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CSE681 – Software Modeling and Analysis
Fall 2013

PROGRAM STRUCTURE

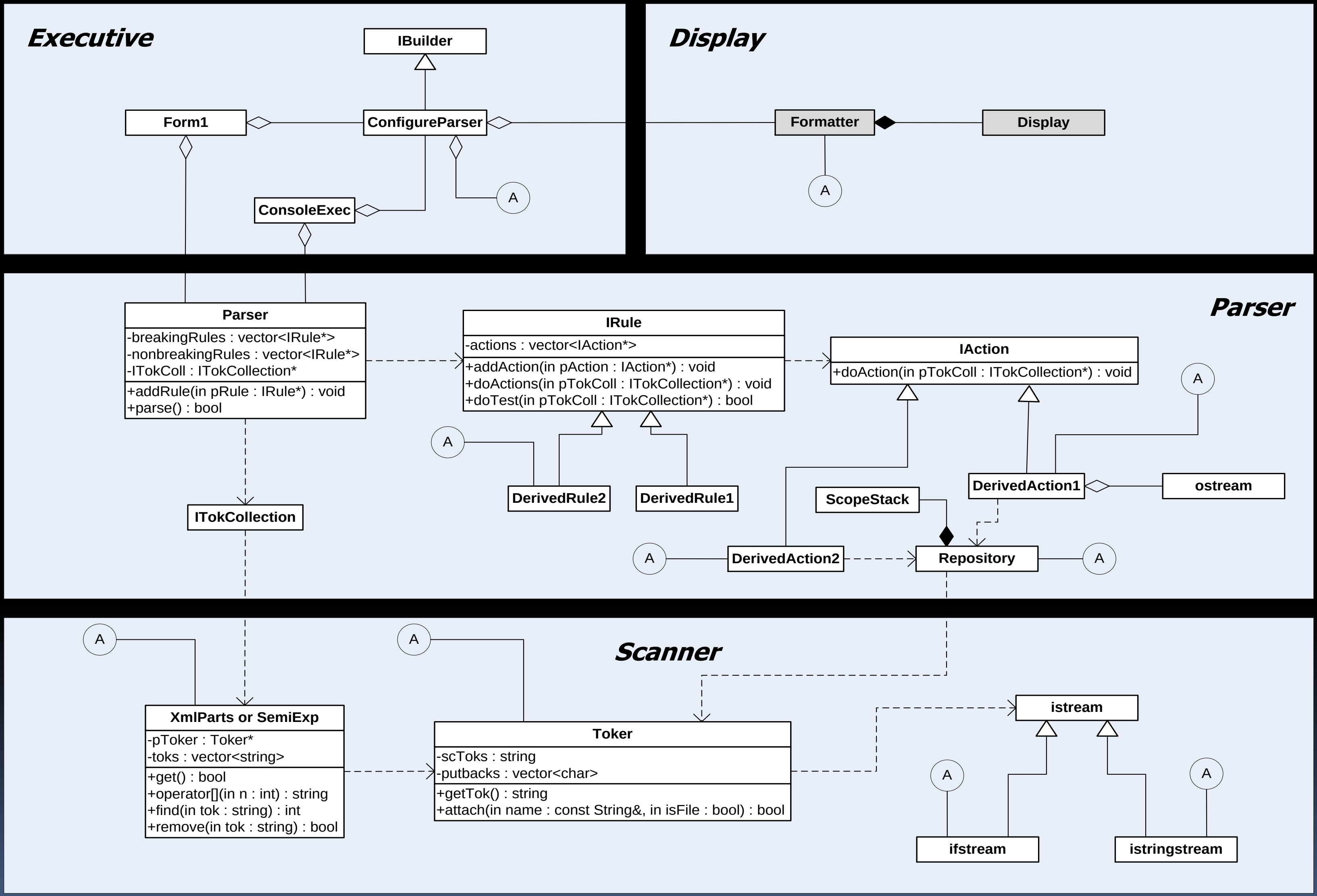
What is Program Structure?

- Partitions
  - Separation of concerns
- Communication
  - How do the parts make requests and send notifications?
- Sharing
  - How is data shared between the parts?
- Control
  - Which parts are responsible?

What is Program Structure?

- Logical:
  - Interfaces, classes, and class relationships
- Package:
  - Package dependency tree, as shown in OCD package diagrams
  - Subsystems, e.g., collection of packages separated by interfaces with each focused on specialized processing
    - For a radar those might be: signal processing, beam forming, data management, operator control, communication.
- Execution:
  - Monolithic Program, e.g., an exe
  - Program with loadable Dynamic Link Libraries (DLLs)
  - Cooperating processes, e.g., client-server, server federation, etc.

Parsing Facility



Executive

IBuilder

Form1

ConfigureParser

ConsoleExec

A

Display

Formatter

Display

A

Parser

Parser

-breakingRules : vector<IRule*>
-nonbreakingRules : vector<IRule*>
-ITokColl : ITokCollection*

+addRule(in pRule : IRule*) : void
+parse() : bool

IRule

-actions : vector<IAction*>

+addAction(in pAction : IAction*) : void
+doActions(in pTokColl : ITokCollection*) : void
+doTest(in pTokColl : ITokCollection*) : bool

IAction

+doAction(in pTokColl : ITokCollection*) : void

ITokCollection

DerivedRule2

DerivedRule1

ScopeStack

DerivedAction1

ostream

DerivedAction2

Repository

A

Scanner

XmlParts or SemiExp

-pToker : Toker*
-toks : vector<string>

+get() : bool
+operator[](in n : int) : string
+find(in tok : string) : int
+remove(in tok : string) : bool

Toker

-scToks : string
-putbacks : vector<char>

+getTok() : string
+attach(in name : const String&, in isFile : bool) : bool

istream

ifstream

istringstream

A

Program Structure Contents

- Data Driven
  - Client server
  - Three tier
  - Model-View-Controller
- Communication Driven
  - Peer-to-peer
  - Service oriented
  - Components
- Thread & Event Driven
  - Single Threaded Apartment (STA)
  - Parallel execution
  - Pipeline execution
- Enterprise Computing
  - Federated systems

DATA DRIVEN STRUCTURES

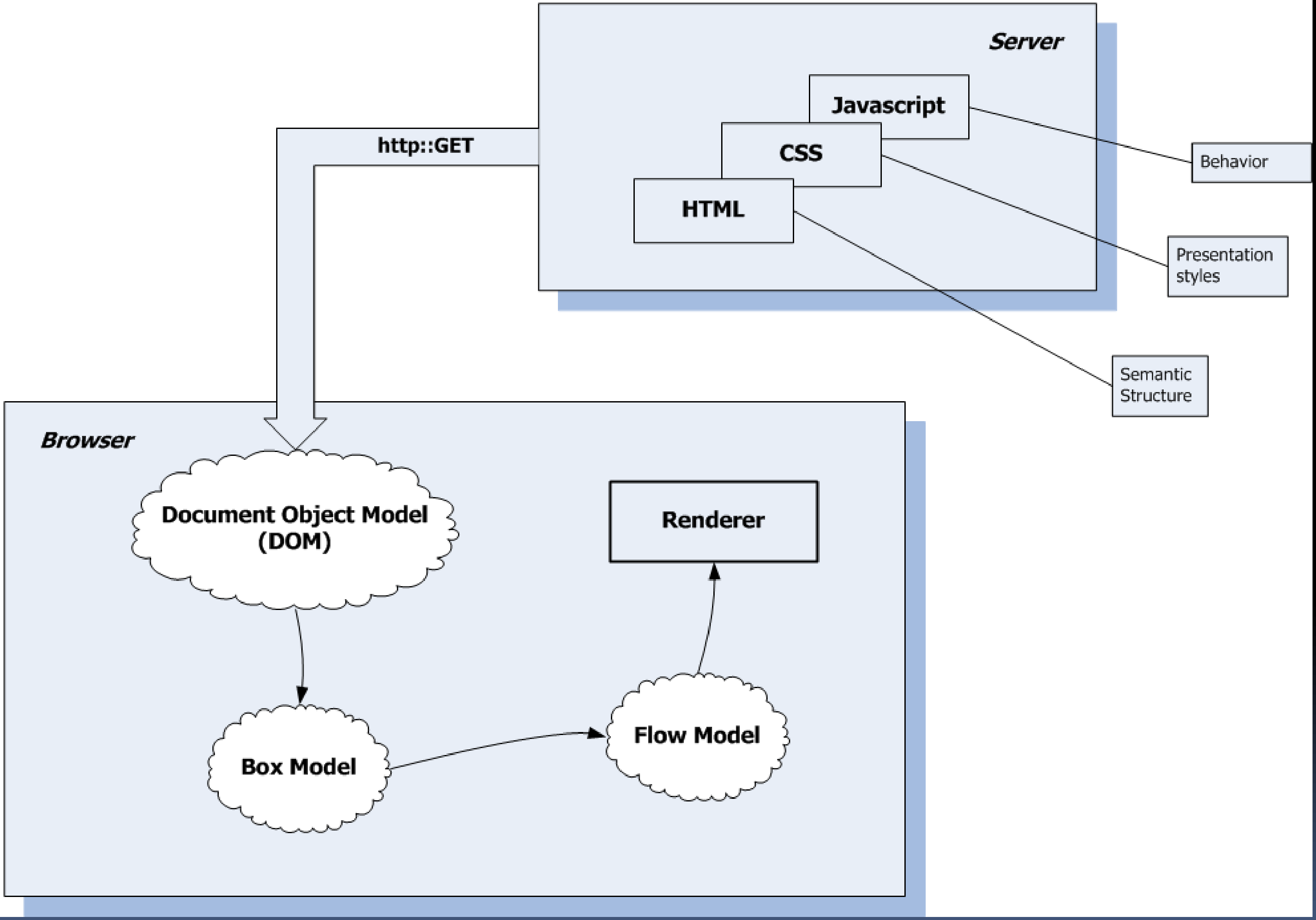
Data Driven Structures

- Some program structures are driven by the presentation and management of data:
  - Client-Server
  - Three-Tier
  - Model-View-Controller
  - Publish and Subscribe

Structure: Client-Server

- Behavior:
  - Server is passive, waits for client requests
  - Server handles multiple concurrent clients
  - Without additional structure system may become tightly coupled and difficult to change
- Example:
  - Web server and browser clients
  - Every class that holds a reference to another thread-safe class

Static Webpage Model



Server

Javascript

CSS

HTML

Behavior

Presentation styles

Semantic Structure

http::GET

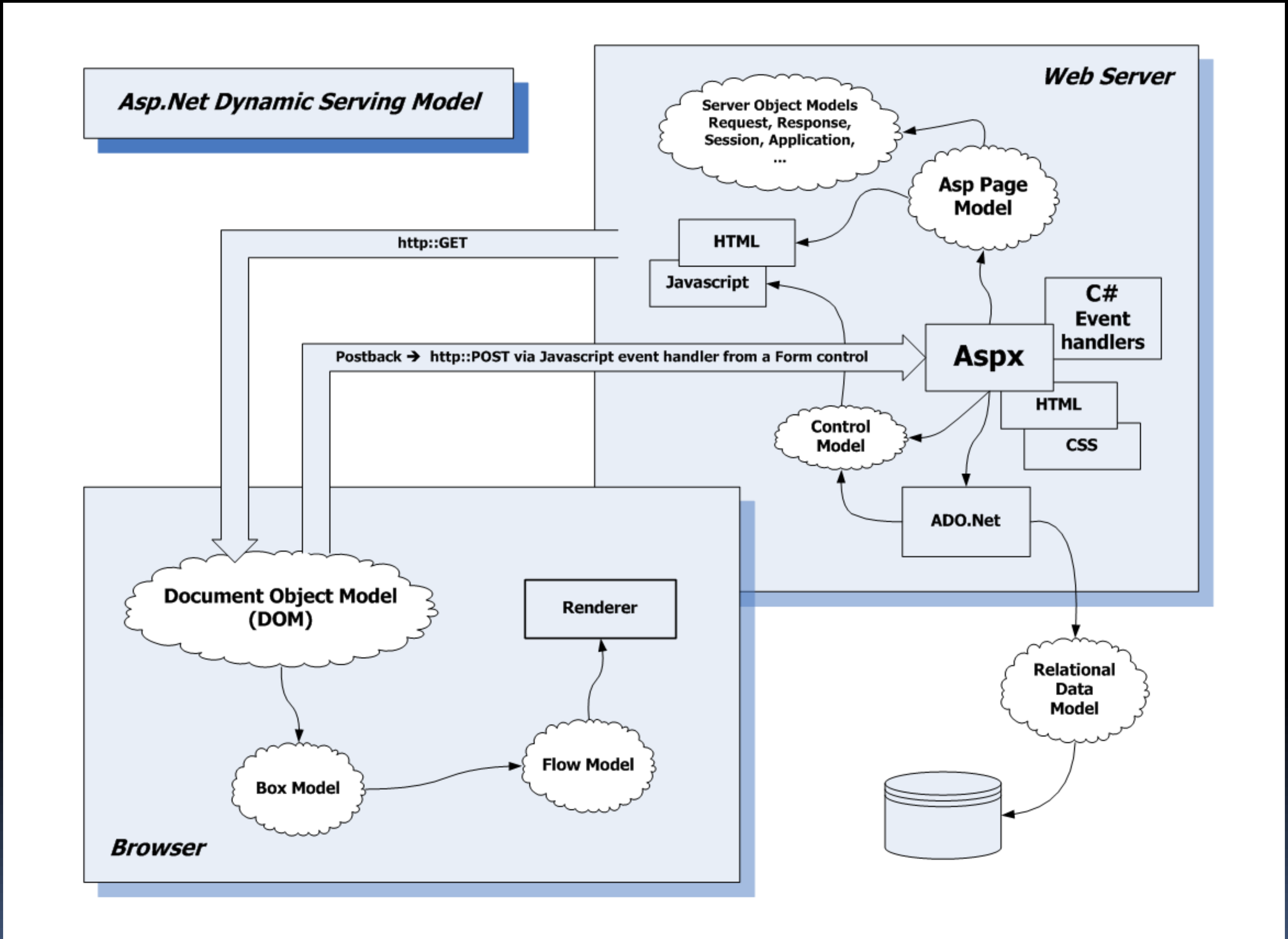
Browser

Document Object Model (DOM)

Renderer

Box Model

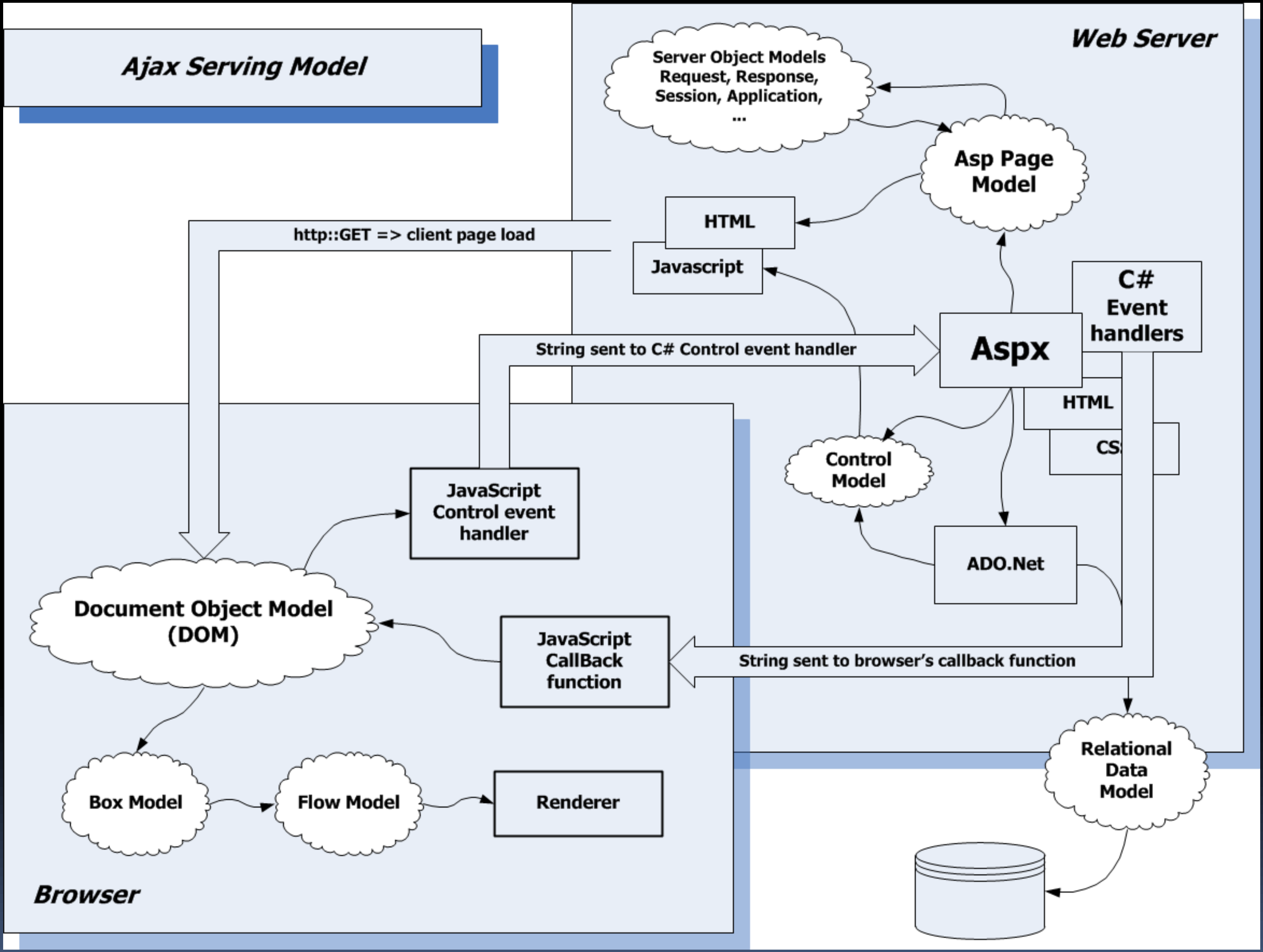
Flow Model



Asp.Net Dynamic Serving Model

Web Server
Server Object Models Request, Response, Session, Application, …
Asp Page Model
HTML
Javascript
http::GET
C# Event handlers
Postback ➔ http::POST via Javascript event handler from a Form control
Aspx
HTML
CSS
Control Model
ADO.Net
Document Object Model (DOM)
Renderer
Relational Data Model
Box Model
Flow Model
Browser

Ajax Serving Model



Web Server

Server Object Models
Request, Response,
Session, Application,
...

Asp Page
Model

HTML

Javascript

http::GET => client page load

C#
Event
handlers

Aspx

String sent to C# Control event handler

HTML

CS

Control
Model

ADO.Net

JavaScript
Control event
handler

Document Object Model
(DOM)

JavaScript
CallBack
function

String sent to browser's callback function

Relational
Data
Model

Box Model

Flow Model

Renderer

Browser

Sharing Data

- Relational Databases – SQL Server
  - ACID – Atomicity, Consistency, Isolation, Durability
  - ACID => Transactional
- File Systems
- Ad. Hoc. in-memory repositories
- Key-Value Stores – Memcached
- Extensible Record Stores – Google's Big Table
  - Distributed partitioned tables
- Document Stores – CouchDB
  - Multi-indexed objects aggregated into domains

Separation of Concerns

- Except for the simplest of applications it’s not a good idea to bind presentation, control, and data together.
  - There often are many views, more than one application mode, many sources of data.
  - If we bind these all together we get spaghetti
    - Very hard to test, hard to maintain, hard to document.

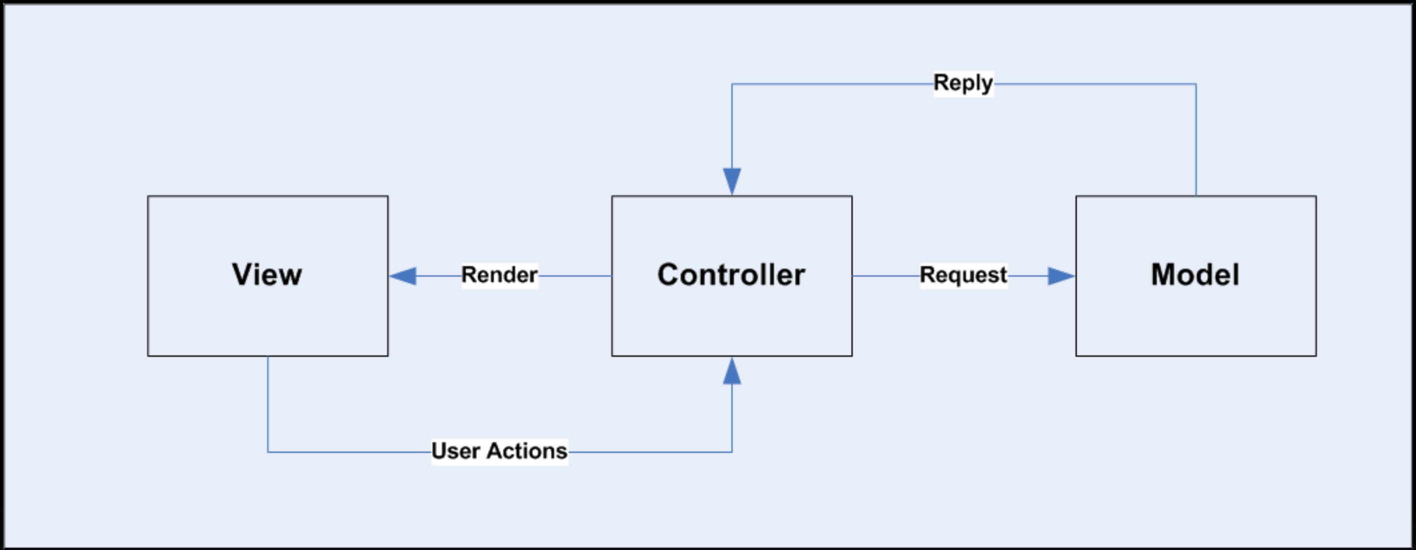
Structure: Three-Tier

- Structure:
  - Partitioned into presentation, application logic, and data management.
  - Intent is to loosely couple these three aspects of an application to make it resilient to change.
- Examples:
  - Most well-designed applications.

Model-View-Controller

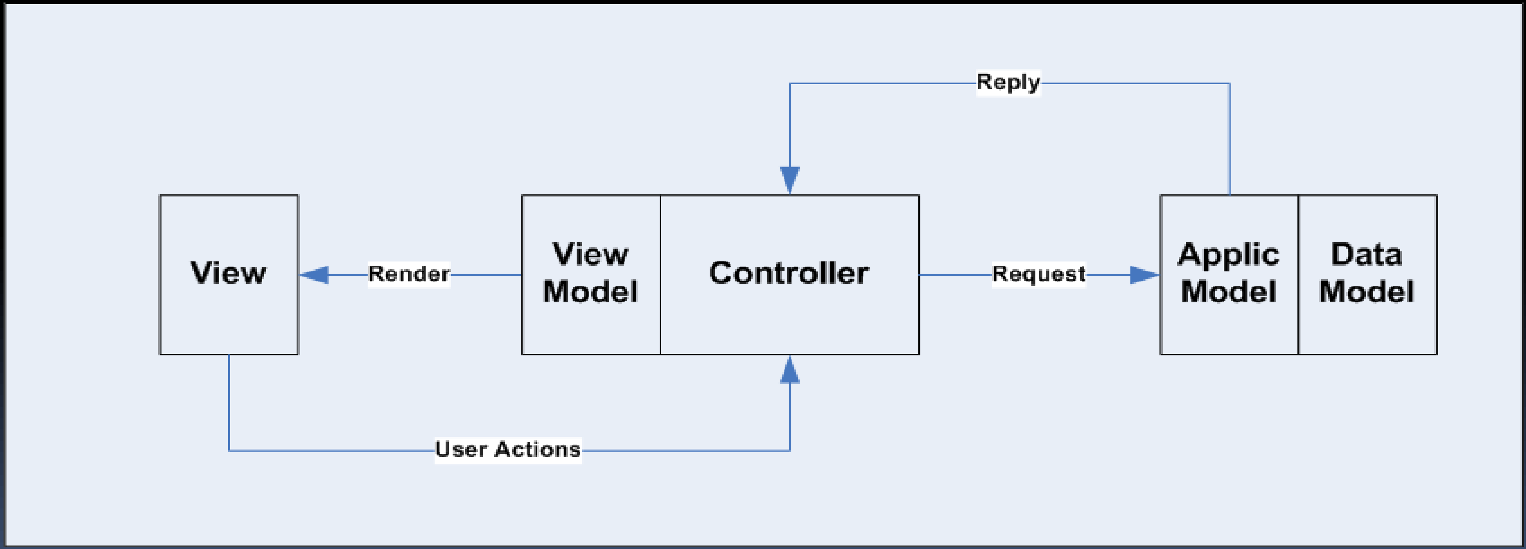
- Structure:
  - MVC is a refined version of the Three-Tier structure, intended to support multiple views and data models.
  - Models do all data storage management.
  - Views present information to user, format output but do no other transformations on data.
  - Controllers accept inputs, implement application processing, and use Models and Views to provide the application’s behavior.
  - Application phases often have one controller each.
  - Models may be shared between controllers.
- Examples: Project #2 Fall ‘10, Asp.Net MVC

Basic MVC Structure



MVC – With View & Application Models

- Views and Models often have some substructure, e.g.:



View – View Model

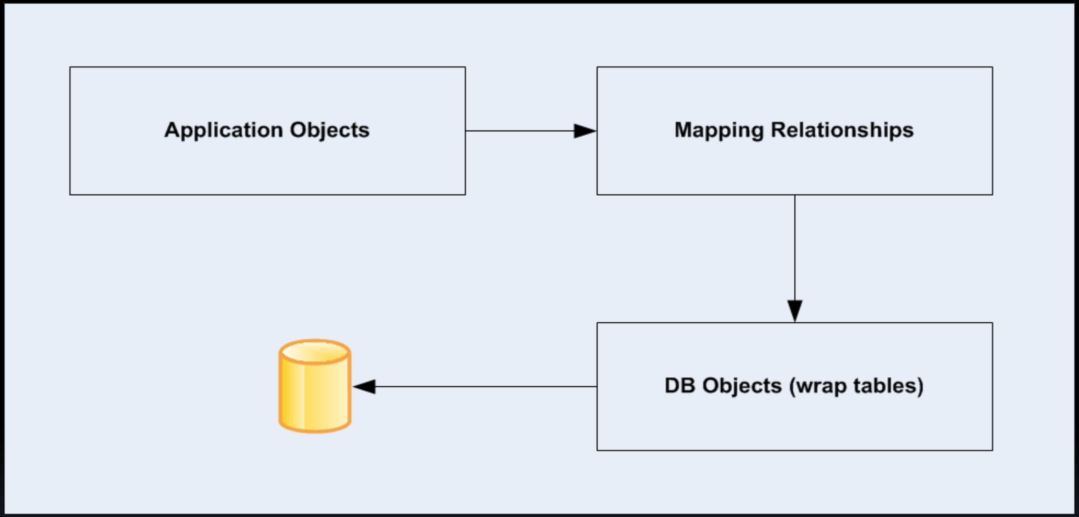
- A view is what gets rendered
- A view model is an abstraction that:
  - Defines resources that many be used in several places.
  - Defines styles that may be used in several places
  - Defines an object model for the application to manipulate

Application vs. Data Models

- Application model
  - Defines classes for all the entities a user knows and cares about, e.g., orders, customers, products, etc.
- Data model
  - Defines wrapper classes for tables and stored procedures
  - Manages connections
- Object to Relational Mapping
  - Relationships between application objects and data objects.

Object Relational Mapping

- Data Layers often have an ORM substructure

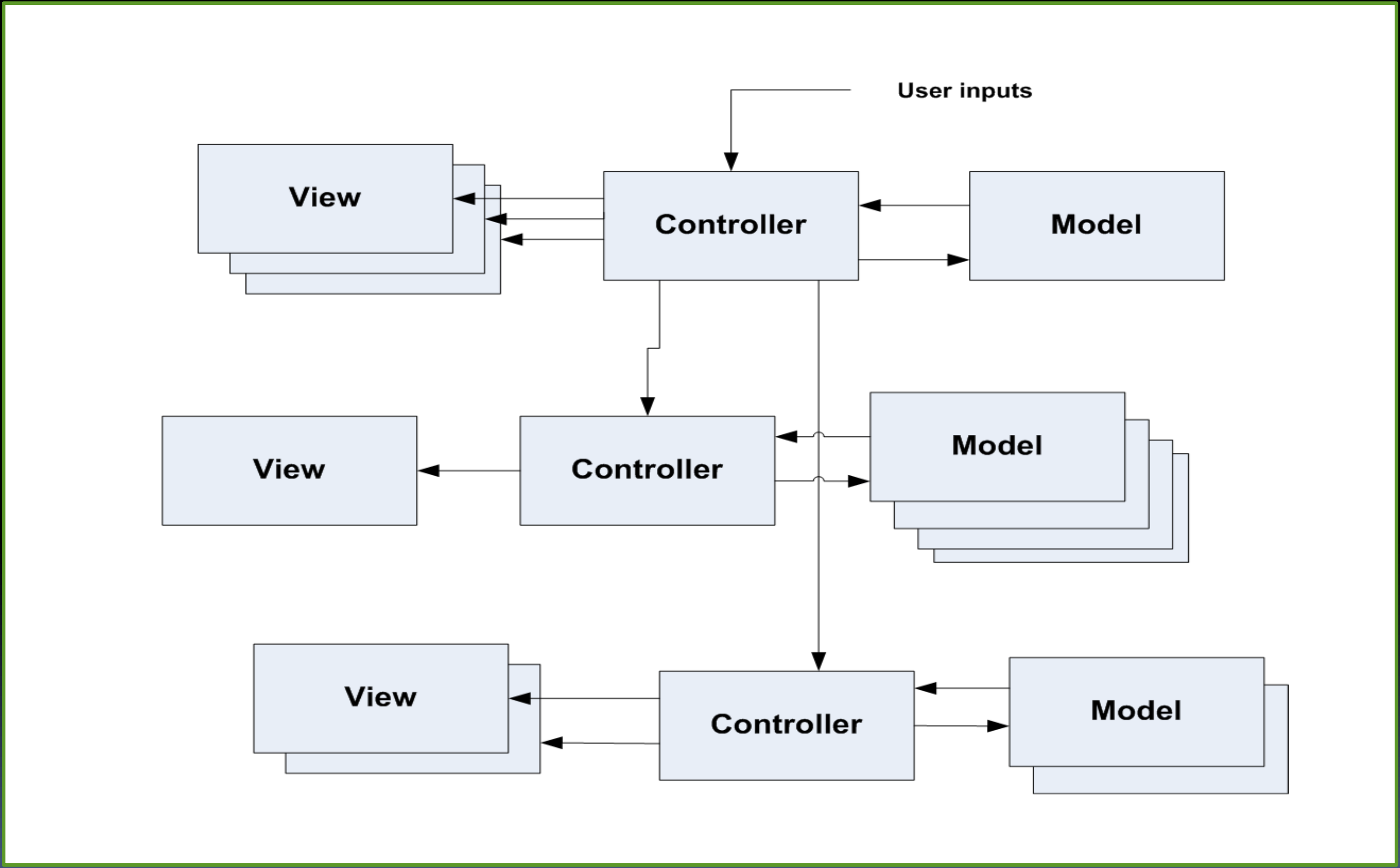


- Examples: Hibernate, Microsoft Entity Framework

N-Tier Structure

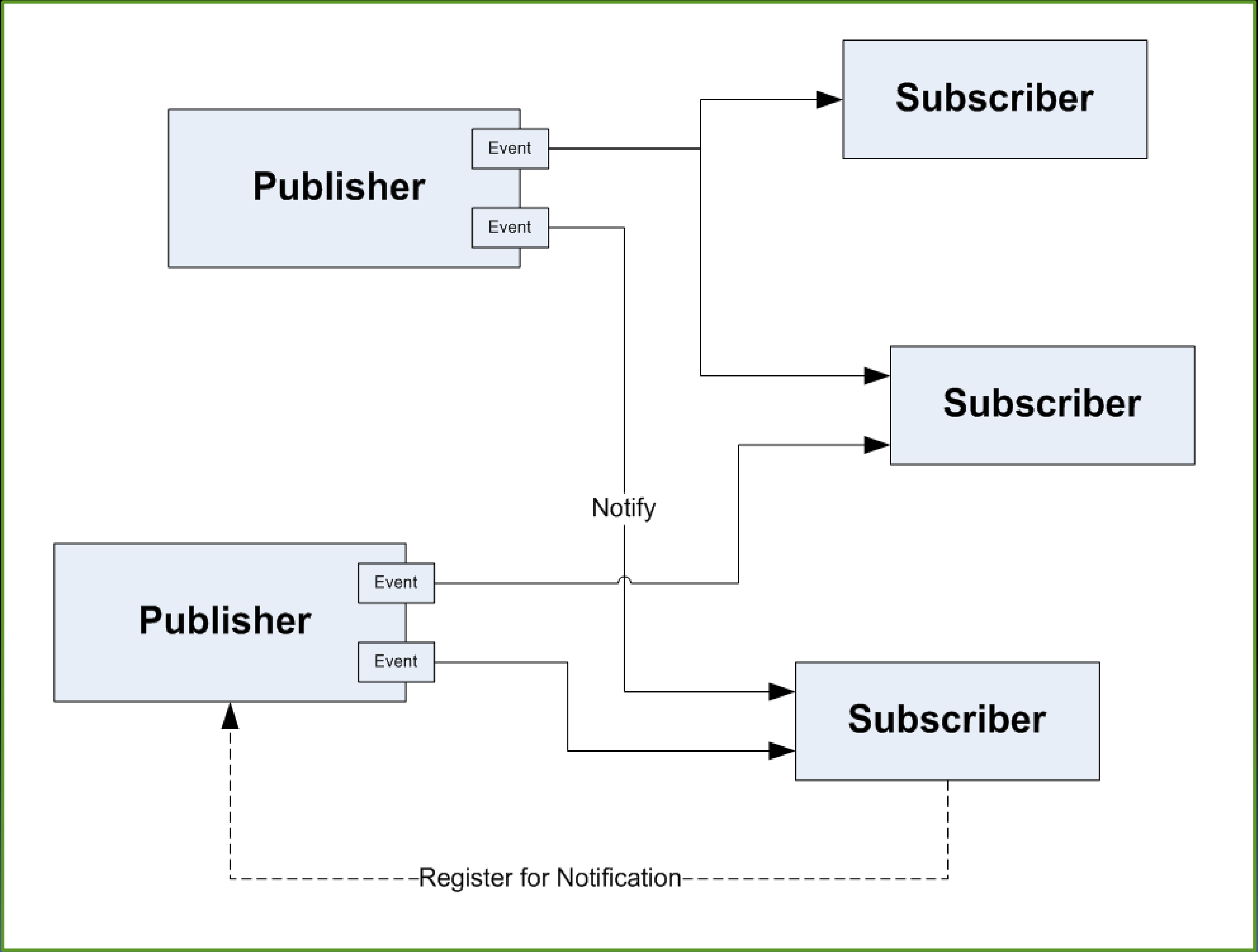
- So, the three tier MVC has morphed into a five tier V-VM-C-AM-DM
  - View – what gets rendered
  - View Model – an abstraction of the view
  - Controller – routes View events to handlers in the Application Model
  - Application Model – classes that model the “business” logic
  - Data Model – models data storage tables
    - Database, XML file, custom data structures

MVC – Multiple Controllers



Structure: Publish & Subscribe

- Structure:
  - Many to many connection of Publishers and Subscribers.
  - Each subscriber registers for notifications with a specific interface.
  - Publishers send notifications to all enrolled subscribers when a publisher event occurs.
  - Publishers can support multiple events.
  - Publishers don’t need to know anything about the subscriber.


Subscriber
Publisher
Event
Event
Subscriber
Notify
Publisher
Event
Event
Subscriber
Register for Notification

Layered Structure

- Provides a structure based on:
  - System Services – things the user doesn't think about
    - Communication, storage, security, file caching, …
  - User Services – things the user manipulates as part of the use of the system
    - Input, Display, Check-in/Check-out, …
  - Ancillary – Things that are not part of the system mission but are necessary
    - Logging, extension hooks, test hooks, …

Component-Based

- Structure:
  - A componentized system is composed of an application with many pluggable component parts.
  - A component is pluggable if it implements a plug-in interface, published by the application, provides an object factory for activating its internal objects, and is packaged as a dynamic link library (DLL).
- Example:
  - http://www.ecs.syr.edu/faculty/fawcett/handouts/CSE681/code/Parser/ almost implements.

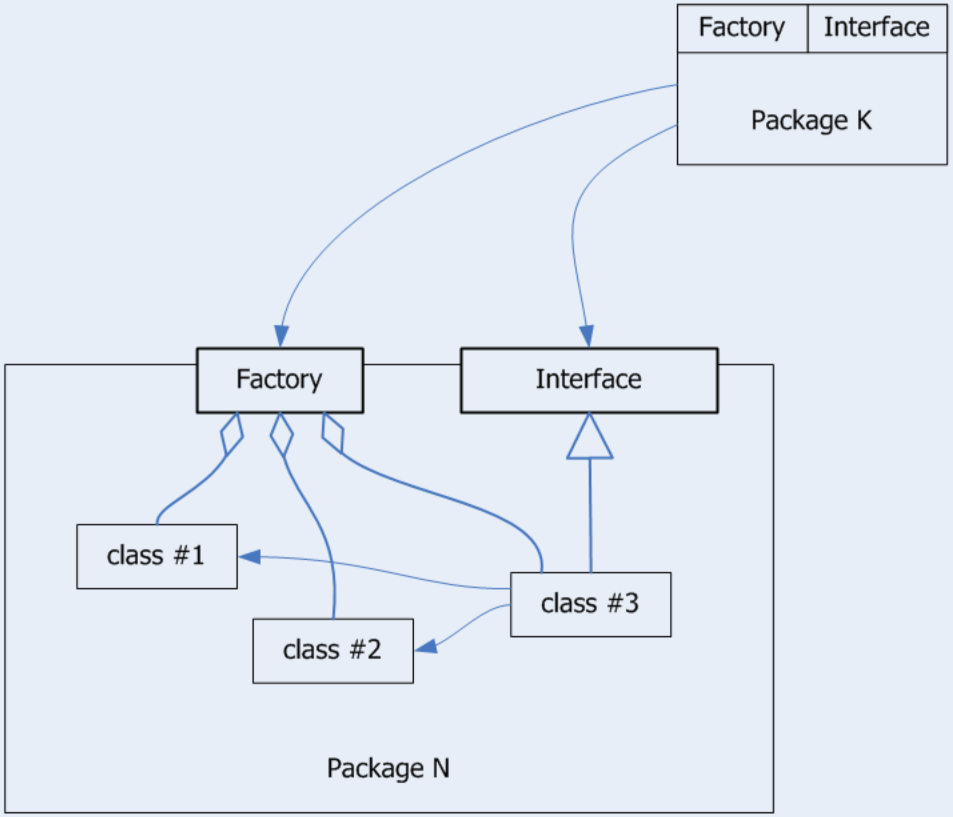
Shielding One Part of a System from Another's Implementation

Factory creates instances of package's classes, so the client does not need to.

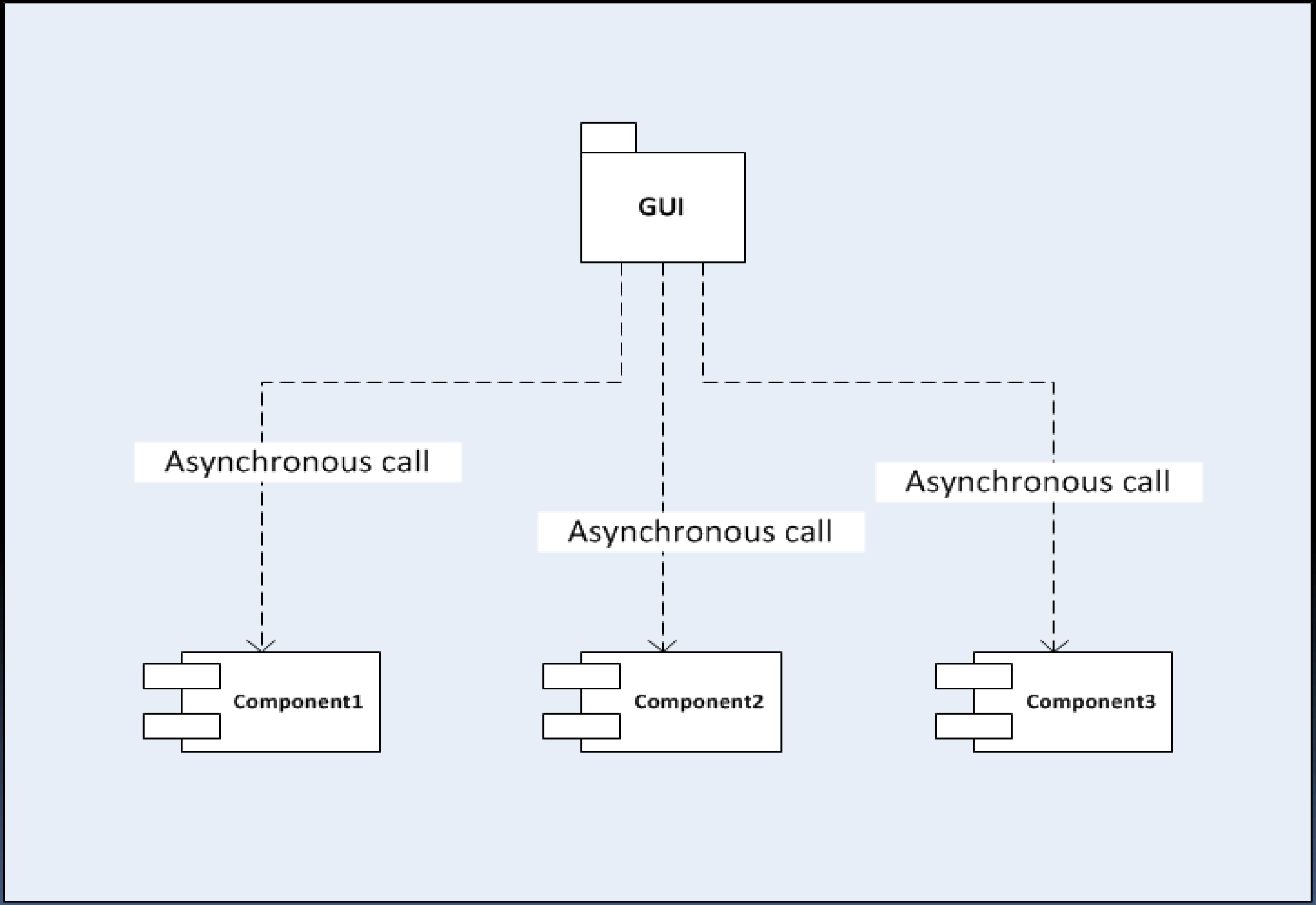
It then returns an interface pointer, bound to class #3, to the client. The interface and its implementing class #3 acts as a mediator for all of the other classes in the package.

All of Factory's functions can be static, so the client does not need to create an instance of that either.

Package K has no binding to Package N's implementation. It only needs to include the header files describing the Interface and Factory.



Example Componentized System



Communication Driven Structure

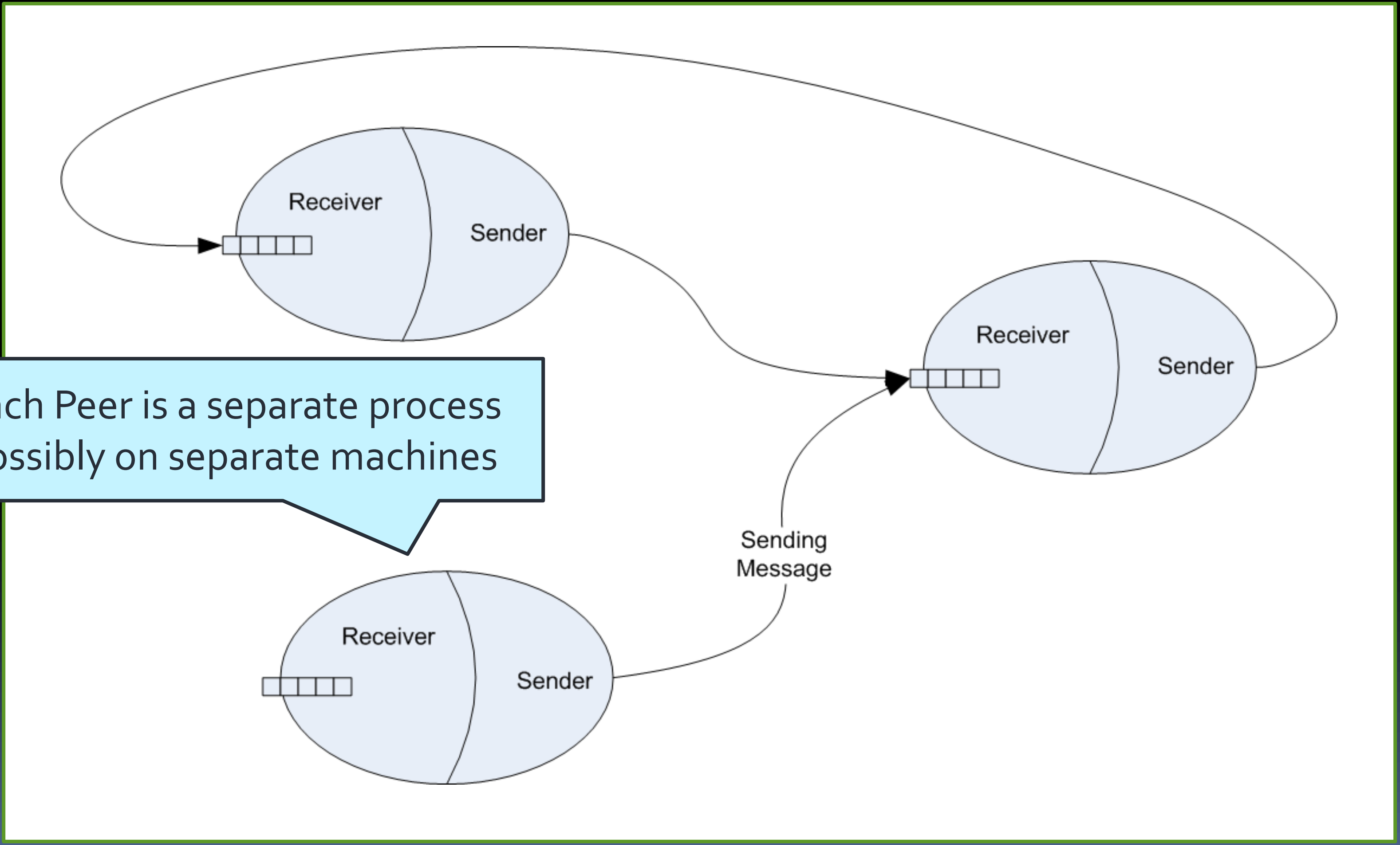
Communication Driven Structure

- When users, data, and application logic are distributed across processes and machines communication becomes important:
  - Peer-to-peer
  - Service oriented

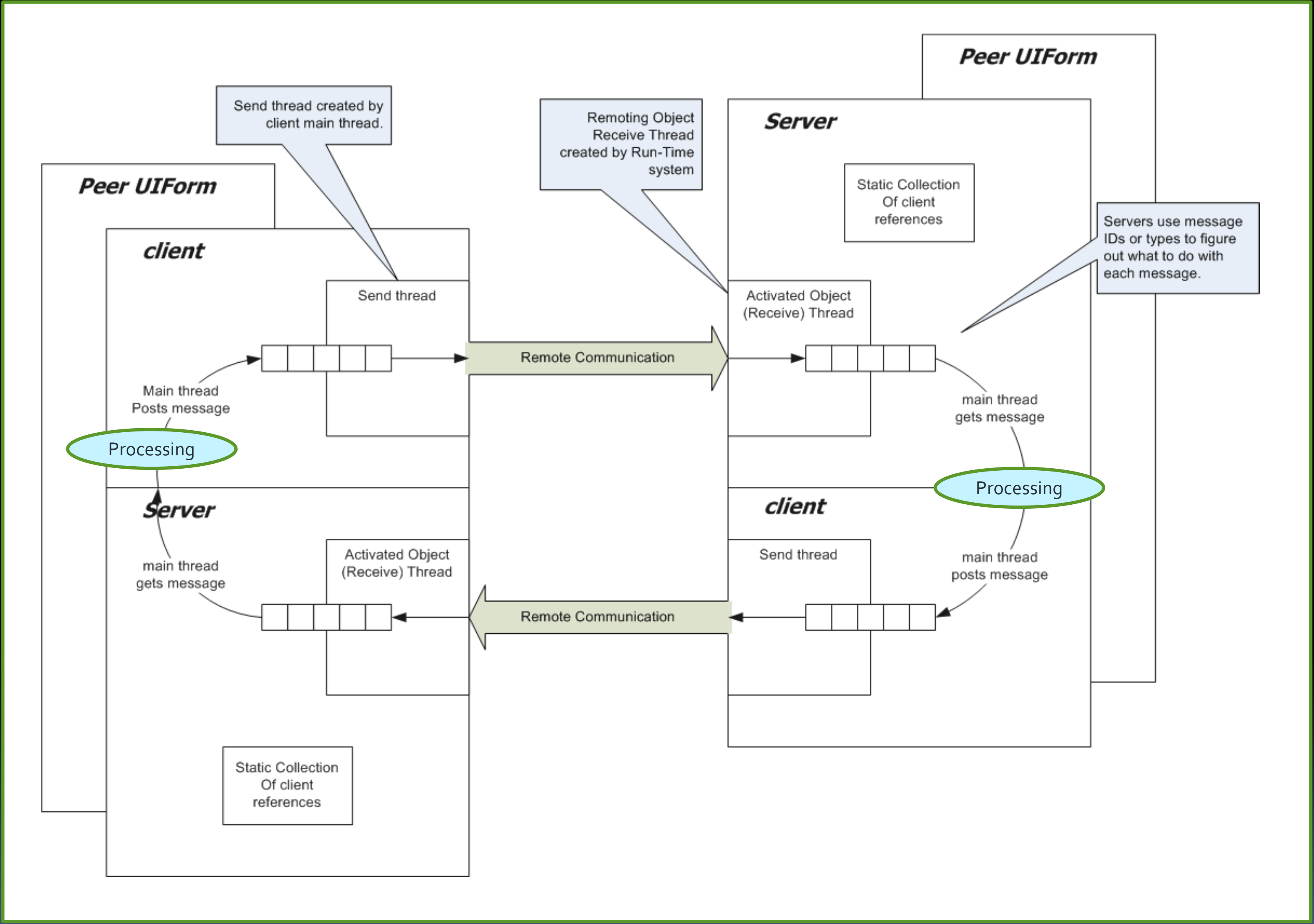
Structure: Peer-To-Peer

- Behavior:
  - Peers interact, sending and receiving messages from each other.
  - Peers are sometimes identical.
  - Many Peer-to-Peer models support central or distributed locater services.
- Examples:
  - http://www.ecs.syr.edu/faculty/fawcett/handouts/CoreTechnologies/SocketsAndRemoting/code/WCF_Fawcett_Examples/WCF_Peer_Comm/
  - Bit-Torrent
  - Napster

Peer-To-Peer Asynchronous Message-Passing Structure



Each Peer is a separate process possibly on separate machines


Peer UIForm
Send thread created by client main thread.
Remoting Object Receive Thread created by Run-Time system
Server
Static Collection Of client references
Peer UIForm
client
Send thread
Activated Object (Receive) Thread
Servers use message IDs or types to figure out what to do with each message.
Remote Communication
Main thread Posts message
main thread gets message
Processing
Processing
Server
client
Activated Object (Receive) Thread
Send thread
main thread gets message
main thread posts message
Remote Communication
Static Collection Of client references

Communication Types

- Remote Procedure Call (RPC):
  - Supports function call semantics between processes and machines.
  - Sends messages over wire but provides stack frames for client and server to support the function call model.
  - Examples: COM, CORBA, WCF
- Message Passing:
  - Sends message with encoded request and/or data
  - Message contains endpoint information for routing
  - Directly supports asynchronous processing
  - Examples: Internet, Web, SMA and OOD projects

Communication Patterns

- <u>TwoWay:</u>
  Synchronous Request, wait for reply
- <u>Duplex:</u>
  asynchronous request, reply sent as callback
- <u>OneWay:</u>
  Send Message and forget
  - Receiver may send result back to requester as a subsequent message
- Examples:
  - All of the above are supported by WCF

Communication Style

- Push Model
  - Send information to a remote endpoint via a service call, perhaps via a message:

    ```
    void PostMessage(Message msg);
    ```

- Pull Model
  - Retrieve information from a remote endpoint via a service call, perhaps by a streaming download:

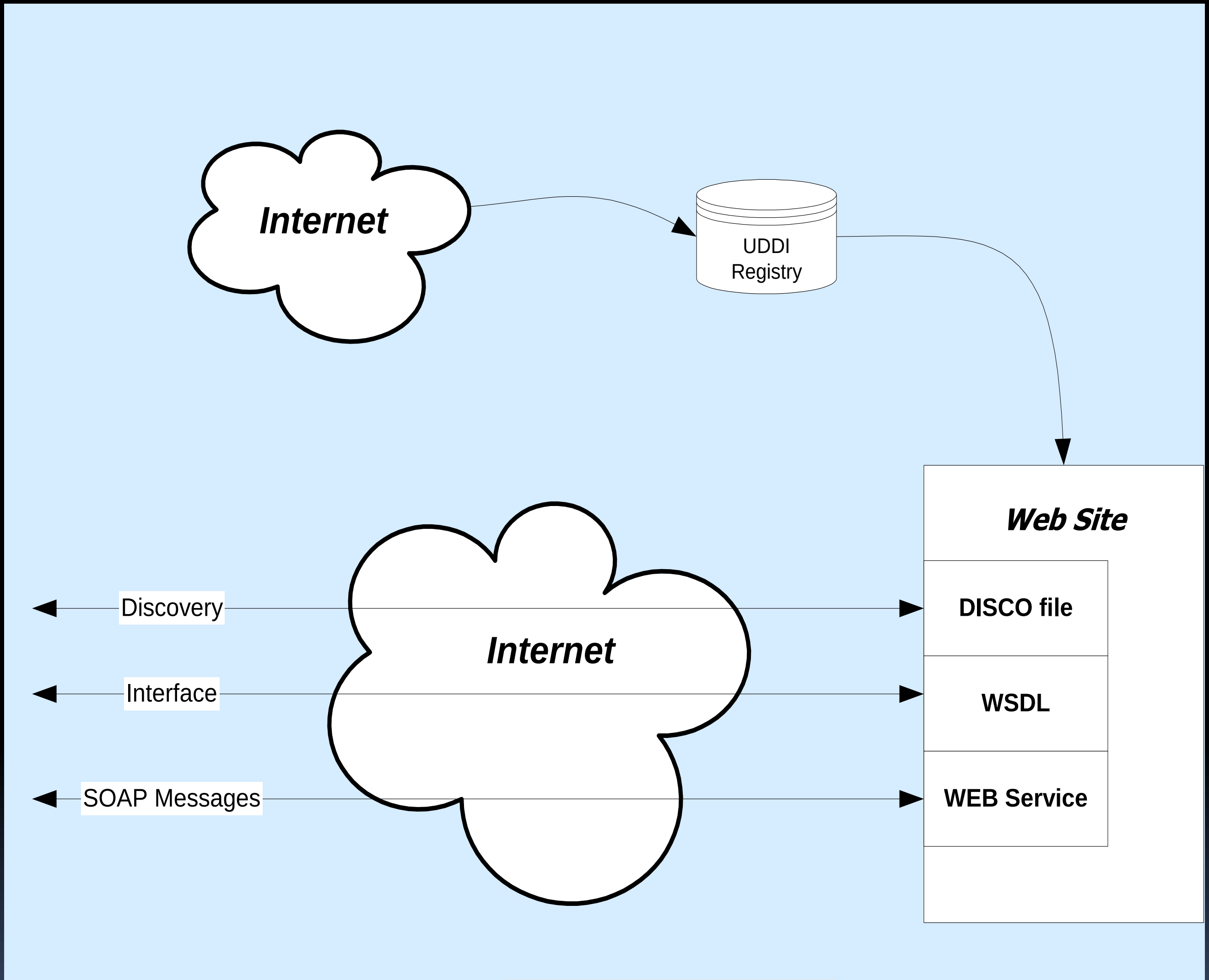
    ```
    Stream downLoad(string filename);
    ```

Communication Style

- Pull Service and Caching
  - A Software Repository could expose a WCF service that provides information about its package contents including dependencies.
  - That allows a client, for example, to pull from the Repository all files in a package dependency list that are not already in its file cache.

Service Oriented

- Structure:
  - Service oriented systems are simply client server.
  - Usually the server is implemented with a web service or operating system service.
    - Web service is a web application that provides an interface for client software to access.
    - OS service is a system application that provides an interface for requests and an administration interface for setting service startup and shutdown policies.
  - Windows Communication Foundation (WCF) has extended that model to support hosting in:
    - desktop application
    - windows service hosted with Windows Service Control Manager (SCM)
    - web service hosted by Internet Information Server (IIS).



C# Web Services, Banerjee, et. al.,
WROX, 2001

REpresentational State Transfer

- REST is a message-passing communication system built on the HTTP protocol, using the Web verbs:
  - Get – retrieve a resource without changing the state of the server.
  - Post – send information to the server that may change its state.
  - Put – place a resource on the server.
  - Delete – remove a resource from the server.
- Its encoding is UTF text, not SOAP or some other complex messaging format, but may use encryption, as in HTTPS.

Thread & Event Driven Structure

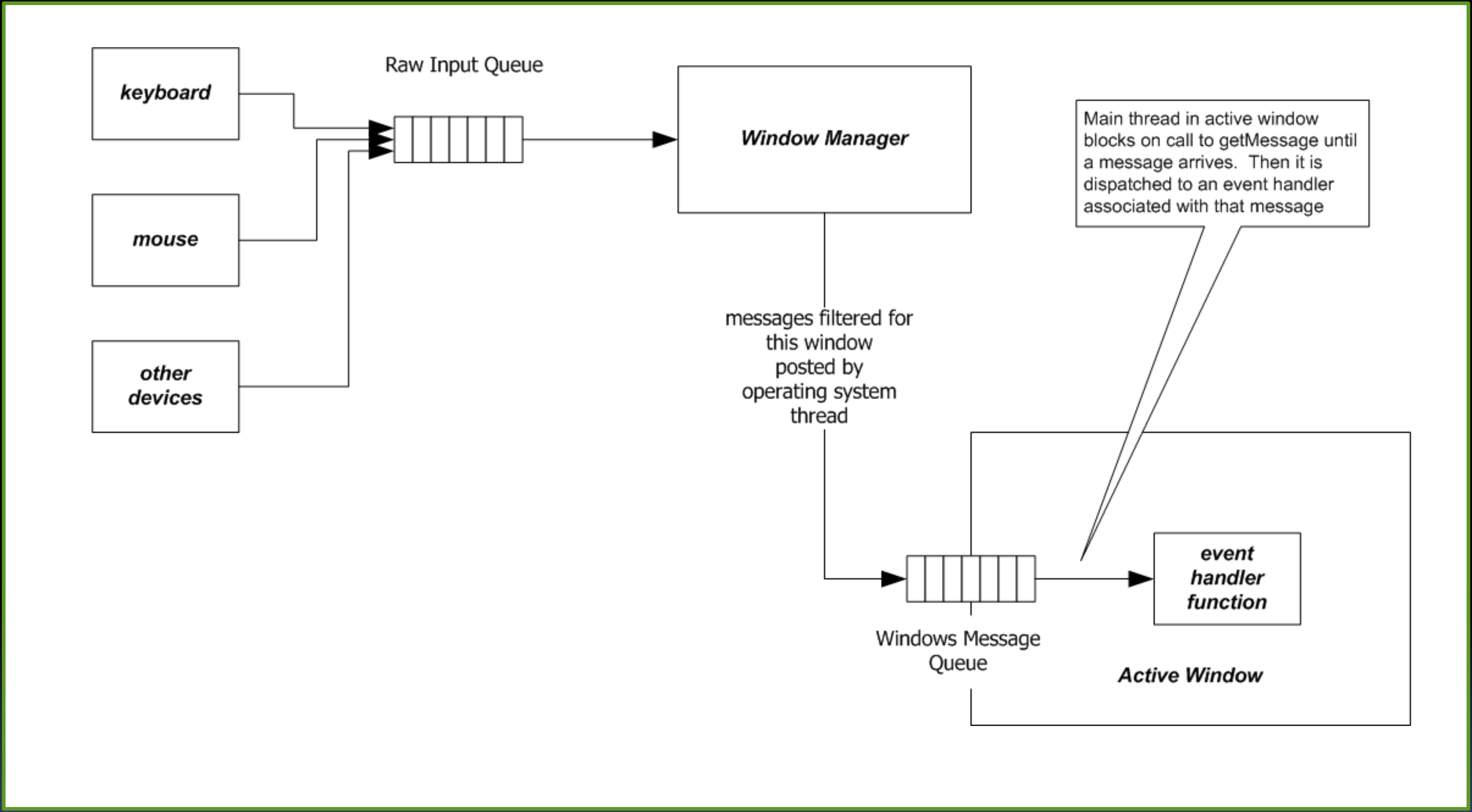
Threading Driven Structure

- Some program structures are a consequence of specific threading models
  - Event-driven and Single Threaded Apartment (STA)
  - Parallel execution
  - Pipelined execution

Structure: Event-Driven

- Structure:
  - Events from multiple concurrent sources generate messages which are enqueued, and typically are processed by a single handling thread.
  - Messages are dispatched to event-handlers for processing.
- Example:
  - Windows processing

Event-Driven


keyboard
mouse
other devices
Raw Input Queue
Window Manager
messages filtered for this window posted by operating system thread
Main thread in active window blocks on call to getMessage until a message arrives. Then it is dispatched to an event handler associated with that message
Windows Message Queue
event handler function
Active Window

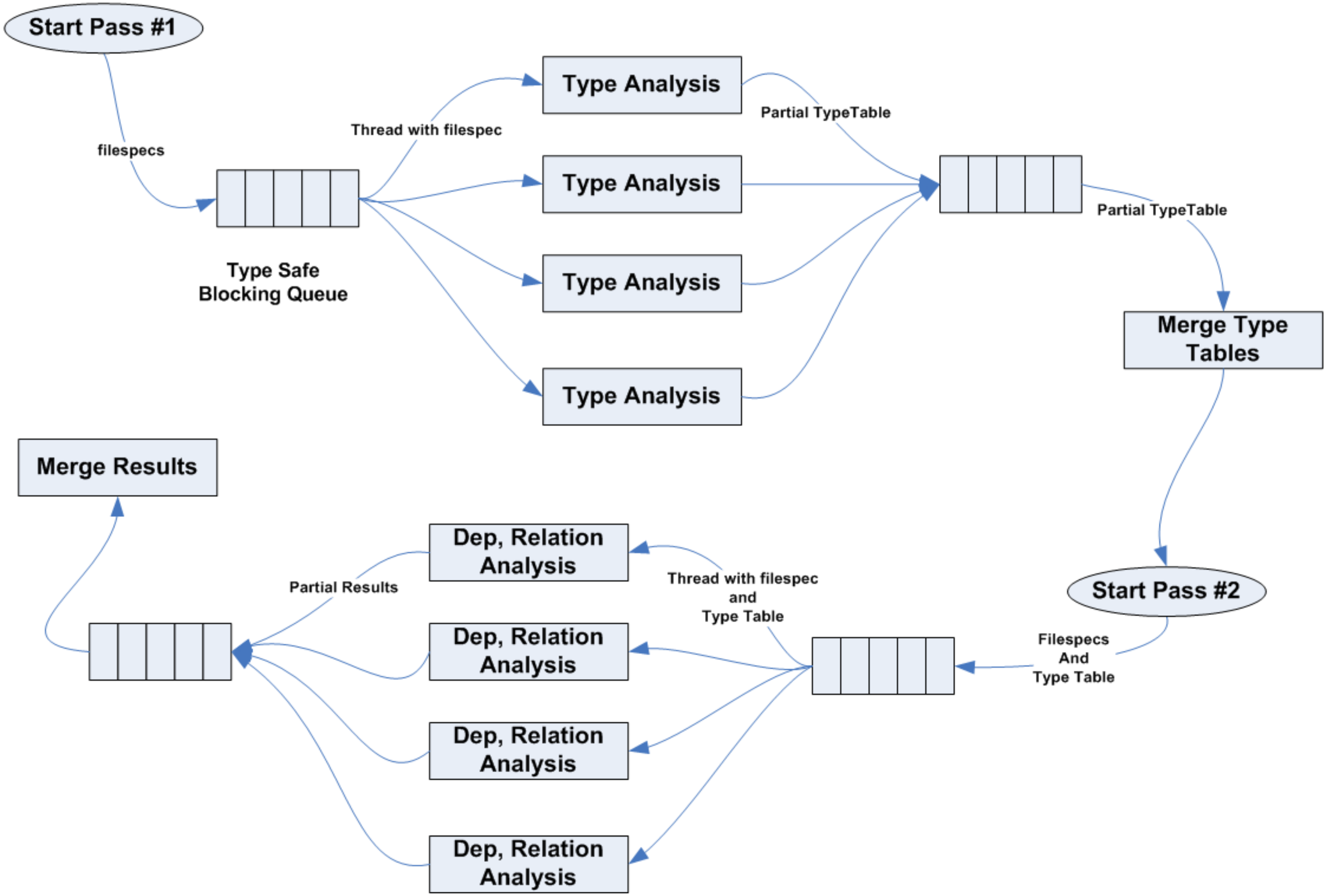
Single Threaded Apartment

- Graphical User Interfaces all use the STA model.
  - Possibly concurrent clients send messages to the GUI's message queue.
  - All messages are retrieved by a single thread, the one that created the window.
  - Child threads, often used to execute tasks for the GUI, are not allowed to directly interact with the window.
  - Instead they must send or post messages to the window's message queue.
  - This is often done with Form.Invoke or Dispatcher.Invoke.

Parallel Execution

- Structure:
  - Often concurrent programs provide enqueued task requests.
  - Threads, perhaps from a thread pool, are dispatched to handle each task.
  - Tasks must be independent in order to fully realize the benefits of concurrency.
- Example:
  - Concurrent execution of dependency analysis tasks.

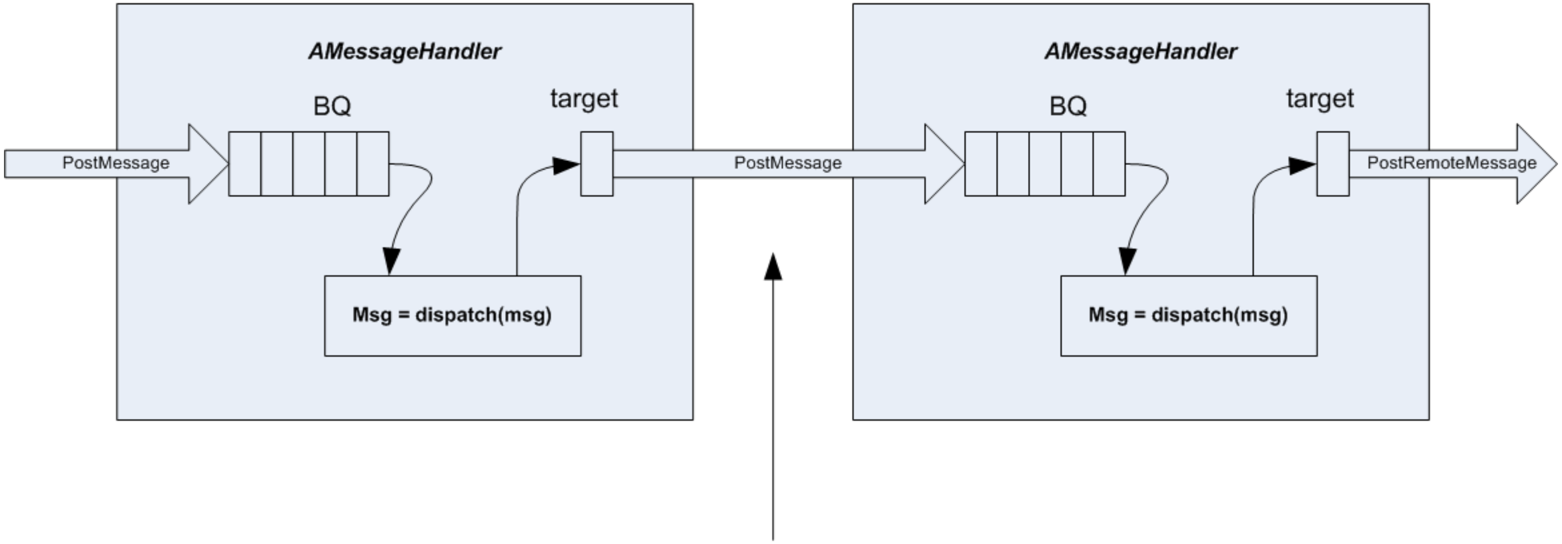
Scheme for Parallel Execution of Dependency and Type Relationship Analysis
Projects #1, #2, #3, #4



Pipeline Execution

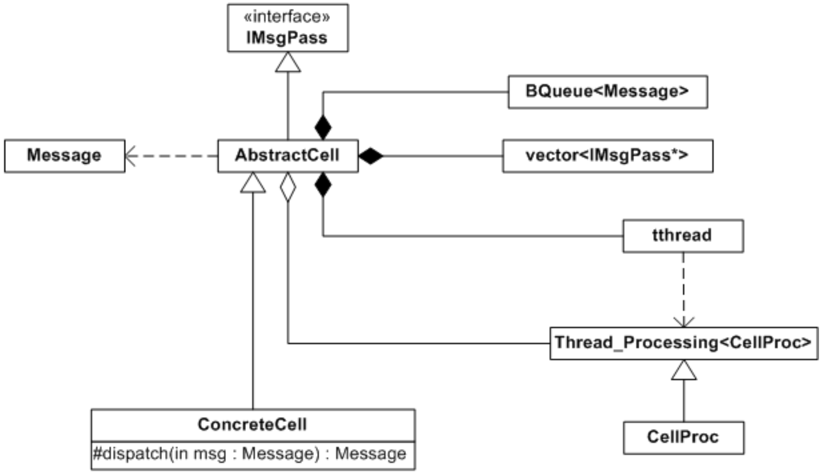
- Structure:
  - Composed of cells.
  - Each cell has a message queue and a child thread that processes messages.
  - Result messages may be sent on to another cell.
  - Each cell type is defined by the way it overrides a virtual message processing function.
- Example:
  - Project #4, CSE687 – OOD, Spring 2010

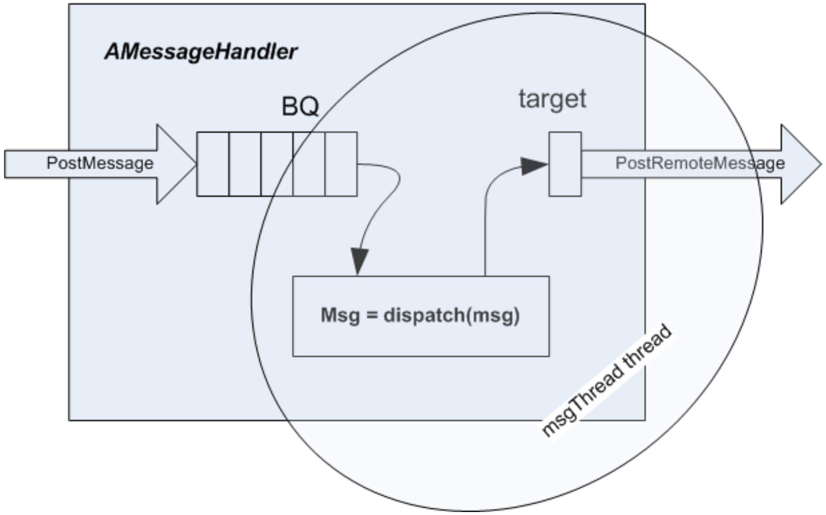
Cell Processing



Executive makes these connections

Cell Structure





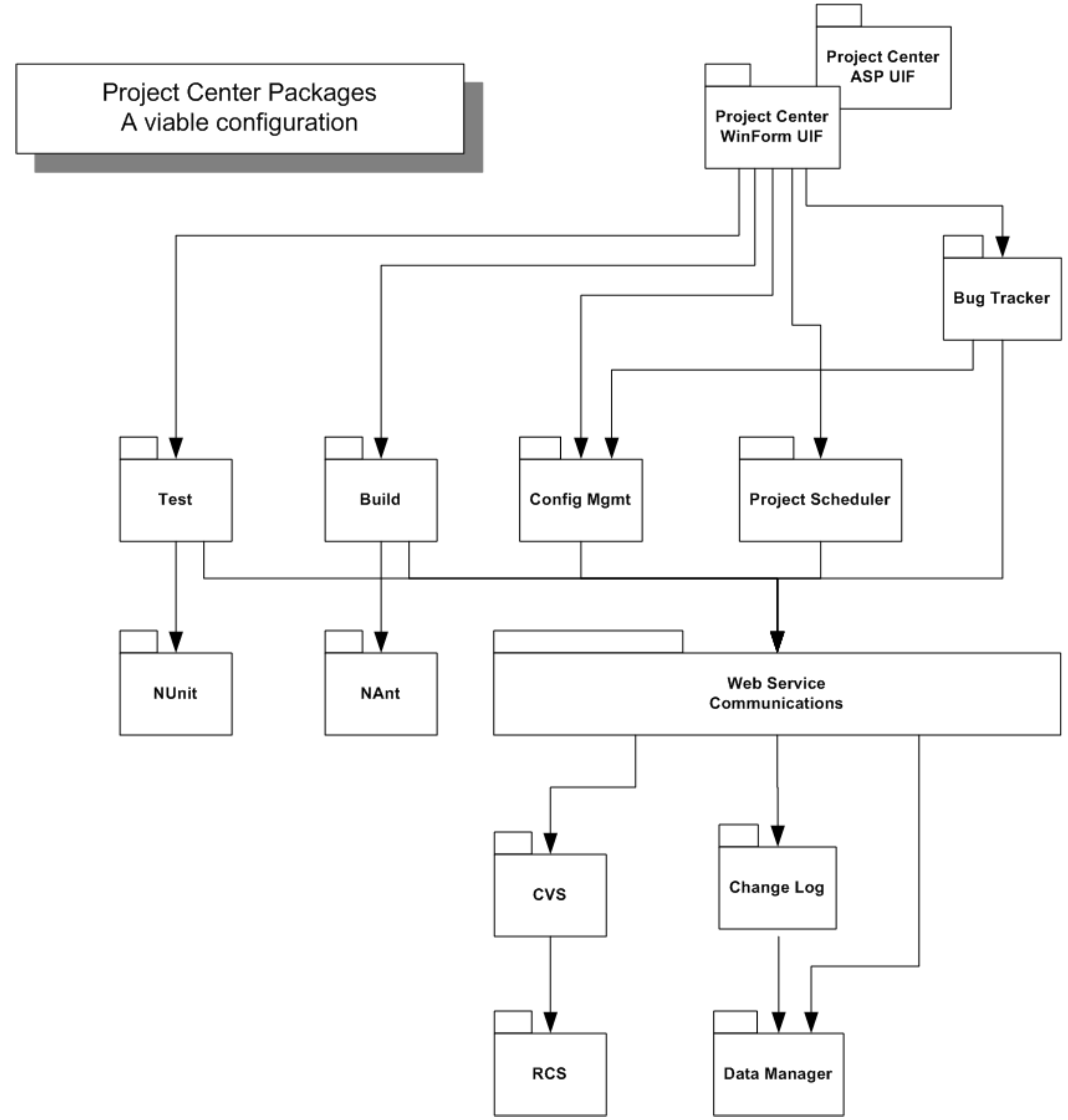
Enterprise Computing

Enterprise Computing

- Large Enterprise Applications are usually constructed as a federation of lower level systems and subsystems.
  - The federation is glued together with network based middleware, or more commonly now, with web services.
- Example: PeopleSoft, used by S.U.
  - Payroll and accounting
  - Academic planning and record keeping
  - Employee services
  - A variety of web applications, like mySlice.

Enterprise App: Project Center

- Federation of tools supporting Software Development
  - Open source tools with integrating wrappers:
    - CVS – configuration managment
    - Nant – sofware builds
    - Nunit – software testing
  - Newly developed and legacy tools:
    - Bug tracker, change tracker, project scheduler
- http://www.ecs.syr.edu/faculty/fawcett/handouts/webpages/ProjectCenter.htm



Project Center Packages
A viable configuration

Project Center ASP UIF

Project Center WinForm UIF

Bug Tracker

Test

Build

Config Mgmt

Project Scheduler

NUnit

NAnt

Web Service Communications

CVS

Change Log

RCS

Data Manager

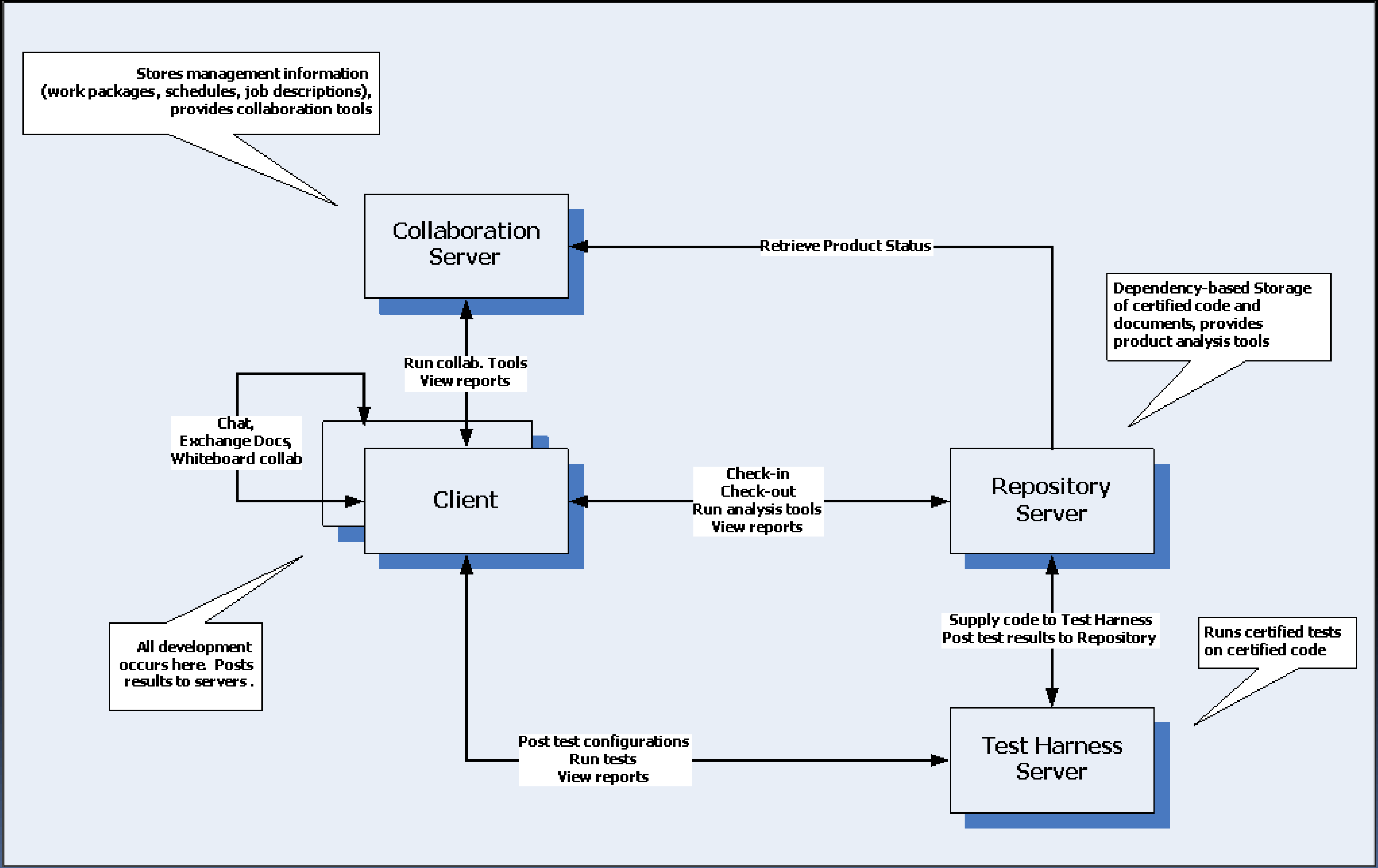
Federation Structure

- Federated Systems often are based on one of two design patterns:
  - ***Façade*** provides an integrating interface that consolidates a, possibly large, set of system interfaces into a single application interface in an attempt to make the system easier to use than working directly with its individual parts.
  - ***Mediator*** serves as a communication hub so that all the various subsystems need know only one interface, that of the mediator.

Collaboration System

- System that focuses on sharing of processes and products among peers with a common set of goals.
  - Primary focus is organizing and maintaining some complex, usually evolving, state:
    - Software development baseline
    - Set of work plans and schedules
    - Documentation and model of obligations
    - Communication of events
- Example:
  - Collab – CSE784, Fall 2007, http://www.ecs.syr.edu/faculty/fawcett/handouts/webpages/CServ.htm

Example Collaboration System



Stores management information (work packages, schedules, job descriptions), provides collaboration tools
Collaboration Server
Retrieve Product Status
Dependency-based Storage of certified code and documents, provides product analysis tools
Run collab. Tools
View reports
Chat,
Exchange Docs,
Whiteboard collab
Client
Check-in
Check-out
Run analysis tools
View reports
Repository Server
All development occurs here. Posts results to servers.
Supply code to Test Harness
Post test results to Repository
Runs certified tests on certified code
Post test configurations
Run tests
View reports
Test Harness Server

Other System Structures

Agent-Based

- System uses Software Agents
  - Semi-autonomous, mobile, task oriented software entities
  - May be scheduled
  - Provide scriptable user specific services
    - Collect information from a large set of data
    - Perform analyses on changing baseline and report
    - Conduct specific tests
    - Make narrowly specified modifications to baseline
- Example:
  - CSE681 Project #5, summer 2009, http://www.ecs.syr.edu/faculty/fawcett/handouts/CSE681/Projects/Pr5Su09.doc

Master's Thesis Research Examples

- The following are all based on Software Matrix structure – Autonomous cells often used with mediator
    - Software Matrix – Gosh, 2004
    - Self Healing Systems – Anirudha, 2005
    - Cross Platform Development – Appadurai, 2007
    - Model-Driven Development – Patel, 2007
- http://www.ecs.syr.edu/faculty/fawcett/handouts/webpages/research.htm

Other Structures

- TeraScale computing:
  - Buzzword defined by Intel to describe parallel execution on a many core processor.
    - Expectations are chips with scores of processors
- Cloud Computing
  - Buzzword adopted by many to describe remote execution and storage of applications defined locally. The cloud provides a stable endpoint that may map onto any one of a large set of computing resources.
  - Example:
    - Microsoft's Azure platform

SMA Projects

- Project #2
  - Cooperating monolithic processes
    - Composit Text analyzer
    - Metadata generator
- Project #4
  - Client-Server
    - May have multiple concurrent clients
    - Both client and server use DLLs for significant processing
- Project #5
  - Federation of clients and servers
    - Focuses on Software Repository server
    - May wish to use virtual servers

THE END