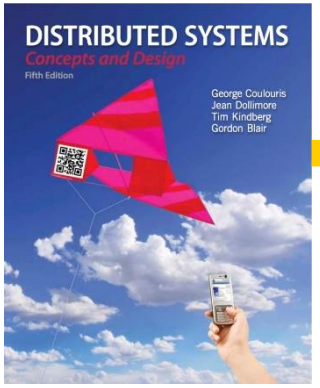

Web Services

Most concepts are drawn from Chapter 9

Slides are revised from Dr. Michael McCarthy at CMU, Dr. Cesare Pautasso at ETH, Prof. Andrew Tanenbaum at UA

Dr. Minxian Xu

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Shenzhen Institute of Advanced Technology, CAS
http://www.minxianxu.info/dcp

天网疏难漏，世网密莫通。我心久不动，一脱二网中
高竹漱清泉，长松迎清风。此时逢此景，正与此心同。
——（宋）邵雍

Review

- Q1: Name and explain three transparencies that should be addressed by distributed file systems.

Review

Access transparency

• Client programs don’ t know if the file is local of remote

Location transparency

• Client programs don’ t know where the file is stored

• Files can be relocated without changing their pathname

Mobility transparency

• Neither client programs nor system administration tables in client nodes need to be changed when files are moved

Performance transparency

• Maintain acceptable performance while the load on the service varies within a specified range

Scaling transparency

• Service can be expanded without loss of performance

Review

- Q2: What are the advantages and disadvantages of using absolute names as a naming strategy?

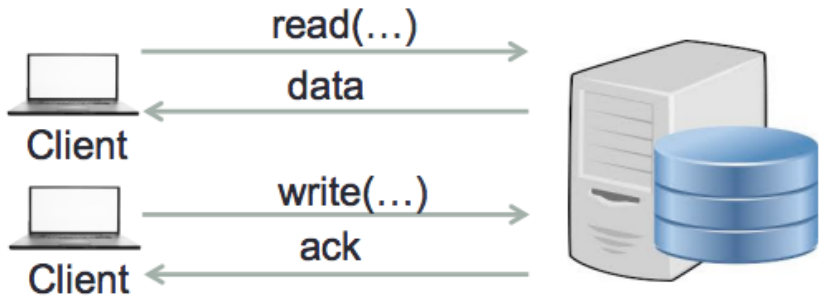
Review

- **Absolute name**
- provides a complete address to a file including both the server and path names: <machine name: path name>
- **Advantages**
- Trivial to find a file once the name is given
- No additional state must be kept since each name is self contained (No global state)
- Greater scalability
- Easy to add and delete new names
- **Disadvantages**
- No location transparency
- File is location dependent and cannot be moved
- Less resilient to failure

Review

- Q3: What are the advantages and disadvantages of the following simple distributed file system?

• RPC to access file system calls
  • No client/local caching

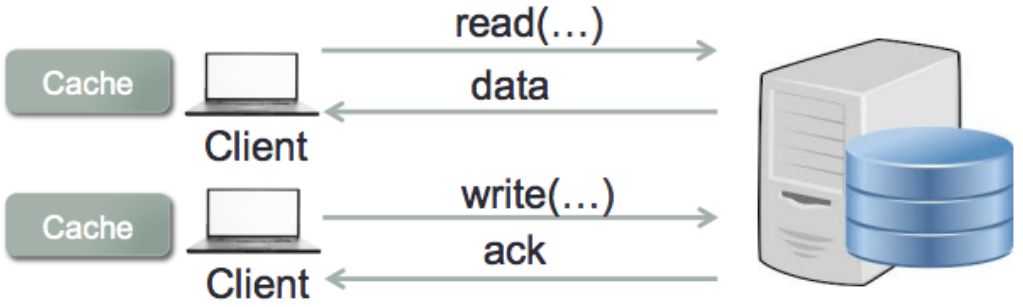


  • **Advantages**
  • Consistent view of file system
  • **Disadvantages**
  • Performance (network access, server becomes potential bottleneck)

Review

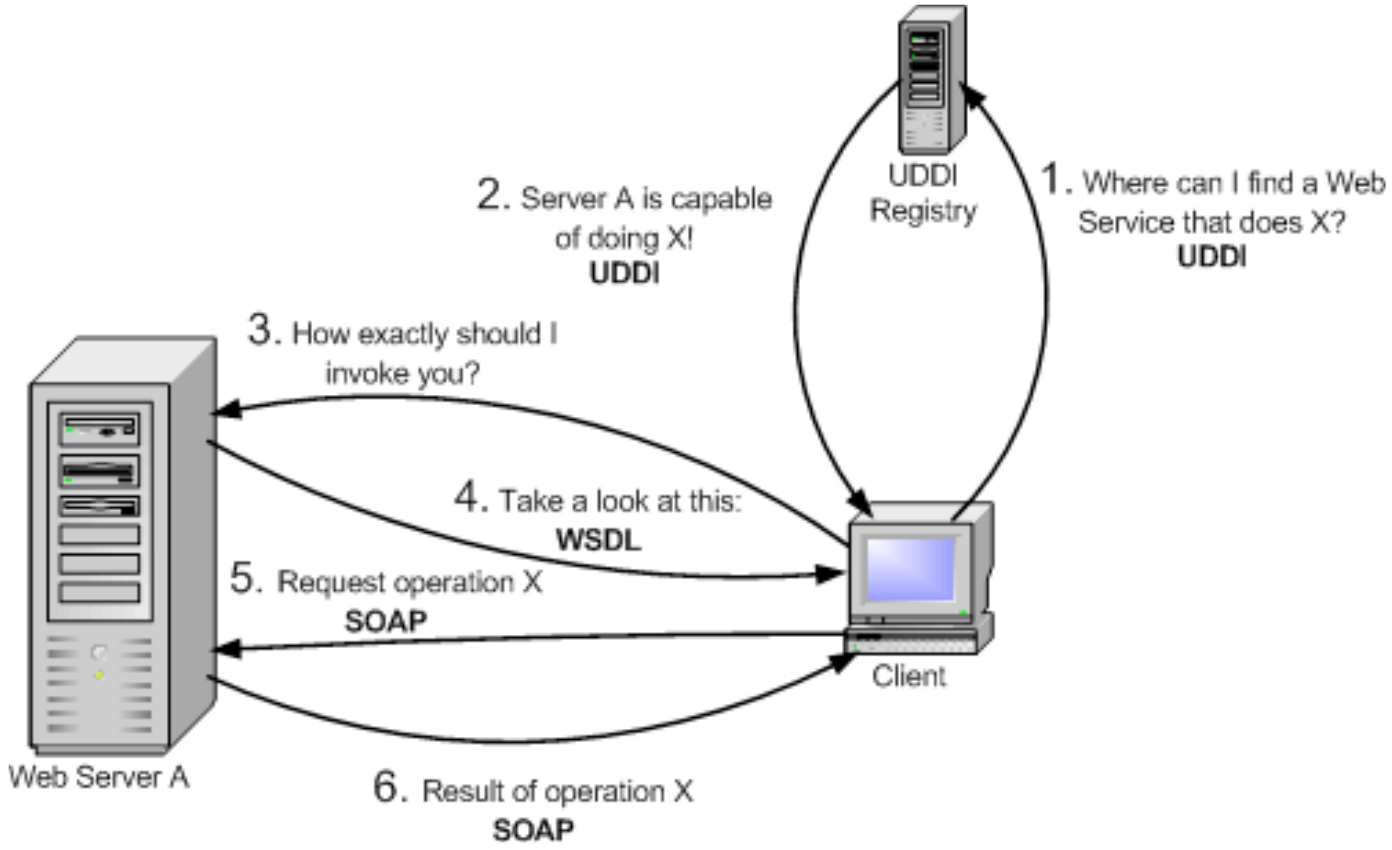
- Q4: What are the advantages and disadvantages of the following simple distributed file system?

• Cache files on clients and perform local file system operations



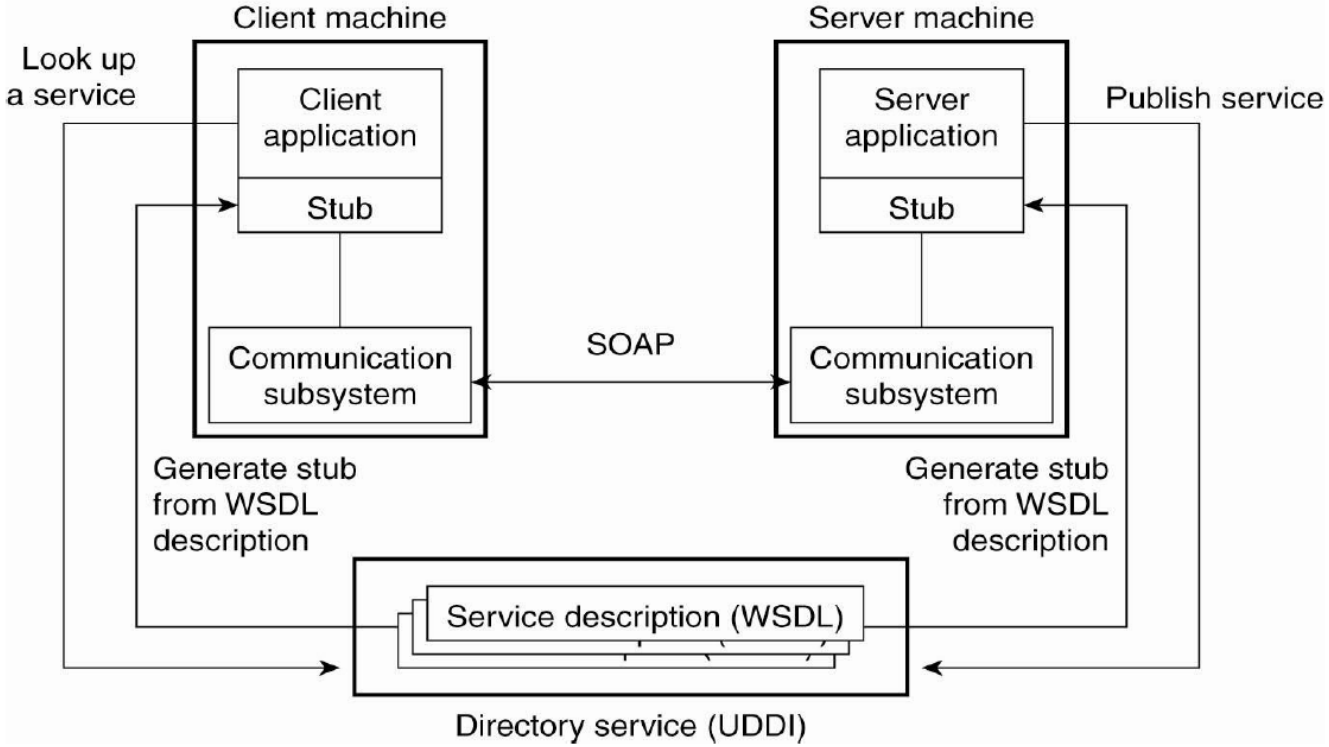
- **Advantages**
- Local operations = better performance
- **Disadvantages**
- What happens when the client fails?
- Where should the client store the cached files?
- Difficult to keep local copy consistent with remote copy

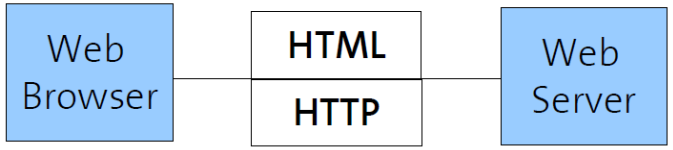
What is a web service?



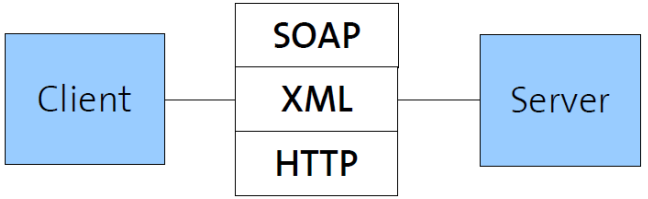
From Globus.org (Grid Computing)

With Subs



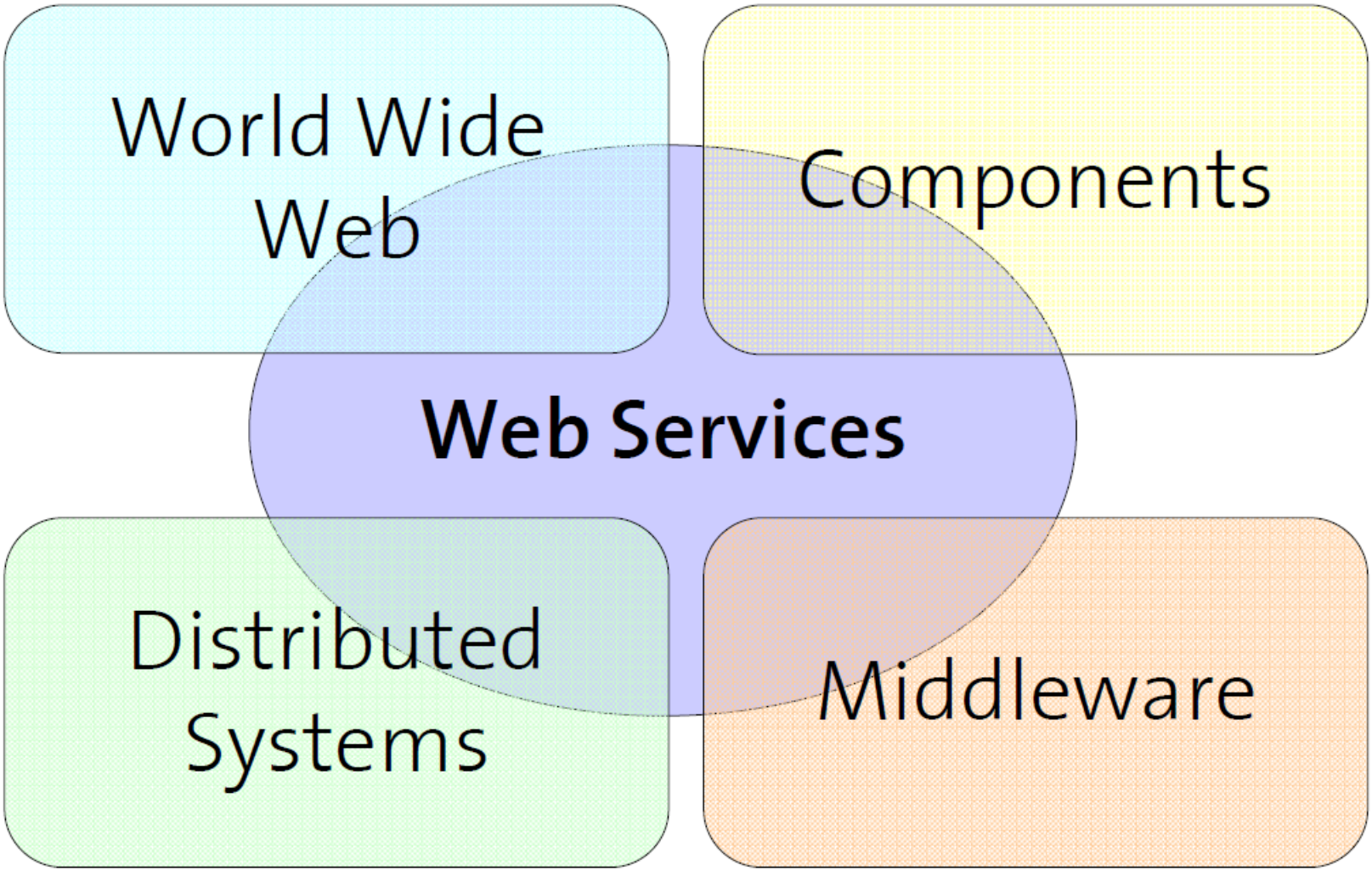


Services offered through a Web site



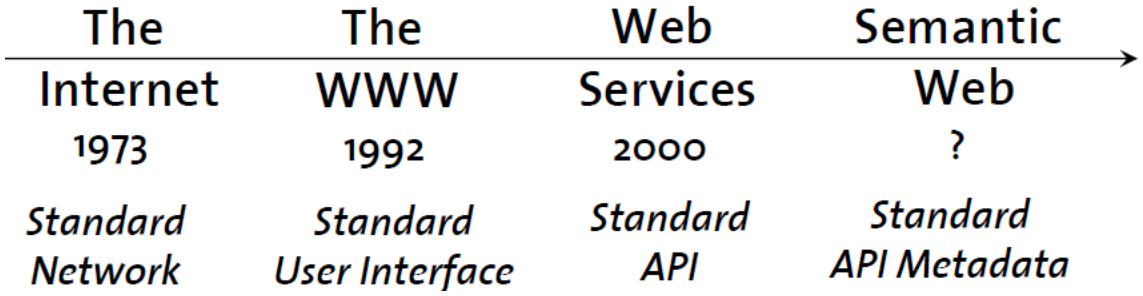
Services offered through Web-wide standardized protocols

Web services in context



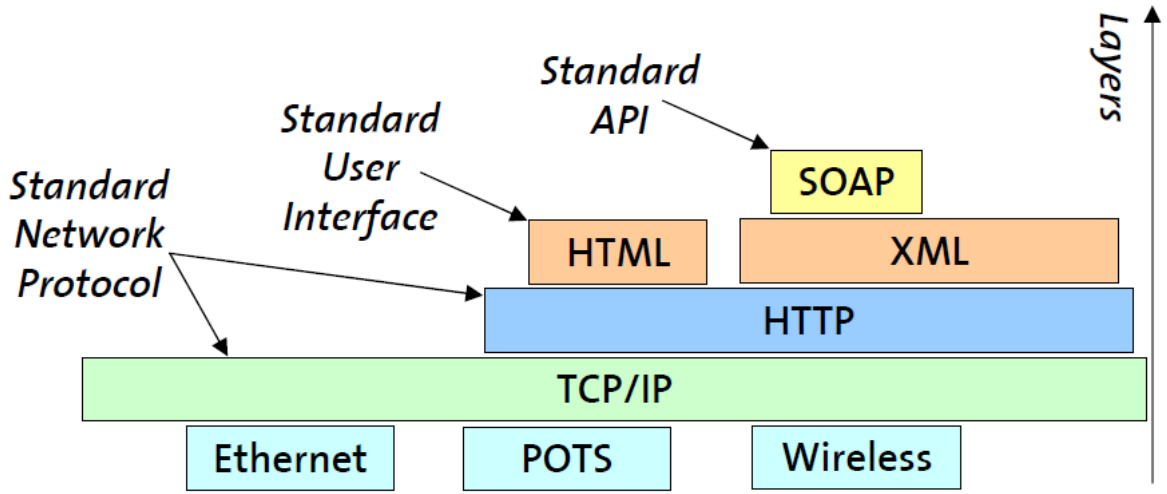
Distributed Systems & Web Services

- Web services provide standards for developing large-scale distributed systems
- One example: “the Grid” is adopting Web services as standard protocols to build a distributed infrastructure for utility based computing
- Web services on the path of success while CORBA distributed objects failed (This is nothing technical, only a matter of widespread industry acceptance)

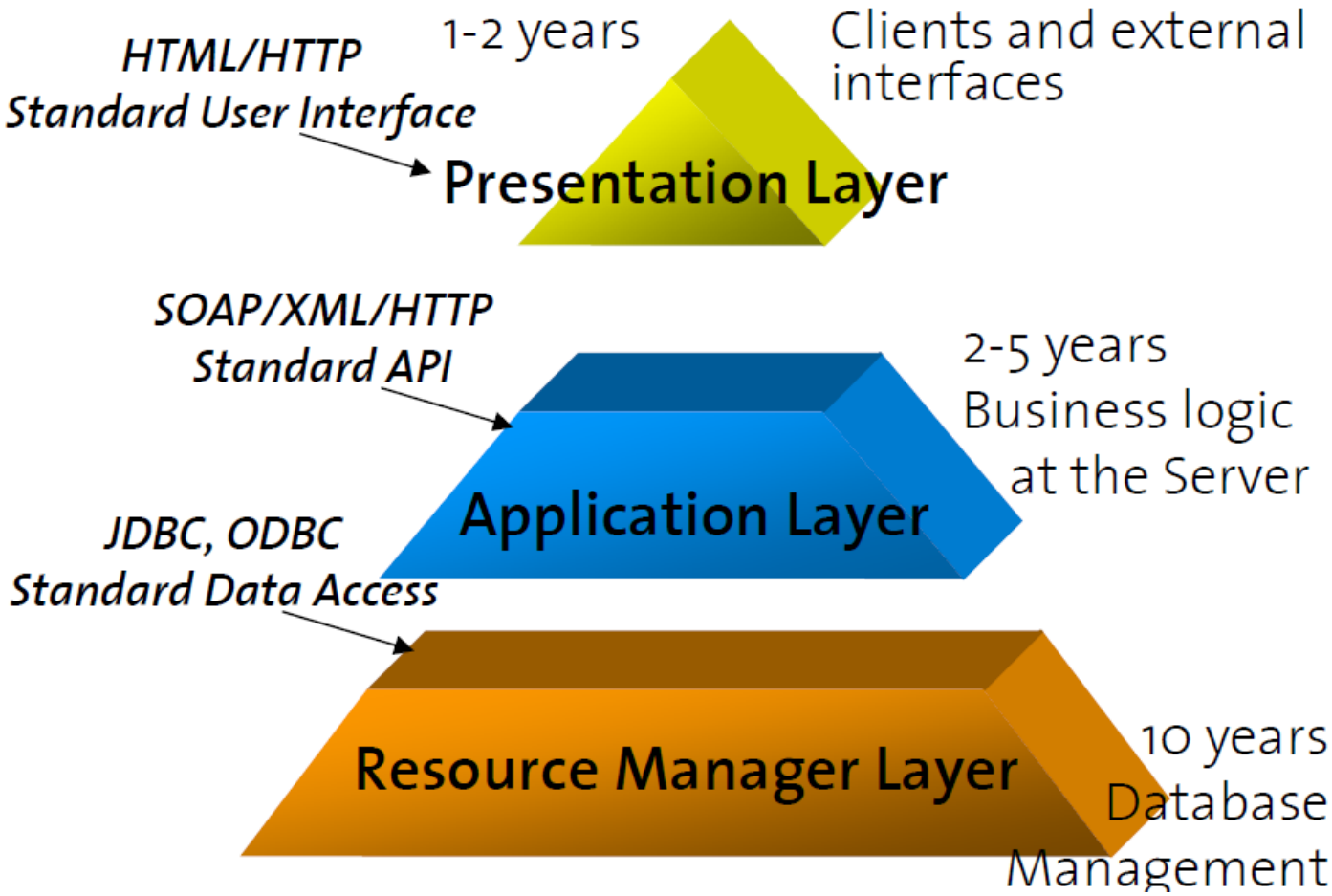


Standards for Distributed Systems

- Distributed systems are built using standardized layers of increasingly higher abstraction levels.
- It took 20 years to go from the TCP/IP (Internet, 1973) standard to the HTTP/HTML (World Wide Web, 1992) standards.
- By reusing HTTP, the time to standardize SOAP/XML was halved (Web Services, 2000).



Layers in Distributed Systems

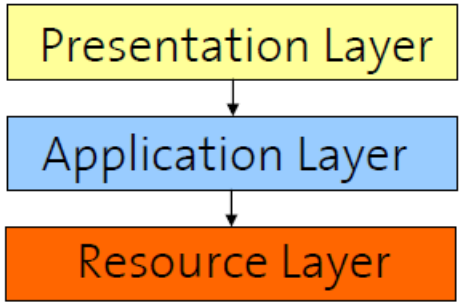


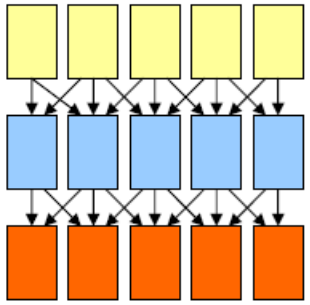
Layers in Distributed Systems

- **Client** is any user or program that wants to perform an operation over the system. To support a client, the system needs to have a **presentation layer** through which the user can submit operations and obtain a result
- The **application logic** establishes what operations can be performed over the system and how they take place. It takes care of enforcing the business rules and establish the business processes. The application logic can be expressed and implemented in many different ways: constraints, business processes, server with encoded logic ...
- The **resource manager** deals with the organization (storage, indexing, and retrieval) of the data necessary to support the application logic. This is typically a **database** but it can also be a text retrieval system or any other data management system providing querying capabilities and persistence.

Distributing the Layers

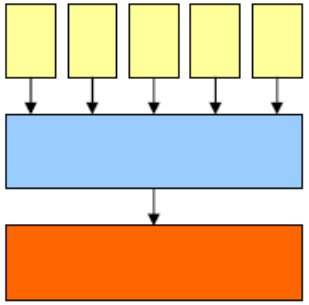
- In general, all layers can be distributed



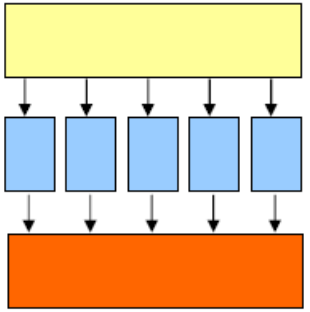


In general, all layers can be distributed

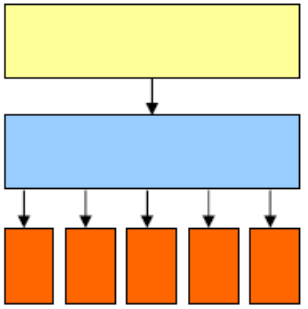
Support for multiple clients



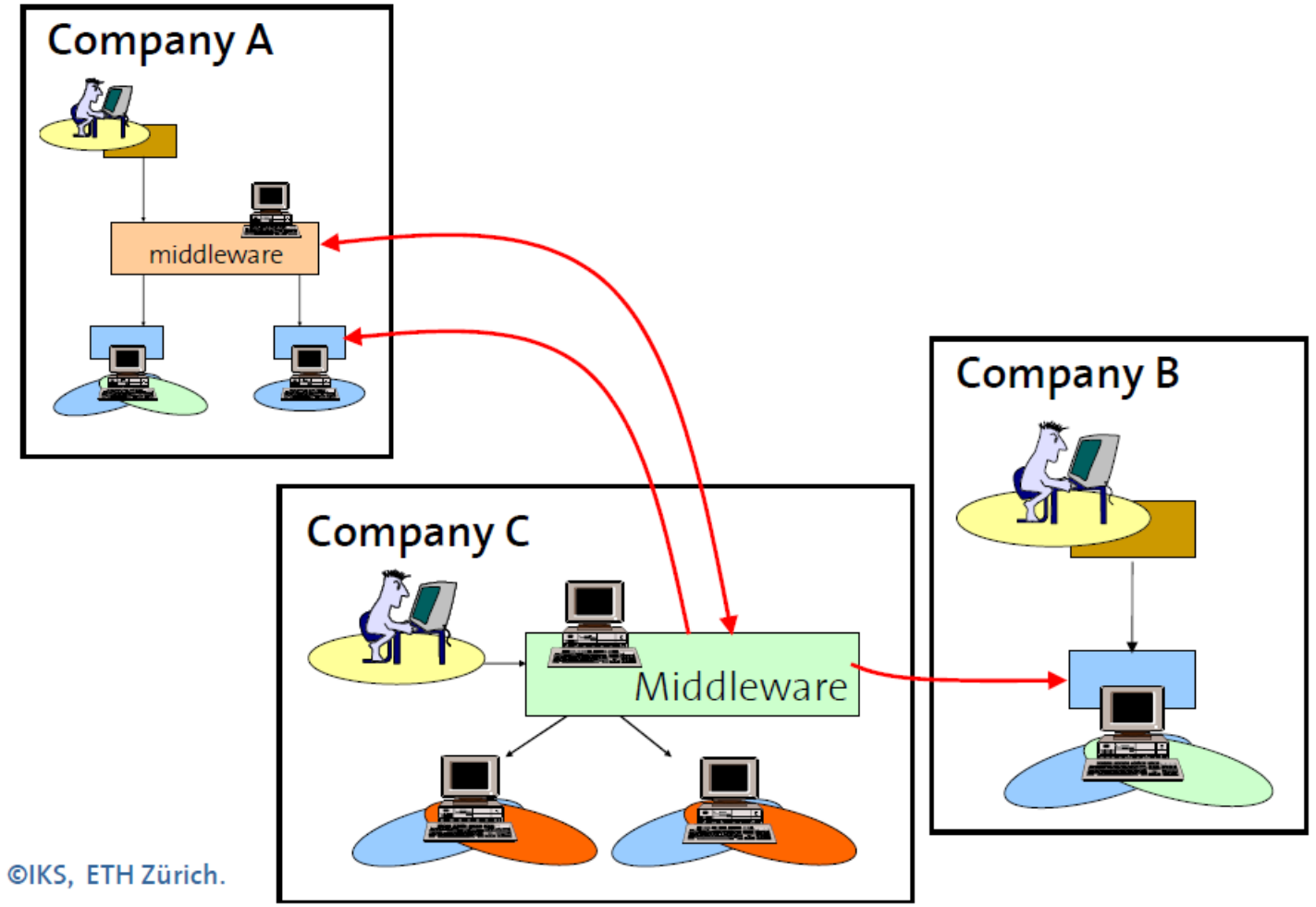
Modular Application Logic



Data Partitioning or Replication

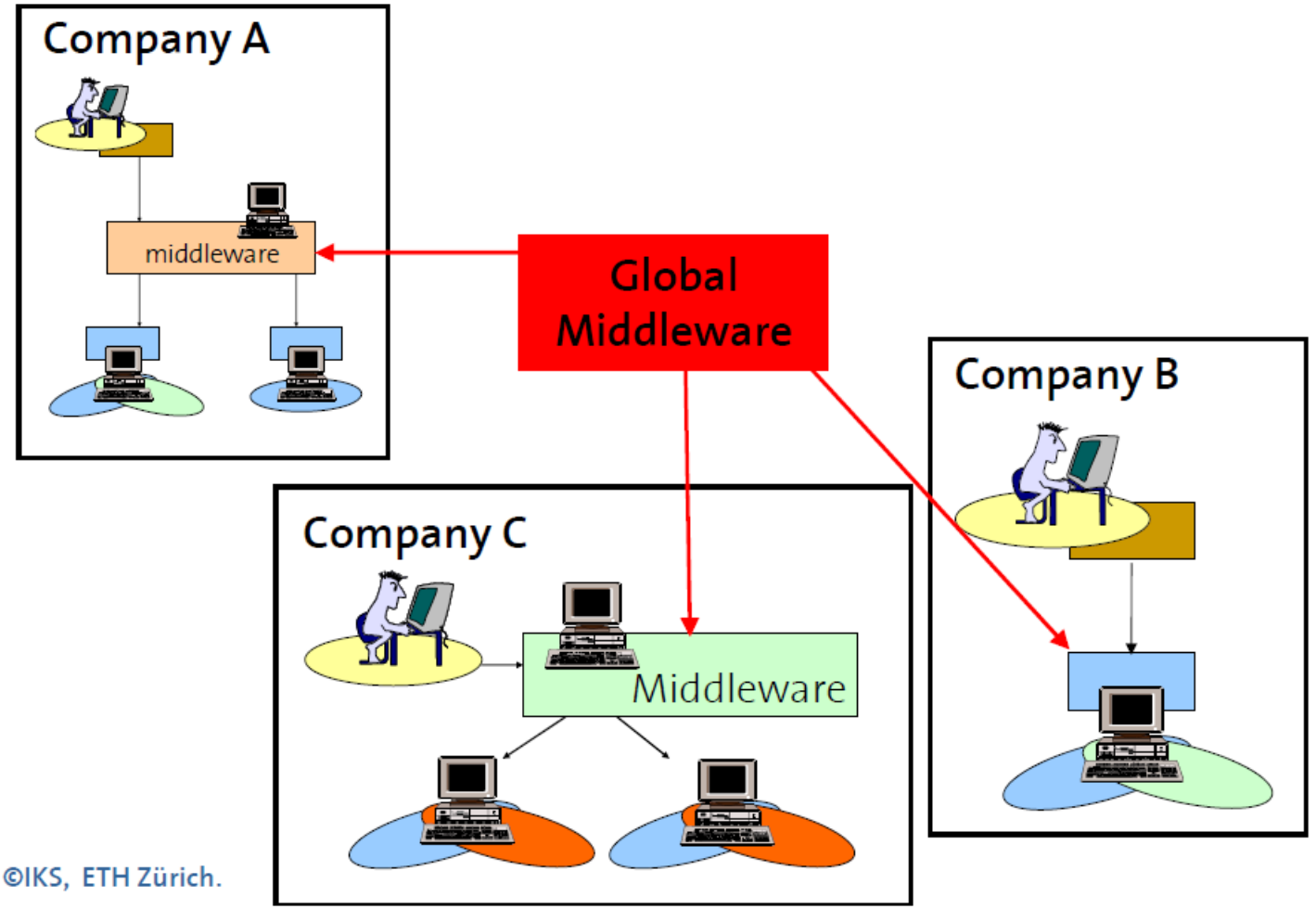


Limitations of Middleware



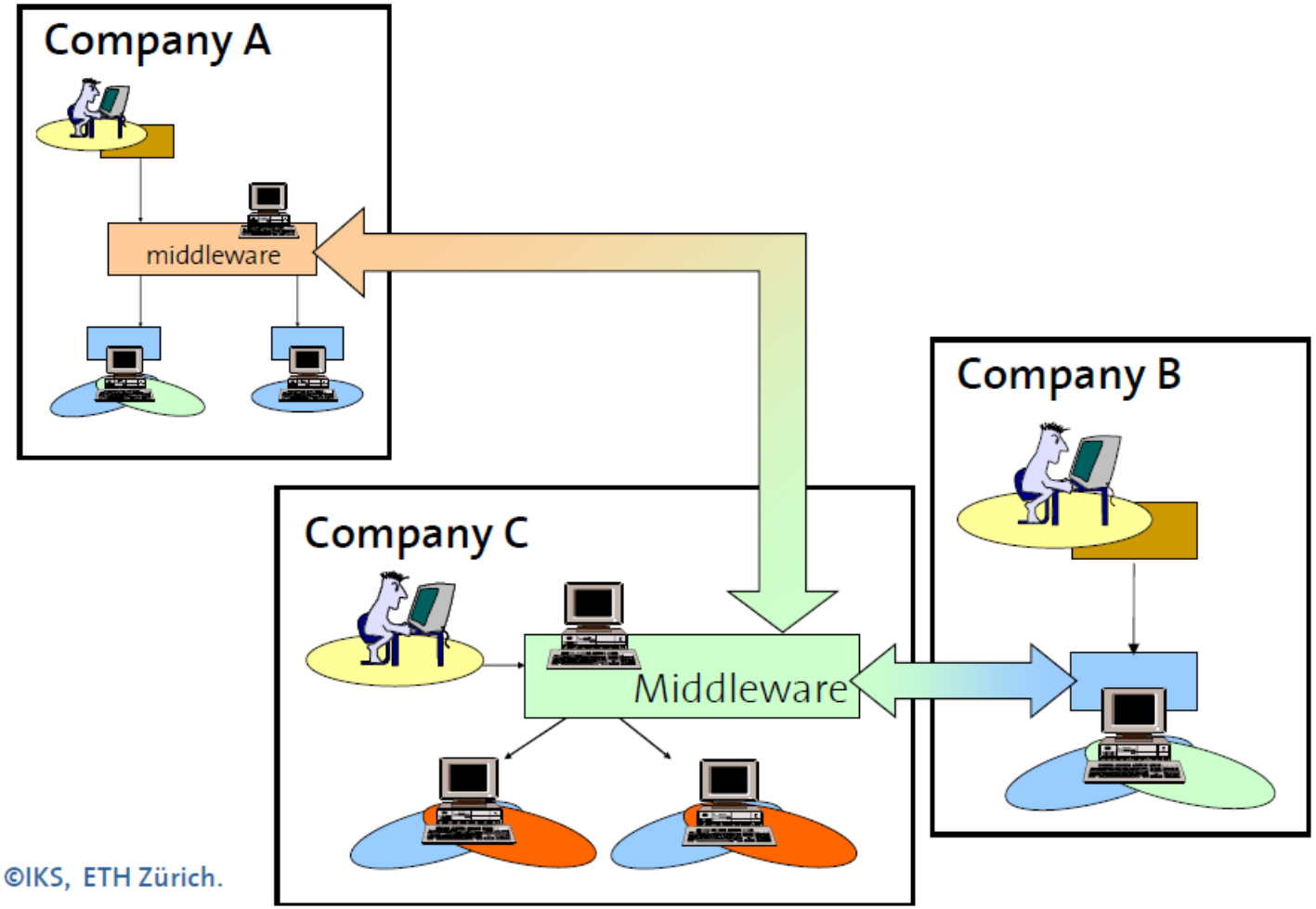
A direct connection between different organizations is not allowed (security breach) and sometimes not possible (incompatible middleware)

Limitations of Middleware



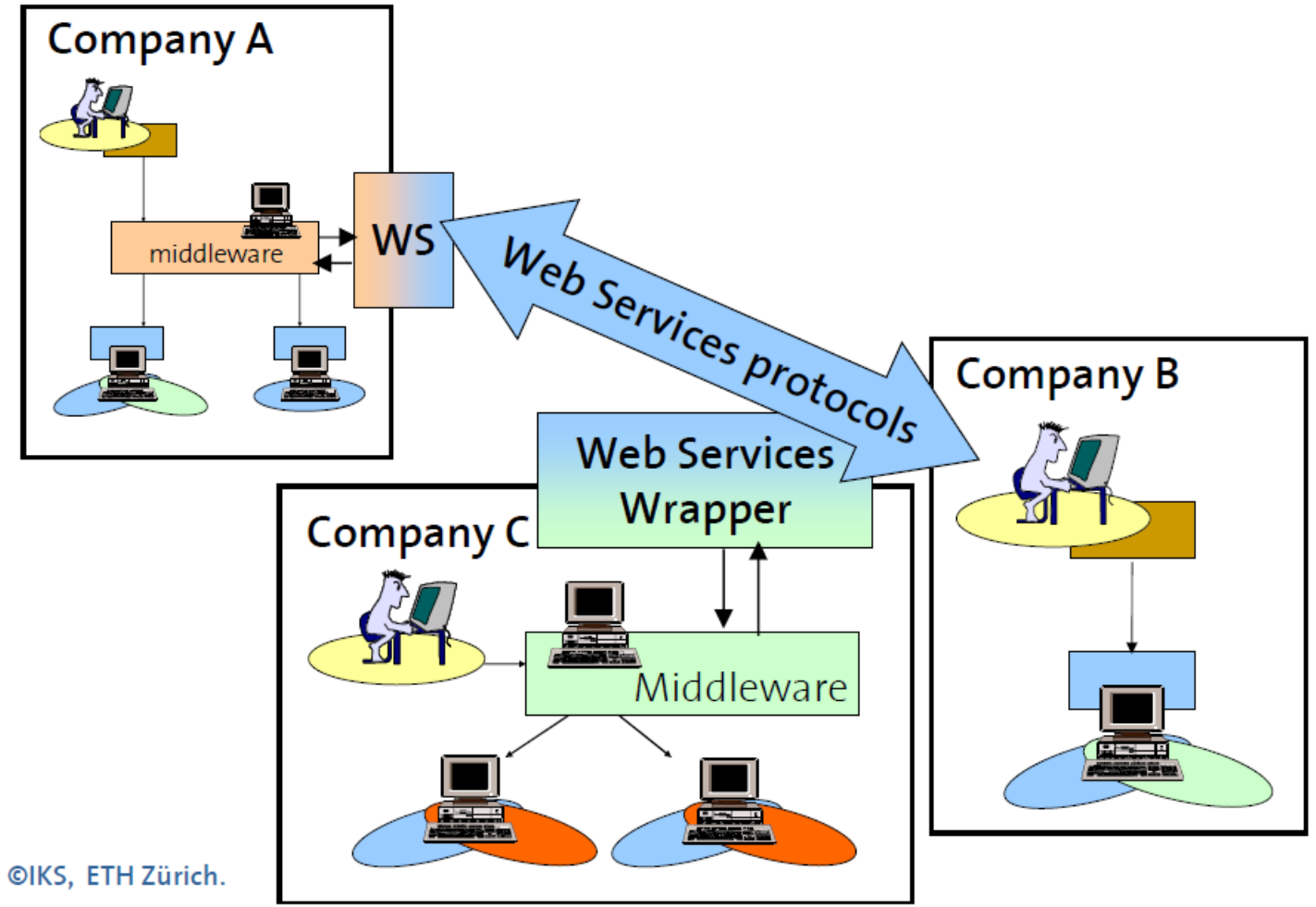
Conceptually, it could be possible to use a global middleware. However, in practice, there is no “place” for it.

Limitations of Middleware



Point to Point solutions are expensive and do not scale well with the number of systems to be integrated

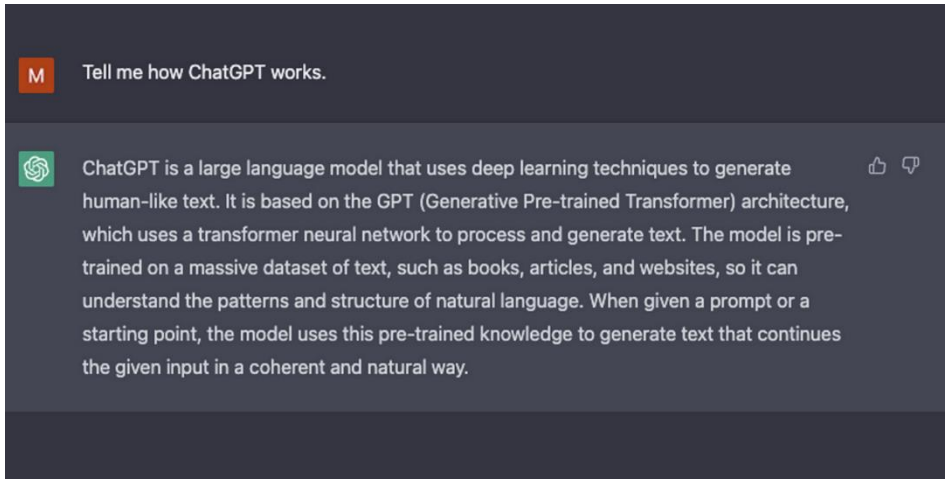
Web services for integration



Publishing the systems to be integrated as Web Services simplifies the integration and keeps the companies decoupled

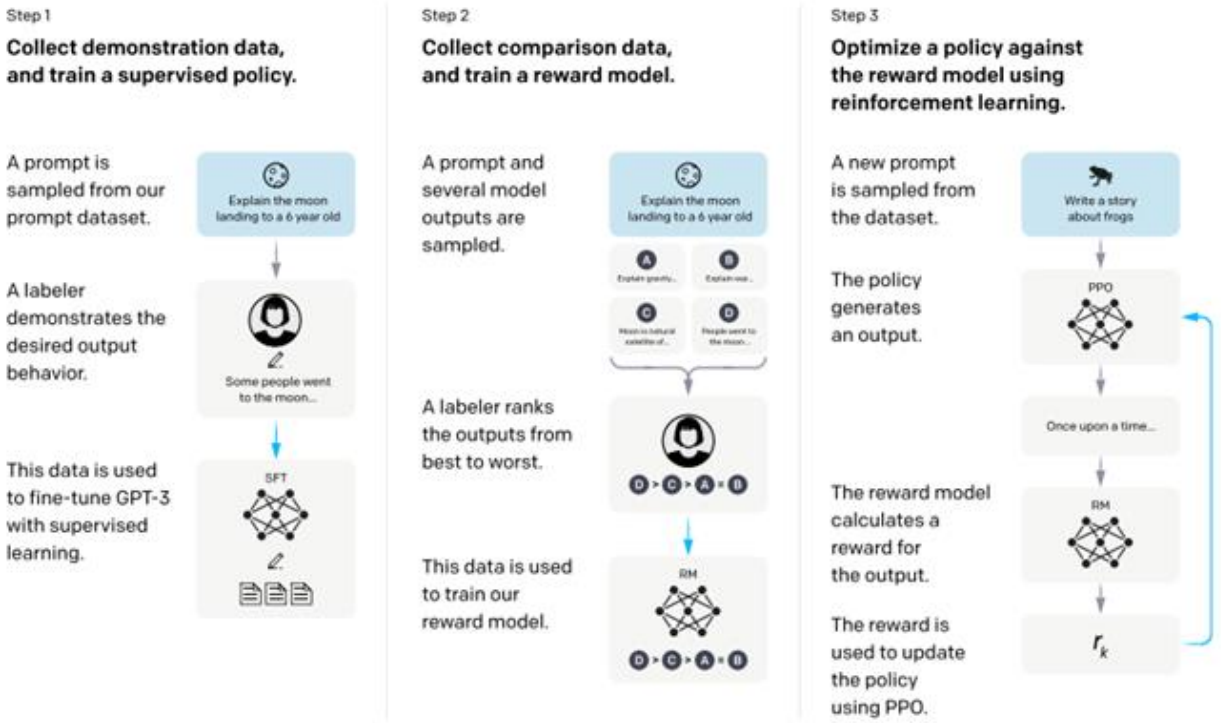
Case: WebGPT

- WebGPT: Browser-assisted question-answering with human feedback
- When we want to scale up to huge datasets and models, eventually one machine won't be enough.
- using multiple machines to do learning!



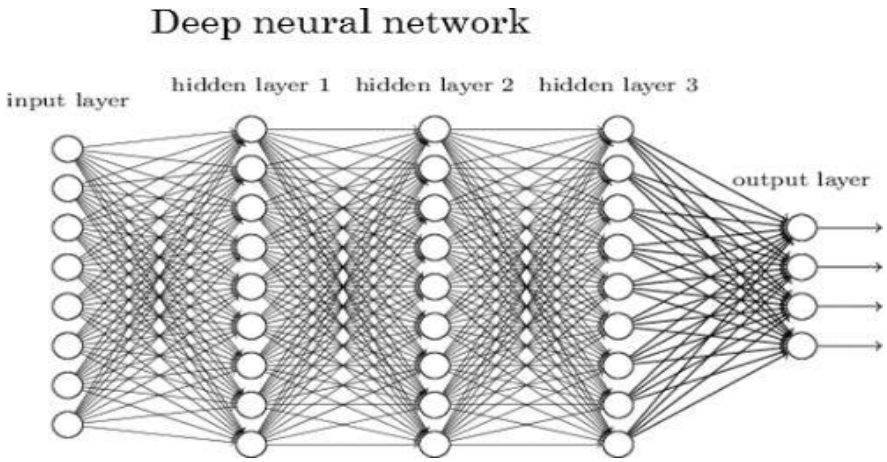
InstructGPT

- (1) Supervised fine-tuning
- (2) Reward model training
- (3) Reinforcement learning via proximal policy optimization on this reward model.



Characteristics & Challenges of AI jobs

- Training Data is **Large** – 1TB to 1PB
- Complex Models with **Billions** and **Trillions** of Parameters
- Parameters are shared globally among worker nodes:
  - Accessing them incurs large **Network costs**
  - Sequential ML jobs require **barriers** and hurt performance by blocking
  - At scale, **Fault Tolerance** is required as these jobs run in a cloud environment where machines are unreliable and jobs can be preempted



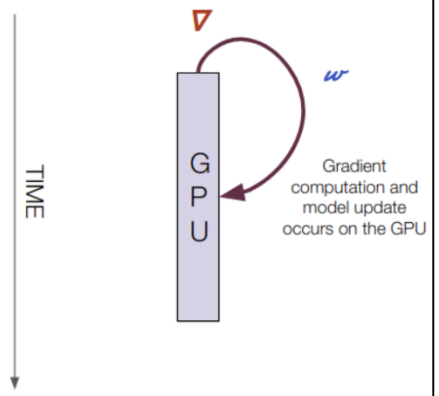
Key Goals and Features of Design

- **Efficient Communication**: asynchronous communication model (does not block computation)
- **Flexible Consistency Models**: Algorithm designer can balance algorithmic convergence and system efficiency
- **Elastic Scalability** : New nodes can be added without restarting framework
- **Fault Tolerance and Durability**: Recovery from and repair in 1 sec.
- **Ease of Use**: easy for users to write programs

Distributed Training for Large Models

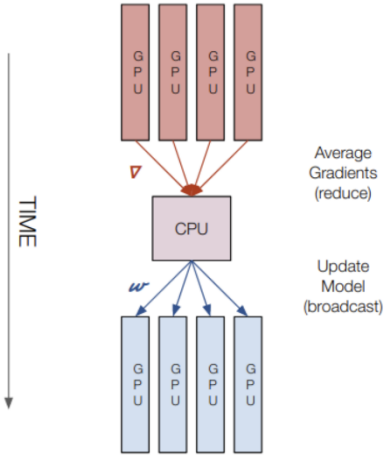
- **Communication Patterns**
  - **Push:** Machine A sends some data to machine B.
  - **Pull:** Machine B requests some data from machine B.
  - **Broadcast:** Machine A sends data to many machines.
  - **Reduce:** Compute some reduction (usually a sum) of data on multiple machines C1, C2, …, Cn and materialize the result on one machine B.
  - **All-Reduce:** Compute some reduction (usually a sum) of data on multiple machines and materialize the result on all those machines.

Single GPU



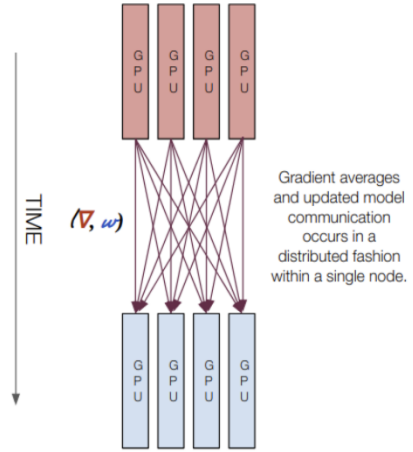
Computation Happens: On one GPU
Gradient transfers: N/A
Model transfers: N/A

Multi GPU Training (CPU Parameter Server)



Computation Happens: On all GPUs and CPU
Gradient transfers: From GPU to CPU (reduce)
Model transfers: From CPU to GPU (broadcast)

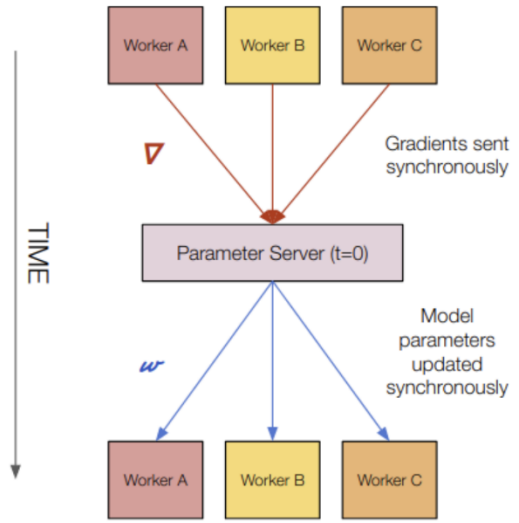
Multi GPU Training (Multi GPU all-reduce)



Computation Happens: On all GPUs
Gradient transfers: GPU to GPU during NCCL all-reduce
Model transfers: GPU to GPU during NCCL all-reduce

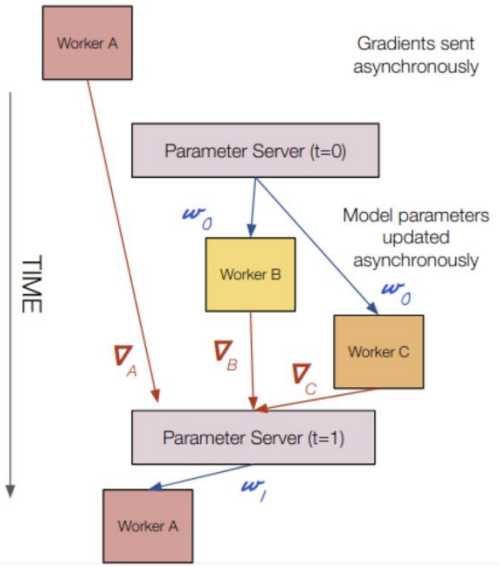
Distributed Training for Large Models

Synchronous Distributed SGD



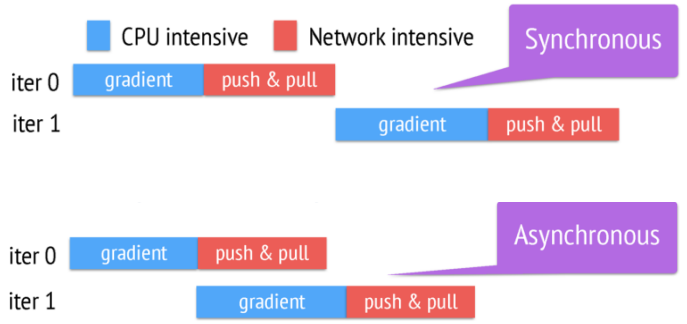
Computation Happens: On all workers and parameter servers
Gradient transfers: Worker to parameter server
Model transfers: Parameter server to worker

Asynchronous Distributed SGD

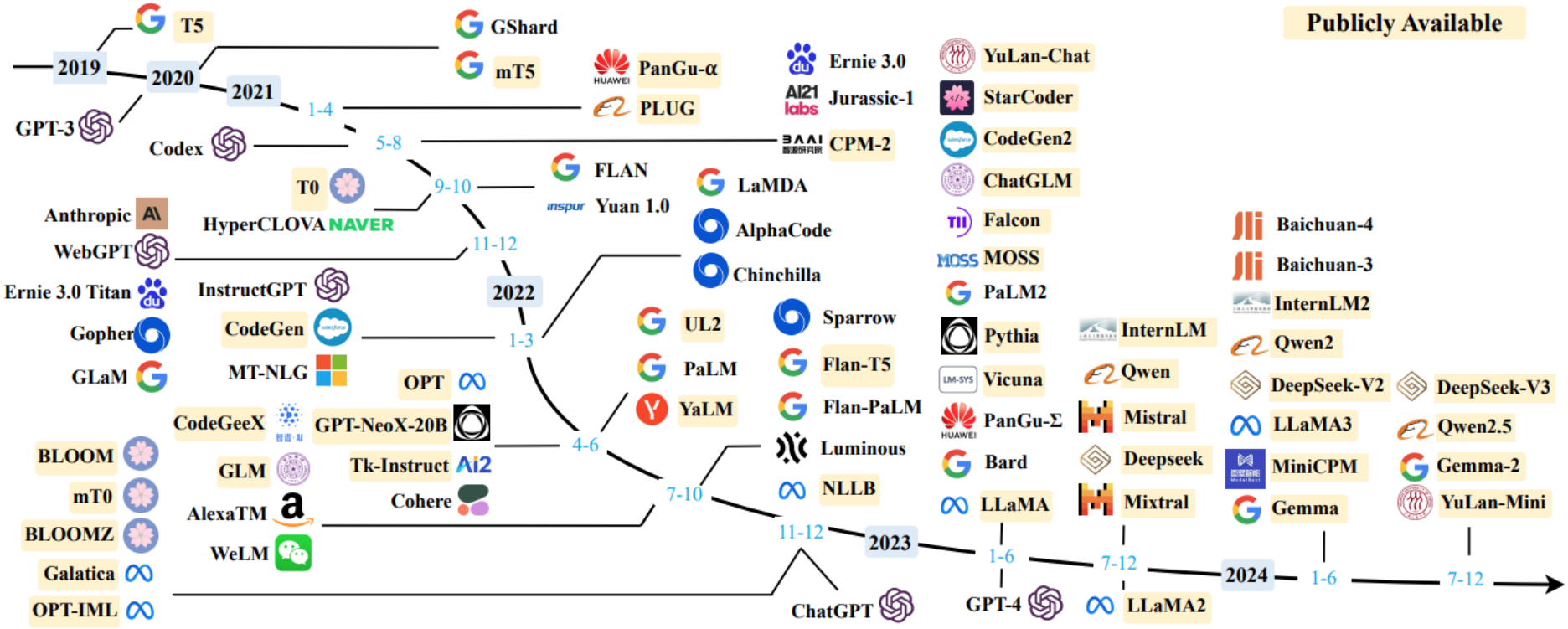


Computation Happens: On all workers and parameter servers
Gradient transfers: Worker to parameter server (asynchronously)
Model transfers: Parameter server to worker (asynchronously)

- Workers get the Assigned training data
- Workers **Pull** the Working set of Model
- Iterate until Stop:
  - Workers **Compute** Gradients
  - Workers **Push** Gradients
  - Servers **Aggregate** into current model
  - Workers **Pull** updated model



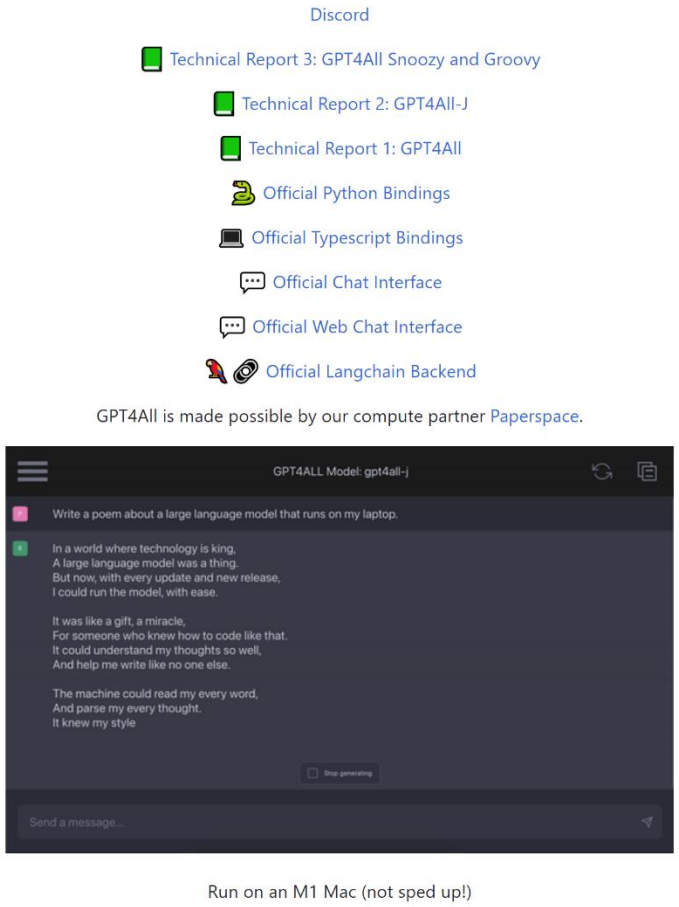
Large models



Ref: A survey of Large Language models

Small GPTs

- GPT4All
  - Run on single computer

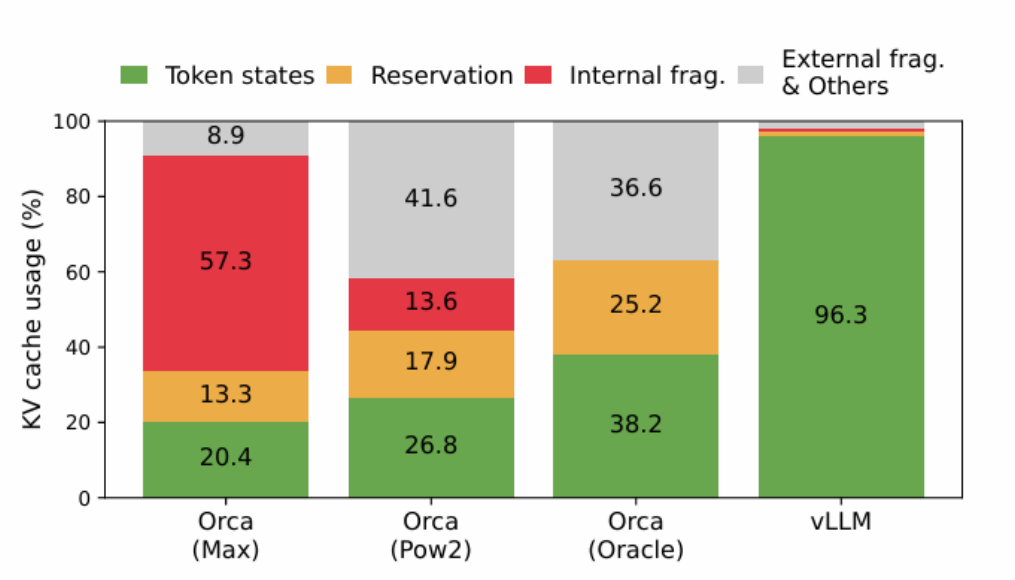


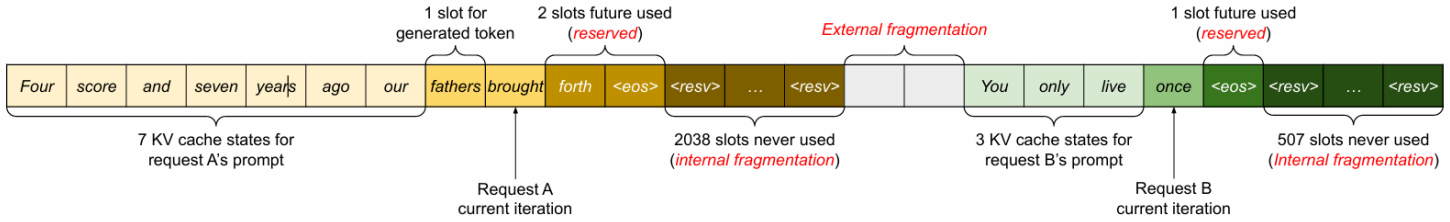
Run on an M1 Mac (not sped up!)

- NanoGPT
  - repository for training/finetuning medium-sized GPTs.

Challenges in memory usage

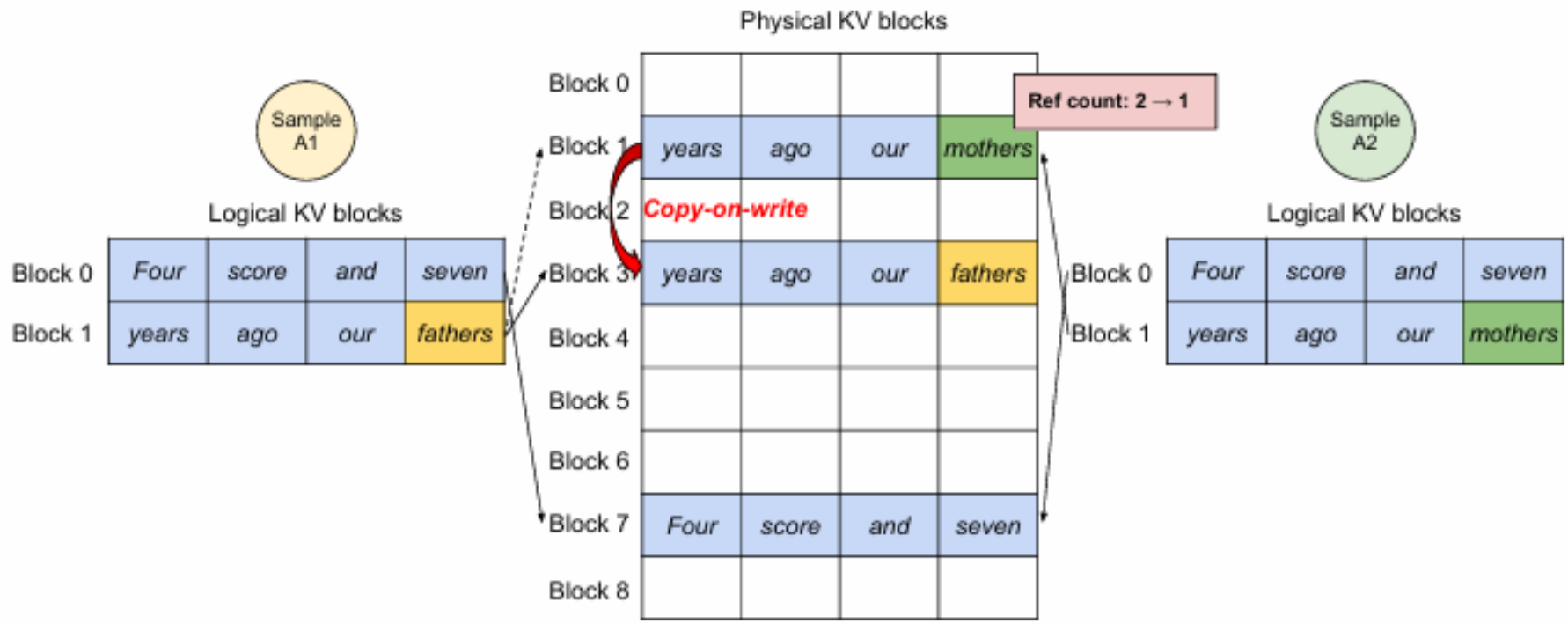
- Many fragments exist in LLM memory usage in distributed systems





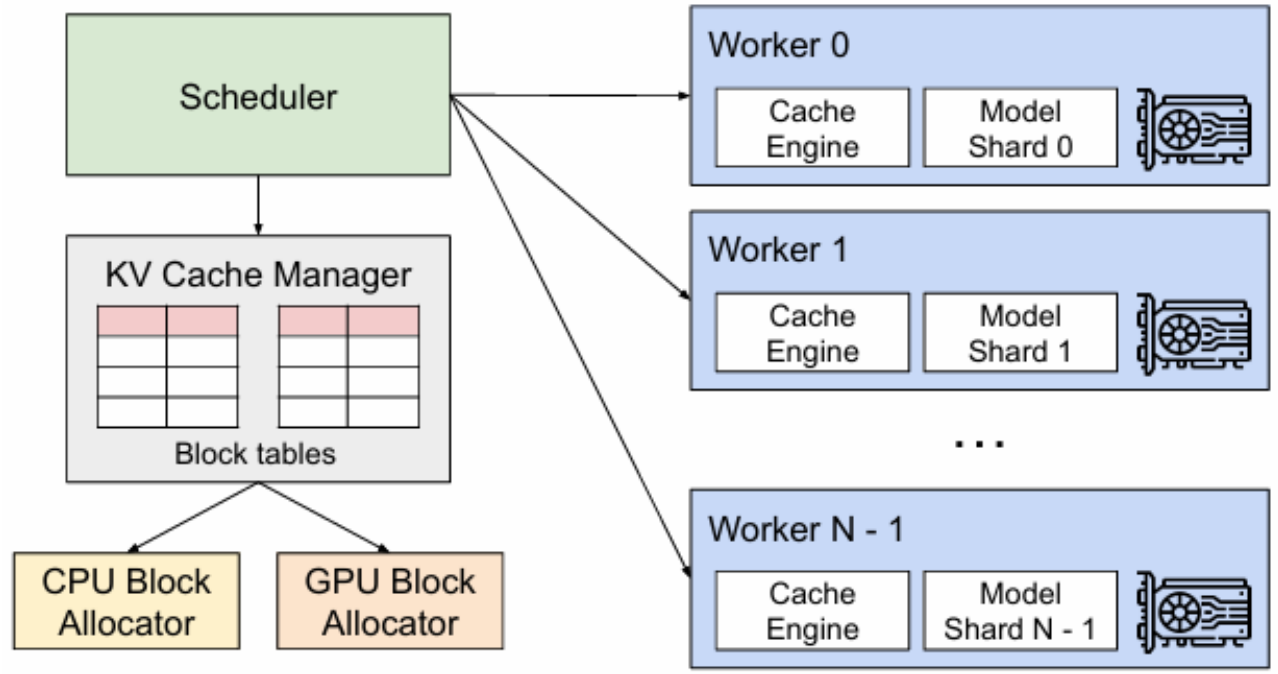
PagedAttention Parallel sample

- Prompts can be shared and only one copy is required
- Reference count points to logic block

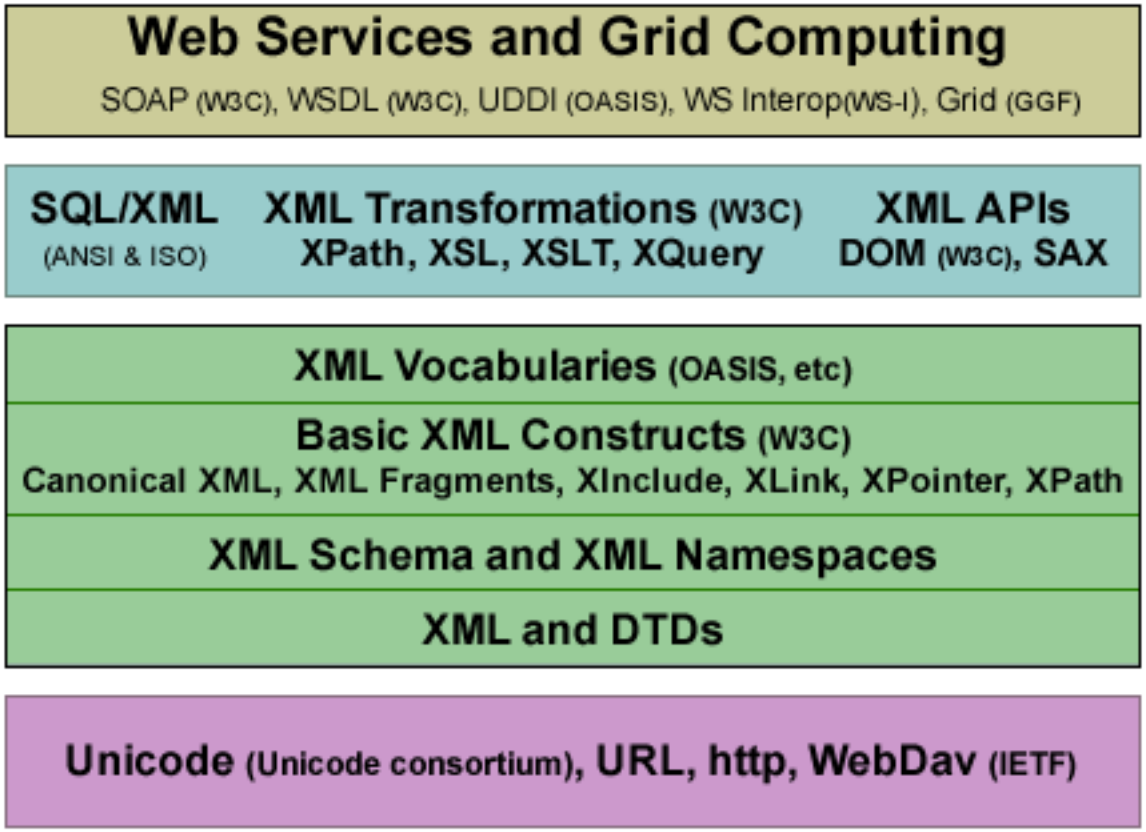


vLLM to optimize memory usage

- Centralized scheduler to coordinate distributed GPU worker nodes

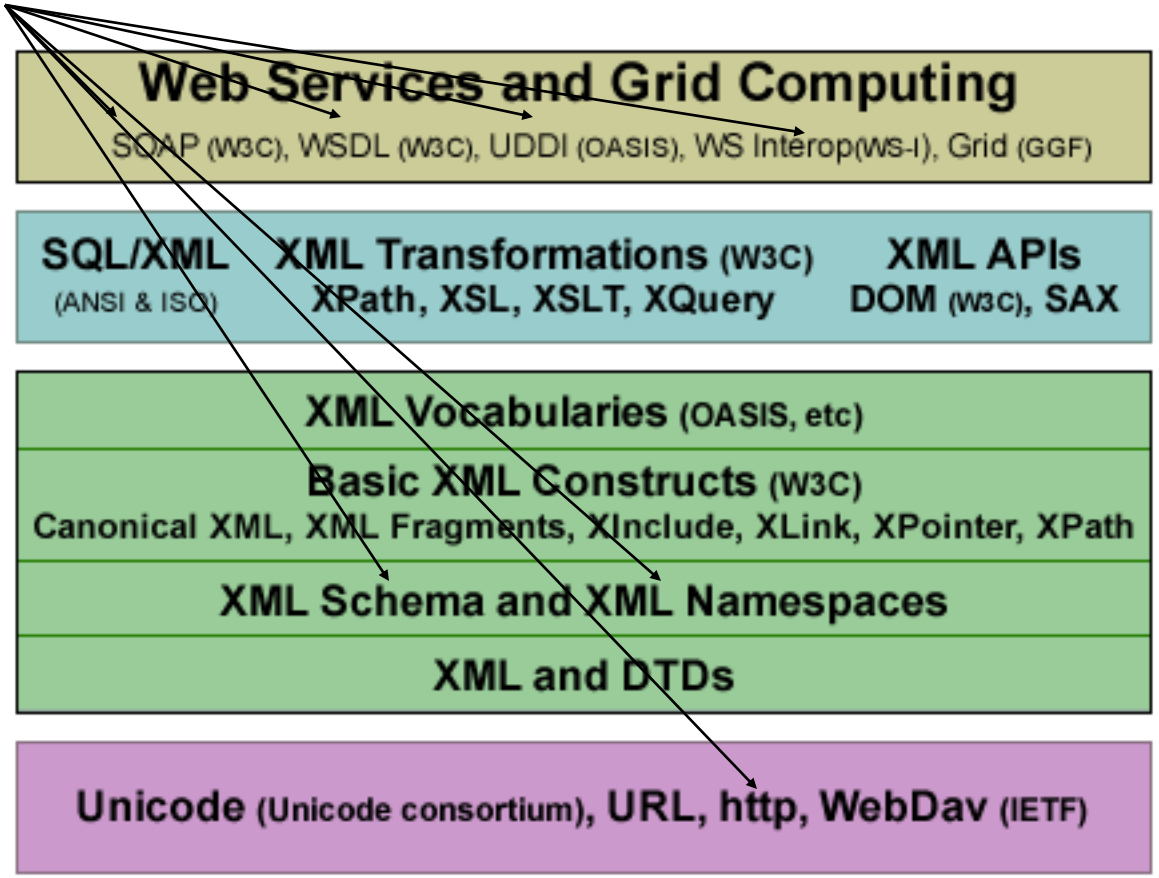


Some Important Standards



Some Important Standards

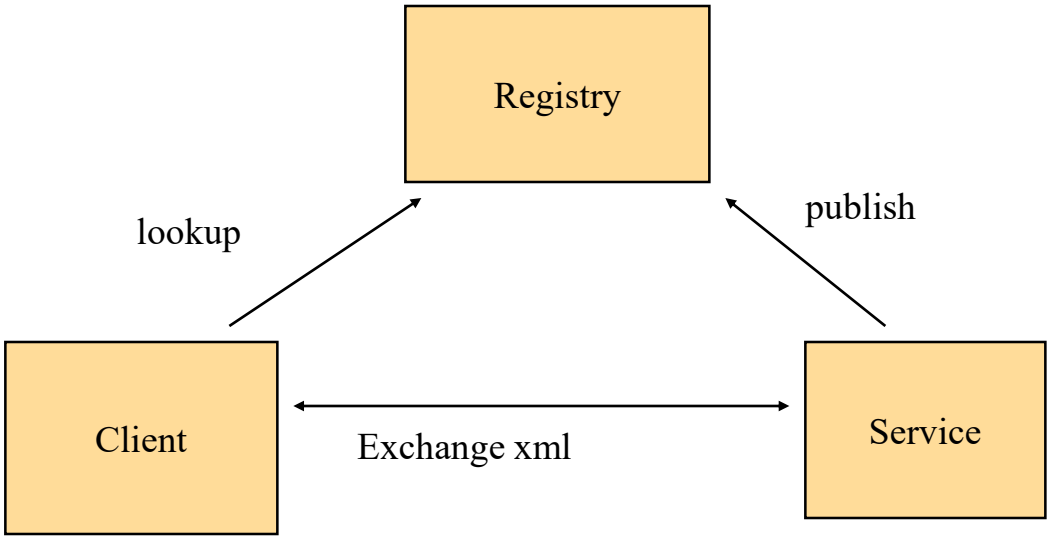
Very important with respect to XML web services.



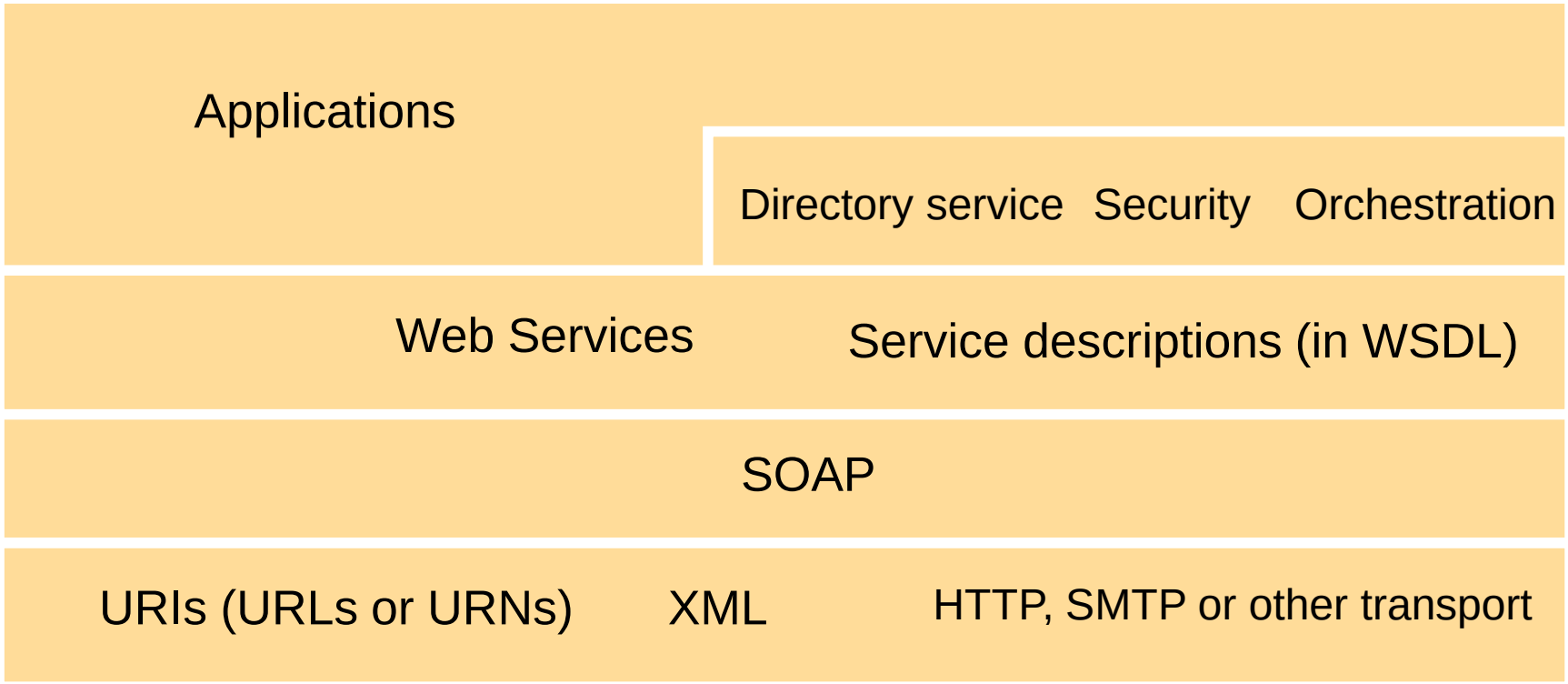
Web Services

- Provide service interfaces.
- Communicate using request and reply messages made of SOAP or some other XML document.
- Have an Interface Definition Language (IDL) called WSDL (Web Service Definition Language)
- May be looked up in a web service UDDI registry (Universal Directory and Discovery Service).
- Are language independent.
- May be synchronous or asynchronous.

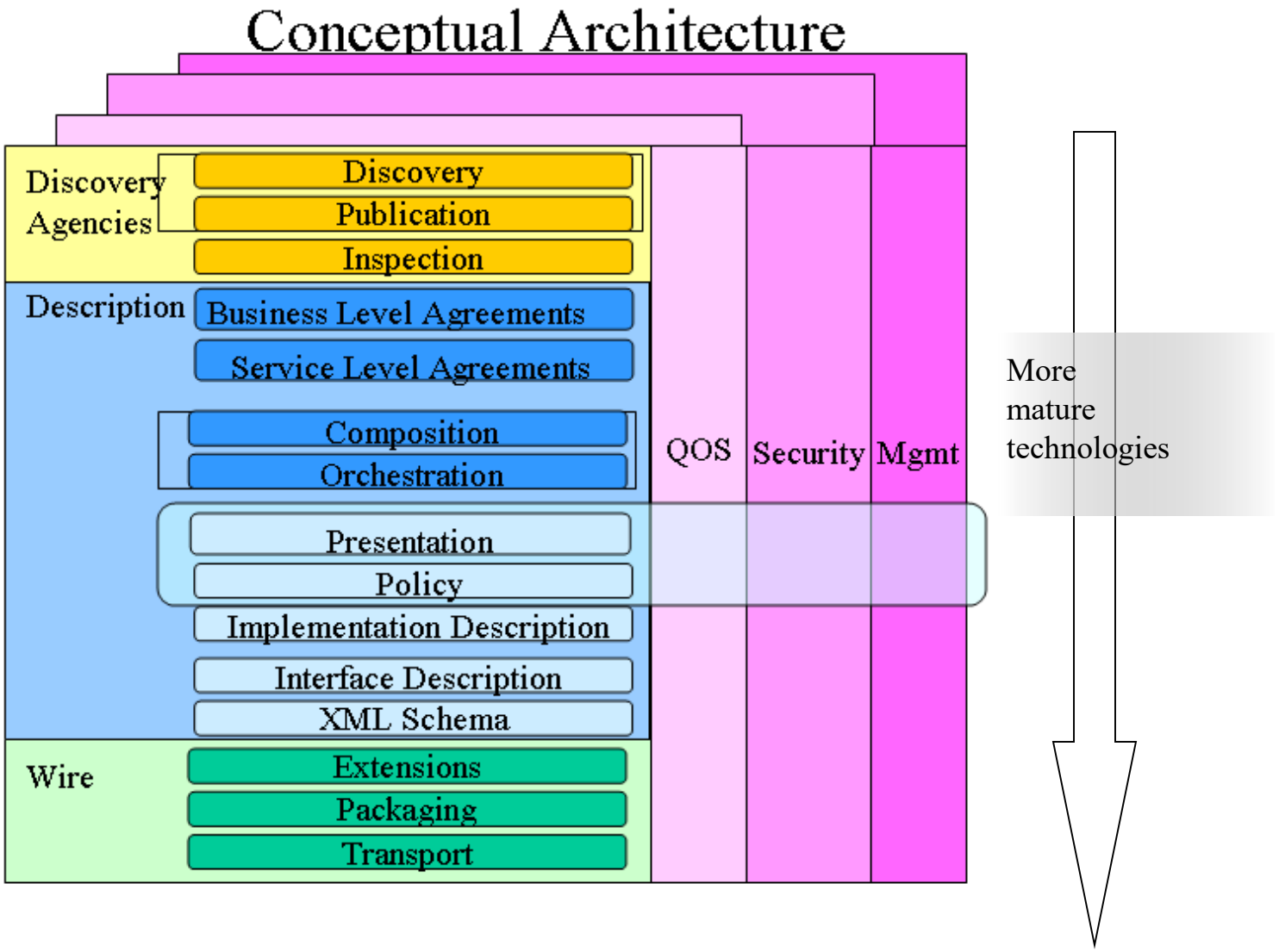
Web Services



Web Services Infrastructure and Components



The Complete Web Services “Stack”



Communication Patterns

- In general, web services use either a synchronous request-reply pattern of communication with their clients or they communicate by asynchronous messages.
- The client does not block on asynchronous calls. Do you block when you are expecting an important phone call? If not then you are planning on handling the call asynchronously.
- To allow for a variety of patterns, SOAP is based on the packaging of single one-way messages.
- SOAP is used to hold RPC style parameters or entire documents.
- SOAP may be used over different transports (SMTP, TCP, UDP, or HTTP)

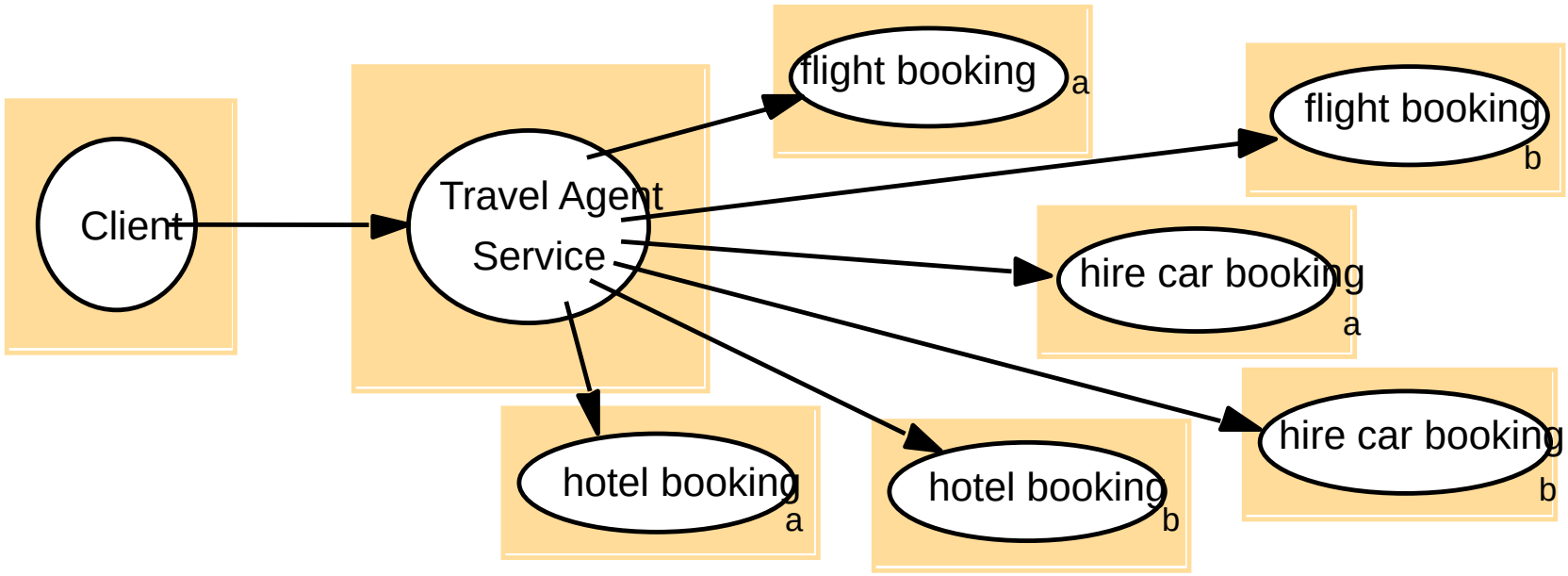
Service References

- URI's are Uniform Resource Identifiers.
- URL's are Uniform Resource Locator URI's that include location information. Thus, resources pointed to by URL's are hard to move.
- URN's are Uniform Resource Name URI's that include no location information.
- A URN lookup service can be employed to determine a URL from a URN.
- URL's are the most frequently used form of URI.

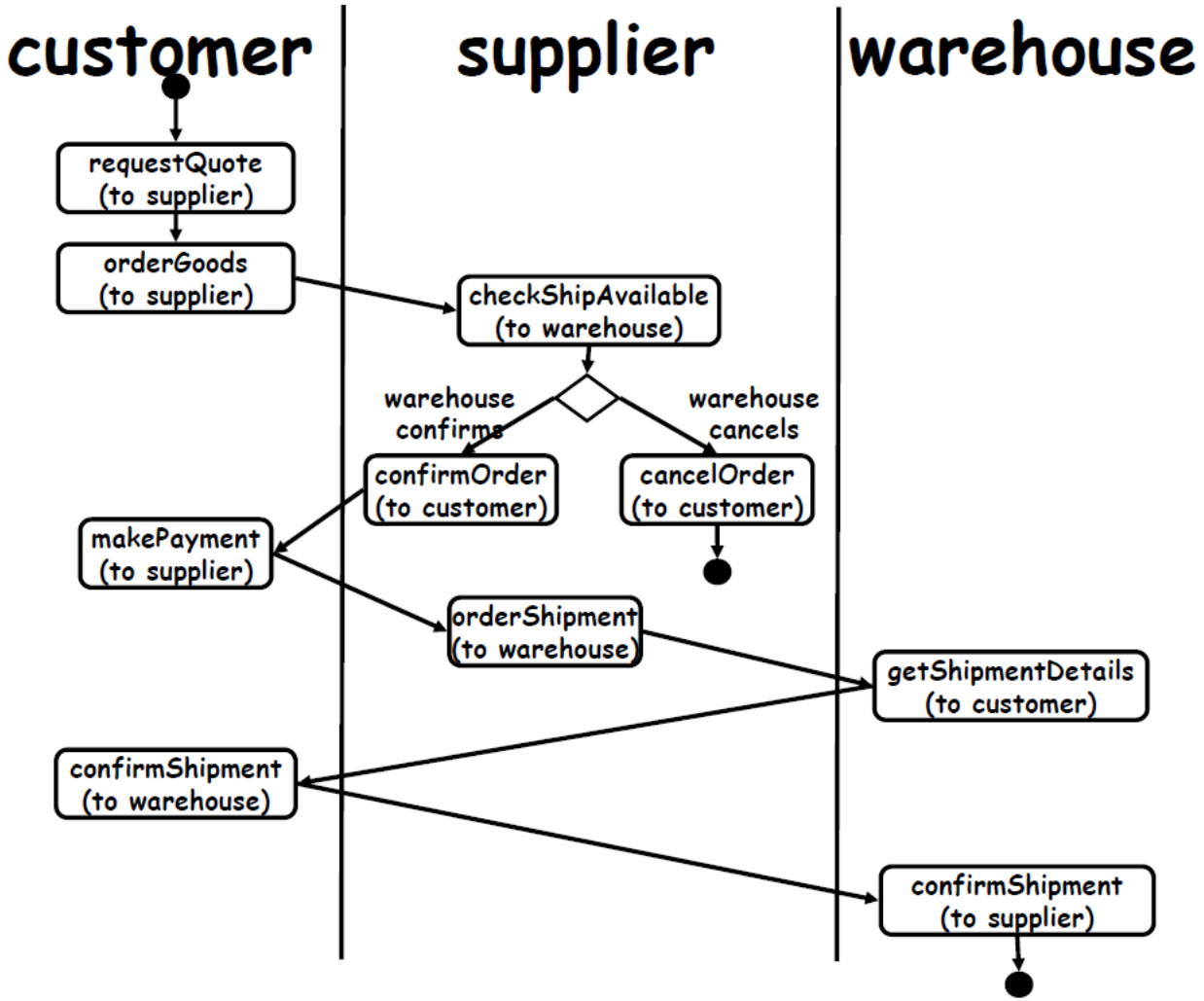
Examples:

URL: http://www.siat.ac.cn
URN: urn:ISBN:0-111-2345-6

Web Service Composition



Web Service Composition and Coordination



The Apache Web Server

- By far the most popular Web server is Apache, which is estimated to be used to host approximately 70% of all Web sites.
- Apache's runtime environment, known as the Apache Portable Runtime (APR), is a library that provides a platform-independent interface for file handling, networking, locking, threads, and so on.

There is a hook to translate a URL to a local file name. Such a translation will almost certainly need to be done when processing a request.

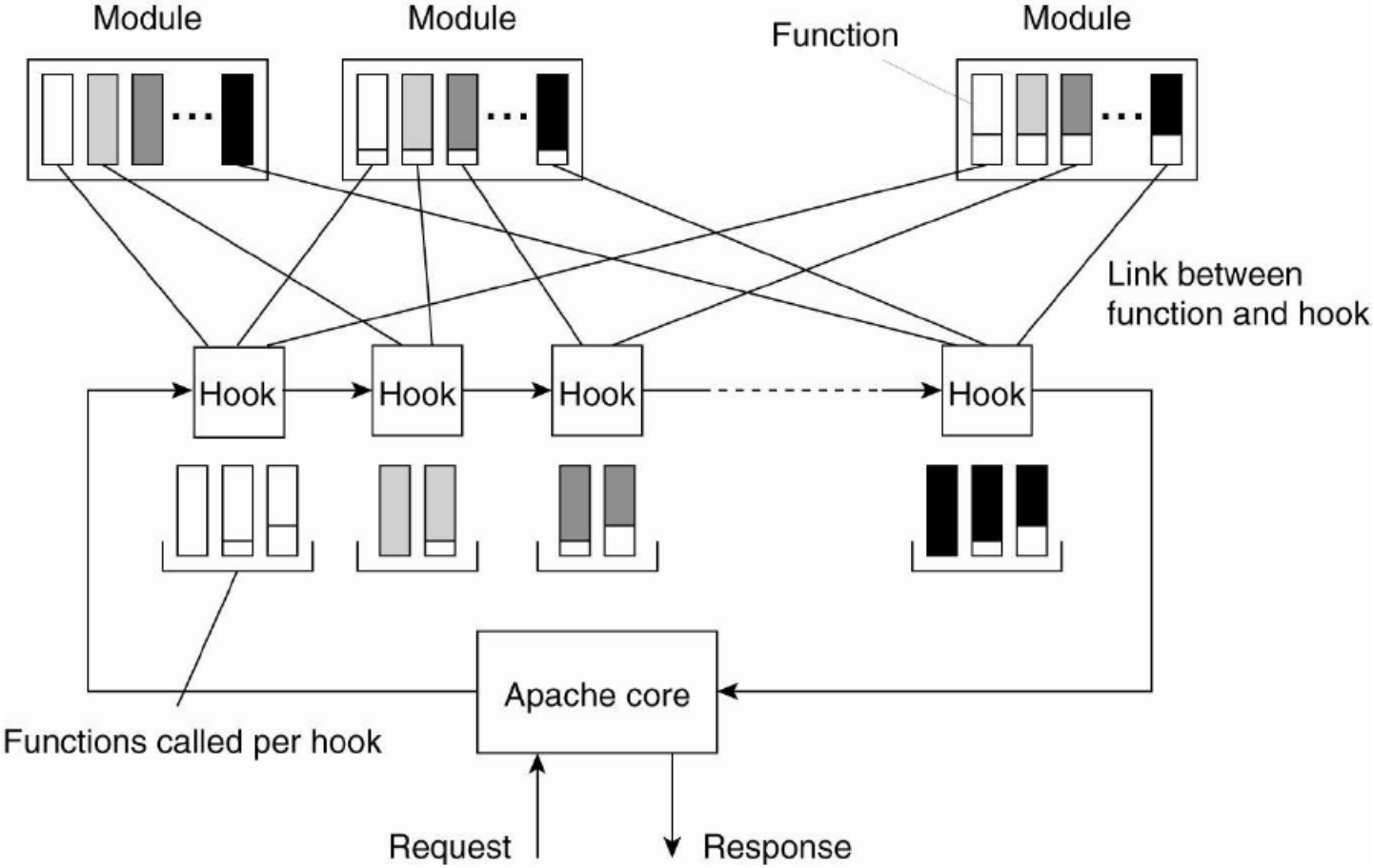
Likewise, there is a hook for writing information to a log

A hook for checking a client's identification

A hook for checking access rights

A hook for checking which MIME type the request is related to (e.g., to make sure that the request can be properly handled).

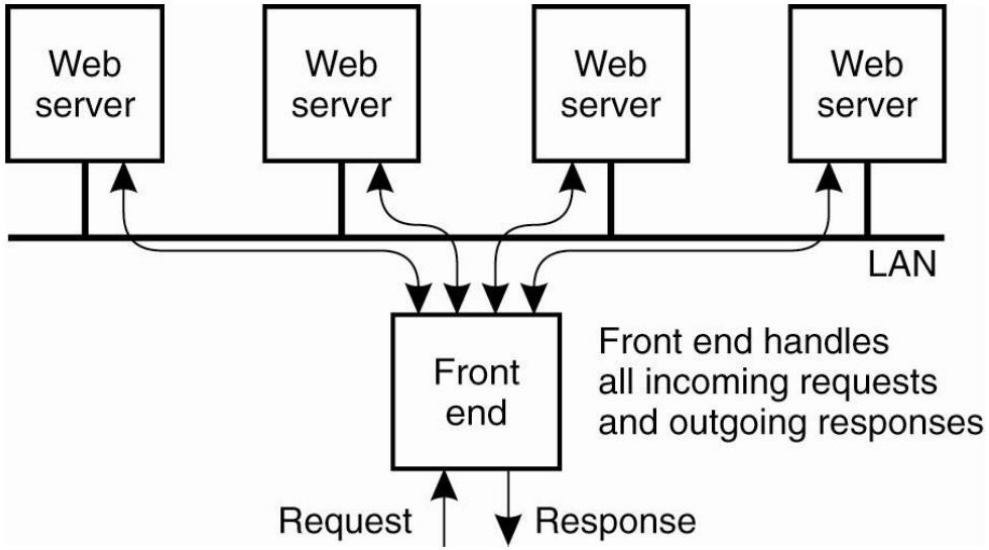
The Apache Web Server



Web server clusters

An important problem related to the client-server nature of the Web is that **a Web server can easily become overloaded**. A practical solution employed in many designs is to simply replicate a server on a cluster of servers and use a separate mechanism, such as a **front end**, to redirect client requests to one of the replicas.

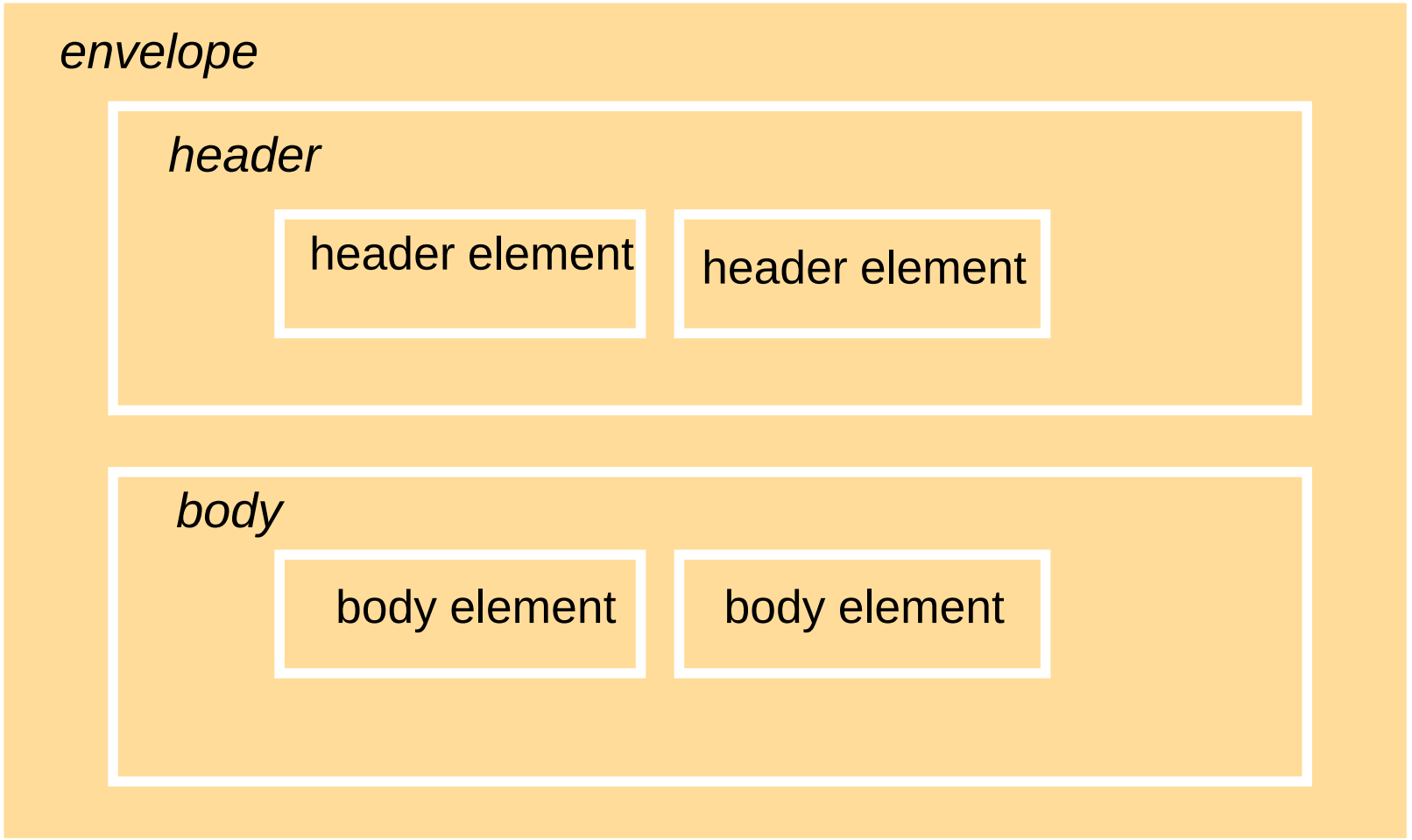
A crucial aspect of this organization is the design of the front end as it can become a serious performance bottleneck, what will all the traffic passing through it.



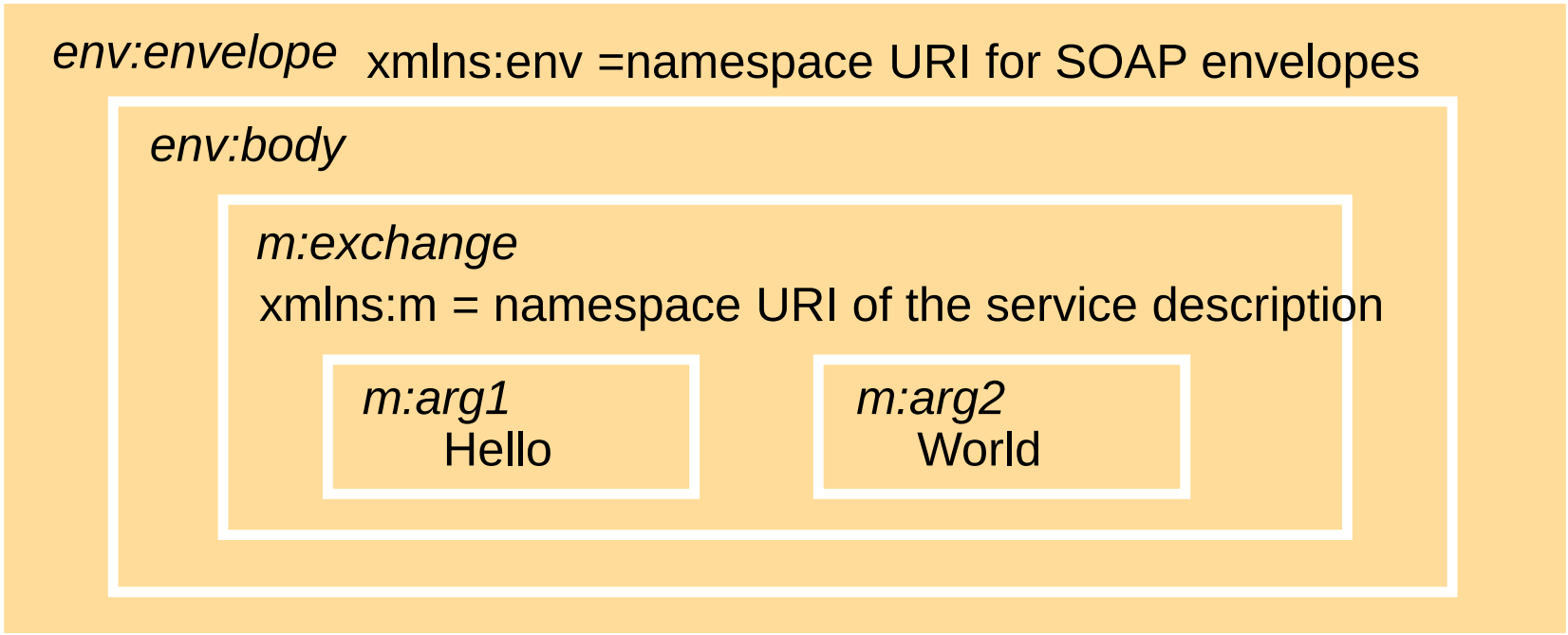
SOAP

- Defines a scheme for using XML to represent the contents of request and reply messages as well as a scheme for the communication of XML documents.
- It is intended that a SOAP message can be passed via intermediaries on the way to the computer that manages the resources to be accessed.
- The intermediaries may process the SOAP to provide security or transaction support as well as other services.
- Typically, the SOAP header is processed by intermediaries and the SOAP body holds the request or reply.

SOAP Envelope

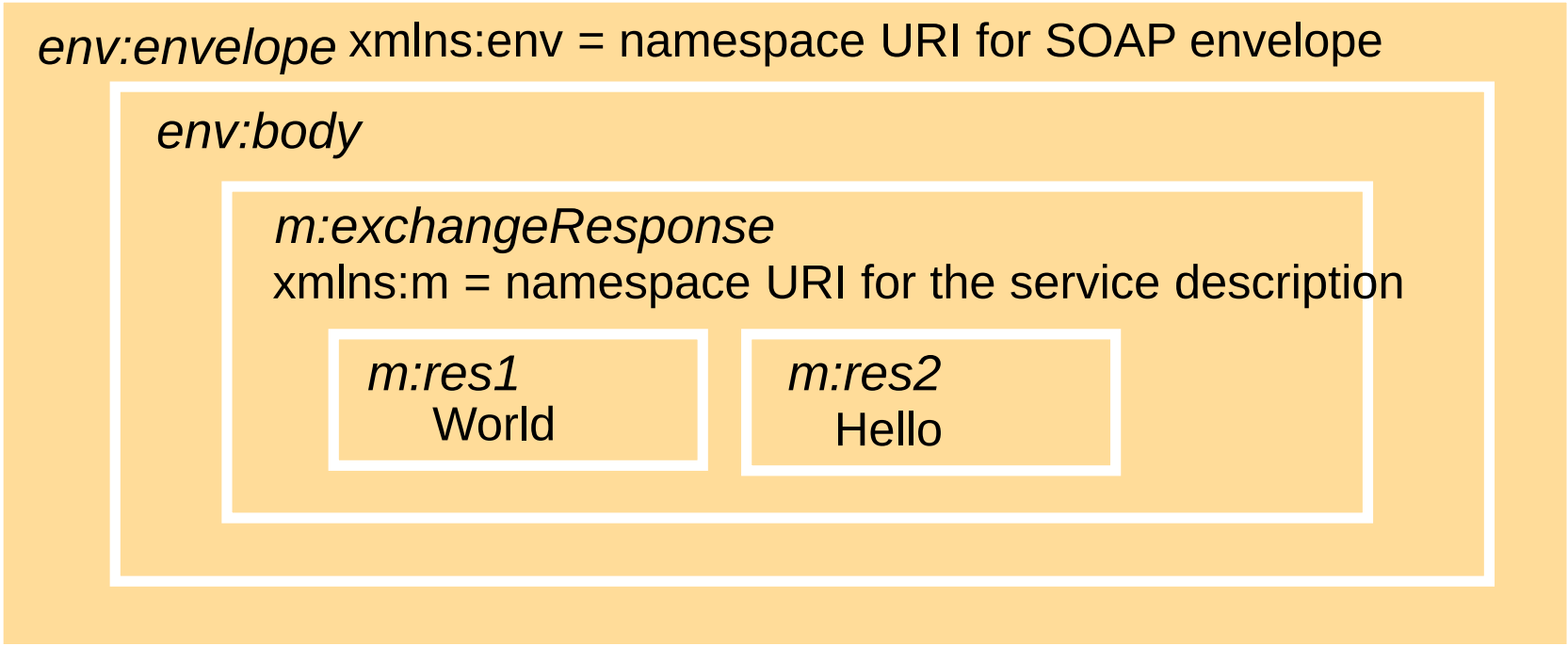


Request Without Headers

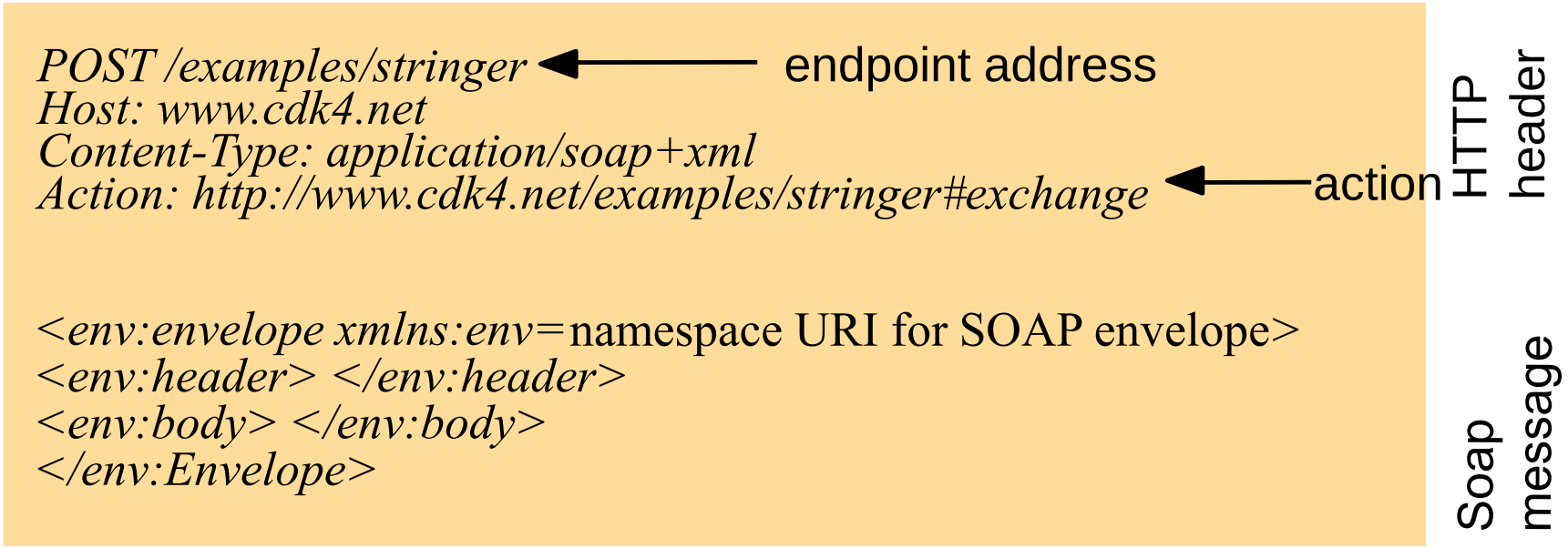


In this figure and the next, each XML element is represented by a shaded box with its name in italic followed by any attributes and its content

Corresponding Reply



HTTP POST Example



A transport protocol is required to send a SOAP document to its destination.

Other transports may be used. WS-Addressing may be used to include destination and source. Thus, different protocols might be used over different parts of the route of a message.

WS-Addressing

```
<S:Envelope xmlns:S="http://www.w3.org/2003/05/soap-envelope"
            xmlns:wsa="http://schemas.xmlsoap.org/ws/2004/08/addressing">
    <S:Header>
      <wsa:MessageID>
          uuid:6B29FC40-CA47-1067-B31D-00DD010662DA
      </wsa:MessageID>
      <wsa:ReplyTo>
          <wsa:Address>http://business456.example/client1</wsa:Address>
       </wsa:ReplyTo>
       <wsa:To>http://fabrikam123.example/Purchasing</wsa:To>
       <wsa:Action>http://fabrikam123.example/SubmitPO</wsa:Action>
    </S:Header>
  <S:Body>
    ...
  </S:Body>
</S:Envelope>
```

Address information included within the document rather than only being specified by the transport.

Distributed Objects?

At first glance, the interaction between client and server seems like RMI.

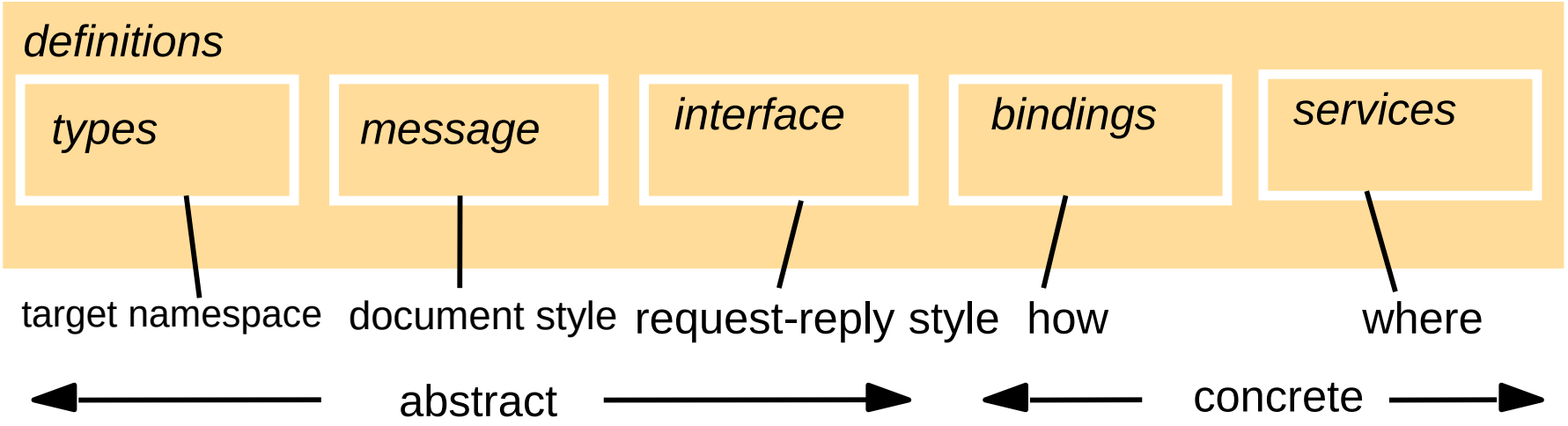
But, RMI permits the creation of **remote objects**. These may then be accessed via remote references.

Web services may create and use objects but never return a remote reference to a remote object. **A web service is a single object that offers a set of procedures**.

Service Descriptions

- The primary means of describing a web service is by using WSDL (the Web Services Description Language)
- XML Schema may be used to describe documents.
- WSDL makes use of XML Schema to describe an exchange of messages.
- A Service Description (WSDL document) is an IDL plus it contains information on how and where the service may be accessed.
- It contains an abstract part and a concrete part. The abstract part is most like a traditional interface. The concrete part tells us how and where to access the service.

The Main Elements in a WSDL Description



A binding is a choice of protocols.
A service holds an endpoint address.
Client or server side code may be generated automatically from the WSDL.
A WSDL document may be accessed directly or indirectly through a registry like UDDI (Universal Directory and Discovery Service).

WSDL MEPS

Name	*Messages sent by*			
	Client	*Server*	*Delivery*	*Fault message*
In-Out	*Request*	*Reply*		may replace *Reply*
In-Only	*Request*			no fault message
Robust In-Only	*Request*		guaranteed	may be sent
Out-In	*Reply*	*Request*		may replace *Reply*
Out-Only		*Request*		no fault message
Robust Out-Only		*Request*	guaranteed	may send fault

XSDL and WSDL

- XSDL (The XML Schema Definition Language) allows us to describe the structure of an XML message
- WSDL allows us to describe message exchanges

WSDL

- A message exchange is called an *operation*
- Related operations are grouped into *interfaces*
- A *binding* specifies concrete details about what goes on the wire

WSDL

- Describes the contract between applications
- Can be automatically generated from a collection of Java or C# classes
- Can be read by utilities that generate client side proxy code or server side skeletons.
- See wsimport (JDK 6.0) or wsdl.exe on the Microsoft side

WSDL Structure

<definition>

<!– abstract definitions →

<types>

<messages>

<portType>

<!– concrete definitions →

<binding>

<service>

</definition>

WSDL Structure

<definition>

<!– Terms found in application code →

<types>

<messages>

<portType>

<!– Handled by XML infrastructure →

<binding>

<service>

</definition>

WSDL Structure

<definition>

<types>

- a container for XSDL Type definitions

  - element names may be defined here as well

WSDL Structure

<definition>

<types>

For example, in Google's WSDL, GoogleSearchResult is defined as a complex type with many elements.

WSDL Structure

<definition>
<types>
<message>

- May have more than one part (think parameters)
- Define the input or output of an operation
- RPC style messages associate a name with a type (defined above)
- Document style messages associate a name with an XML element

</definition>

WSDL Structure

<definition>
  <types>
  <message> Two examples:
    - In Google's WSDL, a doGoogleSearch message is defined with many parts of basic xsd types.
    - In Google's WSDL, a doGoogleSearchResponse message is defined as of type GoogleSearchResult
</definition>

WSDL Structure

<definition>
<types>
<messages>
<portType>

- The definition of an interface or group of operations
- The term “portType” will be replaced with the term “interface” in WSDL 1.2
- Each operation has a name and normally specifies both input and output messages

</definition>

WSDL Structure

<definition>
<types>
<messages>
<portType>

- For example, in Google's WSDL, GoogleSearchPort contains three operations.
- The operation doGoogleSearch has an input message (doGoogleSearch) and an output message (doGoogleSearchResponse.)

</definition>

WSDL Structure

<definition>

<types> <messages> <portType>

<binding>

- Each binding has a unique name that is associated with a particular interface.
- The protocol used is specified.
- Details found here specify how the data will look on the wire.

</definition>

WSDL Structure

<definition>
<types> <messages> <portType>
<binding>

- For example, in Google's WSDL, the binding name GoogleSearchBinding is introduced and is associated with the interface GoogleSearchPort.
- Each operation within that interface is described as soap operations.

</definition>

WSDL Structure

<definition>
<types><messages><portType>
<binding>
<service>

- Defines a collection of ports (endpoints) that exposes a particular binding
- An address is associated with a binding

</definition>

WSDL Structure

<definition>
<types><messages><portType><binding>
<service>

For example, in Google's WSDL, the service name GoogleSearchService is introduced. The interface GoogleSearchPort is associated with the binding GoogleSearchBinding.

The service element holds the address of the service.

</definition>

Writing A Google Client

(1) Get the WSDL from http://www.google.com/apis/

(2) If using .NET run wsdl.exe on GoogleSearch.wsdl.

(3) If using Java and Axis run wsdl2java.bat on GoogleSearch.wsdl.

(4) wsdl2java.bat holds the line

```
java org.apache.axis.wsdl.WSDL2Java  %1
```

The WSDL2Java class is in axis.jar

A Google Client in Java

```
// Running a simple Google RPC client for spell checking

import GoogleSearch.*;                    // wsdl2java generated package

public class MyGoogleClient{

    private static String endpointAddress = "http://api.google.com/search/beta2";

   public static void main(String[] args) throws Exception {

        if(args.length != 1) {
              System.out.println("Usage1: java MyGoogleClient wordToSpellCheck");
              System.out.println(
              "Usage2: java MyGoogleClient \"a phrase to spell check\"");
              System.exit(0);
        }
```

```
    System.out.println("Contacting Google Web Service at  " + endpointAddress);
    System.out.println("Checking on spelling of  '" + args[0]+"'");

   GoogleSearchServiceLocator loc = new GoogleSearchServiceLocator();

   GoogleSearchPort gp = loc.getGoogleSearchPort();

    String answer = gp.doSpellingSuggestion(
                            "n6lHU/FQFHIHzpbzRTPFvrUP4Cw+/k+N",
                            args[0]);

    if(answer == null) System.out.println("Google likes the spelling of  '" + args[0]+"' );
    else System.out.println("Google suggests the spelling '" + answer +"' );
  }
}
```

GoogleSpring2005\java>java MyGoogleClient "Cornegi Melon Universeti"
Contacting Google Web Service at http://api.google.com/search/beta2
Checking on spelling of 'Cornegi Melon Universeti‘

Google suggests the spelling 'Carnegie Mellon University'

A Google Client in C#

```
// run a client against Google's web service
using System;

namespace ConsoleApp
{
    class GoogleClient
    {
        public static void Main(string[] args) {

                    try {
                            GoogleSearchService s =
                             new GoogleSearchService();
```

```
            Console.WriteLine("Enter word to spell check");
            String word = Console.ReadLine();
                    String answer = s.doSpellingSuggestion(
                                "n6lHU/FQFHIHzpbzRTPFvrUP4Cw+/k+N", word);
                    Console.WriteLine("Google returned " + answer);
                }
                catch(Exception ) {Console.WriteLine("Google threw an exception");}
        }
    }
}
```

Web proxy caching

- Client-side caching generally occurs at two places:

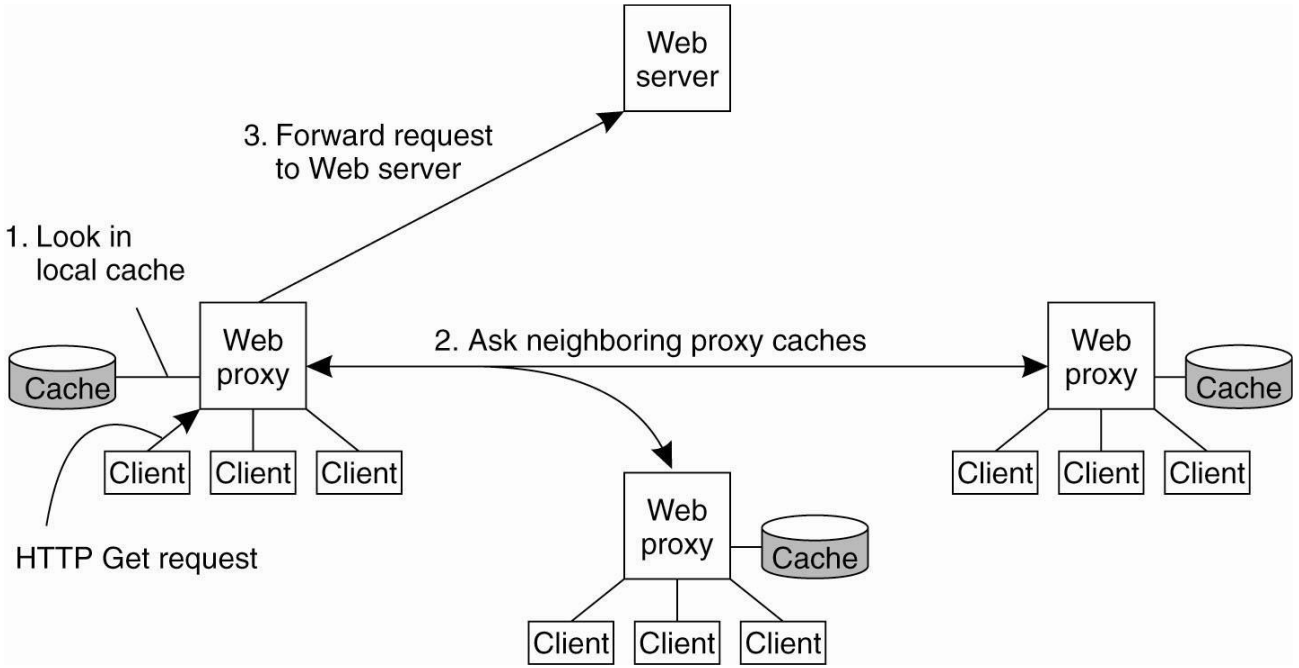
1. Most browsers are equipped with a **simple caching facility**. Whenever a document is fetched it is stored in the browser's cache from where it is loaded the next time. Clients can generally configure caching by indicating when consistency checking should take place.

2. **A client's site** often runs a **Web proxy**. As we explained, a Web proxy accepts requests from local clients and passes these to Web servers. When a response comes in, the result is passed to the client.

- The **advantage** of this approach is that the proxy can cache the result and return that result to another client, if necessary. In other words, a Web proxy can implement a **shared cache**

Web proxy caching

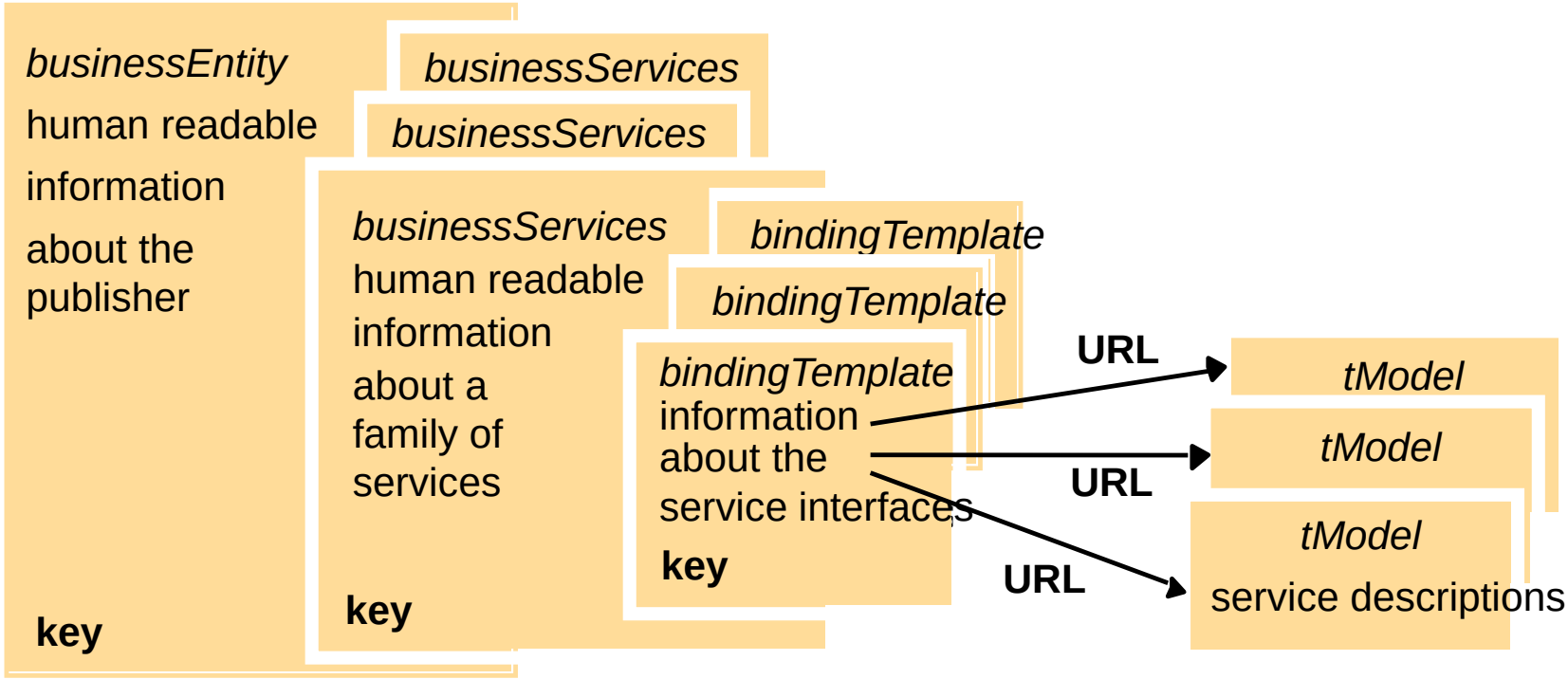
- In addition to caching at browsers and proxies, it is also possible to place caches that cover a region, or even a country, thus leading to **Hierarchical caches**. Such schemes are mainly used **to reduce network traffic**, but have the **disadvantage** of **potentially incurring a higher latency compared to using non-hierarchical schemes**.



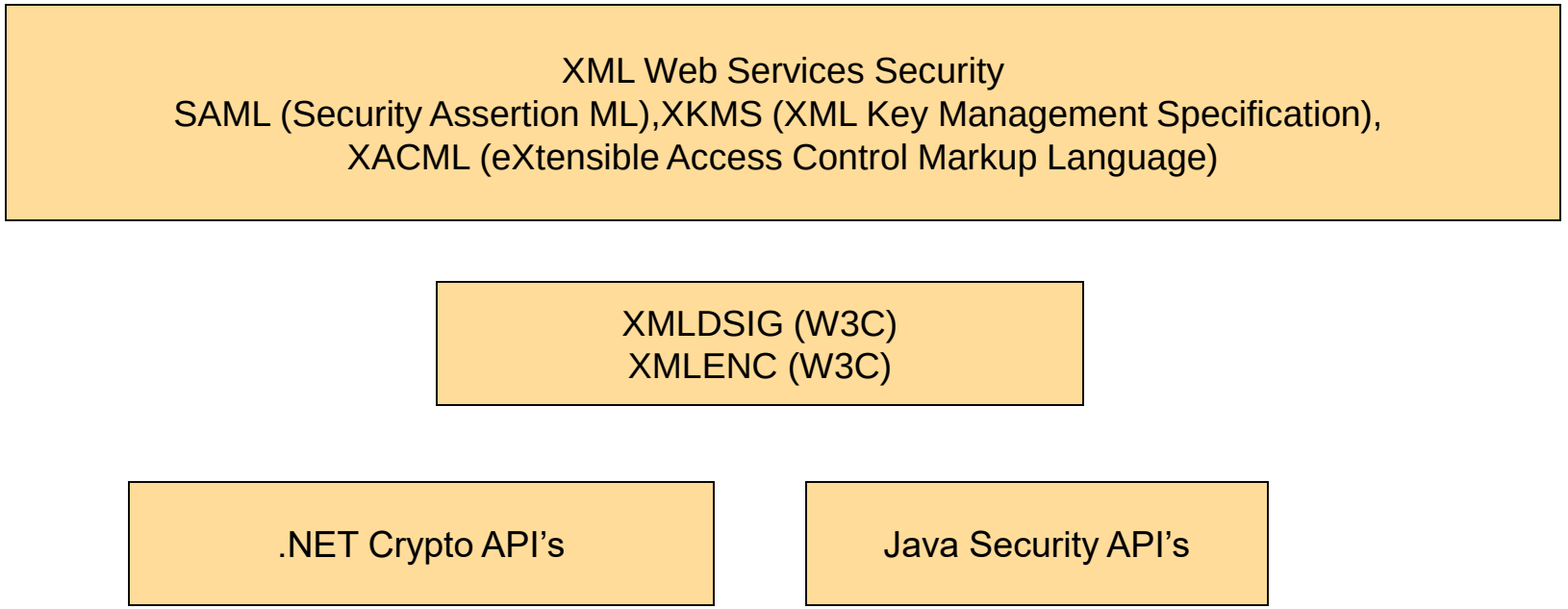
UDDI

- An acronym for Universal Directory and Discovery Services.
- A directory service for use with web services.
- One way to obtain service descriptions.
- May be used within organizations to perform lookups for WSDL documents.
- Supports white pages (lookup by name) and yellow pages (lookup by attribute)
- Provides a publish/subscribe interface.
- Uses replication among many servers for scalability.
- JAXR (The Java API for XML Registries) may be used to interact with UDDI.

UDDI Data Structures



Web Services Security Stack



Travel Agent Scenario

1. The client asks the travel agent service for information about a set of services; for example, flights, car hire and hotel bookings.
2. The travel agent service collects prices and availability information and sends it to the client, which chooses one of the following on behalf of the user:
   (a) refine the query, possibly involving more providers to get more information, then repeat step 2;
   (b) make reservations;
   (c) quit.
3. The client requests a reservation and the travel agent service checks availability.
4. Either all are available;
   or for services that are not available;
   either alternatives are offered to the client who goes back to step 3;
   or the client goes back to step 1.
5. Take deposit.
6. Give the client a reservation number as a confirmation.
7. During the period until the final payment, the client may modify or cancel reservations

The Business Process Execution Language (BPEL) is used to write such scenarios in XML.

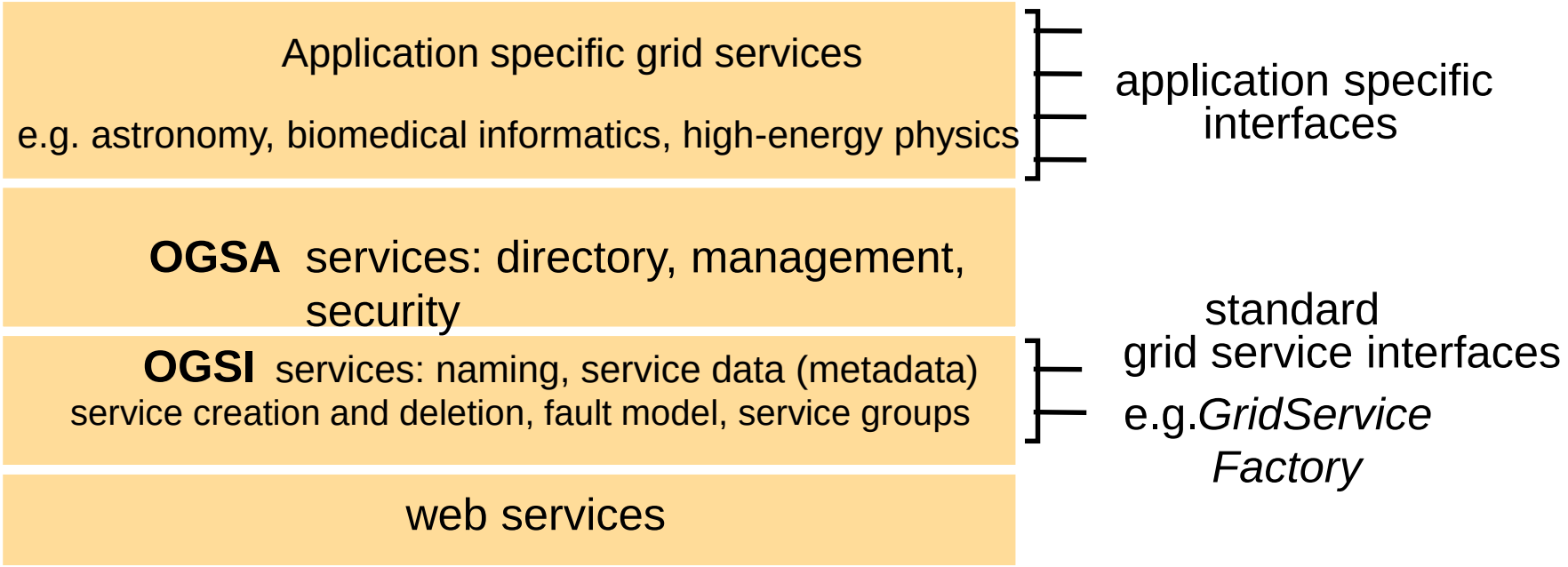
Case Study: The Grid

- Grid refers to middleware that is designed to allow for sharing of resources such as data and CPU cycles on a very large scale.

- Provides for heterogeneity, management, and security.
- Latest version runs over web services.
- The open source Globus Toolkit implements the grid architecture.

- The immense quantity of data in archives makes ftp or web access infeasible.

Open Grid Services Architecture



Some Grid Projects

Description of the project	Reference
1. Aircraft engine maintenance using fault histories and sensors for predictive diagnostics	www.cs.york.ac.uk/dame
2. Telepresence for predicting the effects of earthquakes on buildings, using simulations and test sites	www.neesgrid.org
3. Bio-medical informatics network providing researchers with access to experiments and visualizations of results	nbcr.sdsc.edu
4. Analysis of data from the CMS high energy particle detector at CERN by physicists world-wide over 15 years	www.uscms.org
5. Testing the effects of candidate drug molecules for their effect on the activity of a protein, by performing parallel computations using idle desktop computers	[Taufer et al. 2003] [Chien 2004
6. Use of the Sun Grid Engine to enhance aerial photographs by using spare capacity on a cluster of web servers	www.globexplorer.com
7. The butterfly Grid supports multiplayer games for very large numbers of players on the internet over the Globus toolkit	www.butterfly.net
8. The Access Grid supports the needs of small group collaboration, for example by providing shared workspaces	www.accessgrid.org