Optimization Services (OS)

-- A Framework for Optimization Software

-- A Computational Infrastructure

-- The Next Generation NEOS

-- The OR Internet

Jun Ma

Industrial Engineering and Management Sciences
Northwestern University

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OUTLINE

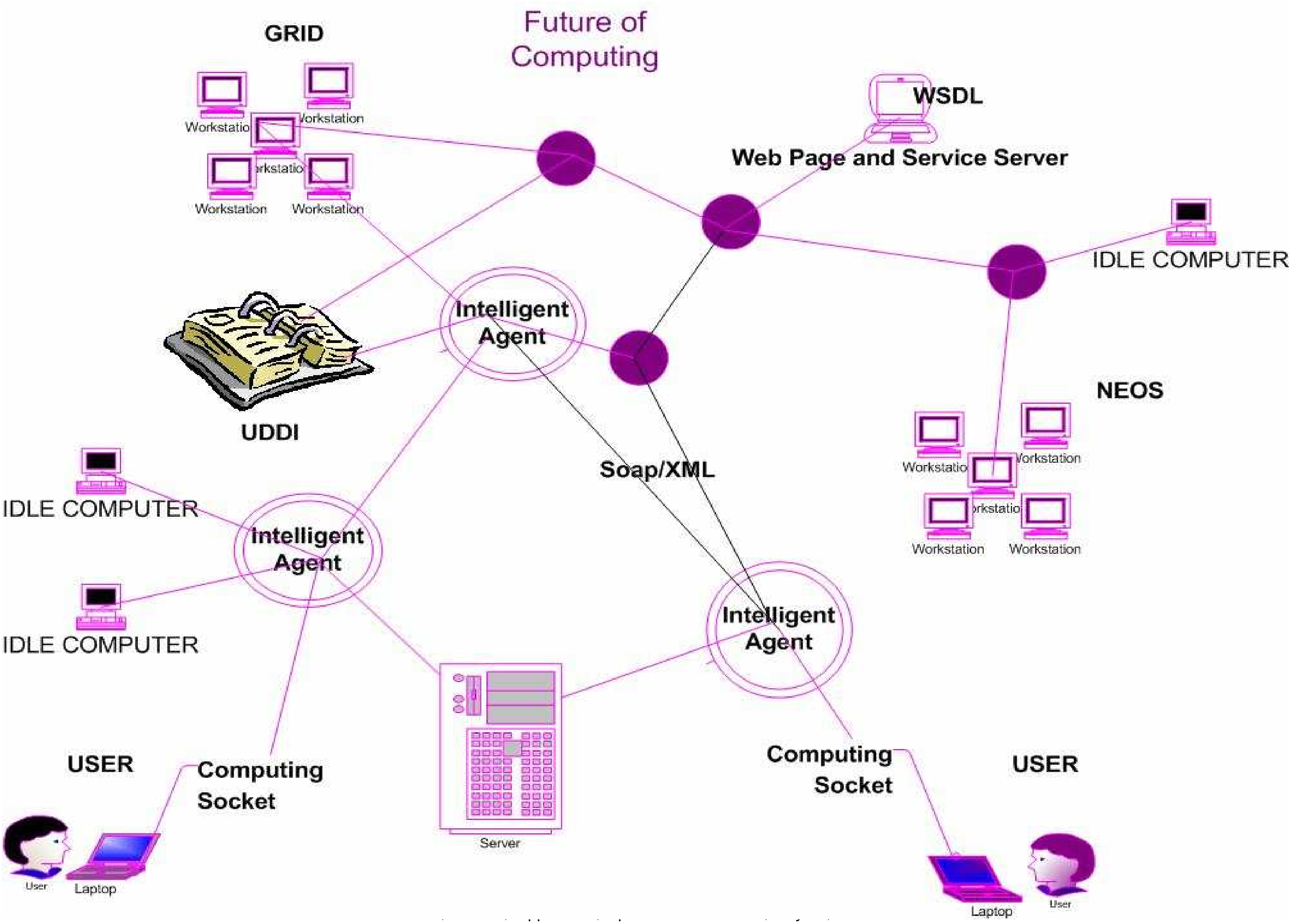
1. **Motivations**

2. Optimization Services and Optimization Services Protocol

3. Future and Derived Research

Motivation

Future of Computing



Motivation

But how… with so many type of components

1. Modeling Language Environment (MLE)

   (AIMMS, AMPL, GAMS, LINGO, LPL, MOSEL, MPL, OPL, MathProg, PulP, POAMS, OSmL)

2. Solver

   (Too many)

3. Analyzer/Preprocessor

   (Analyzer, MProbe, Dr. AMPL)

4. Simulation

   (Software that does heavy computation, deterministic or stochastic)

5. Server/Registry

   (NEOS, BARON, HIRON, NIMBUS, LPL, AMPL, etc.)

6. Interface/Communication Agent

   (COIN-OSI, CPLEX-Concert, AMPL/GAMS-Kestrel, etc.)

7. Low Level Instance Representation

   (Next page)

Motivation

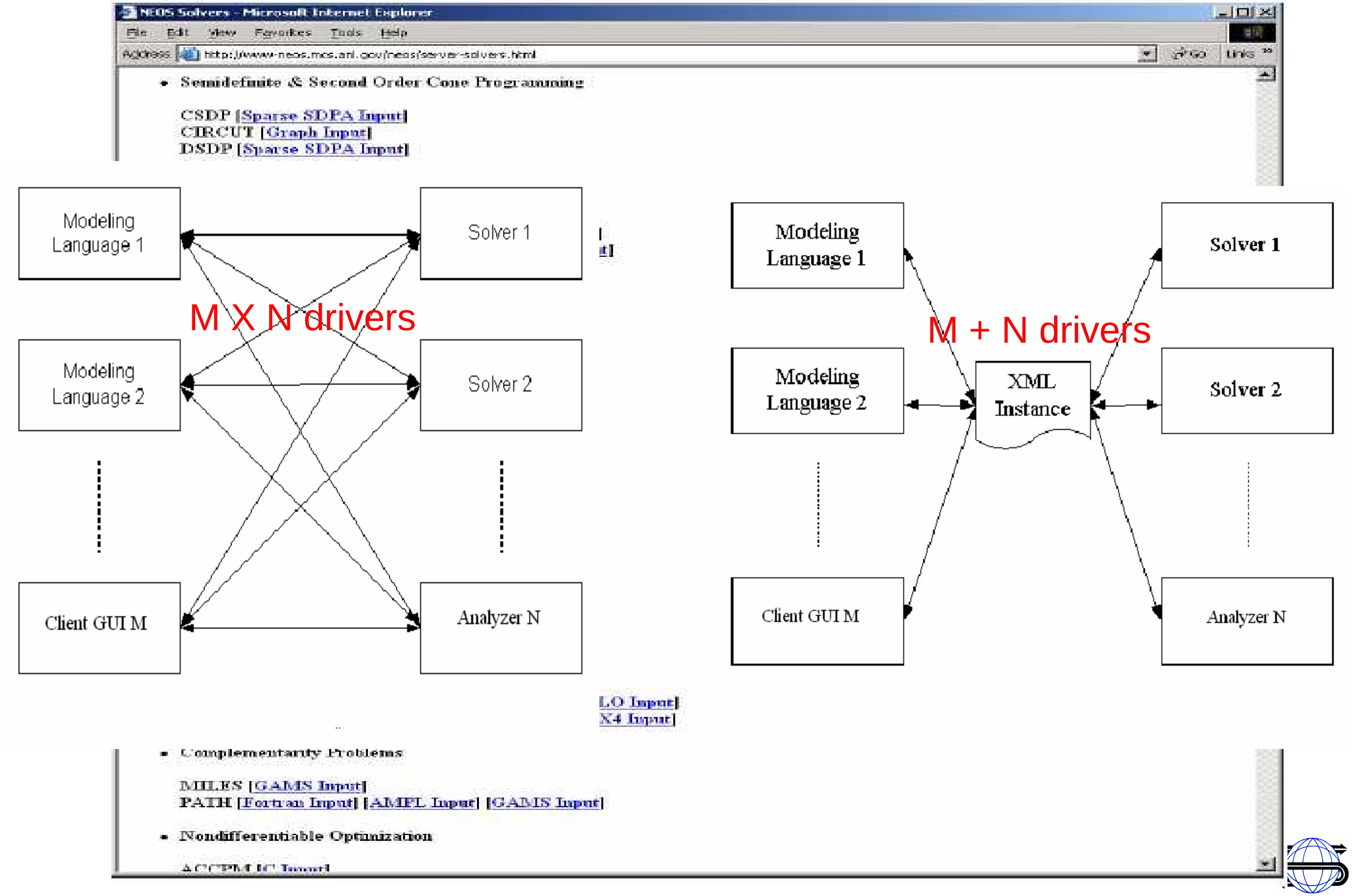
But how… with so many optimization types and representation formats

Linear Programming Quadratic Programming Mixed Integer Linear Programming	MPS, xMPS, LP, CPLEX, GMP, GLP, PuLP, LPFML, MLE instances
Nonlinearly Constrained Optimization Bounded Constrained Optimization Mixed Integer Nonlinearly Constrained Optimization Complementarity Problems Nondifferentiable Optimization Global Optimization	MLE instances SIF (only for Lancelot solver)
Semidefinite & Second Order Cone Programming	Sparse SDPA, SDPLR
Linear Network Optimization	NETGEN, NETFLO, DIMACS, RELAX4
Stochastic Linear Programming	sMPS
Stochastic Nonlinear Programming	None
Combinatorial Optimization	None (except for TSP input, only intended for solving Traveling Sales Person problems.
Constraint and Logic Programming	None
Optimization with Distributed Data	None
Optimization via Simulation	None

OSiL

Motivation

Look at the NEOS server Web site



NEOS Solvers - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Address
Go
Links

http://www-neos.mcs.anl.gov/neos/server-solvers.html

- Semidefinite & Second Order Cone Programming

CSDP [Sparse SDPA Input]
CIRCUIT [Graph Input]
DSDP [Sparse SDPA Input]

[
t]

LO Input]
X4 Input]

- Complementarity Problems

MILES [GAMS Input]
PATH [Fortran Input] [AMPL Input] [GAMS Input]

- Nondifferentiable Optimization

ACCPM [C Input]

Modeling Language 1
Modeling Language 2
Client GUI M
Solver 1
Solver 2
Analyzer N

M X N drivers

Modeling Language 1
Modeling Language 2
Client GUI M
XML Instance
Solver 1
Solver 2
Analyzer N

M + N drivers

Motivation

As if it’s not bad enough …

1. Tightly-coupled implementation (OOP? Why not!)

2. Various operating systems

3. Various communication/interfacing mechanisms

4. Various programming languages

5. Various benchmarking standards

Motivation

Now…

- The key issue is communication, not solution!
- … and Optimization Services is intended to solve all the above issues.

OUTLINE

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2. **Optimization Services and Optimization Services Protocol**

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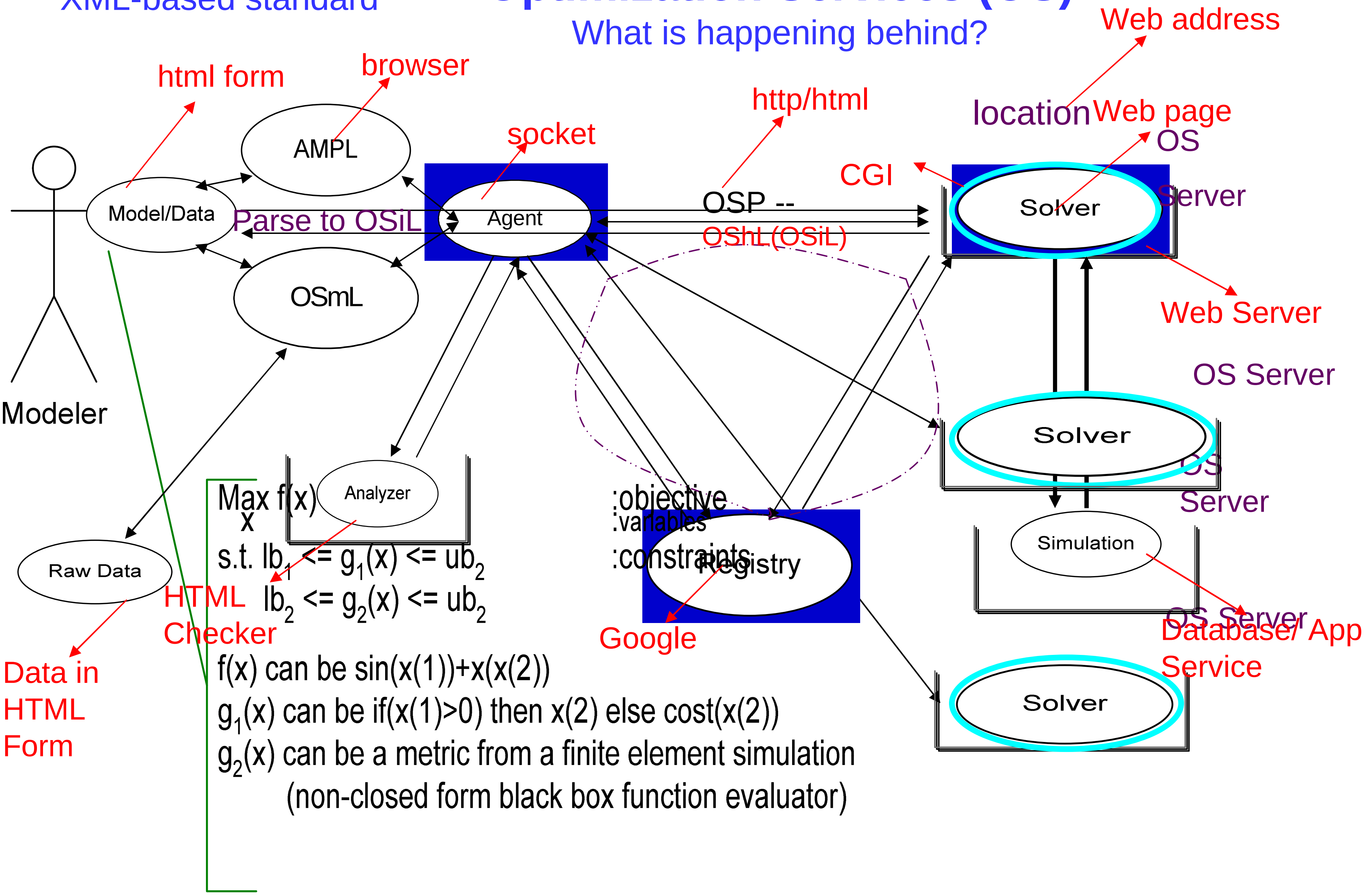
Optimization Services (OS)

XML-based standard

What is happening behind?



Max f(x)
x

s.t. $lb_1 <= g_1(x) <= ub_2$

$lb_2 <= g_2(x) <= ub_2$

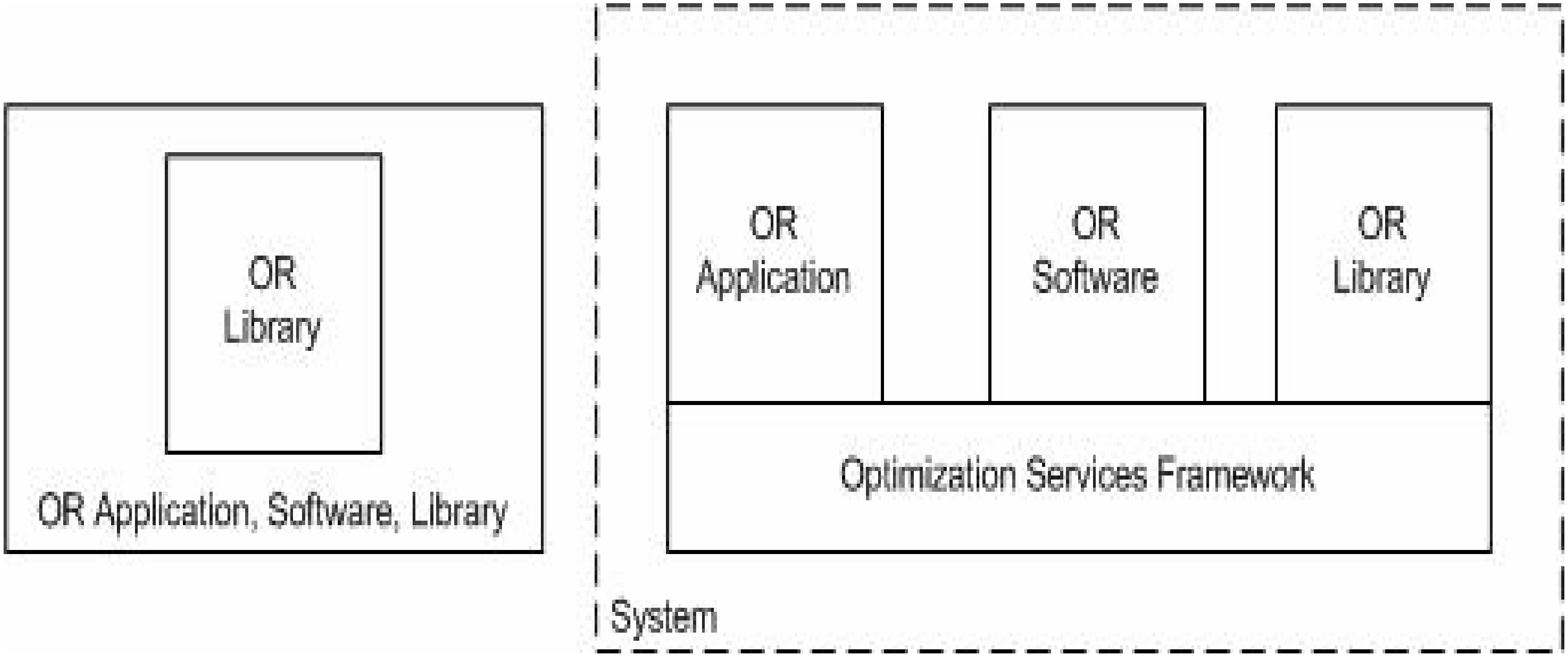
f(x) can be sin(x(1))+x(x(2))

g_1(x) can be if(x(1)>0) then x(2) else cost(x(2))

g_2(x) can be a metric from a finite element simulation (non-closed form black box function evaluator)

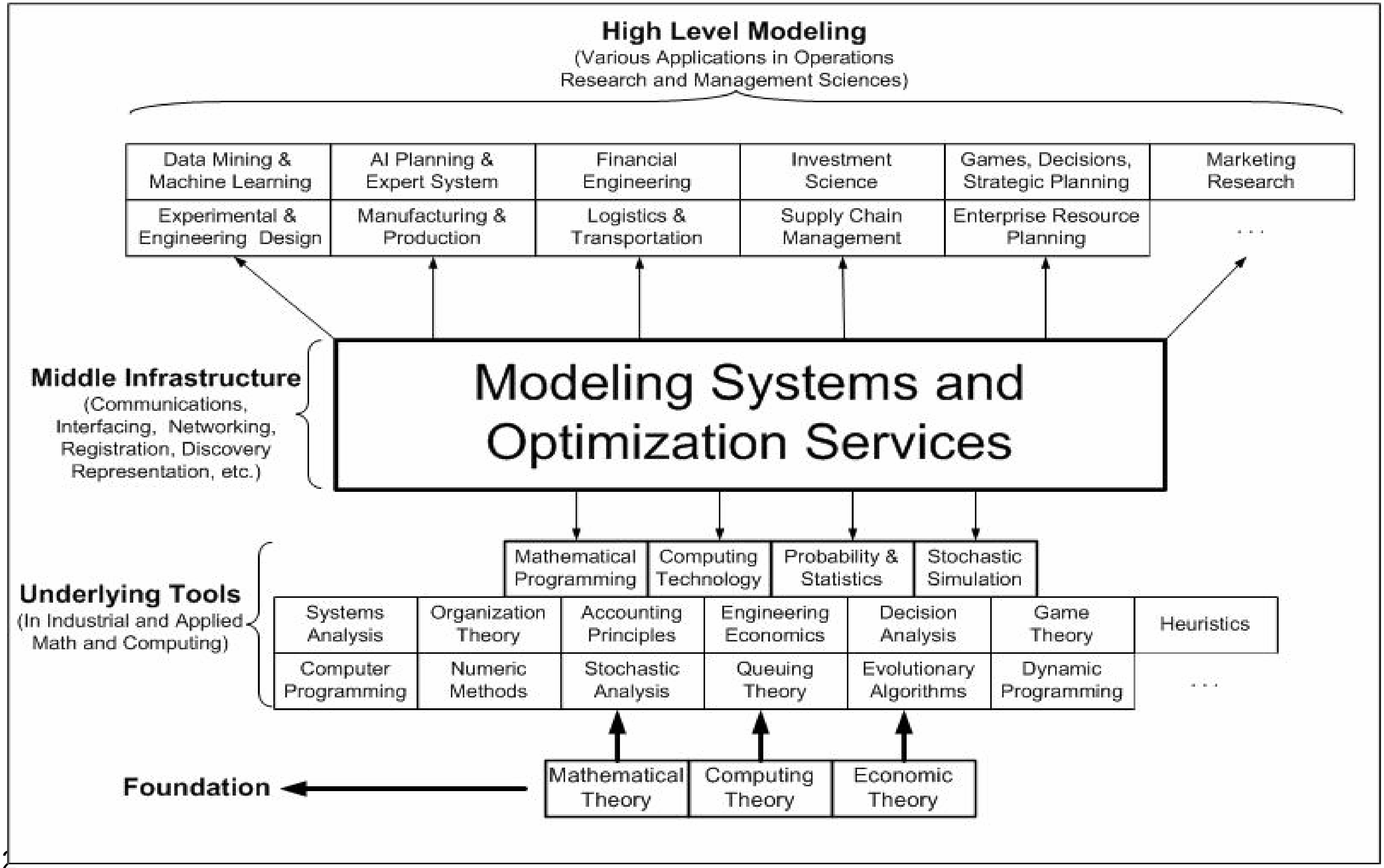
Optimization Services

What is it? – A framework for optimization software


OR
Library
OR Application, Software, Library
OR
Application
OR
Software
OR
Library
Optimization Services Framework
System

Optimization Services

What is it? – A computational infrastructure



High Level Modeling
(Various Applications in Operations Research and Management Sciences)

Data Mining & Machine Learning
AI Planning & Expert System
Financial Engineering
Investment Science
Games, Decisions, Strategic Planning
Marketing Research

Experimental & Engineering Design
Manufacturing & Production
Logistics & Transportation
Supply Chain Management
Enterprise Resource Planning
. . .

Middle Infrastructure
(Communications, Interfacing, Networking, Registration, Discovery Representation, etc.)

Modeling Systems and Optimization Services

Underlying Tools
(In Industrial and Applied Math and Computing)

Mathematical Programming
Computing Technology
Probability & Statistics
Stochastic Simulation

Systems Analysis
Organization Theory
Accounting Principles
Engineering Economics
Decision Analysis
Game Theory
Heuristics

Computer Programming
Numeric Methods
Stochastic Analysis
Queuing Theory
Evolutionary Algorithms
Dynamic Programming
. . .

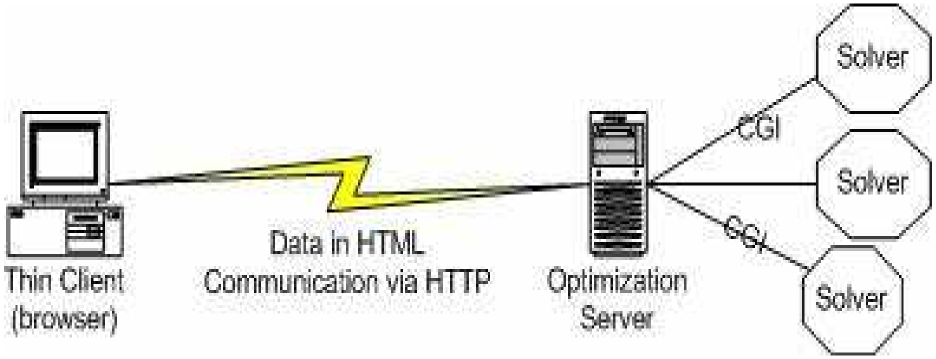
Foundation

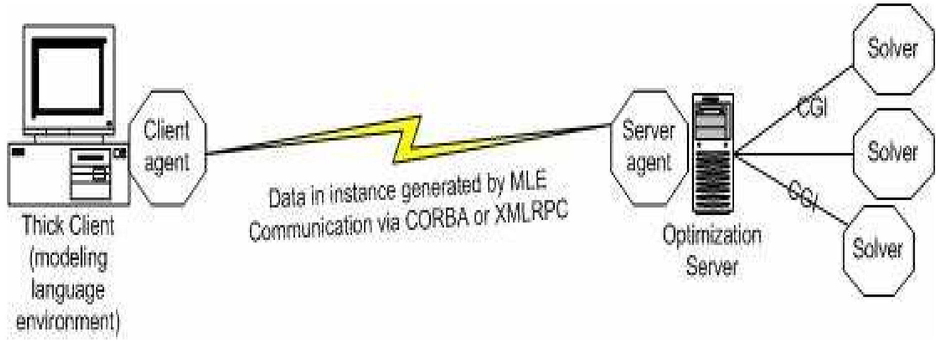
Mathematical Theory
Computing Theory
Economic Theory

Optimization Services

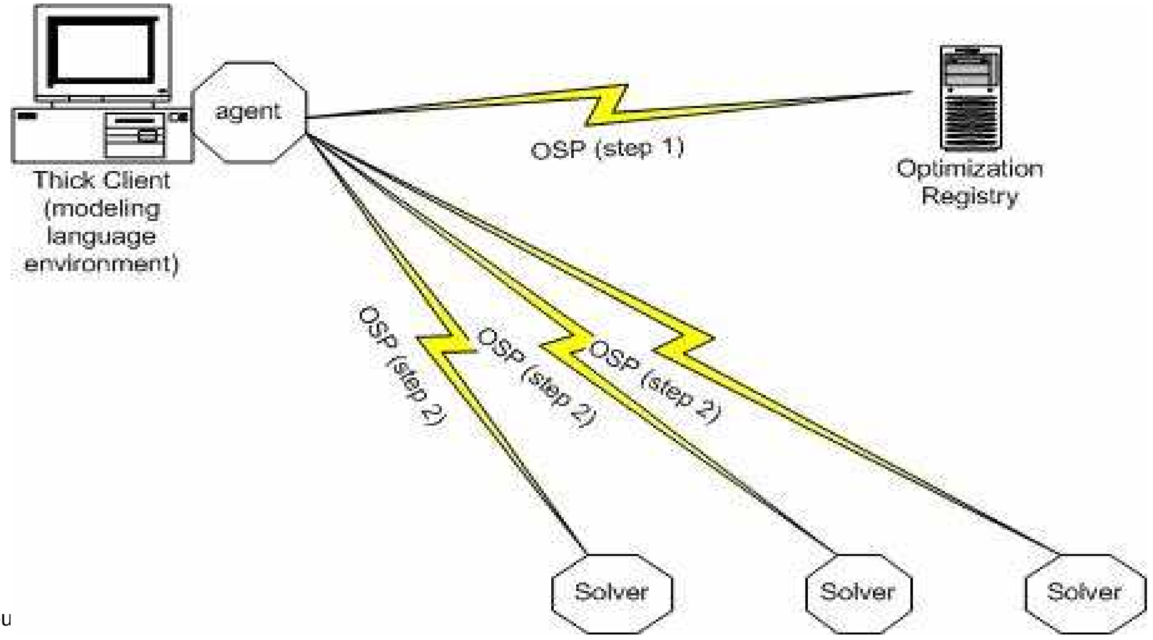
What is it? – The next generation NEOS

NEOS
Server for Optimization



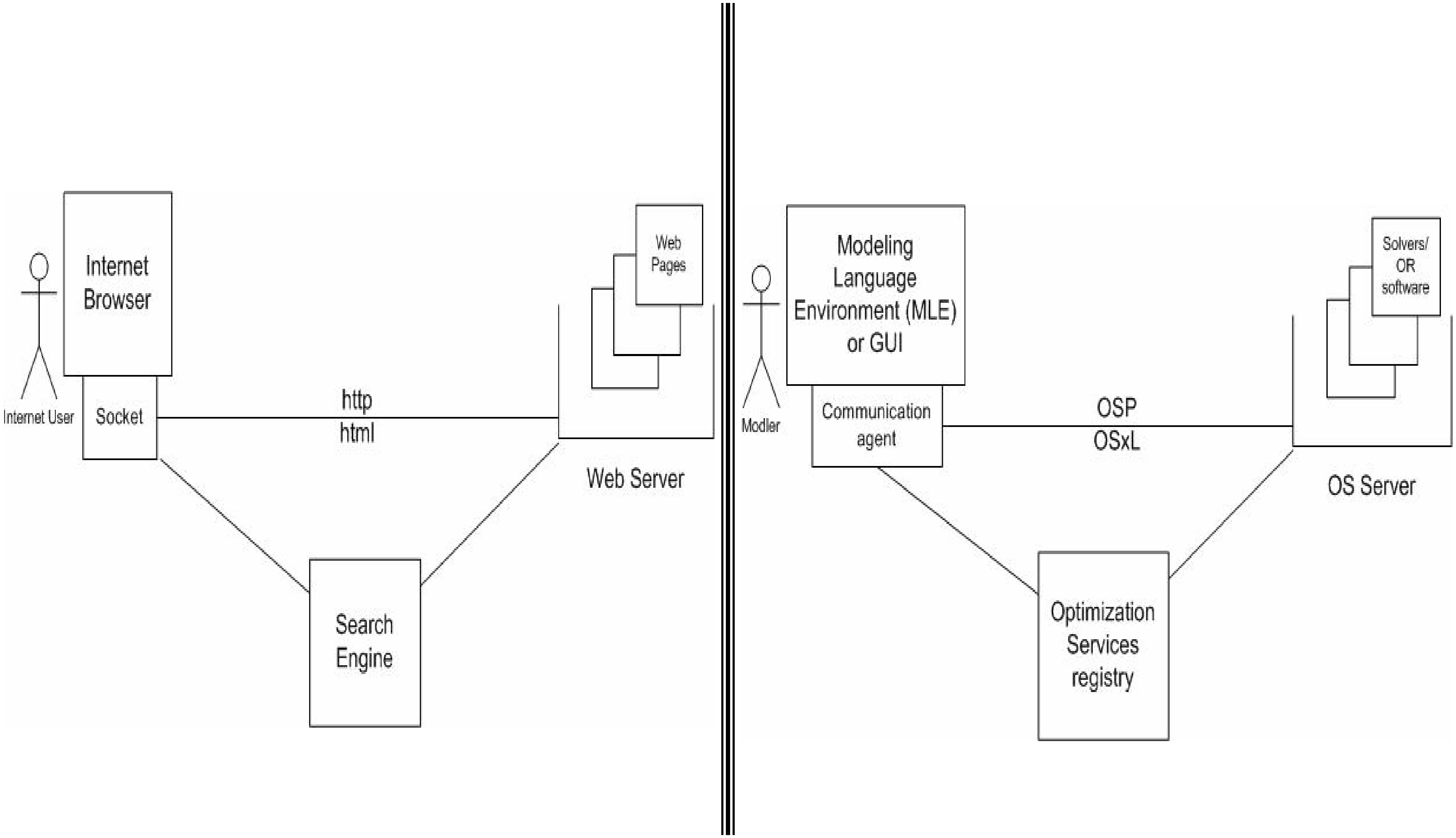


- •The NEOS server and its connected solvers uses the OS framework.
- •NEOS accepts the OSiL and other related OSP for problem submissions
- •NEOS becomes an OS compatible meta-solver on the OS network
- •NEOS hosts the OS registry



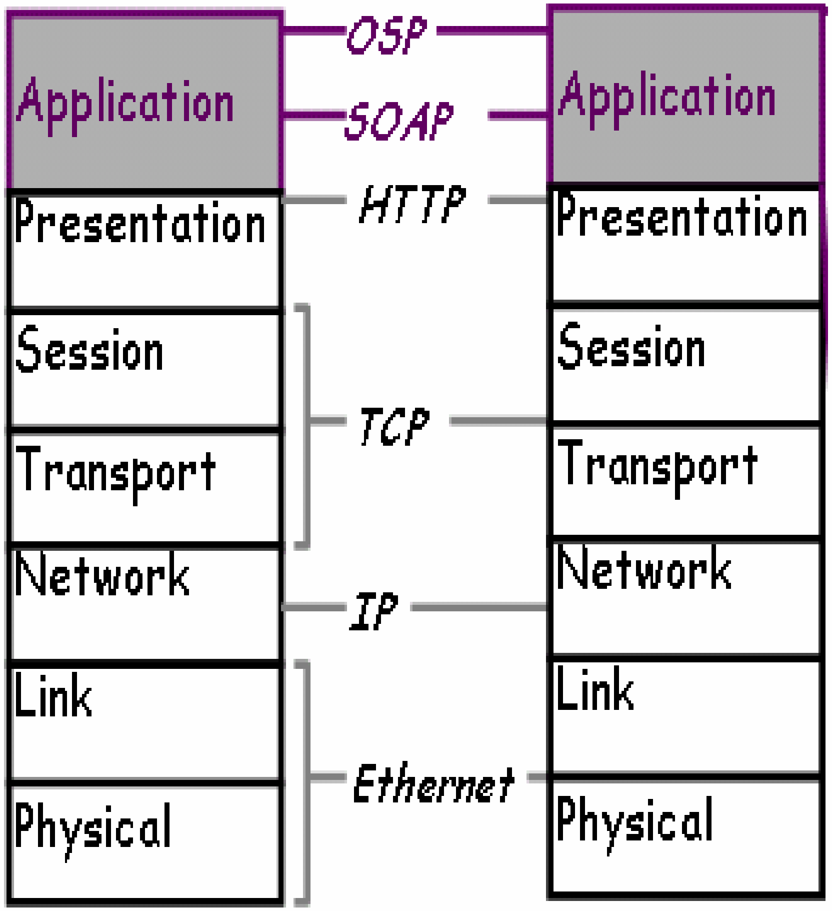
Optimization Services

What is it? – The OR Internet



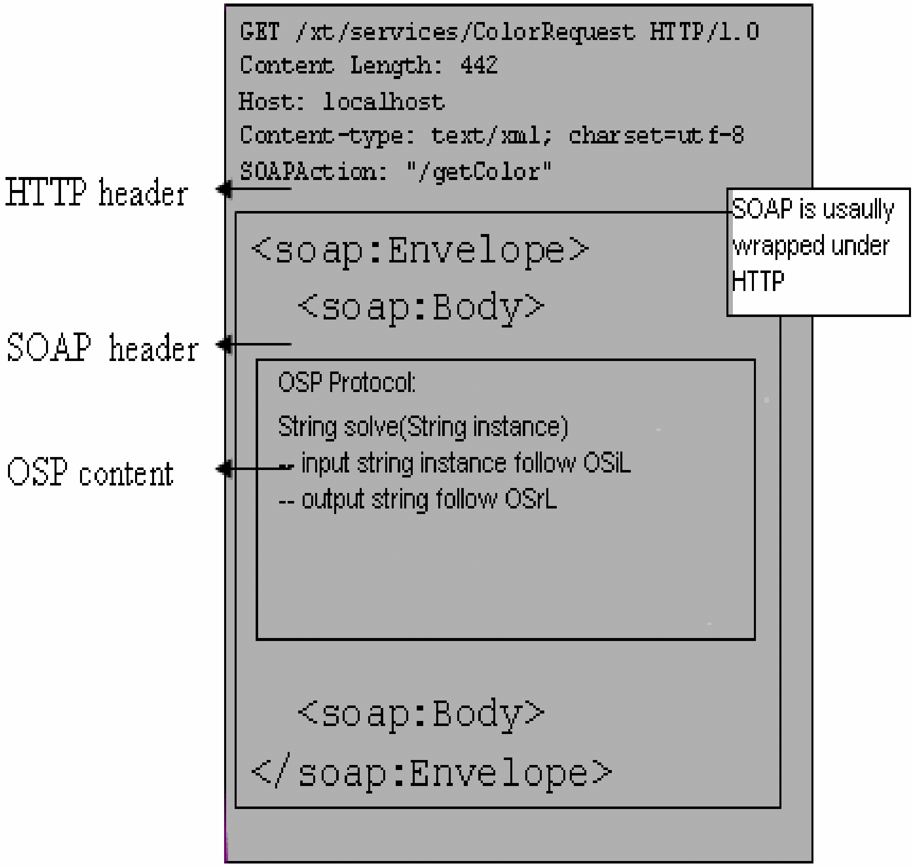
Optimization Services Protocol (OSP)

What is it? – Application level networking protocol
– Interdisciplinary protocol between CS and OR



The 7-layer OSI Model

The 4-layer Internet model

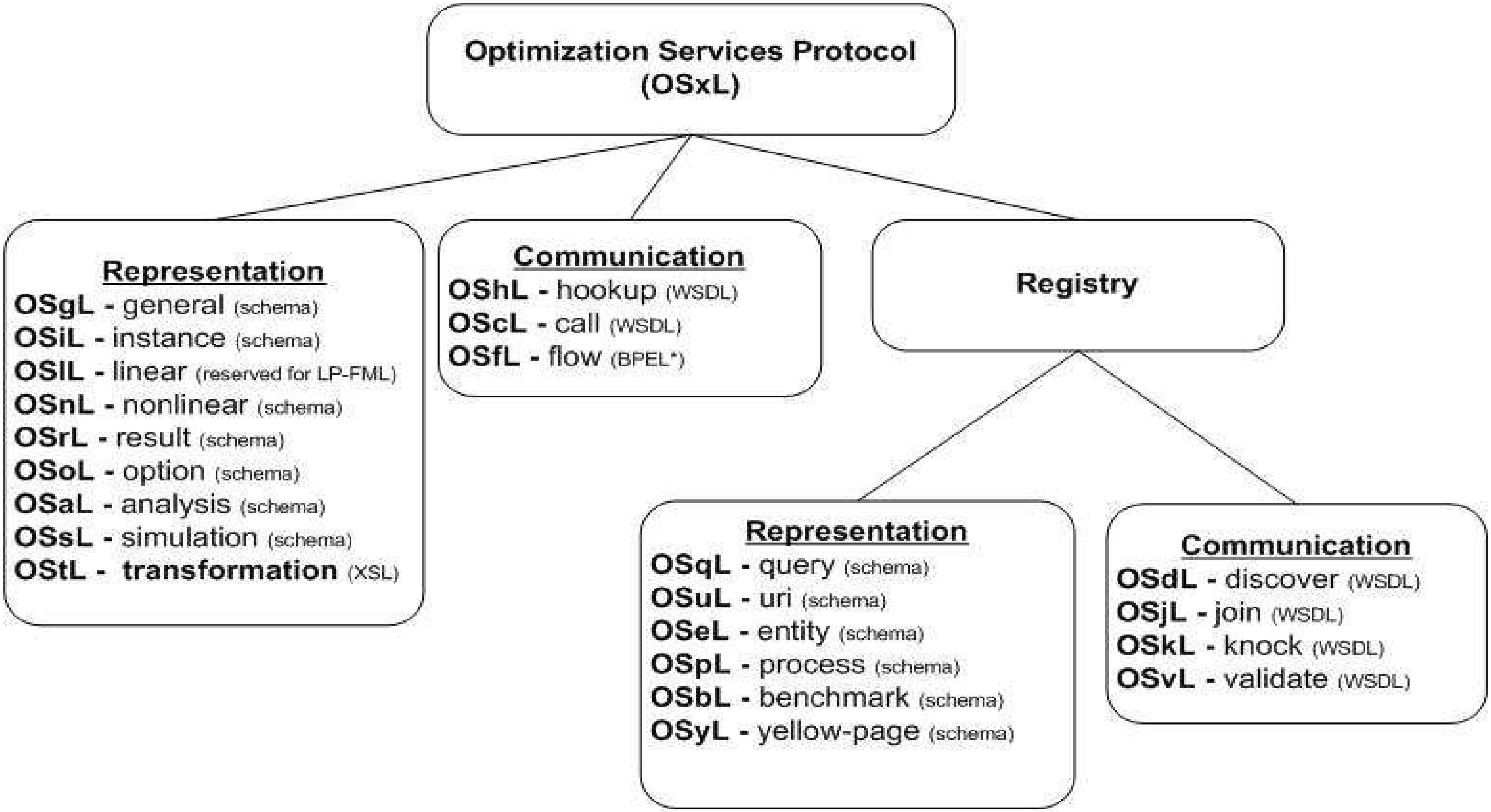


```
GET /xt/services/ColorRequest HTTP/1.0
Content Length: 442
Host: localhost
Content-type: text/xml; charset=utf-8
SOAPAction: "/getColor"

<soap:Envelope>
  <soap:Body>

    OSP Protocol:
    String solve(String instance)
    -- input string instance follow OSiL
    -- output string follow OSrL

  <soap:Body>
</soap:Envelope>
```

SOAP is usaully wrapped under HTTP

Optimization Services Protocol (OSP)

What does the protocol involve? – 20+ OSxL languages



Optimization Services Protocol (OSxL)

Representation

OSgL - general (schema)
OSiL - instance (schema)
OSlL - linear (reserved for LP-FML)
OSnL - nonlinear (schema)
OSrL - result (schema)
OSoL - option (schema)
OSaL - analysis (schema)
OSsL - simulation (schema)
OStL - **transformation** (XSL)

Communication

OShL - hookup (WSDL)
OScL - call (WSDL)
OSfL - flow (BPEL*)

Registry

Representation

OSqL - query (schema)
OSuL - uri (schema)
OSeL - entity (schema)
OSpL - process (schema)
OSbL - benchmark (schema)
OSyL - yellow-page (schema)

Communication

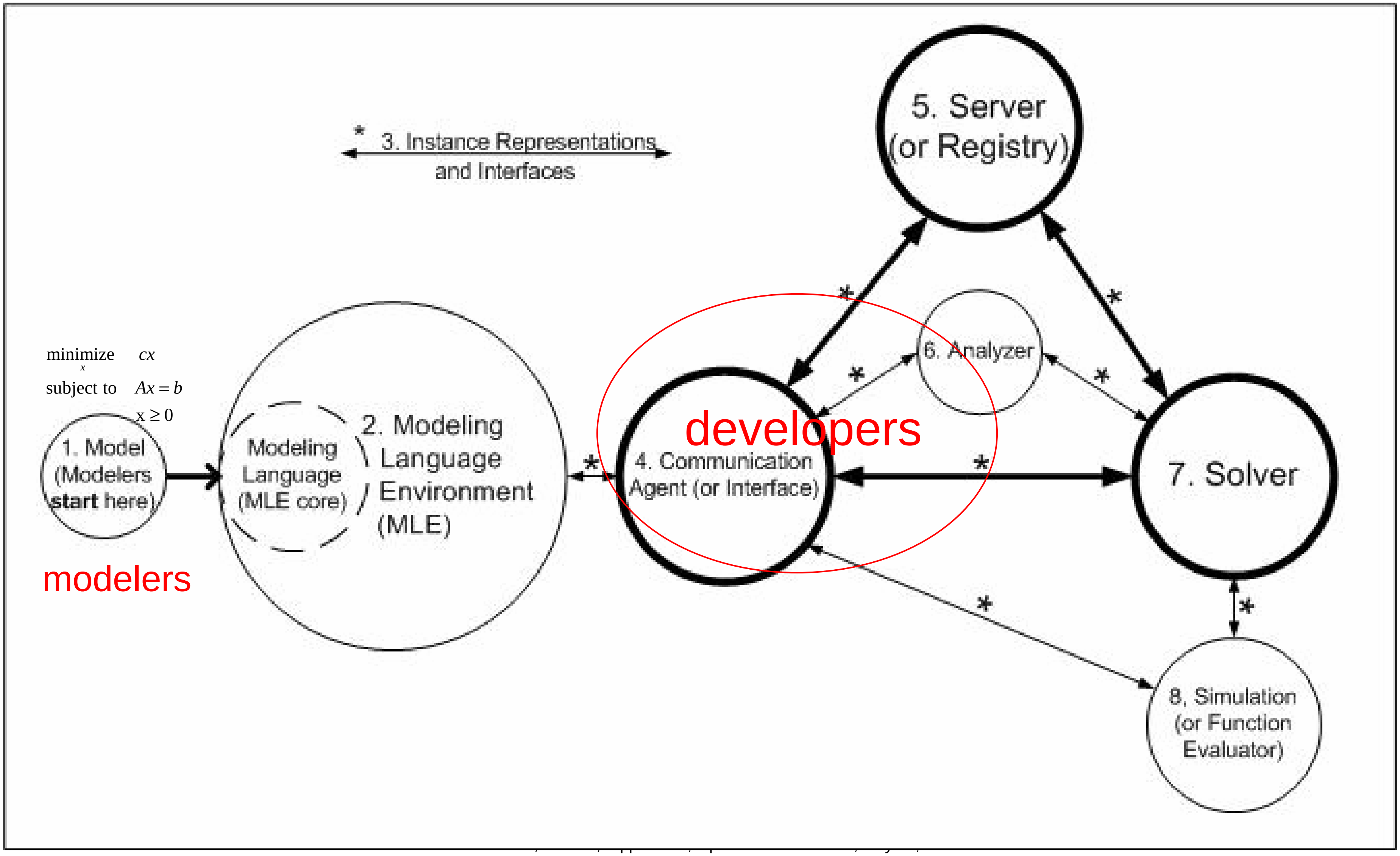
OSdL - discover (WSDL)
OSjL - join (WSDL)
OSkL - knock (WSDL)
OSvL - validate (WSDL)

***OSmL:** a modeling language and NOT an Optimization Services Protocol
***Letters not currently used:** w, z
***BPEL:** Business Process Execution Language for flow orchestration.

Optimization System Background

What does an optimization system look like?

users



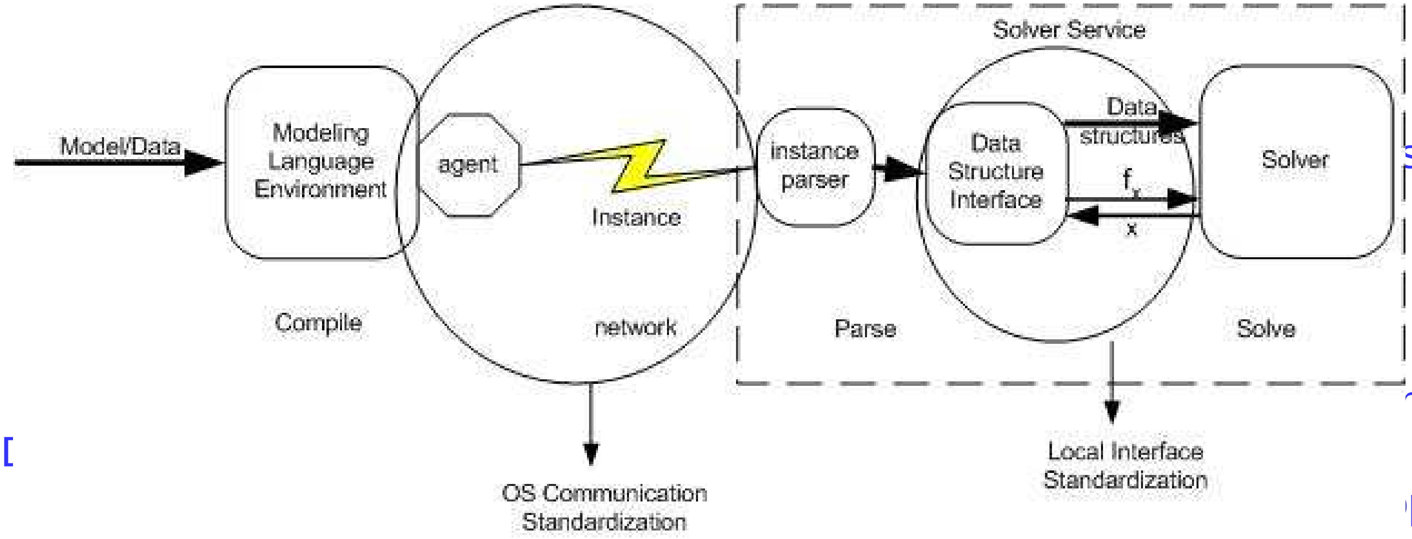
$\underset{x}{\text{minimize}} \quad cx$
subject to $Ax = b$
$x \geq 0$
1. Model (Modelers **start** here)
modelers
Modeling Language (MLE core)
2. Modeling Language Environment (MLE)
* 3. Instance Representations and Interfaces
developers
4. Communication Agent (or Interface)
5. Server (or Registry)
6. Analyzer
7. Solver
8. Simulation (or Function Evaluator)
*

OUTLINE

1. Motivations
2. Optimization Services and Optimization Services Protocol
3. **Future and Derived Research**

Future and Derived Research

- The Optimization Services project
- Standardization
- Problem repository building
- OS server software, library enhancement
- Derived research in distributed systems (coordination, scheduling and congestion control)
- Derived research in decentralized systems
  (registration, discovery, analysis, control)
- Derived research in local systems (OSI? OSiI, OSrI, OSoI?)
- Derived research in optimization servers (NEOS)
- Derived research in computational software
  (AMPL, Knitro, Lindo/Lingo, IMPACT, OSmL, MProbe, Dr. AMPL, etc.)
- Derived research in computational algorithm
  - Parallel computing



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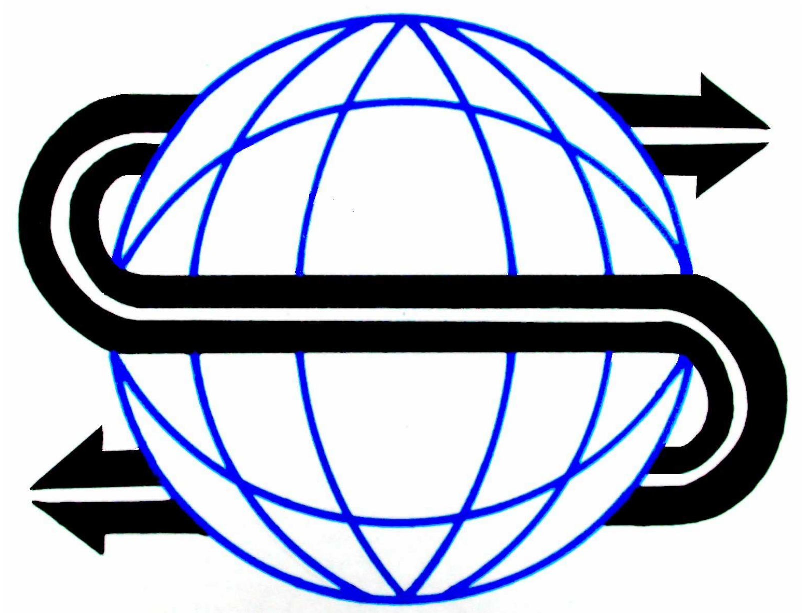
Library developers, registry/server developers, and other auxiliary developers

Computing on demand and “result on demand”



http://www.optimizationservices.org