Distributed Objects and Middleware

Spring Operating System

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* Spring Operating System Introduction
    - Spring became Sun's Solaris operating system
    - Created by Yousef Khalidi as a grad student at Georgia Tech
        + "Clouds" distributed operating system
* How to Innovate OS
    - Brand new OS or better implementation of known OS?
    - Marketplace needs
        + Large complex server software
        + Legacy applications running on existing OS, so industry tends to
        innovate rather than reinvent
    - Intel inside: External interfaces stay the same, but there is
    innovation in the microarchitecture
    - Sun took this approach ("Unix inside")
        + Externally looked like Unix, but provide new APIs for new features
        + Preserve everything good in standard OS, but also provide the
        capability for extensibility and flexibility
* Object based vs Procedural Design
    - Procedural: Some shared state, some private state. Subsystems interact
    through procedure calls
        + State is all over the place (monolithic systems)
    - Object-based: Objects contain the state entirely within the object
        + Methods within the object to manipulate the state of the object
        + Strong interfaces that completely isolate discrete objects
        + Performance consideration: Border crossings across logical
        protection domains can be slow
        + Tornado also took an object-based approach to building OS kernels
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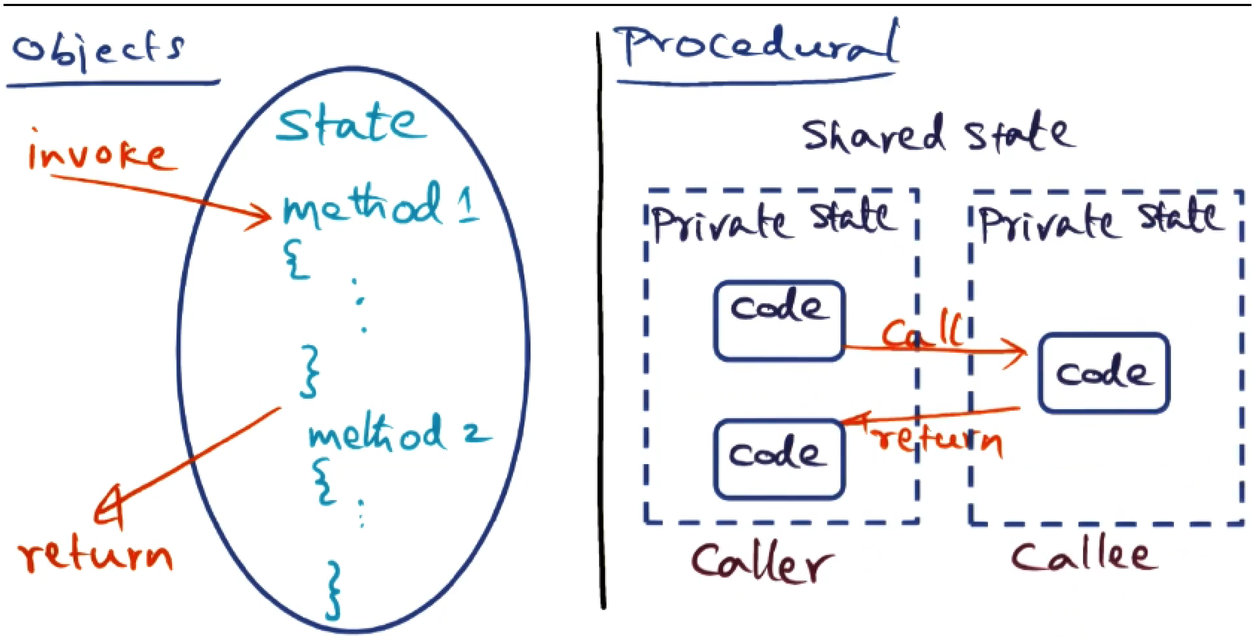

Object-based vs Procedural Design

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* Spring Approach
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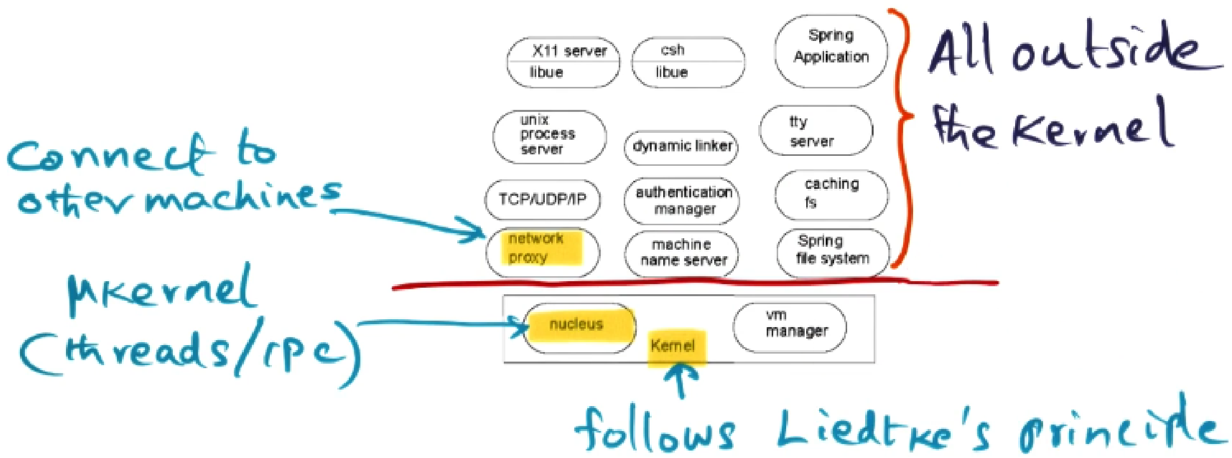
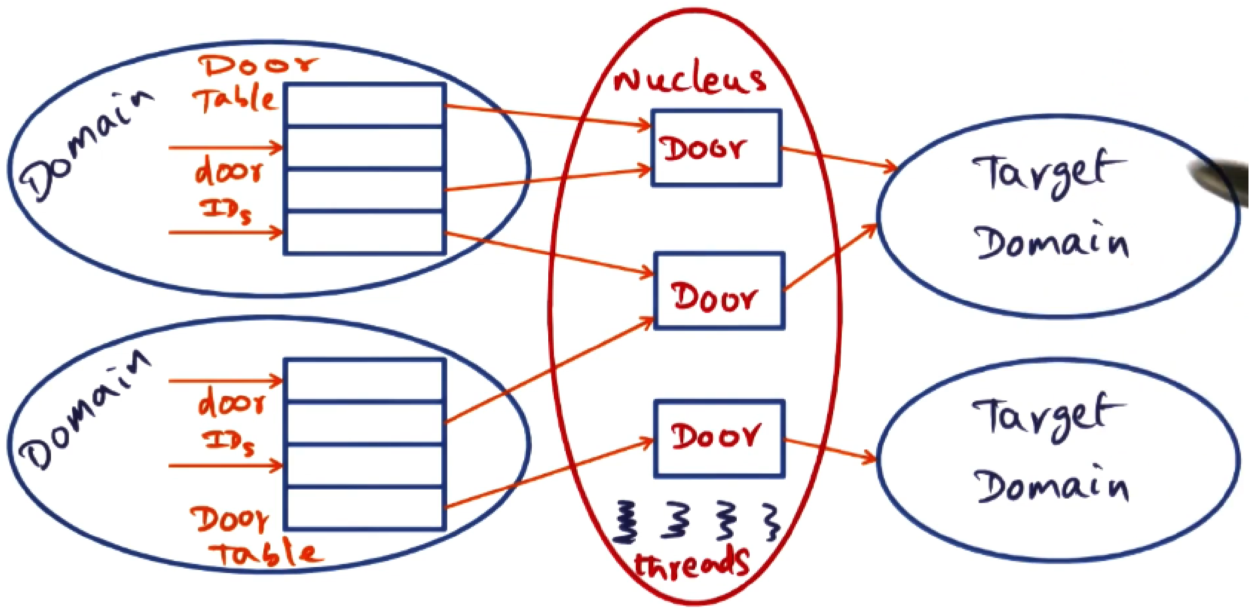
- Strong interfaces: Only thing exposed outside the subsystem is what services are provided by that subsystem, but not how
    + "How" can be changed at any given time
    + Leads to object-orientation
    + Open, flexible, and extensible
    + Don't want to be tied to a specific language
    + Sun used Interface Definition Language (IDL) to expose interfaces
- Extensibility leads to microkernel-based approach
    + Nucleus provides abstractions of threads and IPC
    + Virtual memory manager provides memory management
    + Microkernel is composed of these two systems
    + Follows Liedtke's design principles
- Network proxy is interface that allows connection across machines



Spring Design

* Nucleus Microkernel of Spring
    - "Microkernel" of Spring
    - Only manages threads and IPC
    - Domain: Similar to a Unix process (address space)
    - Door: Provides access to a domain (entry points for target domain)
        + Analogy: Using fopen provides a file descriptor to access a file
        + Same idea, but for processes
    - Nucleus is involved in every door call
        + Nucleus validates that the domain has the permission to use the door handle
        + Client thread is deactivated and the thread is allocated to the target domain so it can execute the invocation
        + Client thread is reactivated once the target domain is complete
        + This makes cross-domain calls very fast
    - Kernel is composition of Nucleus plus memory manager



Nucleus Design

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* Object Invocation Across the Network
    - Object invocation across the network is extended using network proxies
        + Proxies can potentially employ different protocols (LAN, WAN, etc)
    - Key property of building network operating system
    - Proxies are invisible to client and server (unaware if they are on the
    same machine or different machines)
    - Steps for invoking an object across the network
        1. Instantiate a proxy on the server node and establish a door for
        communication between proxy A and the server domain
        2. Proxy A exports a network handle embedding door X to Nucleus A
        3. Proxy B has door Y to connect to Nucleus B
        4. Proxy B uses net handle to connect to nuclei
        5. When the client wants to make an invocation on the server domain,
        it accesses proxy B which communicates with proxy A with door Y which
        communicates with the server domain through door X
    - Proxies are outside the kernel
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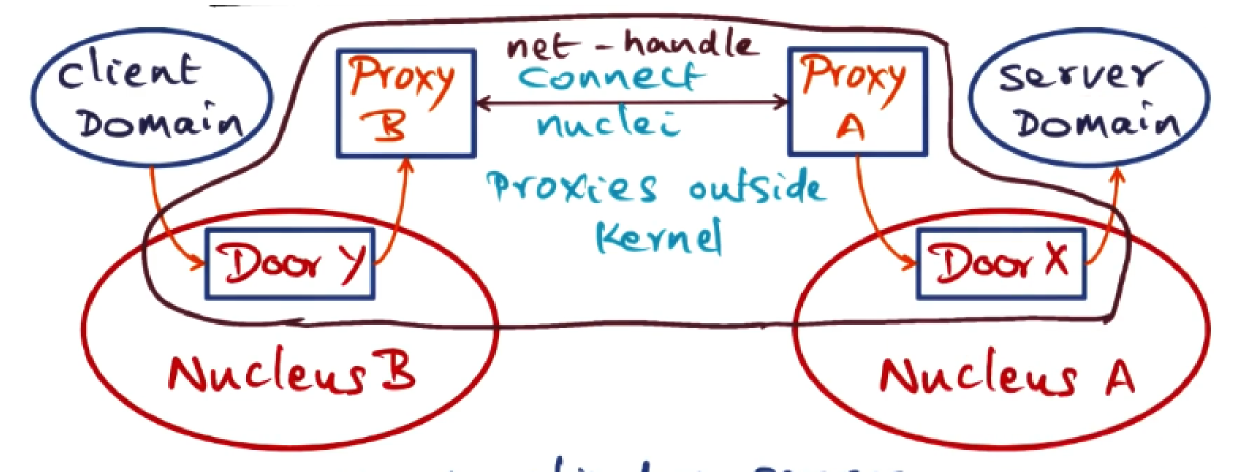

Nucleus Design

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* Secure Object Invocation
    - Server object might need to provide different privelege levels for
    different clients
        + File server might provide different access protections
    - Spring provides this through a "front object"
    - Client domain can only access front object which arbitrates access to
    the underlying object through the access control list (ACL)
    - Policies for accessing underlying object can be implemented through
    different instances of the front object
    - Client can also limit access to its objects
        + Client has full access to file system
        + Client passes a one-time reference to the printing object, which
        passes it to the file system
    - Network accesses are fast and secure due to this implementation
    - External Unix interfaces are identical, but Spring has modified the
    underlying implementation using object technology
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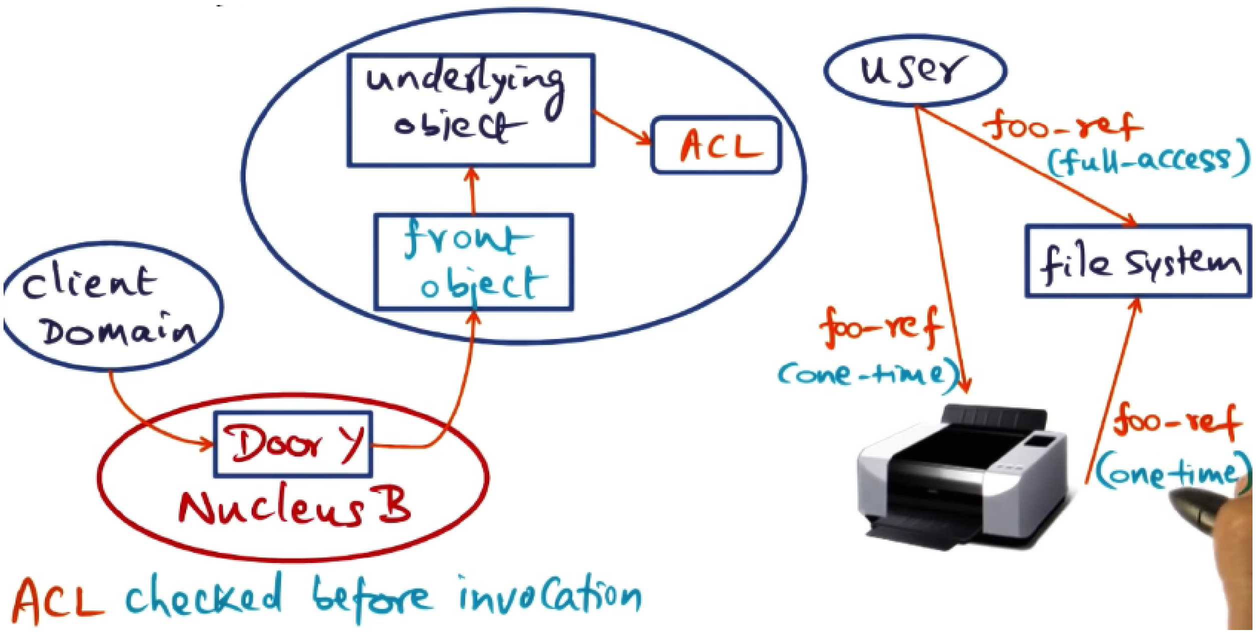

Secure Object Invocation

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* Abstractions
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Feature	Nucleus	Liedtke
Threads	X	X
IPC	X	X
Add Space		X

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* Virtual Memory Management in Spring
    - Linear address space broken into regions (sets of pages)
    - Memory objects: Abstraction that may map a portion of the address
    space to files, swap space, etc. (backing entities)
        + Multiple memory objects can map to the same backing entity
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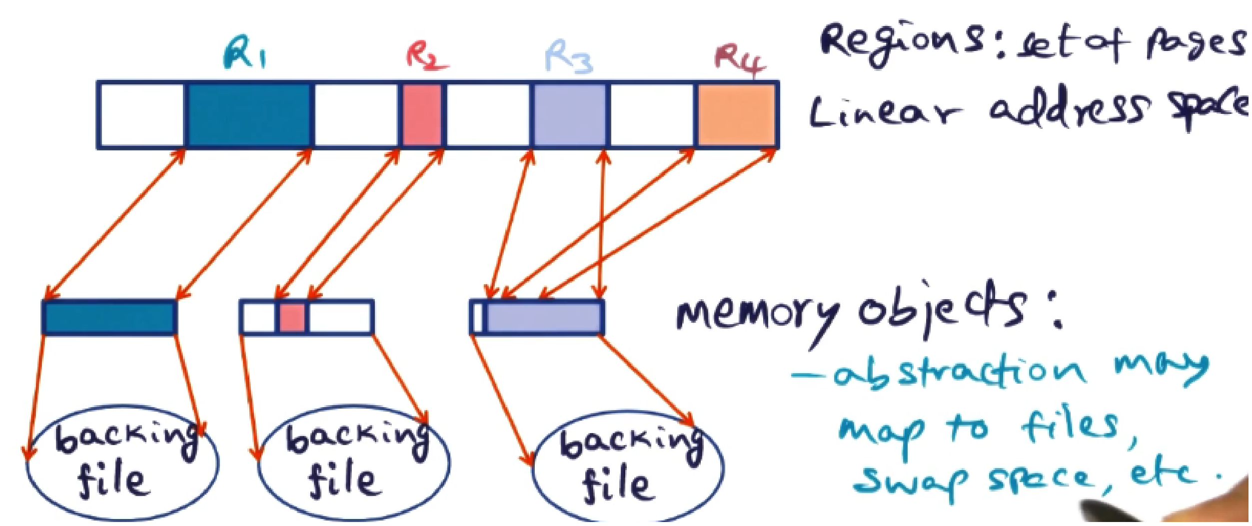

Memory Management in Spring

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* Memory Object Specific Paging
    - Memory object: Virtual memory representation
    - Pager object: Establishes connection between virtual memory and
    physical memory
        + Creates a cached objection representation in DRAM with the virtual
        memory management object
        + Address space manager can make any number of mappings
        + No single paging mechanism used for all memory objects
    - Cache object: Physical memory representation
    - If two VMMs have mappings to the same memory object, it is the
    responsibility of the pager object to coordinate the coherence of the
    cached objects, if this is needed
    - In a single linear address space, you can have multiple pager objects
    managing different regions of the same address space
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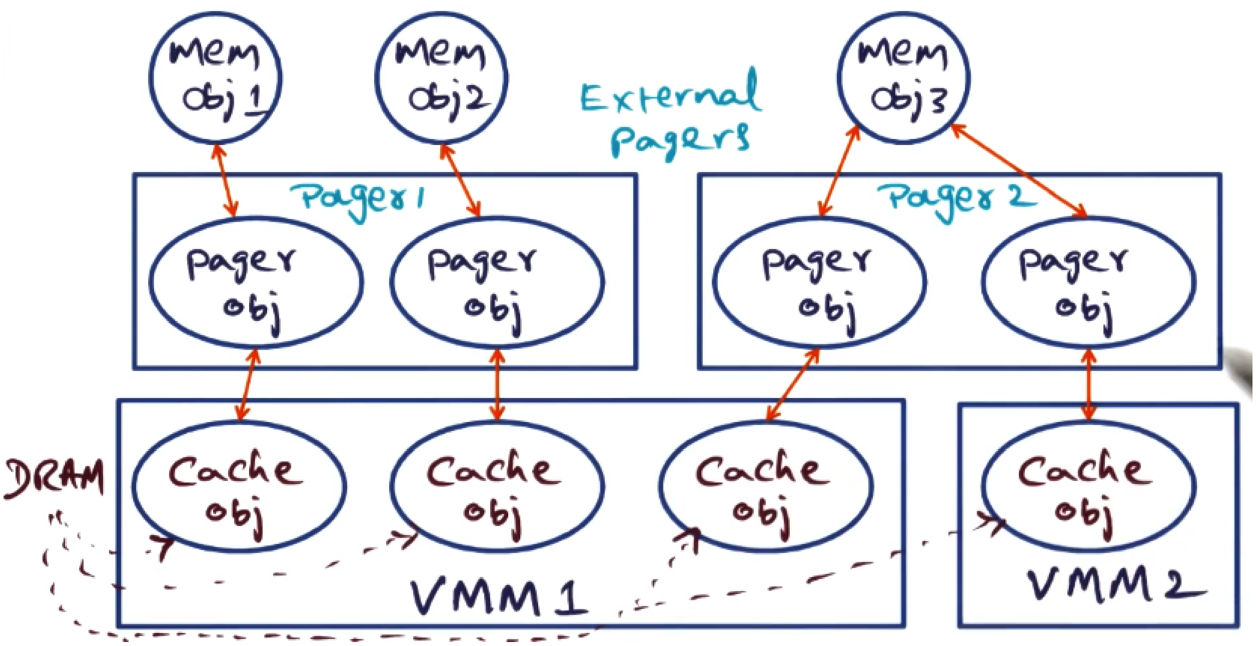

Paging in Spring

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* Spring System Summary
    - Object oriented kernel
        + Nucleus: Threads and IPC
        + Microkernel: Nucleus and address space
        + Door and Doot table: Basis for cross-domain calls
        + Object invocation and cross machine calls
        + Virtual memory management: Address space object, memory object,
        external pages, cached objects
    - Tornado also used object technology, but Tornado used clustered
    objects as a representation for implementing kernel services
    - In Spring, object technology permeates the entire design. It's a
    structuring mechanism as opposed to only an optimization
* Dynamic Client Server Relationship
    - In Spring, clients and servers of the network OS can be on the same
    machine or different machines
        + The client/server interaction should be freed from their physical
        location
    - Client requests are routed to different servers depending on physical
    proximity and current load
        + Similar to how Google works today
    - Server can be cached or replicated
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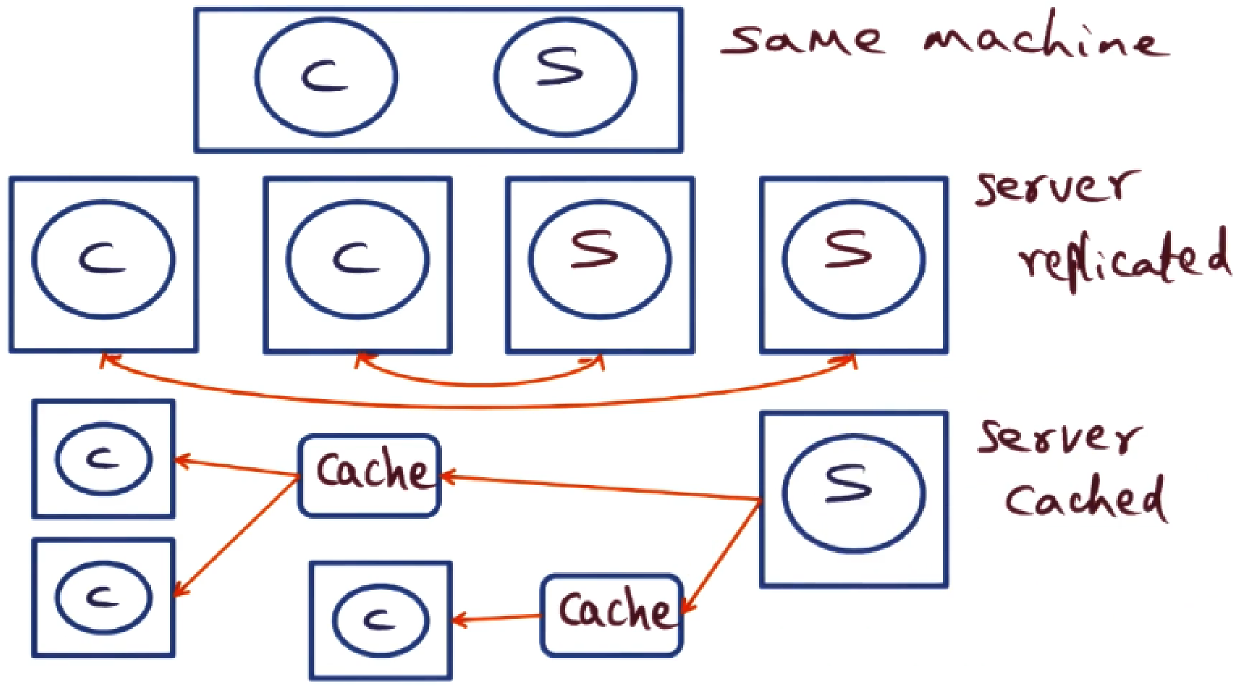

Dynamic Client Server Relationship in Spring

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* Subcontract
    - Subcontracts make dynamic relationship between client and server
    possible
        + Analogous to offloading work to a third party
    - Contract between client and server established through IDL
    - Subcontract is the interface provided for realizing the IDL contract
    - Client doesn't know or care if the server is a singleton, replicated
    - Cient side stub generation is simplified
    - Subcontract responsible for details
    - Can seamlessly add functionality to existing services using the
    subcontract interface
    - Abstracts the underlying server implementation from the client
* Subcontract Interface for Stubs
    - Subcontract specifies if server is on same machine, different machine,
    different processor on the same machine, etc
    - Three mechanisms
        1. Marshaling/unmarshaling for arguments: Subcontract marshals
        appropriately based on where the server is, abstracted from client
        2. On client
            + Invoke: Calls function on server
        3. On server
            + Create: Makes new service
            + Revoke: Remove a service
            + Process: Ready to process invocation requests
* Spring Operating System Conclusion
    - Sun was still building Unix boxes, but had completely revolutionized
    the structure of the network operating system through object technology
    - This formed the basis for Java RMI
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Java RMI

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* Java History
    - Invented by James Gosling at Sun
    - Originally called Oak, later Java
    - Originally invented for use on embedded devices in the early 1990s
    - Intended for use with PDAs, then to set-top boxes, and then onto the
    Internet for powering E-commerce
* Java Distributed Object Model
    - Much of the heavy lifting involved in creating a client/server system
    with RPC (marshaling, unmarshaling, network interface) are subsumed by
    the Java distributed object runtime
    - Remote object: Objects that are accessible from different address
    spaces
    - Remote interface: Declarations for methods in a remote object
    - Failure semantics: Clients deal with RMI exceptions
    - Similarities/differences to local objects
        + Object references can be parameters
        + Parameters only passed as value/result
        + In Java, an object can be passed to a method by reference and
        modified. A remote object cannot be.
* Bank Account Example
    - Server API
        + Deposit
        + Withdraw
        + Balance
     - How best to implement using Java?
* Reuse of Local Implementation
    - Developer uses Java's remote interace to publish an existing local
    interface
    - The developer has to do the heavy lifting
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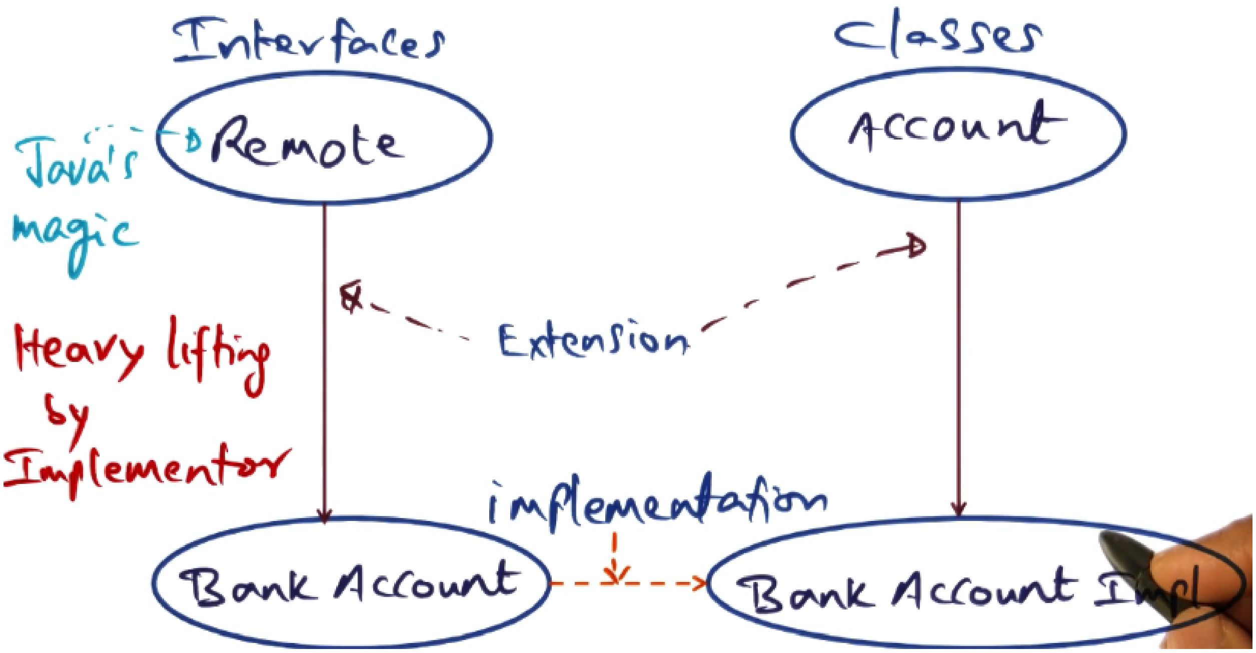

Using Local Implementation of Bank Account

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* Reuse of Remote
    - Developer writes the local object and uses the remote interface,
    identical to the local example
    - The bank account implementation is derived from the Java built-in
    classes for remote object and remote server, not the Account superclass
    - This results in the heavy lifting needed to make the bank account
    object visible to network clients is done by the Java runtime
    - The remote implementation is preferable because the Java RMI is doing
    all of the heavy lifting
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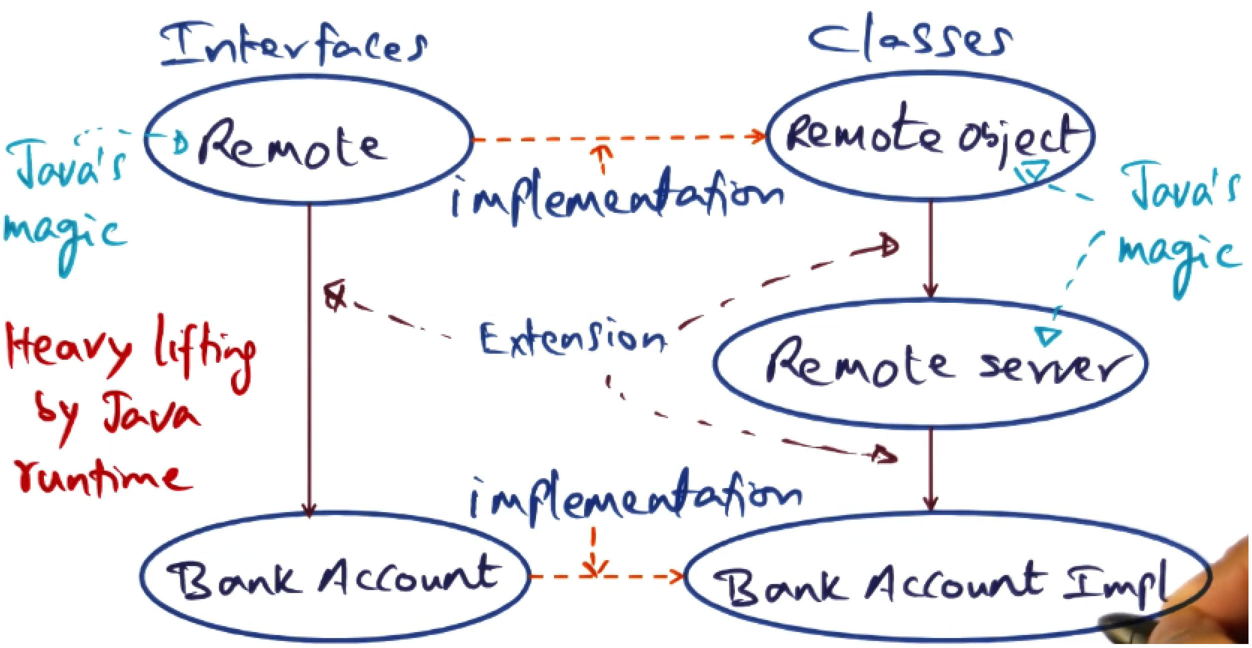

Using Remote Implementation of Bank Account

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* Java RMI at Work (Server)
    - BankAccount acct = new BankAccountImpl();
    - URL url = new URL("mywebaddress");
    - Java.rmi.Naming.bind(url, acct);
* Java RMI at Work (Client)
    - BankAccount acct = Java.rmi.Naming.lookup(url);
    - float balance;
    - acct.depost($);
    - acct.withdraw($);
    - balance = acct.balance();
    - Failures will throw remote exceptions back to the client
        + Client will not know where exactly the server failed
* Java RMI Implementation (Remote Reference Layer)
    - Remote Reference Layer (RRL):
    - Client side stub initiates an RMI call using the RRL
        + All of the marshaling/unmarshaling is handled within the RRL
    - Skeleton exists to unmarshal arguments from the client using the RRL
        + Makes the call up to the server, marshals the result, and goes
        through the RRL to send it
    - There could be several instances of the server; the RRL handles where
    the server is, is it replicated, how it's handling requests, etc
    - Derived from the subcontract mechanism from Spring
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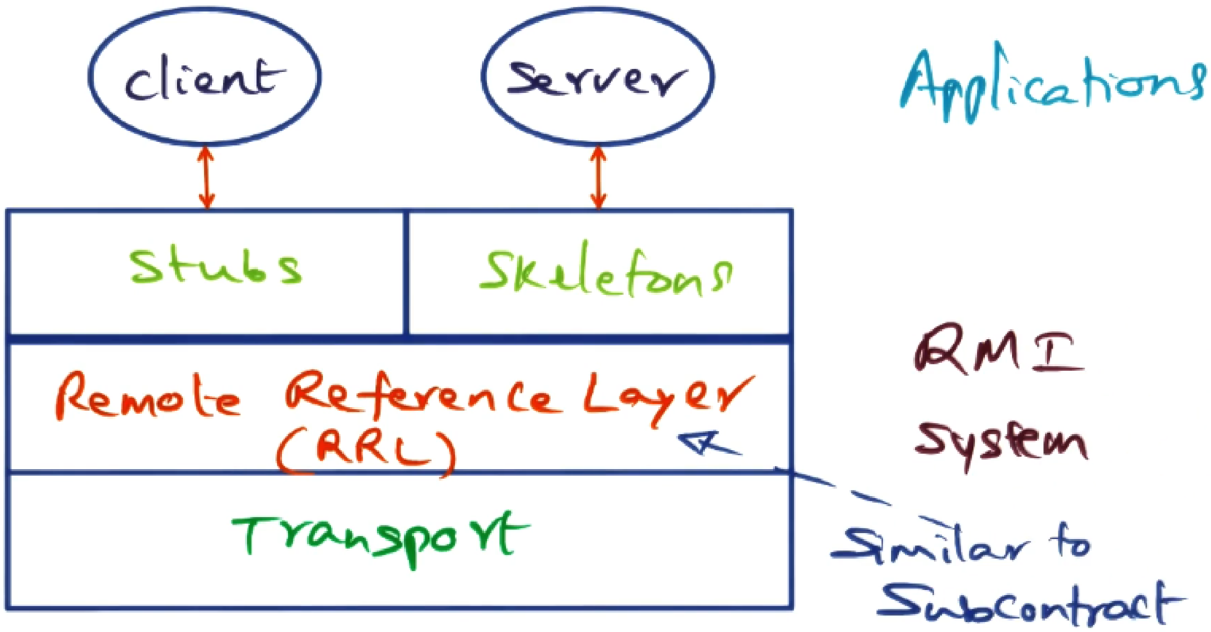

Java Remote Reference Layer

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* RMI Implementation Transport
    - Provides the following connections:
        + Endpoint
        + Transport
        + Channel
        + Connection
    - Endpoint: Protection domain (Java VM) with a table of remote objects
    it can access
        + Server/client can exist within this sandbox
    - Connection Management
        + Setup, teardown, listen
        + Liveness monitoring
        + Choice of transport
    - Transport: Listens on a channel
        + When an invocation arrives, the transport is responsible for
        identifying the dispatcher on the domain (endpoint)
    - Channel: Medium over which communication occurs
        + TCP or UDP
    - RRL decides the right transport to use depending on the location of
    the two endpoints
* Java RMI Conclusion
    - When the time is right, ideas from research form the basis for useful
    tools in industry
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Enterprise Java Beans

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* Enterprise Java Beans Introduction
    - How do we structure the software for a large scale distributed service?
    - Java bean: Many Java objects in a bundle that can be passed easily
    between applications
* Inter Enterprise View
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- Intra Enterprise View: Many services and servers interconnected
    - Inter Enterprise View: Service may not be serviced by a single entity. Instead, many enterprises work together
        + Supply chain model
    - Enterprise challenges
        + Interoperability
        + Interface compatibility
        + System evolution
        + Scalability
        + Reliability
* Enterprise Java Beans Example
    - Giant scale services: Airline reservation, Gmail, web surfing as opposed to a local file service
    - There are many common features across services, such as a shopping cart
    - Don't want to reinvent the service every time
        + Object technology provides the ability to reuse components
* N Tier Applications
    - Presentation layer: Paints the screen on browser
    - Application logic corresponding to what the service provides
    - Business logic corresponding to pricing, etc.
    - Database layer to access information for application and business logic
    - Issues in distributed programs:
        + Persistence
        + Transactions
        + Caching
        + Clustering
        + Security
    - Reduce network communication (latency), reduce security risks, improve concurrency in responding to individual requests
        + "Embarrassingly parallelizable" application
    - Desire to reuse components of application logic as much as possible
* Structuring N Tier Applications
    - Using JEE framework for structuring applications
    - Container: Protection domain, typically in the form of a JVM
        1. Client: Interact with browser on end client
        2. Applet: Interact with browser on end client
        3. Web: Presentation logic
        4. EJB: Business logic (Enterprise Java Beans)
    - Bean: Unit of reuse (bundle of Java objects, such as shopping cart)
        1. Entity: Row of a database (persistent objects with primary keys)
            + Persistence can be built into the bean or container
        2. Session: Associated with a client and temporal window (session)
            + Could be stateful or stateless
        3. Message: Useful for asynchronous behavior
    - Containers host beans
    - Fine-grained beans provides greater opportunity for increasing concurrency of requests
        + Makes business logic more complex
* Design Alternative (Coarse-grain Session Beans)
    - One session bean responsible for the specific needs of the client it is servicing
        + Handles accesses to database
        + Multiple sessions within EJB depending on number of clients
        + Business logic is confined to the corporate network since it's

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    within the EJB container, not the web container
  - Pros:
    + Minimal container services
    + Business logic not exposed
  - Cons:
    + App structure akin to monolithic kernel
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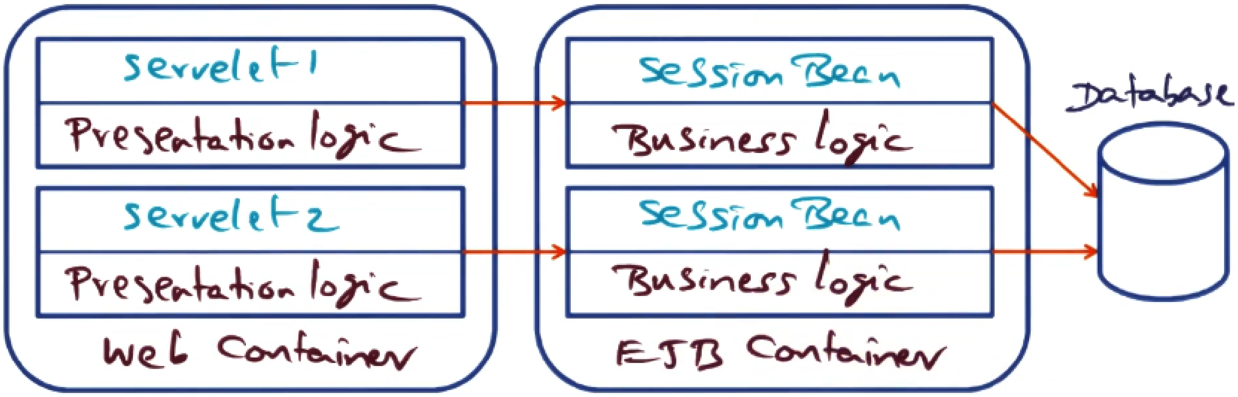

Coarse-grain Session Beans

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* Design Alternative (Data Access Object)
  - Want parallelism in accessing database that coarse-grained doesn't
  provide
    + Database accesses are slow due to disk and network speeds
    + Reduce latency resulting from this slowness
  - Presentation and business logic are contained within the client applet
  - Database accesses are handle by entity beans in EJB container
    + Entity bean can be one or many rows of database
    + Reduces time for database access by exploiting concurrency
    + An entity bean could cluster requests and amortize database access
    if multiple requests are querying the same row
  - Persistence is required for data access object
    + Bean managed persistence
    + Container managed persistence
  - Pros
    + Concurrency
  - Cons
    + Business logic exposed
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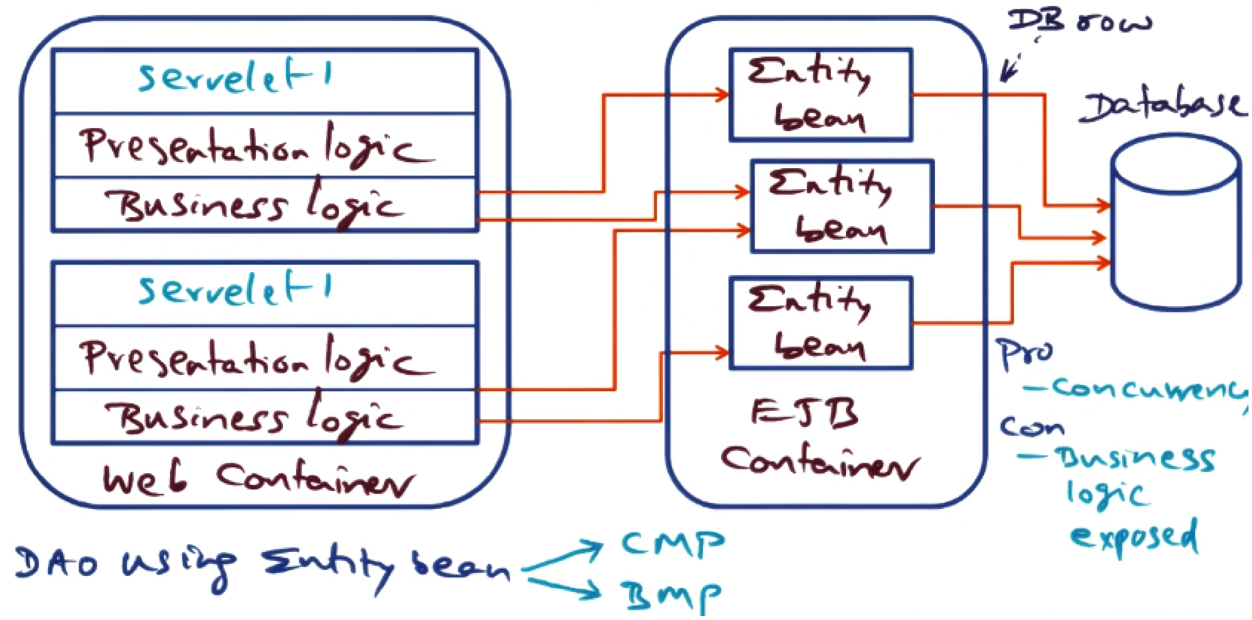
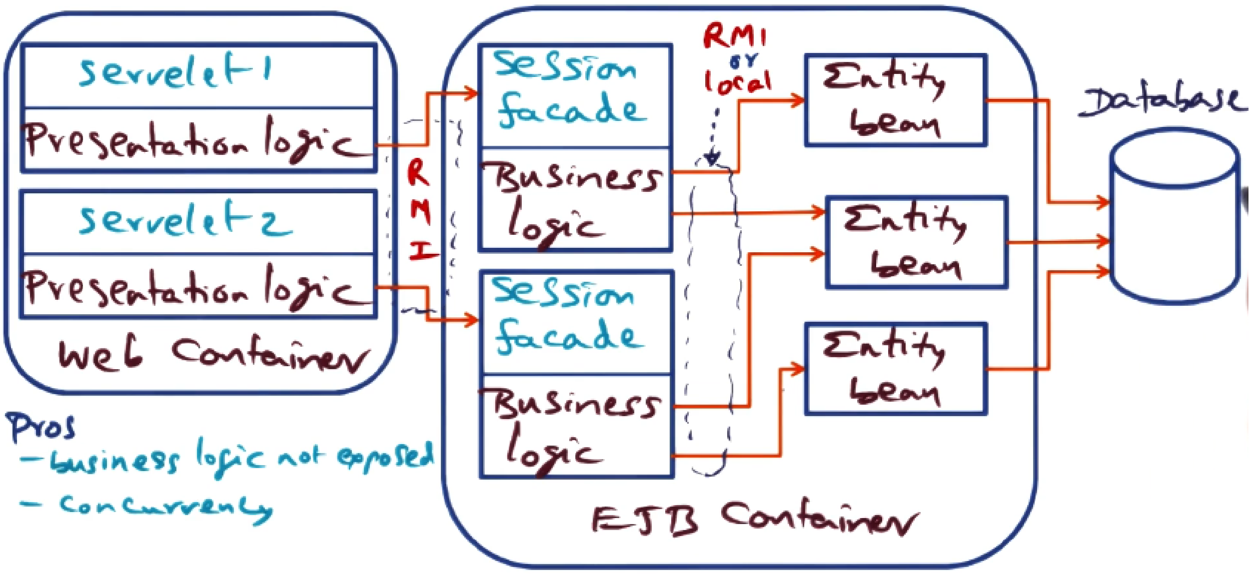


Data Access Object

* Design Alternative (Session Bean with Entity Bean)
    - Use both session and entity beans to achieve parallelism without exposing the business logic
    - Session facade: Worries about data access needs of associated business logic
    - Can farm parallel requests to multiple entity beans
    - Data access objects still use entity beans
    - Web container uses RMI to communicate with the business logic
    - Session facade communicates with entity bean with RMI or locally
        + Local communication eliminates the overhead of the network
    - Pros
        + Business logic not exposed
        + Concurrency
    - Cons
        + Additional network access, but can be mitigated by colocating session facade with entity bean



Session and Entity Bean

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* Enterprise Java Beans Conclusion
    - EJB allows developers to develop business logic without being
    concerned with security and network interfaces
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