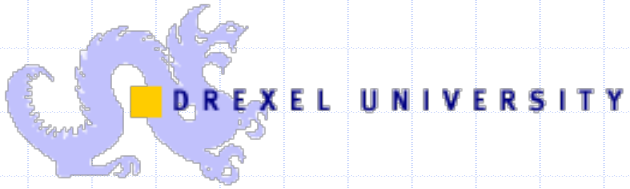



# CS 575: Software Architecture & Design

*Course Overview*

# About The Instructor

**Academic Background**

- B.S., M.S., and Ph.D. in Computer Science
- M.E. in Computer and Telecommunication Engineering
- Involved with CS Department Teaching, Research and Industry collaboration since 1997
- Ph.D. work was is Software Architecture Recovery

**Industry Background**

- Chief Architect at Cigna (Business, Web, Mobile, SOA)
- Founder of Integrated SystemWare

**Contact Information**

- Email: bmitchell@cs.drexel.edu
- Office Hours: Generally before class, but by appointment

# About the Course Title – It probably needs to be changed…

**Software Design?**
**Software Architecture?**
**Both?**

**This course has evolved over the years**

- Started off as an advanced design course – projects aligned towards designing something non-trivial, GoF and code writing focus
- Next Evolution – "Now and Then" – looking at the collective works of the father of software design, David Parnas, and investigating how his seminal research can be applied today
- Pragmatic, Architecture Focused – Architecture focus on a variety of modern problems that blend application-, platform- and integration-concerns associated with building modern, highly reliable, highly scalable solutions.

**We are Here**

# Why study Software Design and Architecture?

**The nature of systems that we commonly build stretch the design skills we first learned**

- Most modern systems are distributed – this introduces a ton of design complexity
- The availability of choices
  - Users of your systems are not a locked in as they have been in the past - things like the cloud are changing things
  - If your design is not good, how can you keep up with competition?
- The pace of software development
  - Software development now requires rapid iterations and the delivery of incremental functionality – what happens if you have a poor design?

# Do I need to know how to Code? What do I need to know how to Code?

**YES – BUT - This is not a deep coding course, but you will need to follow examples that involve the presentation of code. Your project also will require the implementation of a working solution.**

**You should know**

- An OO programing language – Java Preferred
- Working knowledge of how a VM operates

**You will be exposed to**

- Dynamic languages – especially around how dynamic languages support polyglot software development
- Functional languages – eliminating boilerplate, and how functional languages work related to software design
- Designing and architecting for the "browser as a platform" – we will be looking at HTML5/JavaScript solutions and frameworks using my webpage as a working example.

# How will this course operate?

**This course has been upgraded since the last time that I taught it**

- The good is that it will cover lots of new material covering the latest topics in software design and architecture
- The bad is that I will probably only be a week or two ahead of the class preping materials. Please be patient – if you want to work ahead feel free to look into materials related to the topics to be discussed.

**Materials**

- There will not be a course textbook. I could not cover the materials that I want without having multiple textbooks
- There will be links to required reading materials that will complement the lectures and lecture notesð

**Speakers**

- I will probably invite one or two outside speakers to address the class

# How will my grades be derived?

**This class will balance traditional exams and projects with some collaborative activities. Specifically your grade will be derived from the following:**

- Participation in class and in the discussion forums
- Reading Papers, Watching Videos
- An architecture reconstruction project
- A class project
- Final exam is TBD

# Course Deliverables - 1

## Architecture Reconstruction and Documentation

- You will document the high level conceptual architecture of a well-known platform or open source software solution.
- Platform – pick a platform such as netflix, linkedin, twitter, facebook, etc that have a robust engineering site that describes the platform technology choices.
- Open Source Software Solution – pick a popular and widely documented open source solution like git, a component of spring, or anything else where the source code, its build processes, and its directory structures are clearly documented. It would also be helpful if you pick an open source solution that is widely discussed on the web.

## Assignment Deliverables

- A **short paper** describing the architecture of the platform or system that you investigated
- Commentary on the quality of the architecture – what is good, what could be better

**We might allocate one class to examine the best, and most interesting case studies submitted…**

# Course Deliverables - 2

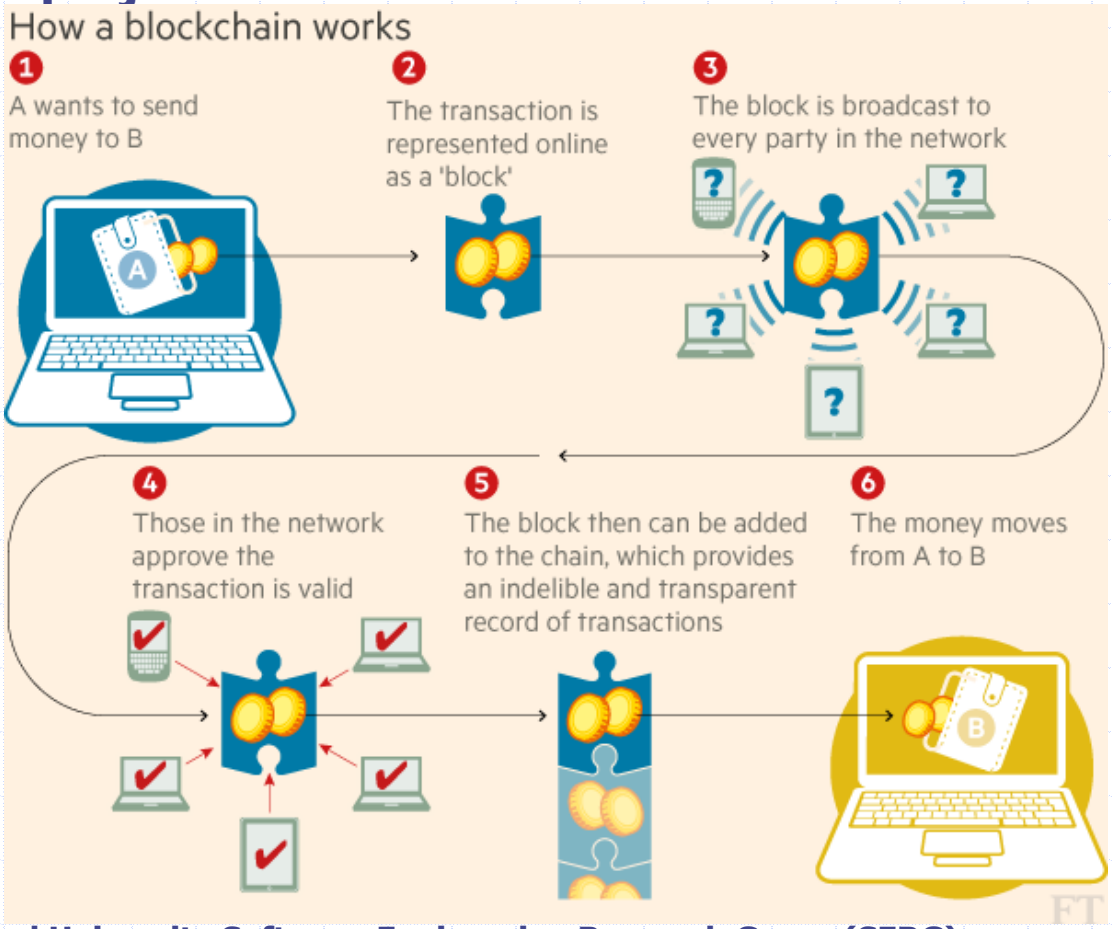
**Implantation of a non-trivial project showcasing a modern software architecture**

- You will implement and deploy a small system demonstrating some of the software architecture and design concepts covered in the class
- This is not expected to be a large software development effort, but what you build should embrace some of the modern software design and/or architecture concepts that we covered in class:
  - Poloyglot development
  - The use of functional programming languages – especially how they support cleaner design
  - The use of domain specific languages – how they change the approach to design and testing
  - Design and architecting for mobile
  - Designing and architecting for the cloud
  - Modern use of web services in designing software
  - Use of cloud architectures

**You can work individually, or in groups. Group projects are expected to be larger efforts. More on this later.**

# Course Deliverables - 2

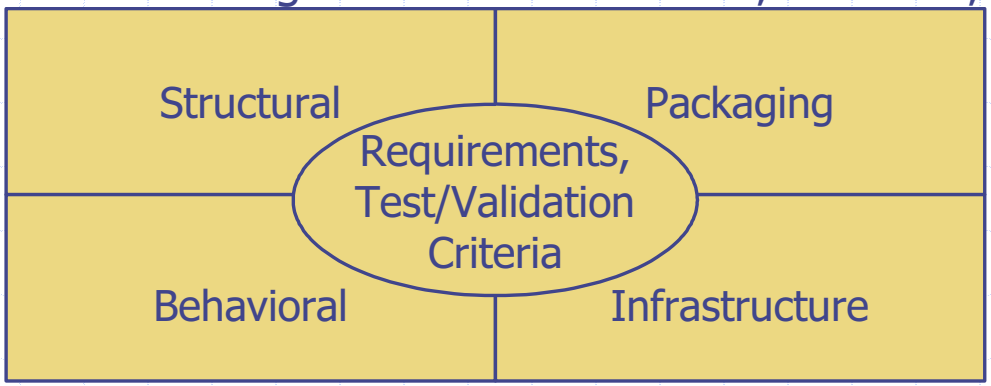
**You can do any project that you want, if you cant think of an idea then the project will be to create a blockchain simulator**



# Course Topics

## Reviewing the basics…

- What is software architecture
- How does it relate to design
- What is the difference between an architecture style, an architecture pattern and a design pattern
- What are views
- What are important views when documenting or describing the architecture of a software system
- Why do we need to do architecture
- Architecture and agile – can this be done, and if so, how?



# Course Topics

Breaking bad habits & being exposed to new things...

- Compare different programing and design models
  - OO, FP
- Why do we have different models?
- What's wrong with OO (specifically Java), and why the current reemergence of FP?

Throughout this course many examples will be provided using Scala, GoLang and modern JavaScript/Typescript to highlight polyglot software development

# Course Topics

## DSL – Domain Specific Languages and the modern software design stack…

- What are DSLs and why are they helpful
- Why are they used
- How to they aid in testability
- How do they layer into an overall architecture
- Internal versus External DSL
  - External: XML, Lex, Regular Expressions, YACC, SQL, …
  - Internal: Scala, Groovy, Ruby…
- Internal DSLs are like libraries but they favor "natural" language of the domain versus the host syntax
  - Metaprogramming in Groovy
  - Implicits and other "sugar" in Scala

# Course Topics

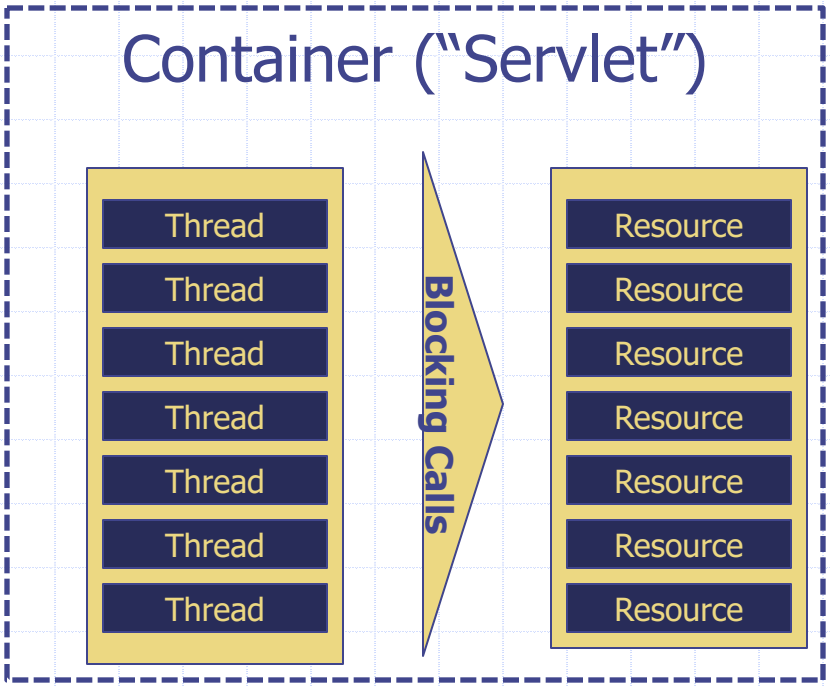
## Designing and architecting for scale

- Investigation into web architectures
- What's the problem with traditional web architectures that impact scalability?
- Promoting stateless and distributing computing to the client
- Functional programming
- The "Reactor" pattern and how it is implemented – Node.js, Netty
- Making distributed computing easier – Actors, Future/Promise models, etc.
- Reactive Programming Model and Frameworks

# Designing/ Architecting for Scale

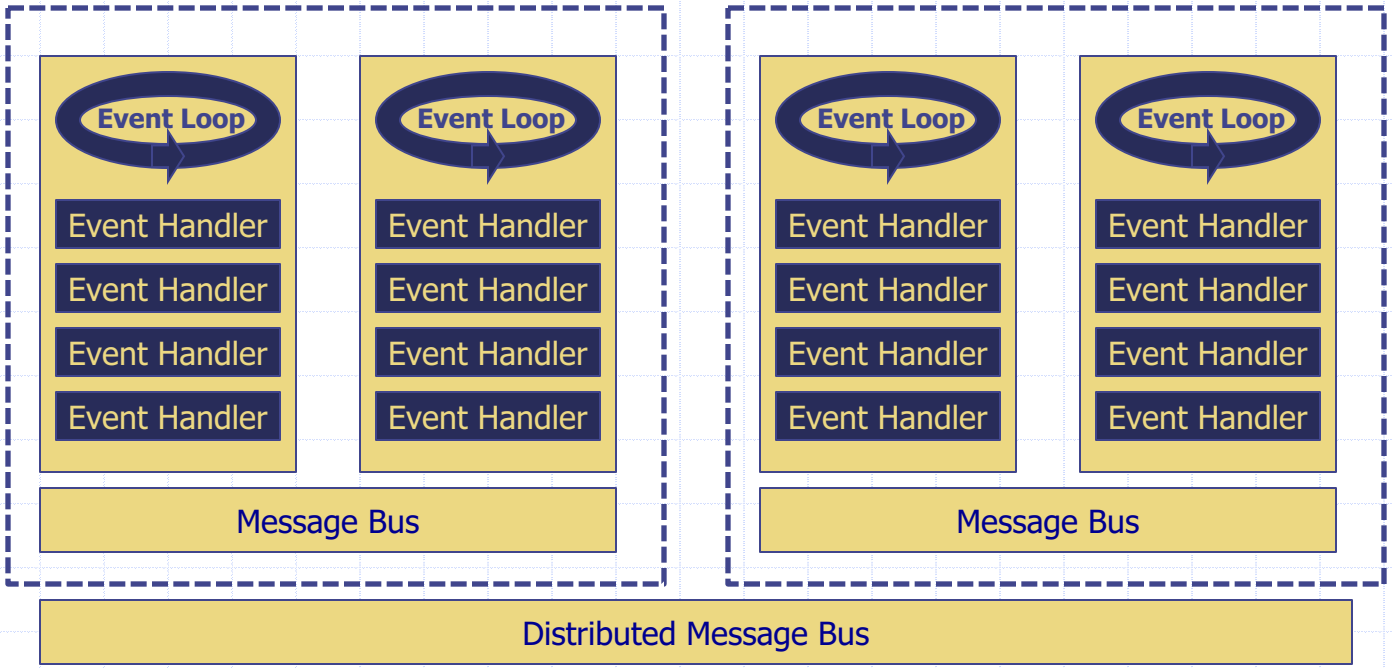
## Traditional Web Architecture

Requests are routed by a container to a thread. The request lives on the thread (uses it) until all of its I/O requests are satisfied and a result is sent back to the caller. Throughput is governed by the number of threads that are allocated to the container



# Designing/ Architecting for Scale

## (Multi-)Reactor Pattern




In this model each server runs a small number of threads, each thread executes an event loop. As requests come in they are assigned to an event handler. The event handler provides a "callback" and gives up control while it is waiting for I/O from a resource

# Designing/ Architecting for Scale

Reactive applications and frameworks that support them are becoming popular for architecting high performance applications.

- Resilient: The ability to recover and repair itself automatically in order to provide seamless business continuity.
- Interactive: Rich, engaging, single page user interfaces that provide instant feedback based on user interactions and other stimuli.
- Scalable: Can scale within and across nodes elastically to provide compute power on-demand when it's needed.
- Event-Driven: Enables parallel, asynchronous processing of messages or events with ease.

Used in the Typesafe Stack, Neflix Architecture, Microsoft Extensions

# Designing/ Architecting for Scale

**Modern languages such as scala make implementing the asynchronous model easier by abstracting threads using an actor model and higher-order concepts such as futures.**

```
val f: Future[List[String]] = future {
  session.getRecentPosts
}
f onComplete {
  case Success(posts) => for (post <- posts) println(post)
  case Failure(t) => println("An error has occured: " + t.getMessage)
}
```

---

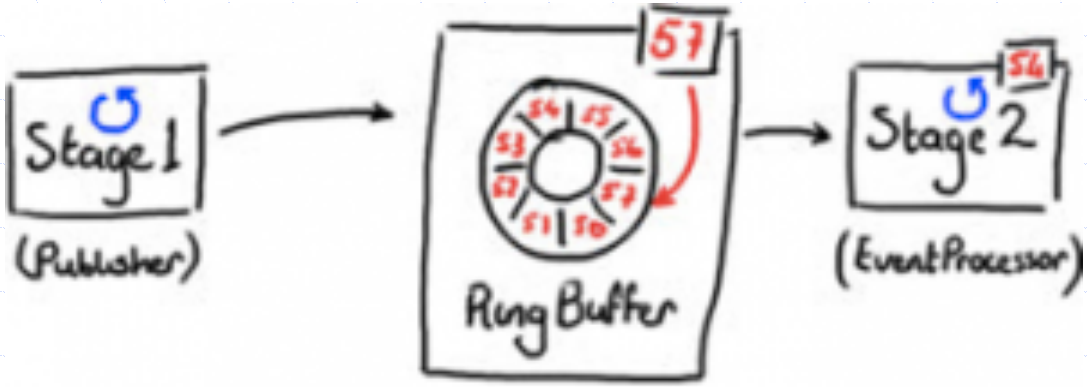
```
val f: Future[List[String]] = future {
  session.getRecentPosts
}
f onFailure {
  case t => println("An error has occured: " + t.getMessage)
}
f onSuccess {
  case posts => for (post <- posts) println(post)
}
```

**Lets take a look at: http://docs.scala-lang.org/overviews/core/futures.html**

**We will also examine how these concepts fit into the Javascript promise model, and Java 8**

# Novel Patterns for Scale

**We will also examine novel patterns that were created to support solutions that run at a very high throughput – one example is the LMAX Disruptor – designed to process 6 million orders per second on a single JVM**

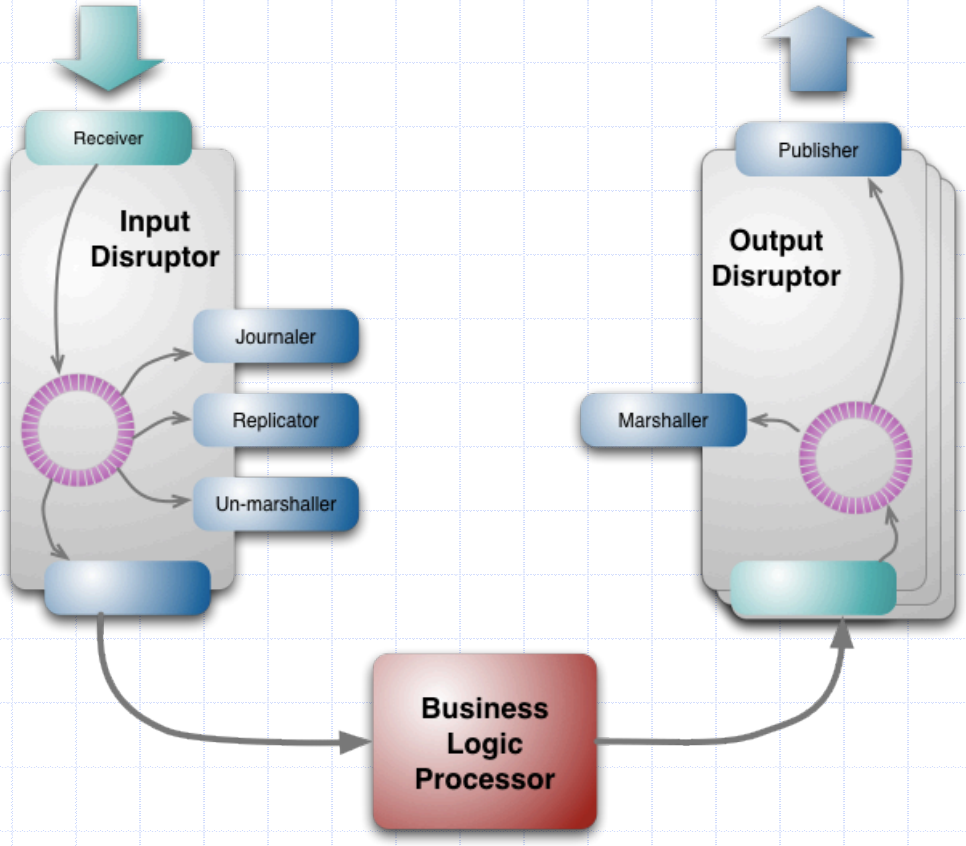



**Use ring buffer data structure to enable contention-free thread sharing, the only thing that is shared is a single volatile variable to ensure that the CPU does not reorder instructions.**

**Avoids issues with using queues and also addresses most concurrency solutions work with either mainly-full or mainly-empty queues – hard to get to a balanced producer/consumer steady state with events.**

# Novel Patterns for Scale

**Lets see how this all comes together by chaining disruptors to form an async event pipeline (picture from MartinFowler.com)**



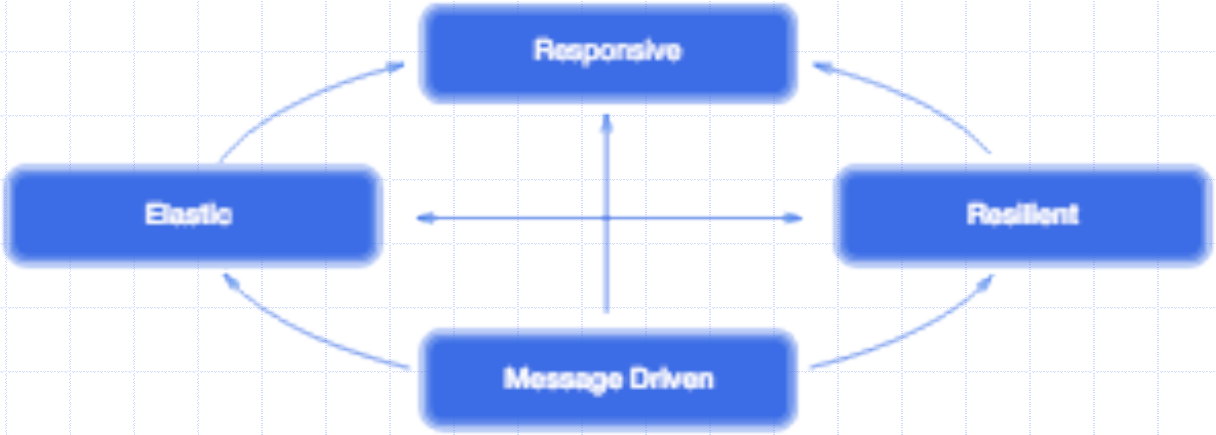
# Distributed Computing Patterns – Reactive Patterns

| | One | Many |
|---|---|---|
| **Synchronous** | `Try[T]` | `Iterable[T]` |
| **Asynchronous** | `Future[T]` | `Observable[T]` |

**Considering the architecture of the hardware becomes important for designing systems that scale. Goal is to make code non-blocking by using other modern constructs introduced as part of reactive extensions libraries.**

**Idea is to use fewer threads, take advantage of all cores, don't block, and embrace eventing and streaming.**

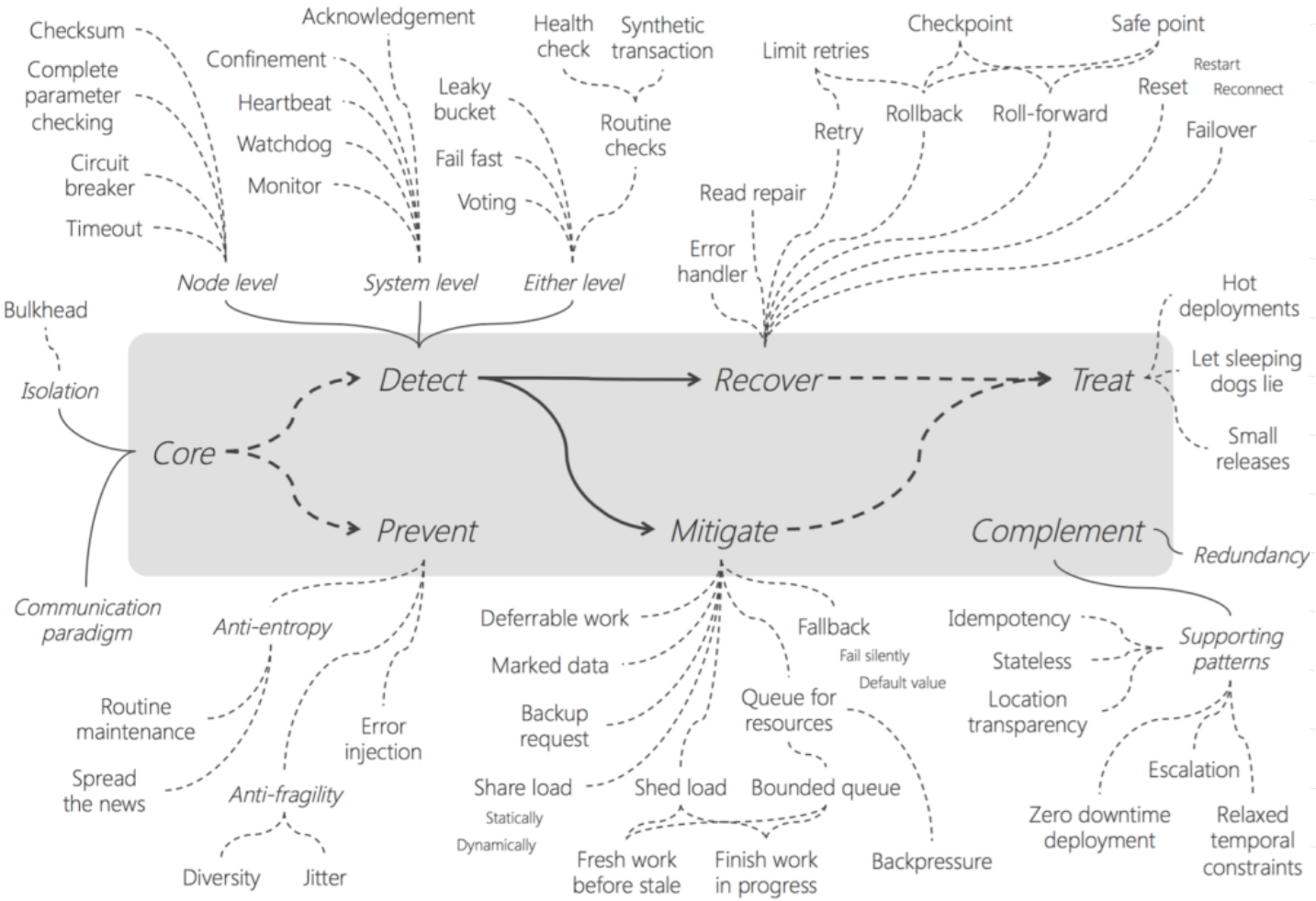
# The Reactive Manifesto




**See: http://www.reactivemanifesto.org/**

- **Responsive – The system responds in a timely manner**
- **Resilient – The system stays responsive in the face of failure**
- **Elastic – The system stays responsive under varying workloads**
- **Message Driven – The system relies on asynchronous message passing to establish a boundary between components that ensure loose coupling**

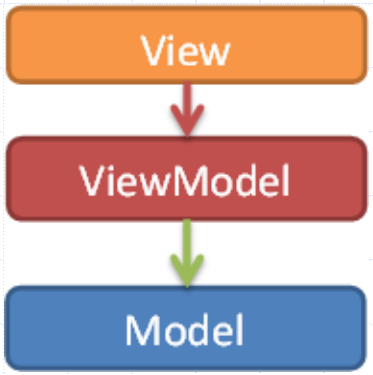
# Resiliency Patterns

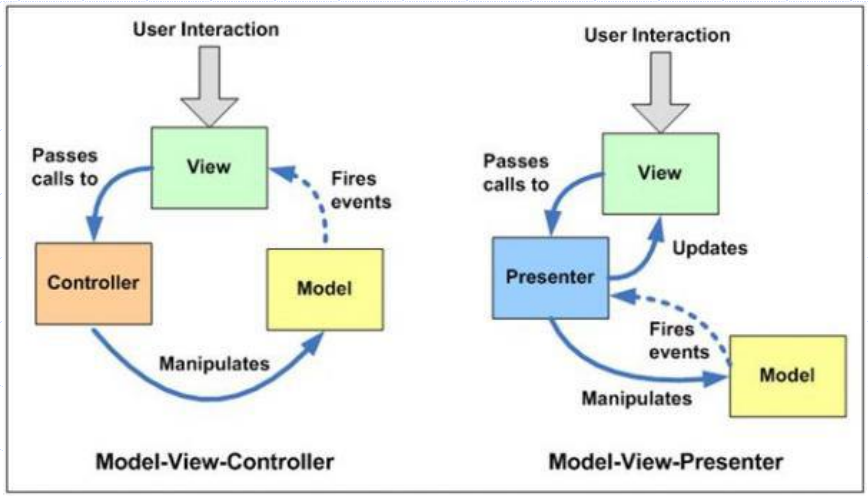


# Course Topics

## Modern Web Architectures

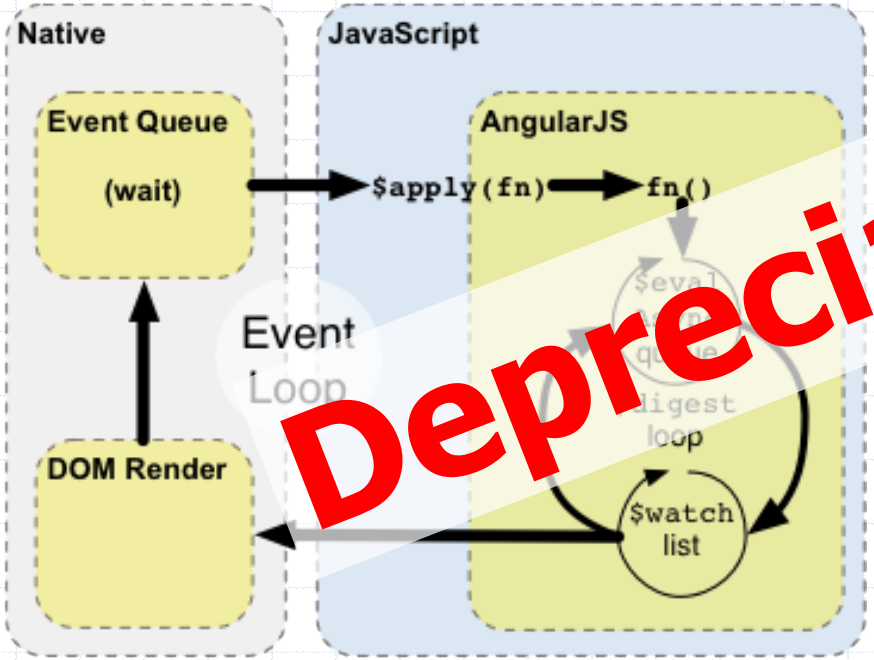

- The HTML 5 ecosystem
- Javascript as a platform
- The MVC, MVVM patterns move to browser
- Bringing server capabilities to the browser – Dependency Injection, Dependency Management, Promise/Future, Configuration Management, etc.
- Application distribution via CDN

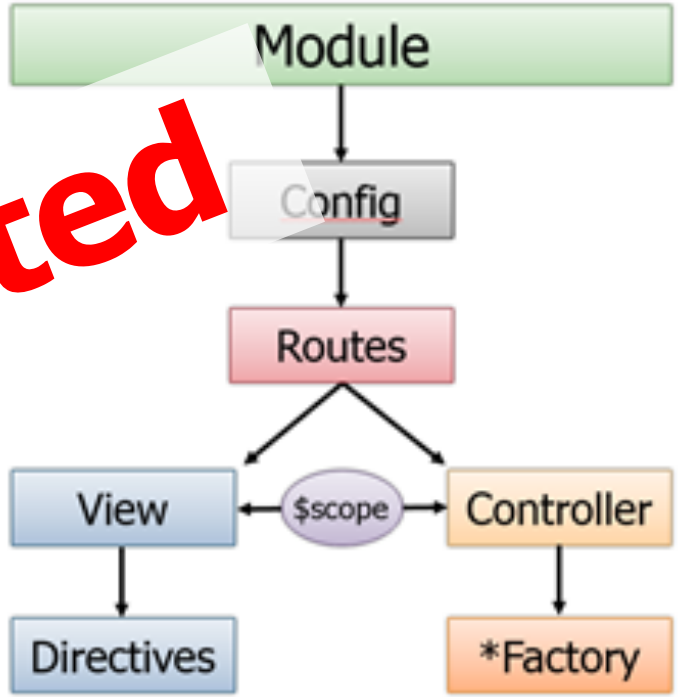


# Course Topics

## Building Modern Web Applications – Architecture for Angular JS

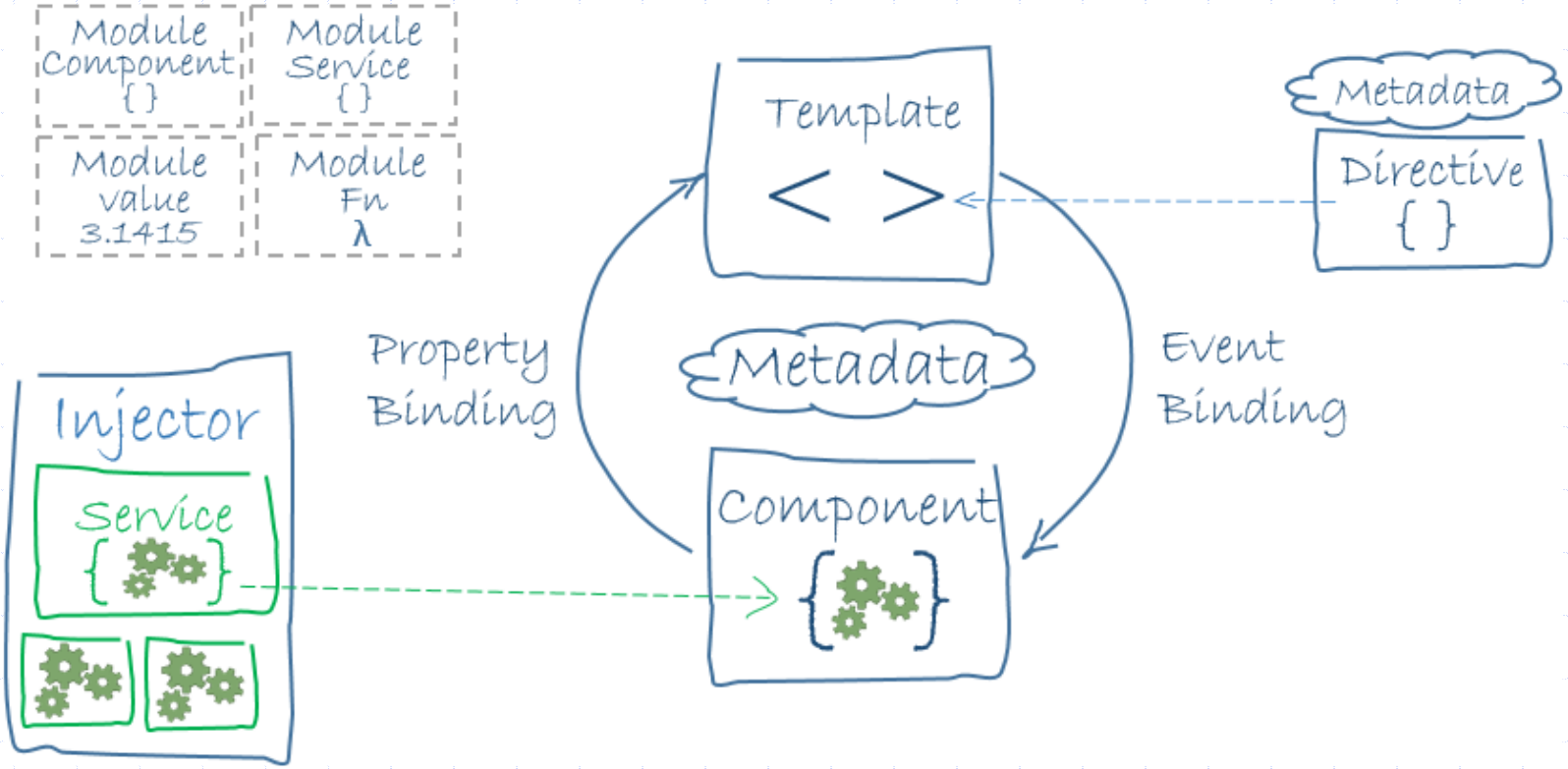



Depreciated

# Course Topics

## Building Modern Web Applications – Modern Architecture – Web Components



# Course Topics

## Service Oriented Architecture

- Why is SOA so important and popular
- Is SOA an Architecture?
- Types of SOA – REST and SOAP

## Event and Streaming Architectures

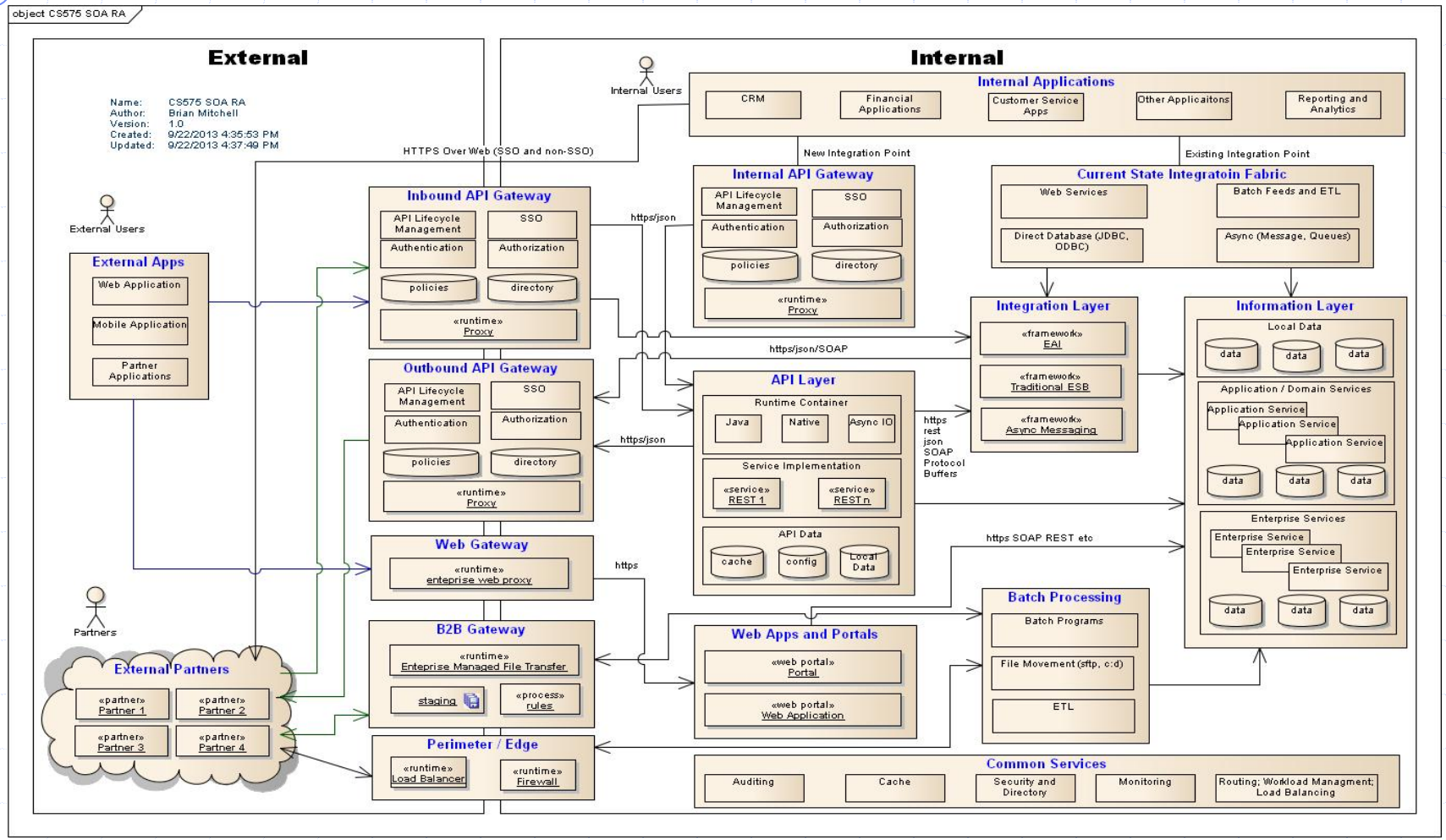
(https://martinfowler.com/articles/201701-event-driven.html)

- What are these?
- What are the interesting patterns?
  - CQRS
  - Event Carried State Transfer
  - Event Sourcing

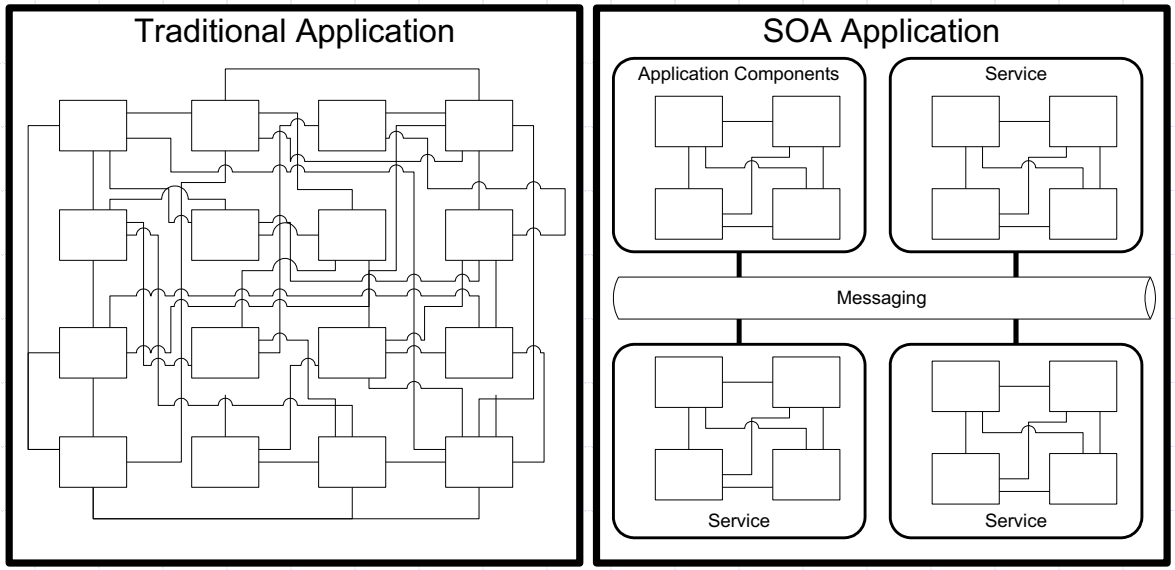
## Microservice Architectures (vs Monolithic Architectures)

- Design considerations

# Course Topics - SOA

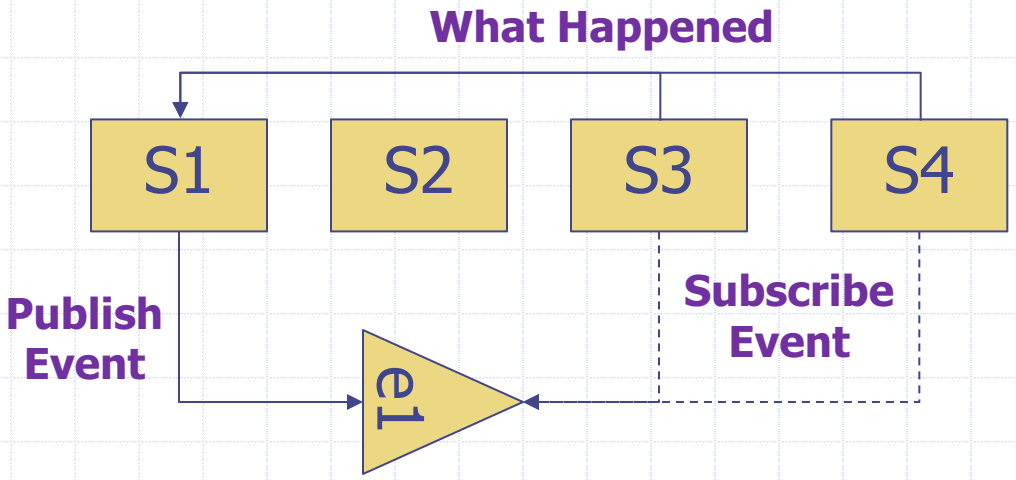


# Traditional versus SOA applications – a line and box view…




- **Applications designed in conjunction with an SOA style are easier to design, implement, maintain and extend due to the loose coupling of components that reside in different services**
  - **The pieces (services) in an SOA are designed with a courser granularity than an design based on traditional components, making the system simpler to deal with**
  - **The messaging interfaces between the services in an SOA have structure and semantics allowing them to be intelligently routed and provisioned based on application-specified policies**

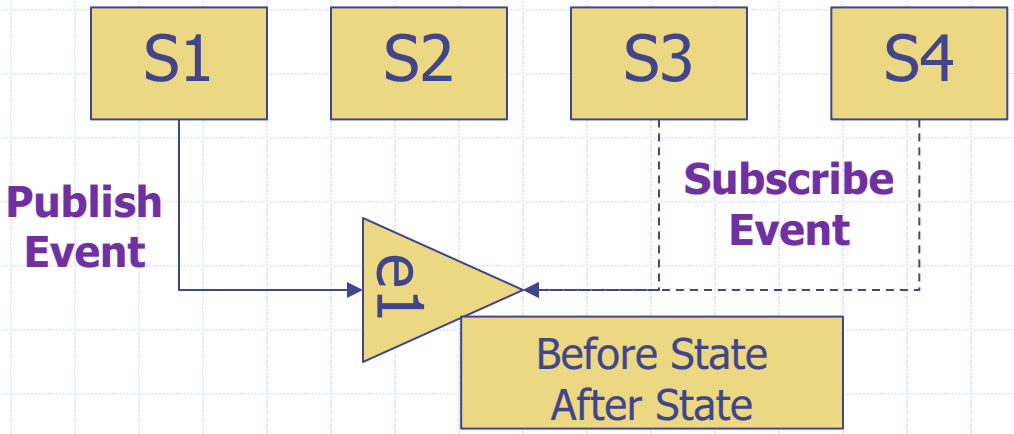
# Event and Streaming Architectures




Event Notification
Loosen coupling with pub/sub patterns
Interest is only in if the event has occurred

Source: The Many Meanings of Event-Driven Architecture – Martin Fowler

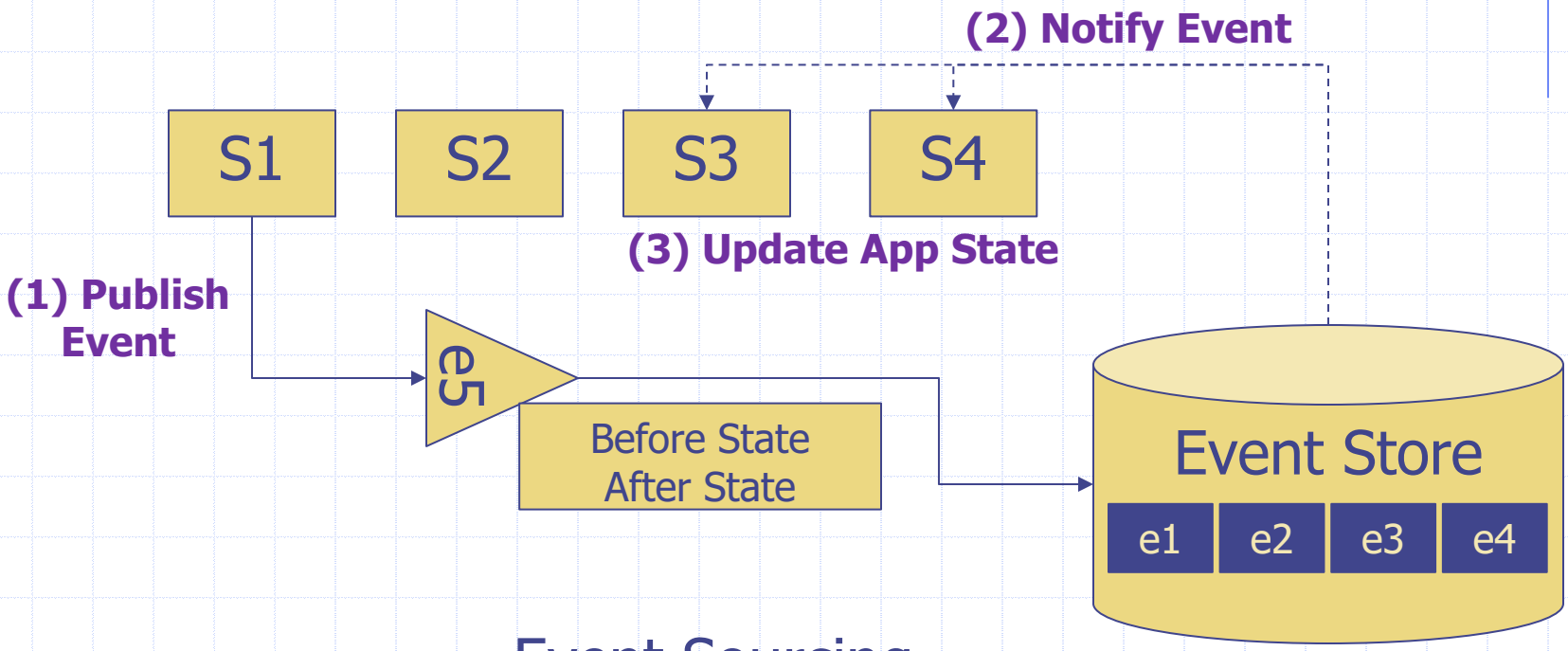
# Event and Streaming Architectures




Event Carried State Transfer
Loosen coupling with pub/sub patterns
Eventual Consistency

**Source: The Many Meanings of Event-Driven Architecture – Martin Fowler**

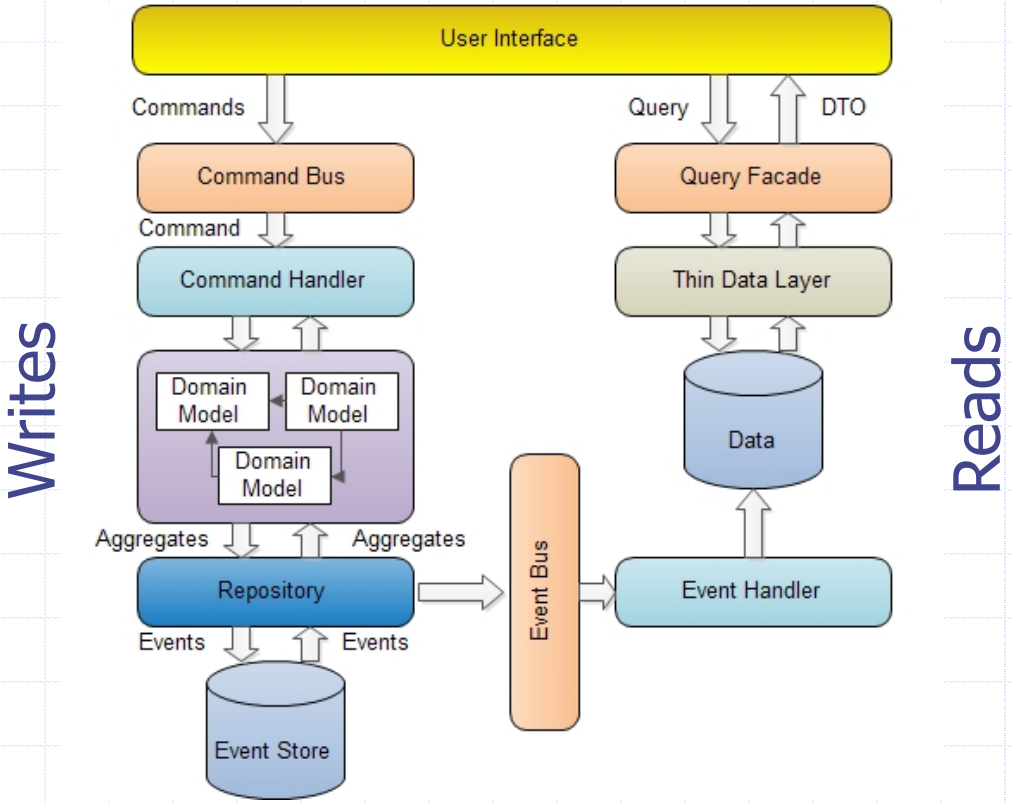
# Event and Streaming Architectures




Event Sourcing
Event Store Maintains State Over Time
Loosens Coupling

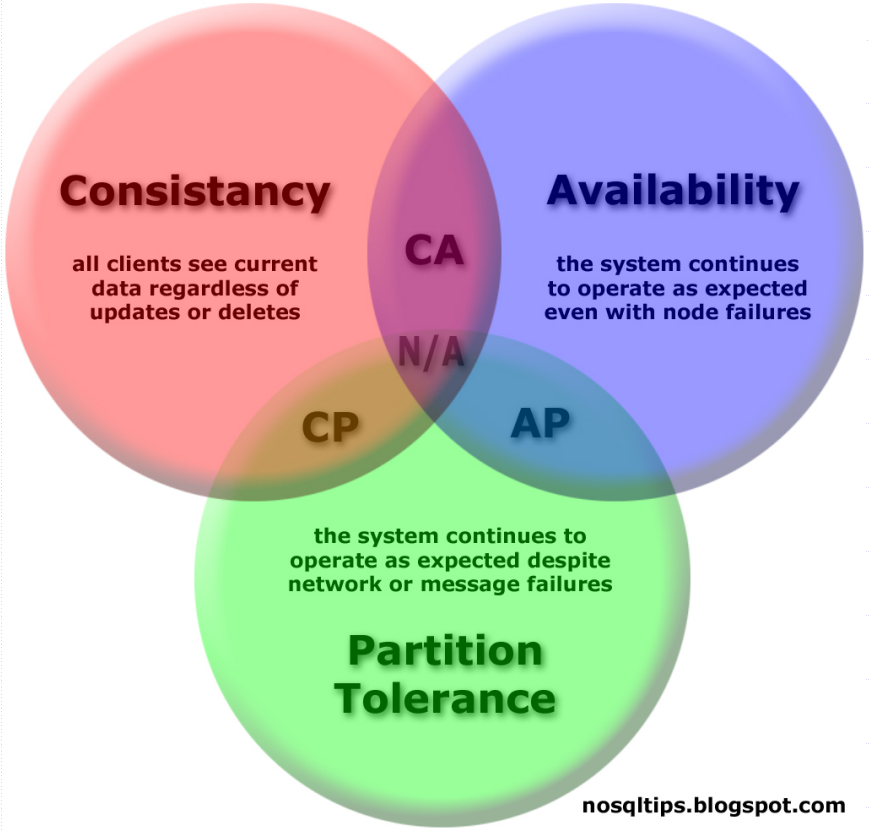
Source: The Many Meanings of Event-Driven Architecture – Martin Fowler

# Event and Streaming Architectures




Scalability and Consistency via Separate Handling of Reads and Writes (CQRS)

# Course Topics - CAP



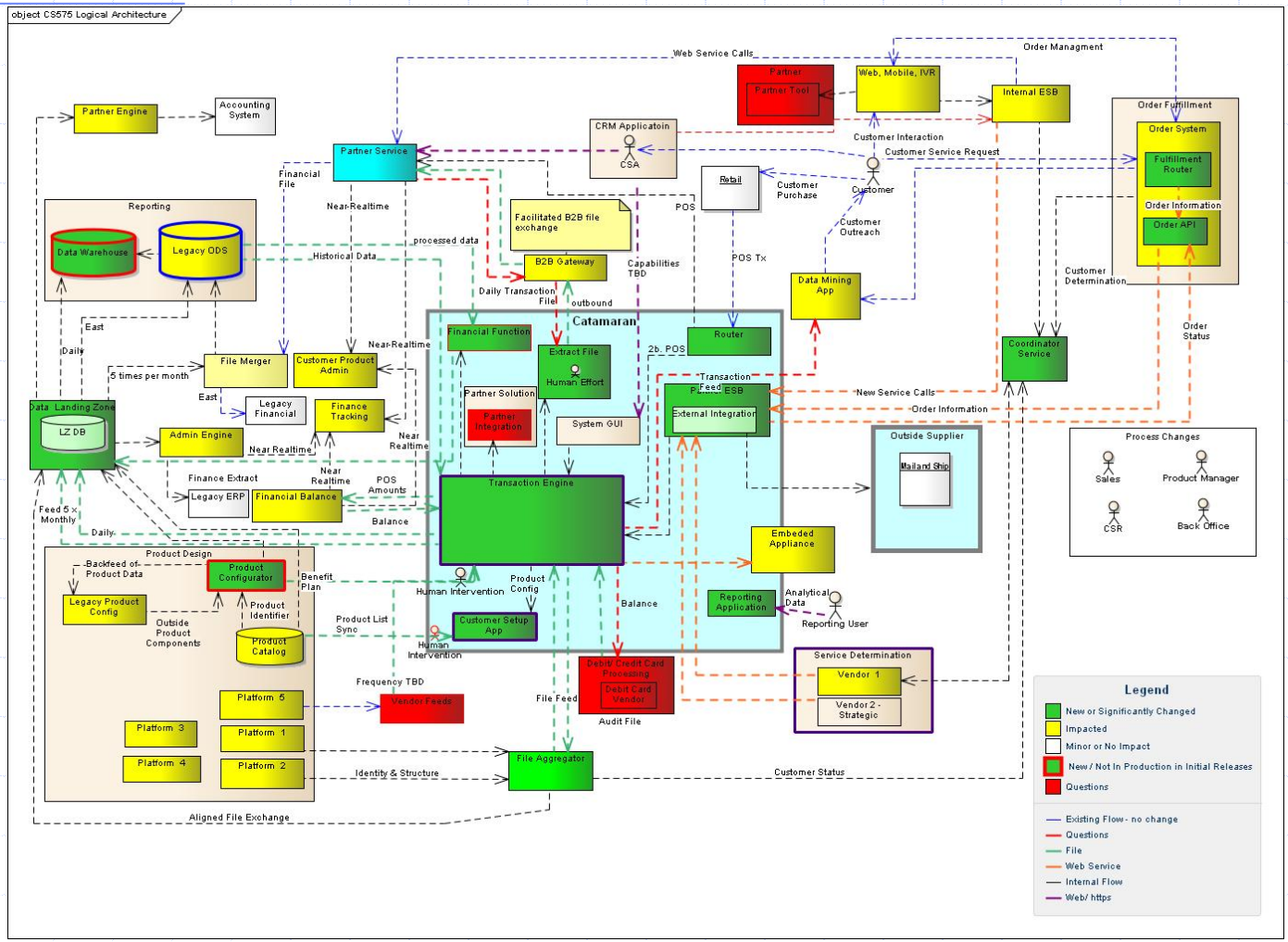

CAP Theorem and its impact on design and architecture

# Course Topics

## Modeling Software Architectures

- Why do we model
- Important views
- Communicating to stakeholders
- Reference, Conceptual, Logical, and Application architectures
- Use of tooling to model software architectures

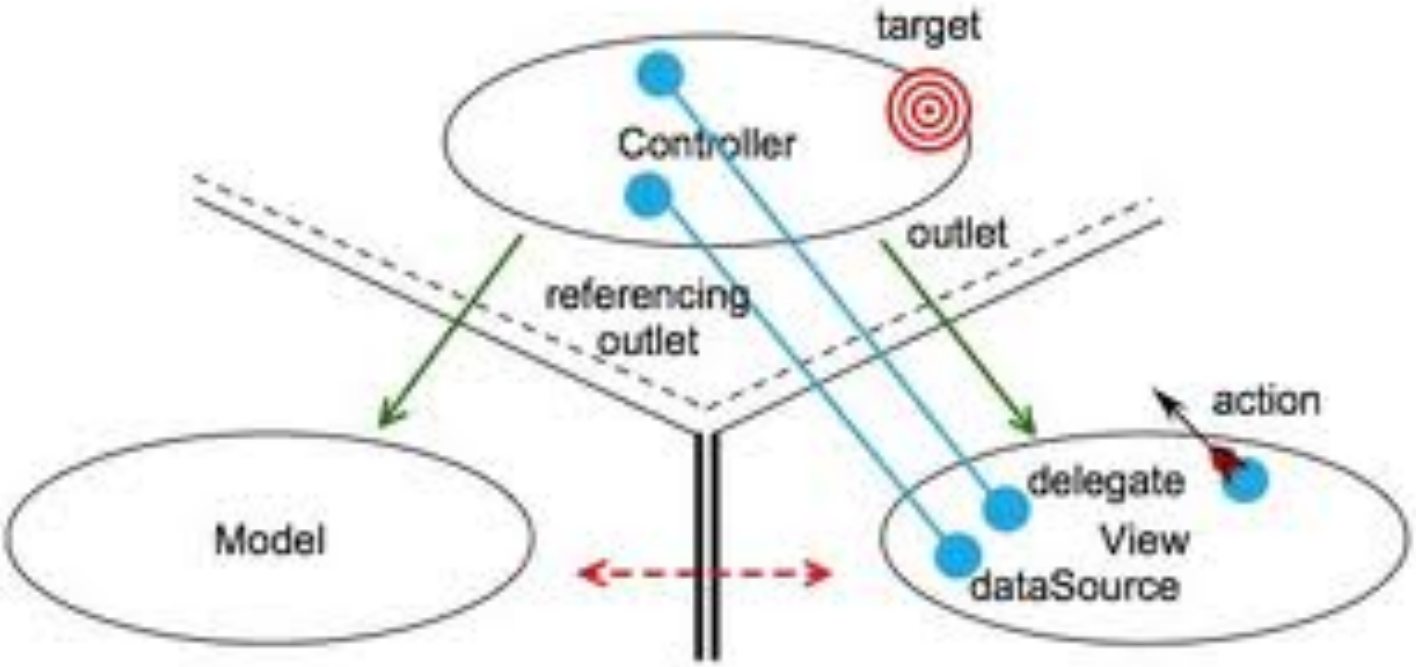
# Modeling Architecture Example



# Course Topics

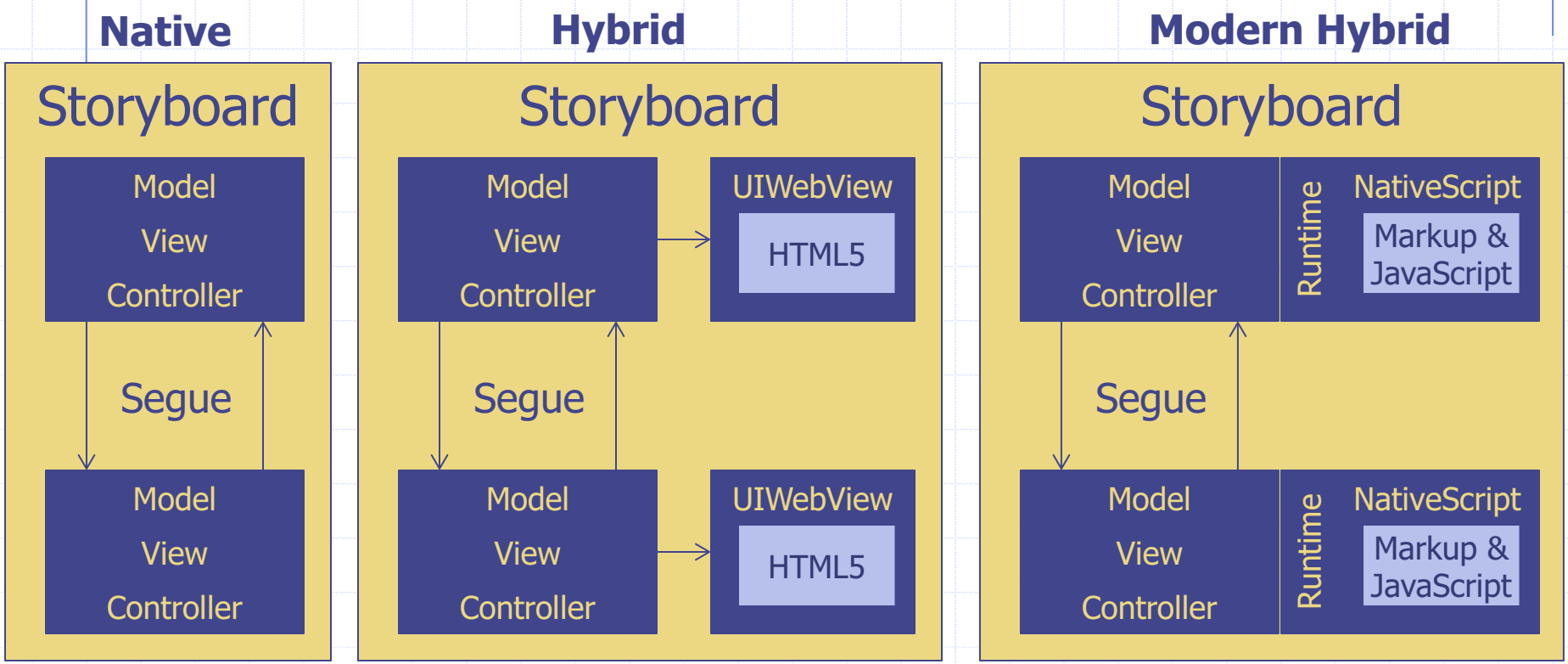
## Mobile Architectures

- Design considerations for mobile architectures
- Designing native, hybrid and responsive applications



# Course Topics

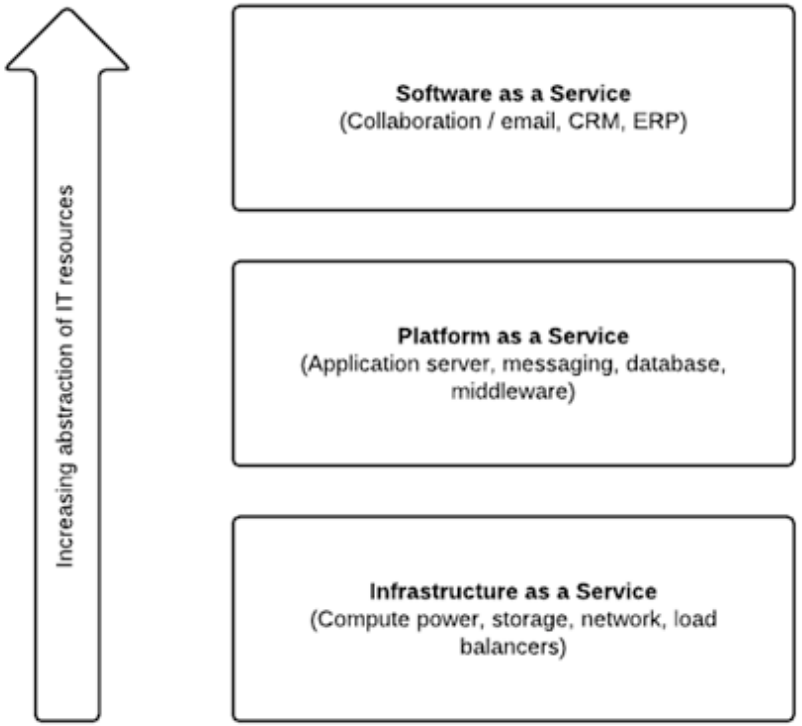
## Types of Mobile Architectures



# Cloud Native Applications


# Course Topics

## Cloud Models




**Infrastructure as a Service (IaaS)** - Hardware for compute, storage, network, and similar functions is delivered as a service. Examples of IaaS date back to mainframes.

**Platform as a Service (PaaS)** - Application platform components, such as application runtimes, databases, and messaging infrastructure, are delivered as a service.

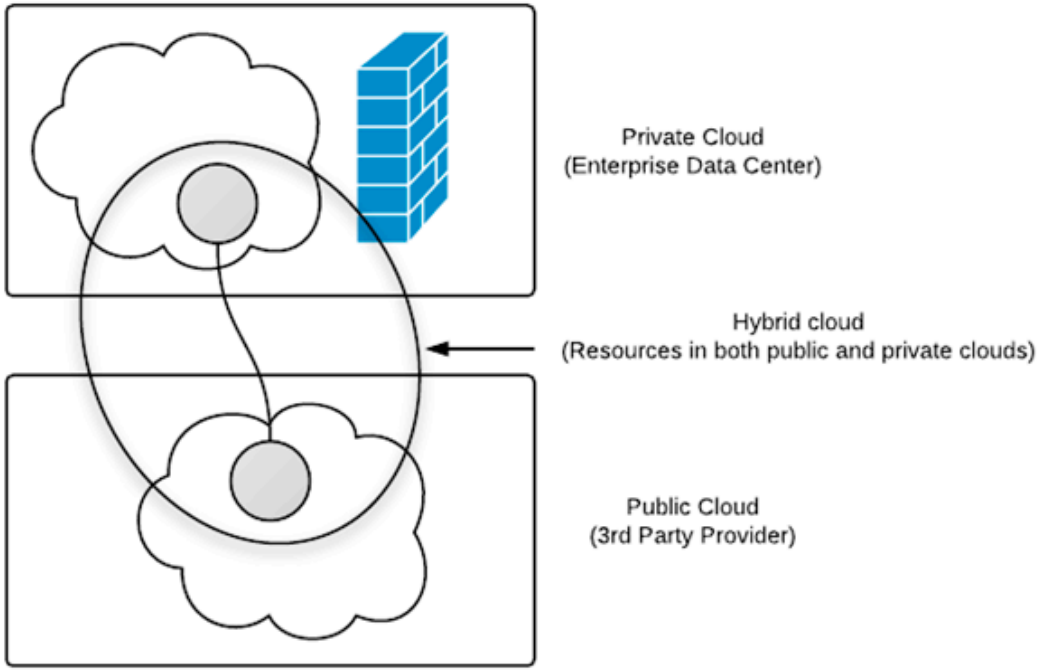
**Software as a Service (SaaS)** - Core business applications, such as email, CRM, HCM, and office ERP applications, are delivered as a service.

We will also look at deployment architectures that are platform friendly – check out docker at http://docker.io

Materials adopted from: http://www.oracle.com/technetwork/articles/cloudcomp/jimerson-ha-arch-cloud-1669855.html

# Course Topics

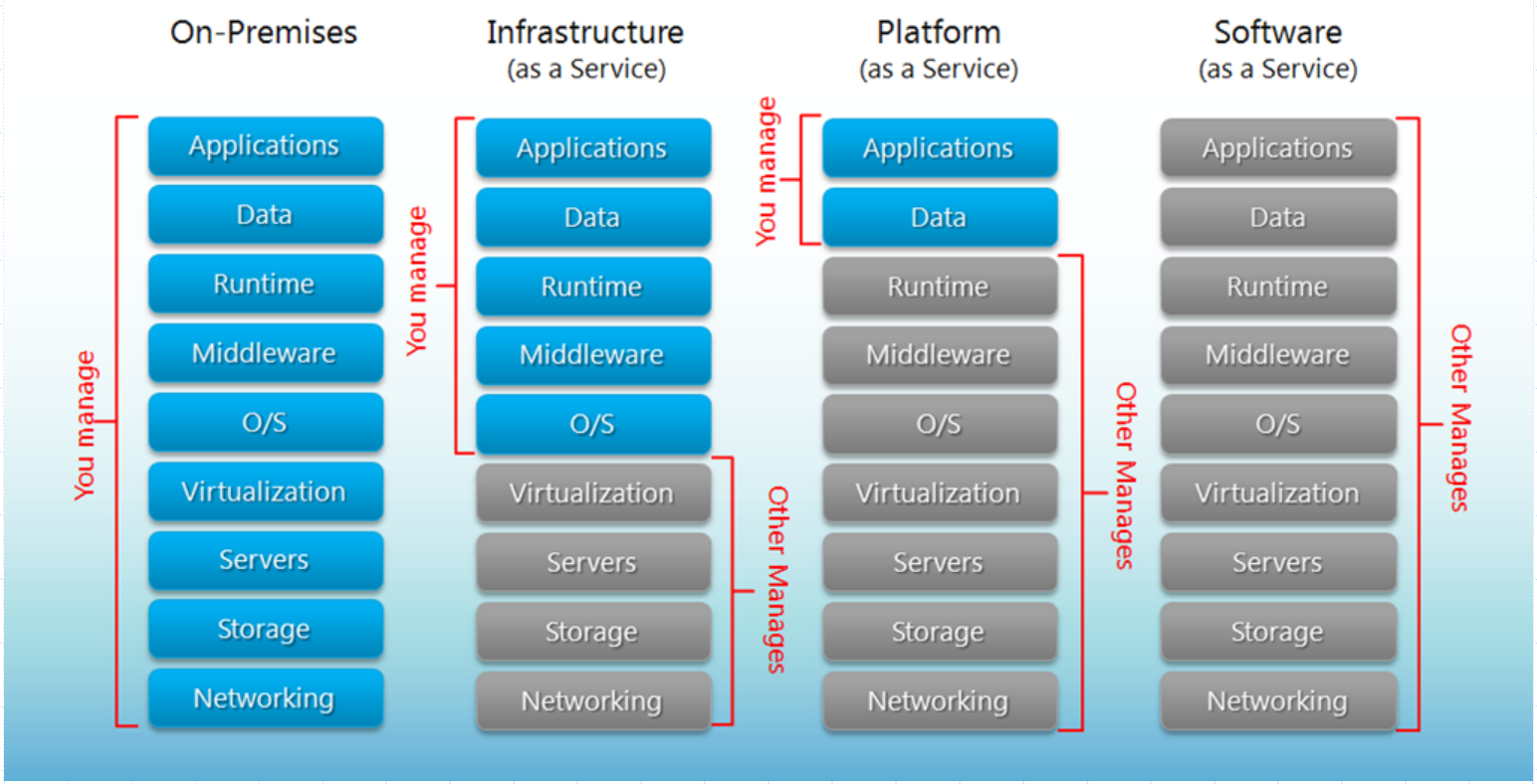
## Cloud Models




Materials adopted from: http://www.oracle.com/technetwork/articles/cloudcomp/jimerson-ha-arch-cloud-1669855.html

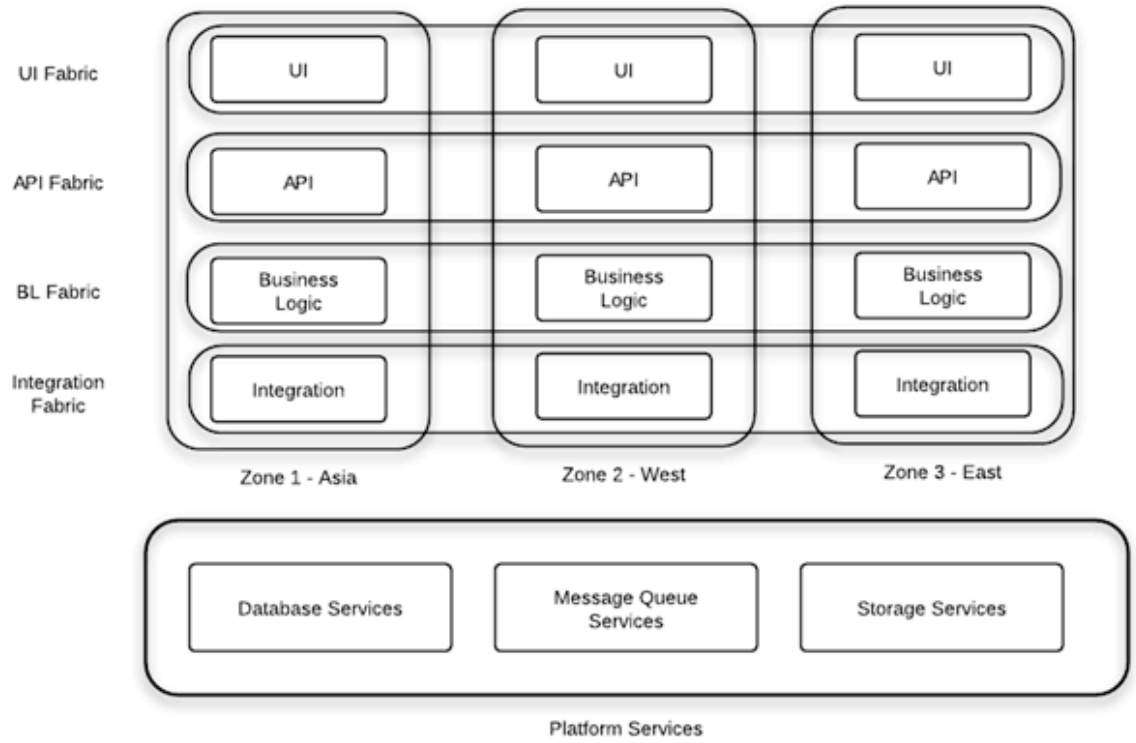
# Course Topics

## Cloud Architectures Types of Cloud Topologies



# Course Topics

## Cloud Models




Materials adopted from: http://www.oracle.com/technetwork/articles/cloudcomp/jimerson-ha-arch-cloud-1669855.html

# Course Topics

## Cloud Models – Architecture Considerations

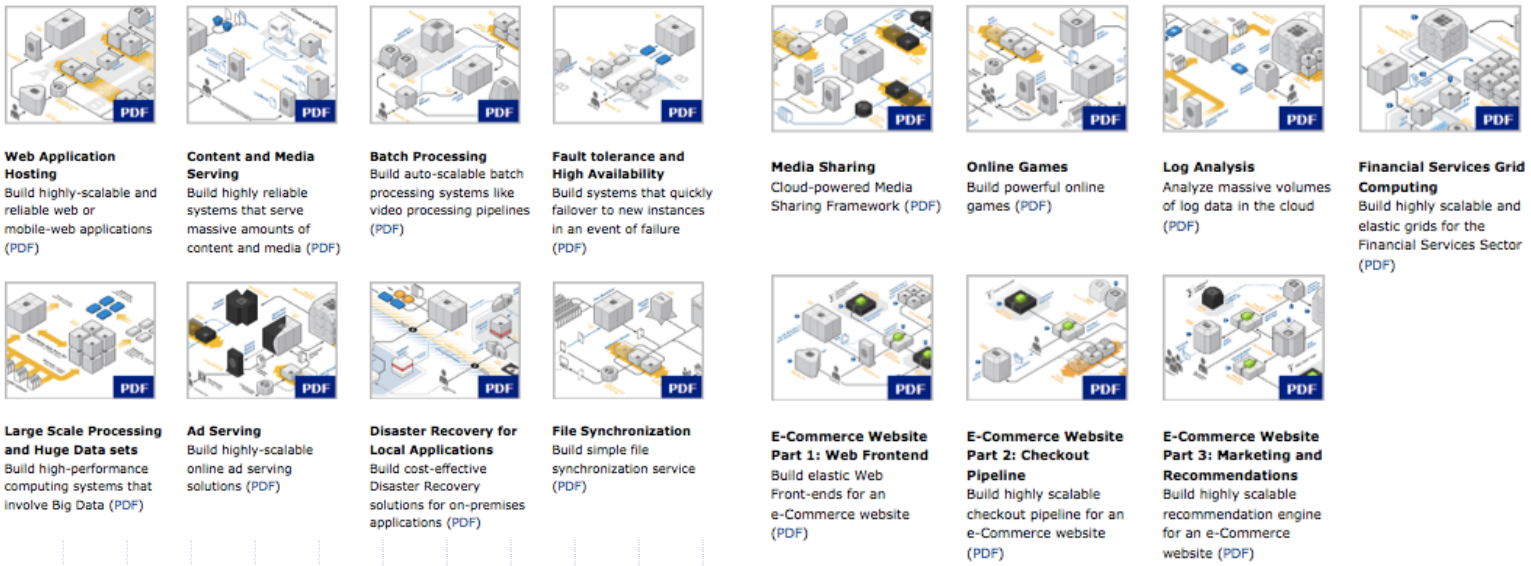
- Run across multiple zones
- Distributed data management
- Multi-zone, possible global data replication
- Event driven applications
- Client caching and offline access
- Graceful degradation in the face of failures
- Asynchronous Messaging
- Atomic and Idempotent services

Materials adopted from: http://www.oracle.com/technetwork/articles/cloudcomp/jimerson-ha-arch-cloud-1669855.html

# Course Topics

## Example – AWS Patterns

http://aws.amazon.com/architecture/



**Web Application Hosting**
Build highly-scalable and reliable web or mobile-web applications (PDF)

**Content and Media Serving**
Build highly reliable systems that serve massive amounts of content and media (PDF)

**Batch Processing**
Build auto-scalable batch processing systems like video processing pipelines (PDF)

**Fault tolerance and High Availability**
Build systems that quickly failover to new instances in an event of failure (PDF)

**Media Sharing**
Cloud-powered Media Sharing Framework (PDF)

**Online Games**
Build powerful online games (PDF)

**Log Analysis**
Analyze massive volumes of log data in the cloud (PDF)

**Financial Services Grid Computing**
Build highly scalable and elastic grids for the Financial Services Sector (PDF)

**Large Scale Processing and Huge Data sets**
Build high-performance computing systems that involve Big Data (PDF)

**Ad Serving**
Build highly-scalable online ad serving solutions (PDF)

**Disaster Recovery for Local Applications**
Build cost-effective Disaster Recovery solutions for on-premises applications (PDF)

**File Synchronization**
Build simple file synchronization service (PDF)

**E-Commerce Website Part 1: Web Frontend**
Build elastic Web Front-ends for an e-Commerce website (PDF)

**E-Commerce Website Part 2: Checkout Pipeline**
Build highly scalable checkout pipeline for an e-Commerce website (PDF)

**E-Commerce Website Part 3: Marketing and Recommendations**
Build highly scalable recommendation engine for an e-Commerce website (PDF)