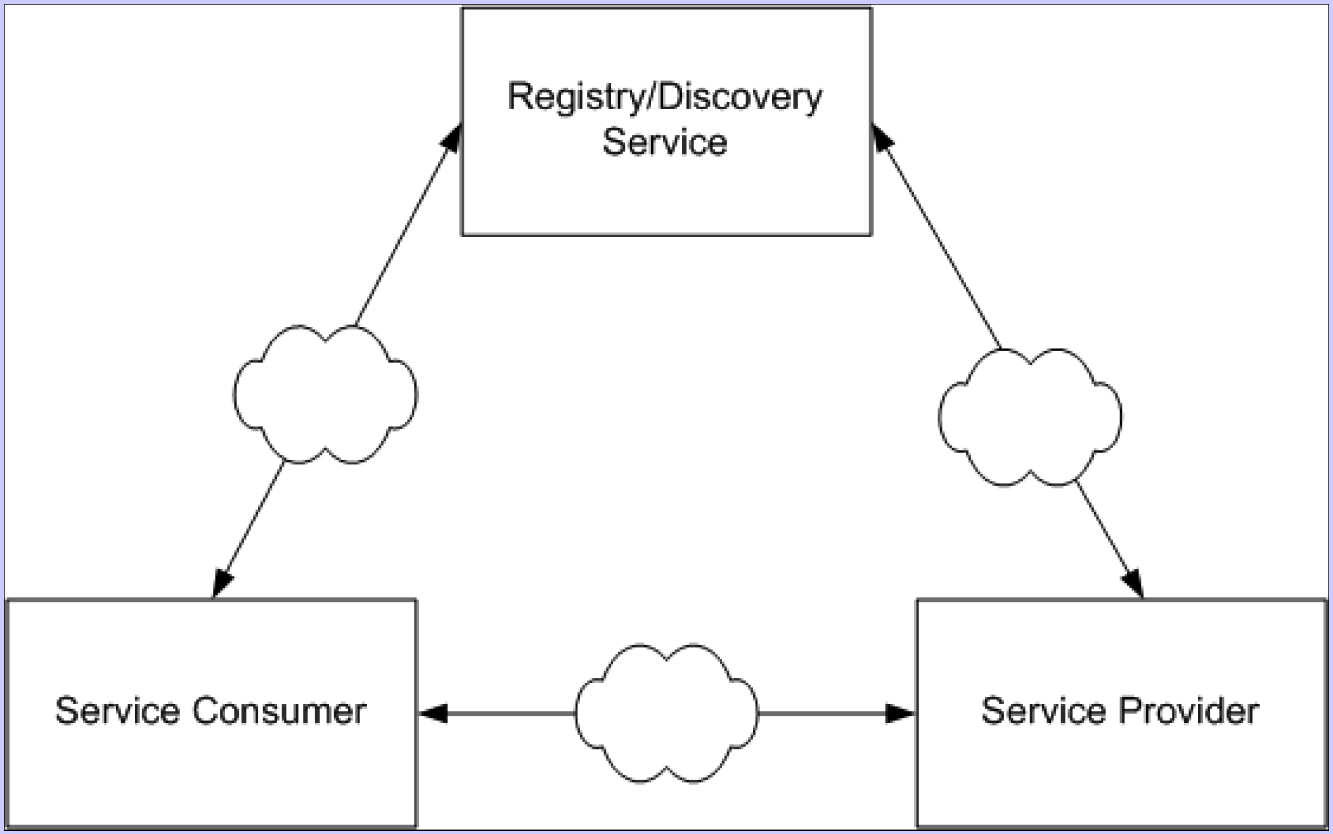
Optimization Services

In the rest of the talk we describe how to blend together:

- A Service Oriented Architecture (SOA) using Web Services
- Optimization Service Protocols – one way to view optimization systems is as a set of protocols
- Solver and Client Service implementations based on Web Services and OS Protocols

Service Oriented Architectures

Key Trend: An important trend in industry is the move to services oriented architectures and Web services. **All** of the major players such as IBM, Microsoft, Oracle, Sun, etc are talking about service oriented architectures and bringing out products.



Service Oriented Architectures

An SOA is a **philosophy** for how a distributed component architecture should work it is not a specific technology

Web Services is a technology that implements this philosophy.

Definition: Web Services is SOAP over a transport protocol such HTTP, SMTP, FTP, etc.

HTTP is the most common protocol and is the protocol we use HTTP in our implementations.

Web Services

Web Services is Popular because:

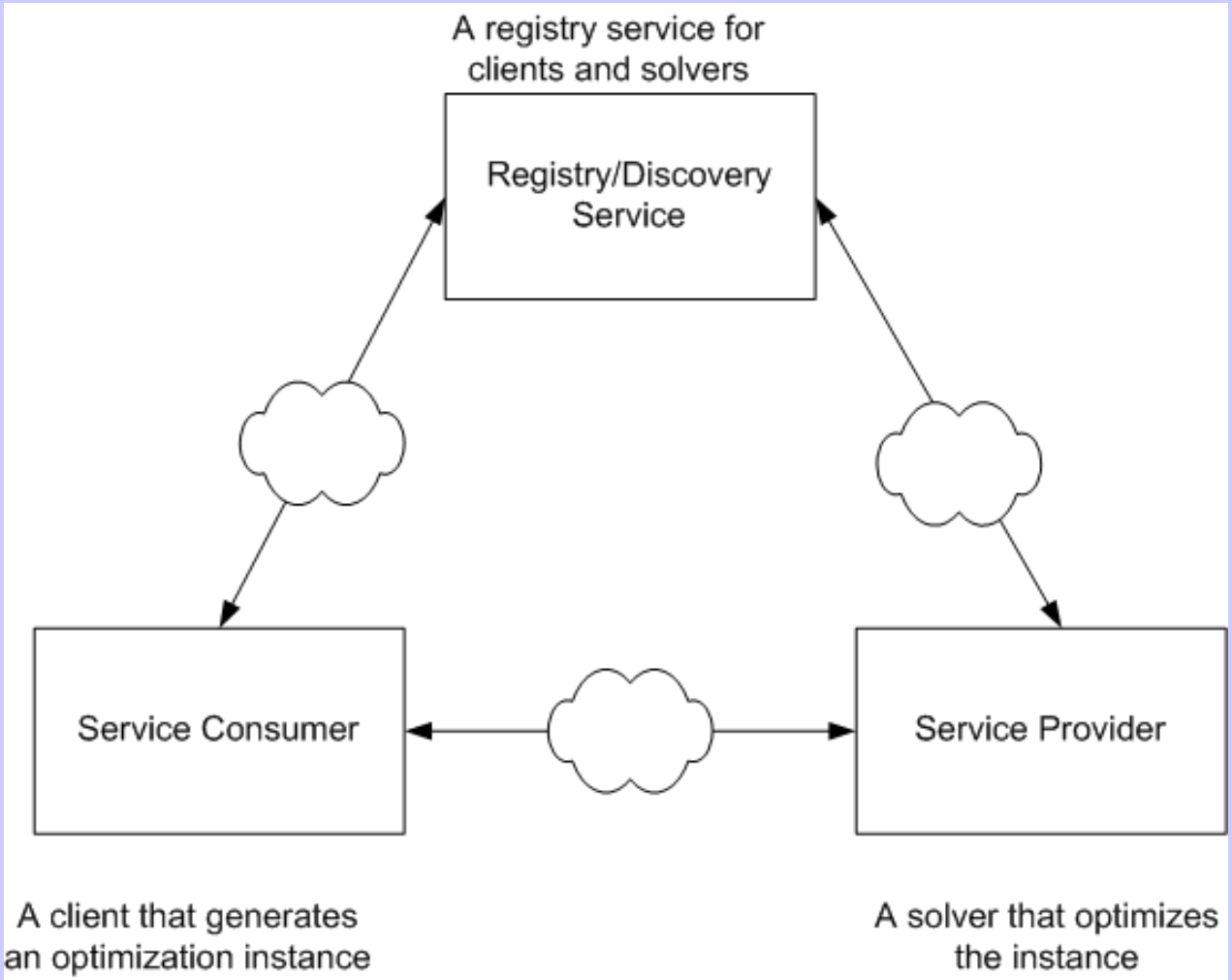
- Uses open standards, e.g. HTTP, XML, SOAP
- Can be used to develop rich clients
- Can be used by components people not necessary

Web Services makes use of three major protocols:

- SOAP (Simple Object Access Protocol)
- WSDL (Web Services Discovery Language)
- UDDI (Universal Description, Discovery, and Integration)

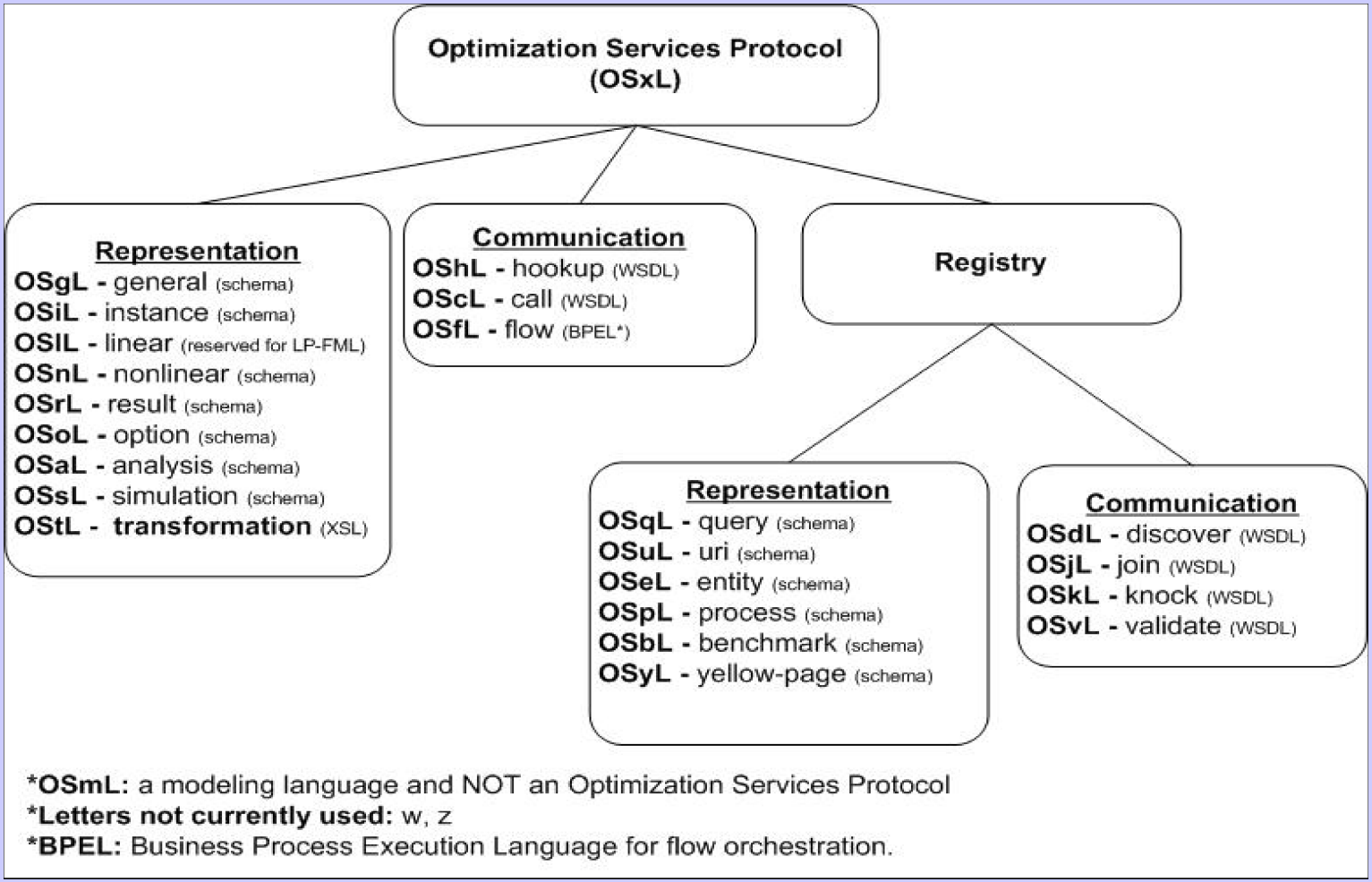
Optimization As a Web Service

Optimization Services: a service oriented architecture for optimization using Web services (SOAP over HTTP)



OSProtocols

Optimization Services: A set of protocols for **representation**, **communication**, and **registry**.



OSProtocols: Representation

The representation protocols are standards based on XML schemas. Several of the key representation standards include:

- **OSiL:** Optimization Services Instance Language. This is perhaps the most important representation protocol. OSiL is a standard for representing a very broad class of optimization problem instances. This standard is critical for exchanging problem instances between a solver (server) and a modeling language (client).
- **OSnL:** General nonlinear terms are handled separately, by defining an OSnL schema. Every element defined in the OSnL schema is an `OSnLNode` element that is of type `OSnLNode`. This leads to very efficient parsing.
  We take a very object-oriented approach. An `OSnLNode` is much like an abstract class in C++ or Java.

OSProtocols: Representation

The representation protocols are standards based on XML schemas. Several of the key representation standards include:

- **OSrL:** Optimization Services Result Language. This a standard for solver (server) to communicate back to the modeling language (client) the result of the optimization.
- **OSoL:** Optimization Services Option Language. This is a standard for communicating options to a solver, e.g. solve using dual simplex.

There is also **OSInstance** that is a standard for representing problem instances in-memory. Classes in OSInstance correspond to ComplexTypes in the corresponding XML Schema.

OS Protocols: Representation

The representation standards are all XML based. The information is in a text file with data and markup.

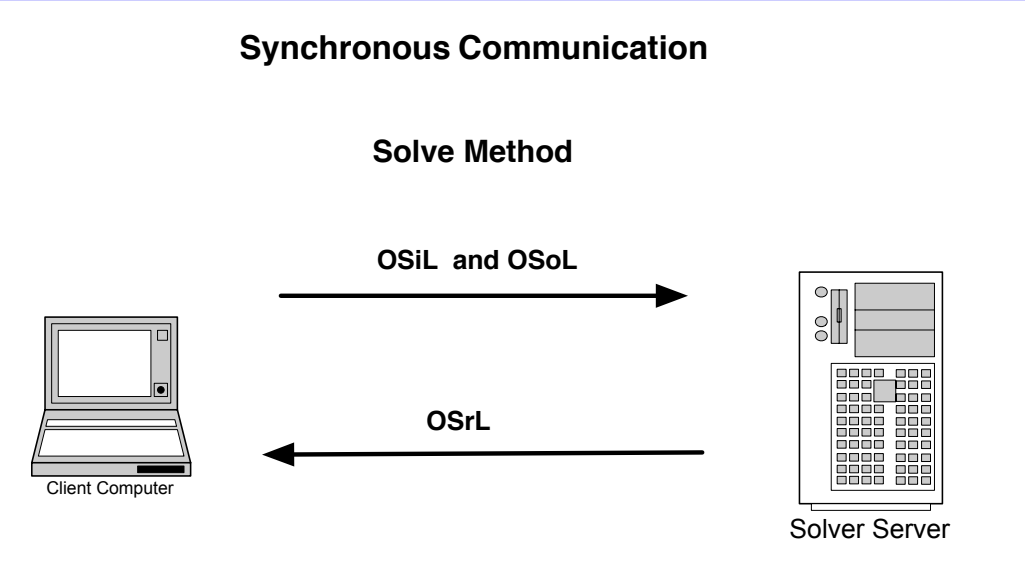
```
<variables>
     <values>
          <var idx="1" value="540.2"/>
          <var idx="2" value="241.9"/>
          <var idx="3" value="34"/>
     </values>
</variables>
```

OSProtocols: Communication

The key protocol is Optimization Service Hookup Language (OShL). A set of methods that control communication between a client and a server.

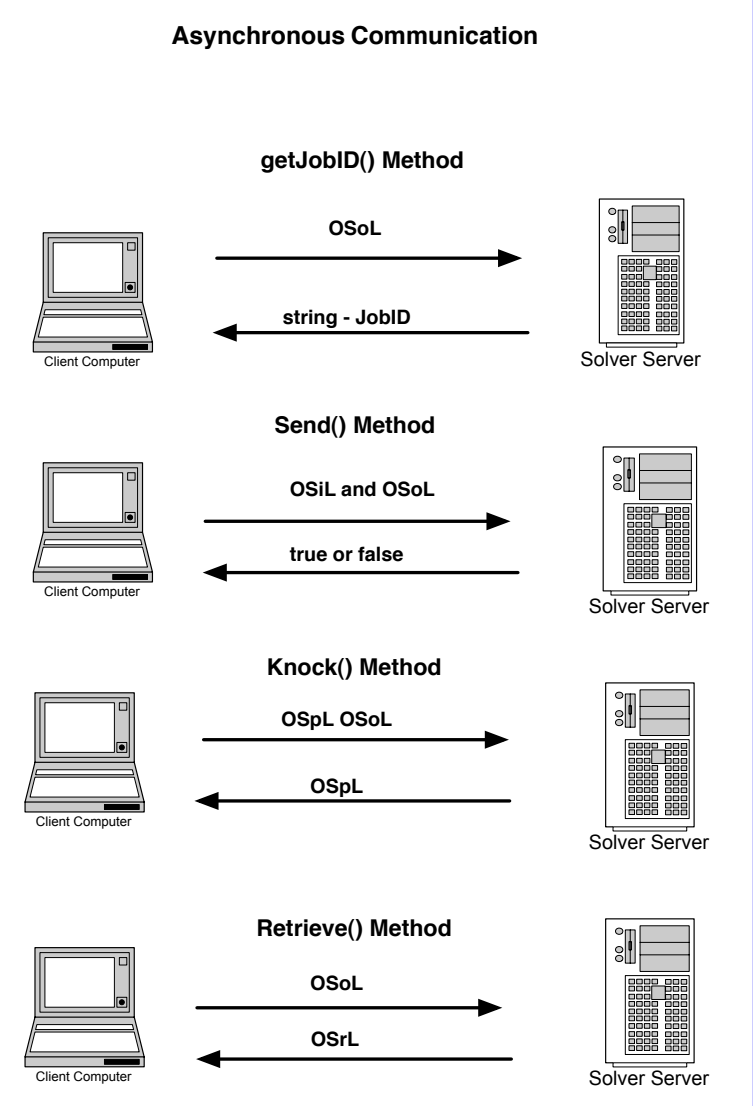
Synchronous Service:

- `solve(xsd__string osil, xsd_string osol)`



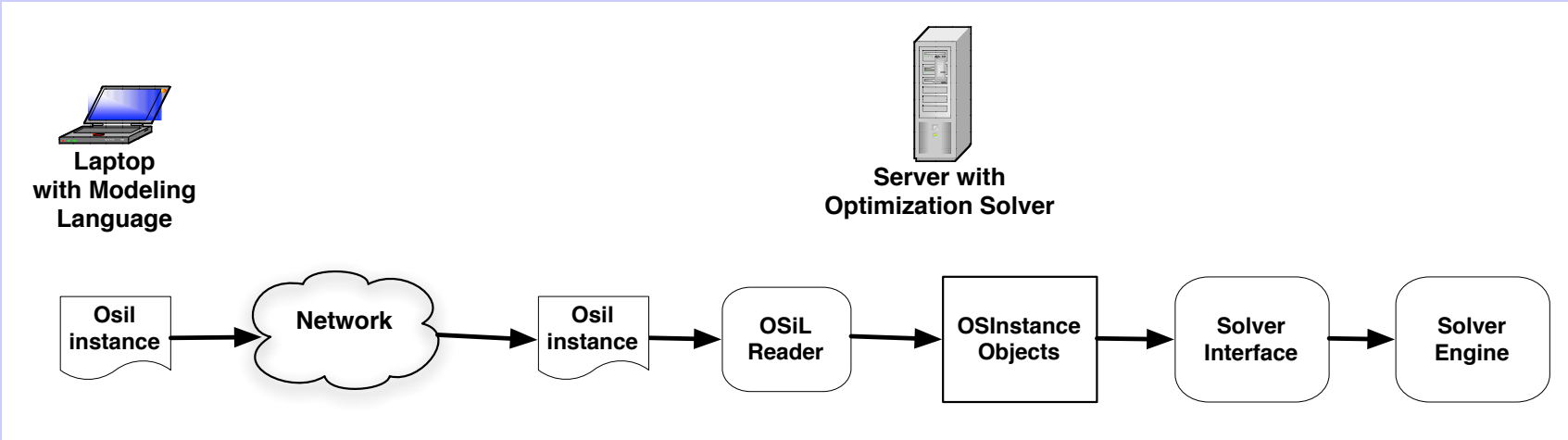
OSProtocols: Communication

Asynchronous Communication and Calls:



Solver Service – An OS Implementation

Optimization Services is a set of protocols. We now describe server and client services built on optimizations services.



Solver Service – An OS Implementation

Implementing a Solver Service

- On the solver end expose an optimization solver (or problem analyzer).
- This is most easily done by using an existing Web Server that supports Web Services.
  1. Apache + Tomcat
  2. Tomcat (Java or C++) – We have implemented both.
  3. JBoss
  4. IIS
  5. High end – Websphere, Weblogic, Oracle, Geronimo
- Programming language is irrelevant but Java dominates the XML world.

Solver Service – An OS Implementation

Implement the OS Communication standard:

- `solve(osil, osol)`:
  - Takes OSiL and OSoL and returns OSrL (string/file version)
  - Synchronous call, blocking request/response
- `getJobID(osol)`
  - Gets a unique job id generated by the solver service
  - Maintain session and state on a distributed system
- `send(osil, osol)`
  - Same signature as the solve function but returns a boolean
  - Asynchronous (server side), non-blocking call
- `knock(ospl, osol)`
  - Get process and job status information from the remote server
- `retrieve(osol)`
  - Retrieving result from anywhere anytime
- `kill(osol)`
  - kill remote optimization jobs
  - Critical in long running optimization jobs

Solver Service – An OS Implementation

The `solve(osil, osol)` method in detail for a CoinSolverService.

```
string OSSolverService::solve(string osil, string osol)
{
     OSServiceUtil serviceUtil;
     serviceUtil.m_solver = new CoinSolver();
     char* osrl = &serviceUtil.solve(osil, osol)[0];
     return osrl;
}
```

The `serviceUtil` object used above has a data member that is the implementation of an abstract `DefaultSolverClass`.
If you use the OS libraries you do not need to worry about `getJobID()`, `send()` `kill()`, `knock()`, and `retrieve()`. They are done for you.

Solver Service – An OS Implementation

OSSolver Library: If you use this library (available in both Java and C++) it is trivial to hook your solver into our API.

- The API provides a `DefaultSolver` class. It is an abstract class.
- The `DefaultSolver` class has the pure virtual function

```
virtual string solve(string osil, string osol) = 0;
```

- Define your own class that inherits from `DefaultSolver` and implements the `solve()` method for your solver.

Solver Service – An OS Implementation

Programming language becomes important at this point. What if, e.g. your solver is C++ and the Web Service is in Java. Two options.

- Option 1: Use JNI (Java Native Interface). Call the `solve()` method using JNI. A bit risky.
- Option 2: Implement a Java `solve()` method in the Java Web Service that use the Java Runtime class. Use this to launch a C++ executable. Pass the executable the OSiL and OSoL as files. Then have the executable write a file with the OSrL and pass this back in the SOAP envelope.

The OSSolver Library - COIN Solver Example

Here is how the CoinSolver class works.

```
class CoinSolver : public DefaultSolver{
public:
     string solve(string osil, string osol);
};
```

Now implement the CoinSolver solver.

```
string CoinSolver::solve(string osil, string osol)  {
     solverName = osol;
     OSiLReader* osilreader;
     OSInstance* theosinstance = 0;
     OsiSolverInterface* solver = 0;
```

⋮

The OSSolver Library - COIN Solver Example

Implementation of CoinSolver solve() method (continued).

```
    if(osol == "glpk")
        solver = new OsiGlpkSolverInterface();
    else
        solver = new OsiClpSolverInterface();
    osilreader->readOSiL( osil );
    theosinstance = osilreader->getOSInstance();
    if(!setOSInstance( theosinstance )) return 0;
    return optimize();
}
```

Important: the CoinSolver class must put the OSInstance object into the COIN data structures such as the CoinPackedMatrix

Client Service – An OS Implementation

The SOAP – first there is a header

```
POST /os/ossolver/LindoSolverService.jws HTTP/1.0
Host: gsbkip.chicagogsb.edu
Content-Type: text/xml; charset=UTF-8
Cache-Control: no-cache
Pragma: no-cache
SOAPAction: "OSSolverService#solve"
Content-Length: 2335
```

The key line is the POST command. It tells the server which service to use. In this case it is LINDO.

Client Service

The SOAP – then the **envelop.** In this case we are implementing a **solve** over the network.

```
<SOAP-ENV:Envelope>
     <SOAP-ENV:Body>
         <solve>
              <osil xsi:type="xsd:string">
                    The OSiL string goes here
              </osil>
              <osol xsi:type="xsd:string">
                    The OSoL string goes here
             </osol>
         </solve>
    </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```

Client Service

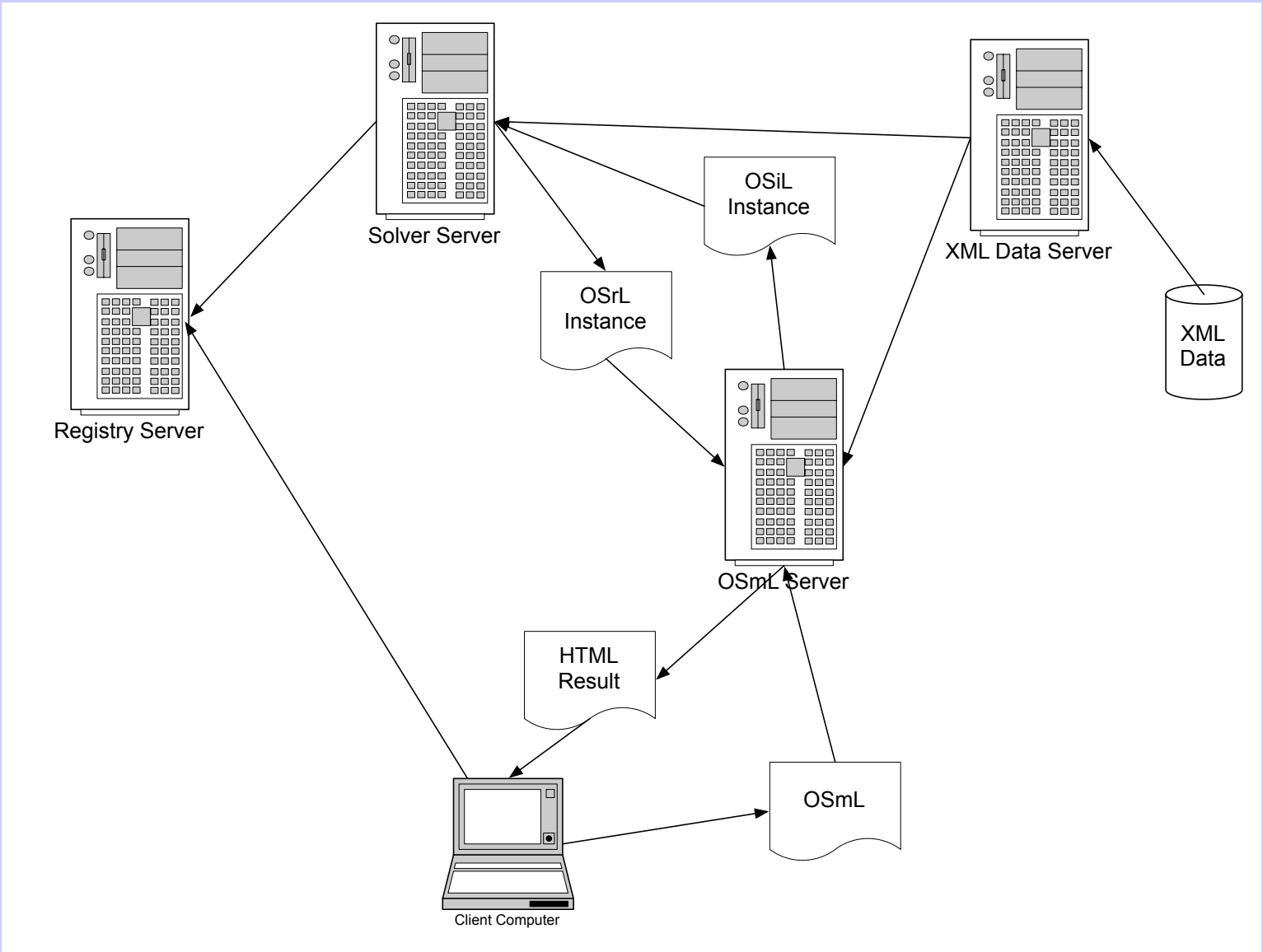
WSDL – Web Services Discovery Language.

You can use products such as Apache Axis and Visual Studio .NET to generate code from the WSDL.

For example:

`http://gsbkip.chicagogsb.edu/os/osolver/COINSolverService.jws?`

Summary: An Example of Optimization Services



Summary

Modeling languages that can generate OSiL:

- AMPL (linear OSiL – use nl2osil.exe)
- OSmL (native linear and nonlinear)
- POAMS (native linear OSiL???)

Solvers:

- CLP - through COIN OSI
- FORTMP - LPFML
- GLPK – through COIN OSI
- IMPACT - native support
- KNITRO - using function callbacks
- LINDO – using instruction list format