Middleware and Distributed Systems

Patterns

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Broker

- Buschmann et.al.: A System of Patterns
- Architectural Pattern
- six components: clients, servers, brokers, bridges, client-side proxies, server-side proxies
- responsibility of broker: (un)register servers, offer APIs, transfer messages, error recovery, interoperate with other brokers through bridges, locate servers
- CORBA: What is the ORB?

ORB: Connection Management

- Network transparency: clients should not need to explicitly establish and close network connections
- Implicit binding: ORB creates connection on first request
- Connection reuse: multiple requests to same server object should use the same TCP connection
- Connection multiplexing: multiple stub objects referring to remote objects of the same server should reuse
- Connection re-establishment of broken connections
- Location forwarding: invoking a request might result in a location-forward error
- Connection shutdown: "idle" connections should be closed

Connection Shutdown

- Problem: Either client or server may need to close a connection to reclaim OS resources
- Client can shutdown at any time, but shouldn't if it still waits for a response (connection won't be idle)
- Server should not shutdown while processing requests
    - Problem: what if requests are still in transit?
    - CloseConnection: Server indicates that no request is known at the time of closing
        - Client can abort all requests with COMPLETED_NO, or retry

Proxy

- Gamma et.al.: Design Patterns
- Control access to an object using another proxy object
- RPC: Proxy delegates operation to remote object
    - buffer management
    - marshaling
    - access to connection management
    - blocking operations

Proxy: Marshaling

- Issues:
  - Avoid copying
  - Deal with alignment
  - Deal with endianness
  - Time vs. size
- Demo: Fnorb, ORBit, Mico

Adapter

- Gamma et.al.
- Adjust interface of a class to another one, expected by the client
- CORBA: Object Adapter (OA) - is it an adapter?

Adapter: Dispatching

- Skeleton: Adapter between ORB and object implementation (servant)
- Unmarshaling of parameters
  - CORBA: can only unmarshal parameters once operation name is known
- Invocation of method
  - Implementation of interface by inheritance from skeleton: interface methods are abstract in skeleton class
- Demo: Fnorb, ORBit, Mico

Portable Object Adapter

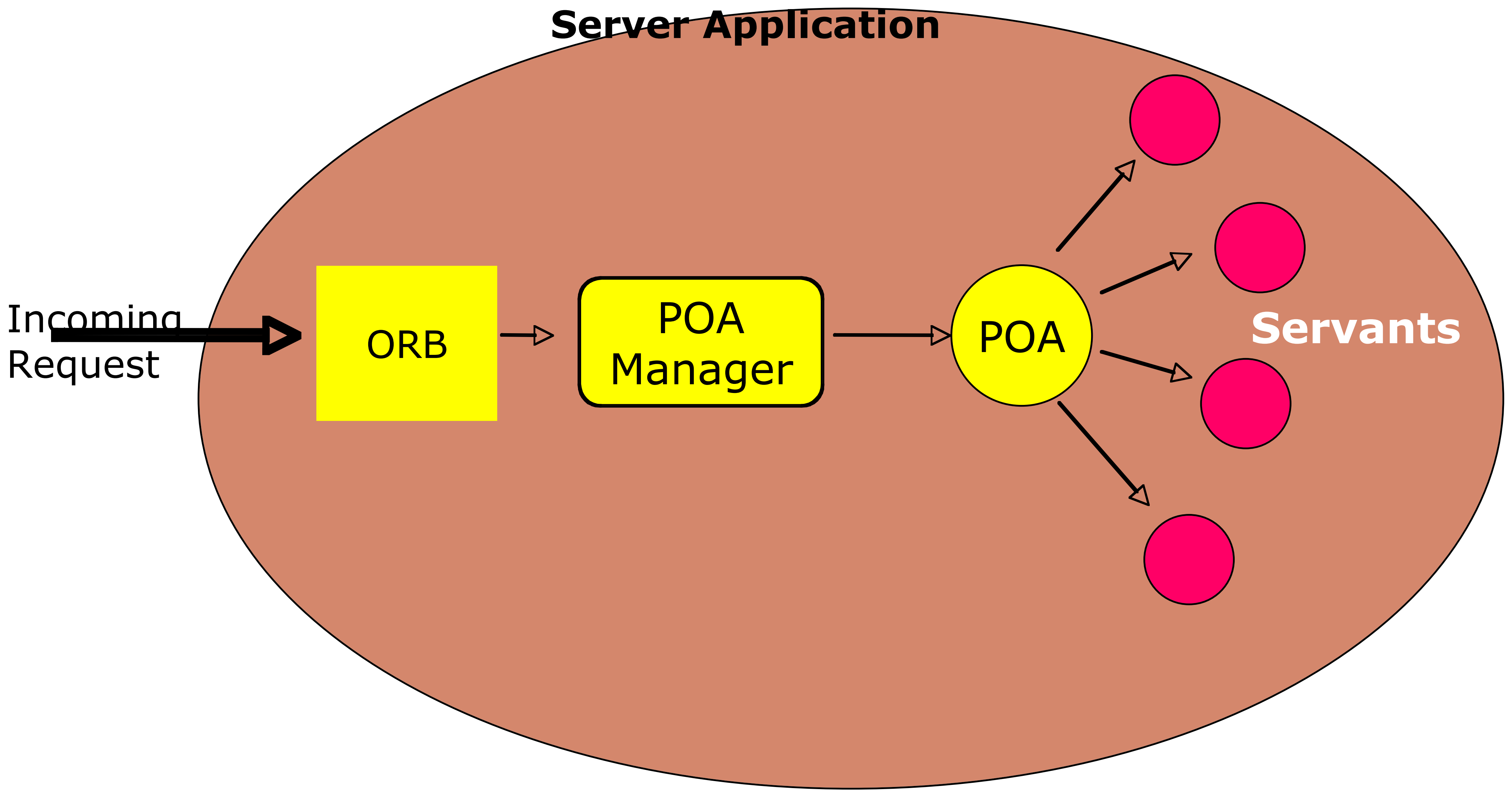
Replaces Basic Object Adapter (BOA) of CORBA 2.1. It specifies details of object activation (broker pattern), and allows, in a flexible way

- to assign object references to servants
- to transparently „activate“ of servants
- to assign „policies“ to servants

The definition of the POA interfaces itself is in IDL:

- POA interfaces are „local“ interfaces
- C++ implementation objects (servants) have the IDL type <u>native</u>
  - Implementations inherit from specified base class (adapter pattern)

Flow of Incoming Requests



POA Features

- Provide unique programming interface for servant development across implementations and languages
- Provide support for transparent activation of objects
- Allow a single servant to support multiple object identities simultaneously
- Allow multiple distinct instances of the POA to exist in one server
- Provide support for transient objects with minimal programming effort and overhead
- Provide support for implicit activation of servants with POA-allocated object ids
- Allow object implementations to be maximally responsible for an objects behaviour.
- Provide an extensible mechanism for associating policy information with objects implemented in a POA.
- Allow programmers to construct object implementations that inherit from static skeleton classes, generated by IDL compilers, or a DSI implementation

POA Architecture

- Servant: Implementation object, determines run-time semantics of one or more CORBA objects
- ObjectID: unique identification of object within a POA (type: sequence<octet>)
- Active Object Map: table associating ObjectID values and servants
- Incarnate: The action of creating or specifying a servant for a given ObjectID
- Etherealize: The action of detaching a servant from an ObjectID
- Default Servant: Servant that is associated with all ObjectID values not mentioned in the active object map

POA Functions

- Each POA defines a namespace for servants.
- All servants within a POA have the same implementation characteristics (policies). The Root POA has a standardized set of policies.
- Each (active) servant is associated to a POA.
- POAs determine the relevant servant upon incoming requests, and invoke the requested operation at the servant.

Functions of the POA Manager

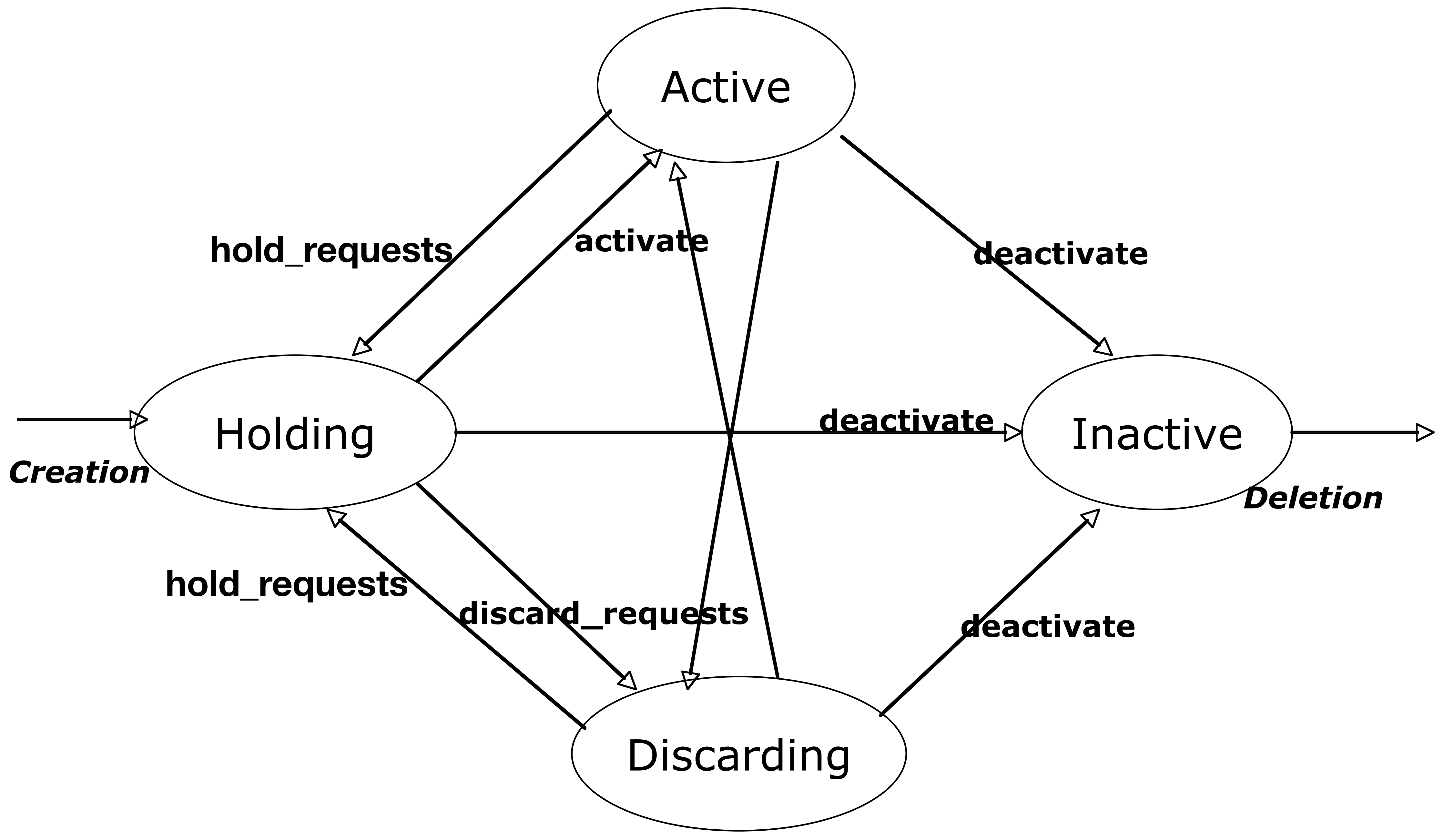
Each POA is assigned a POA manager, which is set when the POA is created.

The POA manager controls the flow of requests for one or multiple POAs

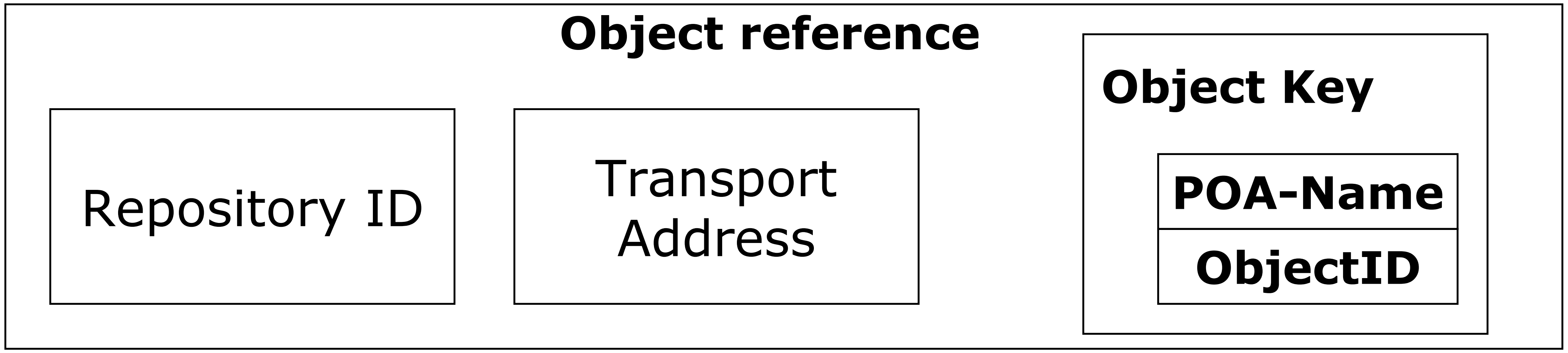
The POA manager always has one of the following states:

- Active: Requests are processed
- Holding: Reqests are saved
- Discarding: Requests are refused with the TRANSIENT exception
- Inactive: Requests are rejected, connections are shut down

POA Manager State Transitions



Structure of an Object Reference



Object Incarnation

- Association of an object reference with a servant
- Two-way association:
  - Given the servant, create an object reference: Activation
  - Given the object reference, find a servant: Incarnation
- POA interface provides operations for activation; policies decide what modes of activation and incarnation are supported
- C++ mapping adds _this

```
MyXImpl servant(17);
MX_var object = servant._this();
```

- In the default case (POA of servant is RootPOA), _this does:
  - Create an object in the RootPOA (generating a transient ObjectID)
  - Associate the ObjectID with the servant in the active object map of the root POA
  - Create an object reference for this object
  - Return the object reference

Initializing the Server-Side ORB Runtime

- Initialize the ORB: CORBA::ORB_init(/* ... */);
- Get a reference to the RootPOA:
  orb->resolve_initial_references("RootPOA");
- Narrow the RootPOA to PortableServer::POA
- Obtain the servant manager of the root POA: poa->the_POAManager();
- Activate the servant manager: poa->activate();
- Create a servant instance
- Activate the servant: servant->_this();
- Start the ORB mainloop: orb->run();

POA Creation

- Standard policies
  - Thread policy: ORB_CTRL_MODEL
  - Lifespan policy: TRANSIENT
  - Object Id Uniqueness Policy: UNIQUE_ID
  - Id Assignment Policy: SYSTEM_ID
  - Servant Retention Policy: RETAIN
  - Request Processing Policy: USE_ACTIVE_OBJECT_MAP_ONLY
- Used for RootPOA, and as the default for new POAs

Reference Creation

- Create reference not associated with a servant:
  - create_reference, create_reference_with_id
- Associate a servant with an object reference
  - activate_object, activate_object_with_id
  - Use id_to_reference, servant_to_reference to obtain object reference
- Perform implicit activation
  - according to language mapping
  - Use servant_to_reference

Object Activation

- Reference may be associated with a servant (active) or not (inactive)
- RETAIN policy: activated objects are added to active object map
  - Objects get explicitly activated through activate_object[_with_id]
  - Objects get automatically activated through servant manager added by set_servant_manager
  - USE_DEFAULT_SERVANT policy: Objects get automatically associated with the default servant
- NON_RETAIN
  - Objects active only during the request
  - Activation occurs through the servant manager, or with the default servant
- If no object can be activated for a request: OBJECT_NOT_EXIST
  - If there should be a servant manager but is none: OBJ_ADAPTER

Implicit Activation

- IMPLICIT_ACTIVATION policy requires SYSTEM_ID and RETAIN policies
- Interface of servant is determined from skeleton, or _primary_interface of DynamicImplementation
- Implicit activation happens through servant_to_reference, servant_to_id, or _this (C++, Java)
- UNIQUE_ID: only inactive servants are activated
  - Otherwise, the active object is returned
- MULTIPLE_ID: implicit activation always creates a new reference
  - Language-mapping specific: _this returns „current“ object if invoked in the context of an operation implementation

Multi-Threading

- Explicit main loop: ORB operations
  - work_pending, perform_work, run, shutdown
- Threading models:
  - Single-threaded: POA is thread-unaware
  - ORB-controlled: ORB creates and terminates threads at will
  - Main thread: All POAs with that policy have their events processed in the same (main) thread

- All interfaces are defined in PortableServer
  - CORBA 2.6: All interfaces are local
- POA
- POAManager
- ServantManager
- ServantActivator
- ServantLocator
- AdapterActivator
- Current

- Policy interfaces:
  - ThreadPolicy
  - LifespanPolicy
  - IdUniquenessPolicy
  - IdAssignmentPolicy
  - ImplicitActivationPolicy
  - ServantRetentionPolicy
  - RequestProcessingPolicy
- PortableServer::Servant is a native type

POAManager

```
local interface POAManager {
    exception AdapterInactive{};
    enum State {HOLDING, ACTIVE, DISCARDING, INACTIVE};
    void activate()
                raises(AdapterInactive);
    void hold_requests(in boolean wait_for_completion)
                raises(AdapterInactive);
    void discard_requests(in boolean wait_for_completion)
                raises(AdapterInactive);
    void deactivate(
          in boolean etherealize_objects,
          in boolean wait_for_completion)
                raises(AdapterInactive);
    State get_state();
};
```

AdapterActivator

- Implemented by application
- Used to activate unknown adapters
- Associated with POAs

```
local interface AdapterActivator {
    boolean unknown_adapter(
        in POA parent,
        in string name);
};
```

Servant Managers

- Implemented by application
- Associated with POAs of appropriate policy
- Activate objects on demand
- Managers can raise **ForwardRequest** exception
- Two kinds
  - Activators: activate objects which get put into AOM
    - Used with RETAIN
    - Typically dispose etherealized servants
  - Locators: activate objects for the period of a single call
    - Used with NON_RETAIN
    - Typically cache servants across multiple invocations
- Base interface: ServantManager
  - local interface ServantManager{ };

Servant Activators

```
local interface ServantActivator : ServantManager {
    Servant incarnate (
       in ObjectId oid,
       in POA adapter)
          raises (ForwardRequest);
    void etherealize (
       in ObjectId oid,
       in POA adapter,
       in Servant serv,
       in boolean cleanup_in_progress,
       in boolean remaining_activations);
};
```

Servant Activators (2)

- Invocations to incarnate and etherealize are serialized and mutually exclusive
- Incarnations cannot overlap
- Etherealization may take time until all requests complete
- Invoking new request on an object that is being etherealizeds:
- Requests are blocked or rejected

Servant Locators

```
local interface ServantLocator : ServantManager {
     native Cookie;
     Servant preinvoke(
        in ObjectId oid,
        in POA adapter,
        in CORBA::Identifier operation,
        out Cookie the_cookie)
           raises (ForwardRequest);
     void postinvoke(
        in ObjectId oid,
        in POA adapter,
        in CORBA::Identifier operation,
        in Cookie the_cookie,
        in Servant the_servant);
};
```

Servant Locators (2)

- One pair of preinvoke/postinvoke per request
- No serialization:
    - Locator can use Cookie to match preinvoke and postinvoke

POA Policies

- Policy objects: represent configuration information
- Policy type, policy value
- Generic ORB operation to create policy objects
- POA-specific operations to create POA policies
- Example: Thread policies

```
const CORBA::PolicyType THREAD_POLICY_ID = 16;
enum ThreadPolicyValue {
        ORB_CTRL_MODEL, SINGLE_THREAD_MODEL, MAIN_THREAD_MODEL
};
local interface ThreadPolicy : CORBA::Policy {
        readonly attribute ThreadPolicyValue value;
};
interface POA { // ...
        ThreadPolicy create_thread_policy(in ThreadPolicyValue value);
}
```

Lifespan Policy

- TRANSIENT: Objects cannot outlive the POA
  - Requests received after POAManager is deactivated receive OBJECT_NOT_EXIST
- PERSISTENT: Objects exist independent from POA
  - Typically combined with USER_ID policy, and perhaps servant manager
  - For SYSTEM_ID POAs, proprietary mechanisms might be used

IdUniquenessPolicy

- UNIQUE_ID: active servants support only one object id
- MULTIPLE_ID: a servant may be associated with more than one object id
  - Meaningless in combination with NON_RETAIN

IdAssignmentPolicy

- USER_ID: object Ids created by application
- SYSTEM_ID: object Ids created by POA

ServantRetentionPolicy

- RETAIN: activated servants are put into AOM
- NON_RETAIN: objects are etherealized at the end of the request.
  - Requires either USE_DEFAULT_SERVANT or USE_SERVANT_MANAGER

RequestProcessingPolicy

- USE_ACTIVE_OBJECT_MAP_ONLY: objects not found in the AOM don‘t exist
- USE_DEFAULT_SERVANT: Objects not found in the AOM are associated with the default servant
  - Need to invoke set_servant
  - Requires MULTIPLE_ID policy
- USE_SERVANT_MANAGER:
  - NON_RETAIN: Need to set servant locator
  - RETAIN: Need to set servant activator

ImplicitActivationPolicy

- IMPLICIT_ACTIVATION: support implicit activation
  - Requires SYSTEM_ID and RETAIN
- NO_IMPLICIT_ACTIVATION: implicit activation is not supported

POA Interface: Exceptions

```
local interface POA {
 exception AdapterAlreadyExists {};
 exception AdapterNonExistent {};
 exception InvalidPolicy {unsigned short index;};
 exception NoServant {};
 exception ObjectAlreadyActive {};
 exception ObjectNotActive {};
 exception ServantAlreadyActive {};
 exception ServantNotActive {};
 exception WrongAdapter {};
 exception WrongPolicy {}
```

POA Interface: POA Creation and Destruction

```
POA create_POA(
        in string adapter_name,
        in POAManager a_POAManager,
        in CORBA::PolicyList policies)
              raises (AdapterAlreadyExists, InvalidPolicy);
POA find_POA(
        in string adapter_name,
        in boolean activate_it)
              raises (AdapterNonExistent);
void destroy(
        in boolean etherealize_objects,
        in boolean wait_for_completion);
```

POA Interface: Policy Creation

```
ThreadPolicy create_thread_policy(in ThreadPolicyValue value);
LifespanPolicy create_lifespan_policy(in LifespanPolicyValue value);
IdUniquenessPolicy create_id_uniqueness_policy(
        in IdUniquenessPolicyValue value);
IdAssignmentPolicy create_id_assignment_policy(
        in IdAssignmentPolicyValue value);
ImplicitActivationPolicy create_implicit_activation_policy(
        in ImplicitActivationPolicyValue value);
ServantRetentionPolicy create_servant_retention_policy(
        in ServantRetentionPolicyValue value);
RequestProcessingPolicy create_request_processing_policy(
        in RequestProcessingPolicyValue value);
```

POA Interface: Attributes

```
readonly attribute string the_name;

readonly attribute POA the_parent;

readonly attribute POAList the_children;

readonly attribute POAManager the_POAManager;

attribute AdapterActivator the_activator;
```

POA Interface: Servant Managers

```
ServantManager get_servant_manager()
            raises (WrongPolicy);
void set_servant_manager(
       in ServantManager imgr)
            raises (WrongPolicy);
```

POA Interface: Default Servants

```
Servant get_servant()
        raises (NoServant, WrongPolicy);
void set_servant(in Servant p_servant)
        raises (WrongPolicy);
```

POA Interface: Activation and Deactivation

```
ObjectId activate_object(
        in Servant p_servant)
              raises (ServantAlreadyActive, WrongPolicy);
void activate_object_with_id(
        in ObjectId id,
        in Servant p_servant)
              raises (    ServantAlreadyActive,
                    ObjectAlreadyActive, WrongPolicy);
void deactivate_object(
        in ObjectId oid)
              raises (ObjectNotActive, WrongPolicy);
```

POA Interface: Reference Creation

```
Object create_reference (
        in CORBA::RepositoryId intf)
              raises (WrongPolicy);
Object create_reference_with_id (
        in ObjectId oid,
        in CORBA::RepositoryId intf
);
```

POA Interface: Identity Mapping

```
ObjectId servant_to_id(in Servant p_servant)
            raises (ServantNotActive, WrongPolicy);
Object servant_to_reference(in Servant p_servant)
            raises (ServantNotActive, WrongPolicy);
Servant reference_to_servant(in Object reference)
            raises(ObjectNotActive, WrongAdapter, WrongPolicy);
ObjectId reference_to_id(in Object reference)
            raises (WrongAdapter, WrongPolicy);
Servant id_to_servant(in ObjectId oid)
            raises (ObjectNotActive, WrongPolicy);
Object id_to_reference(in ObjectId oid)
       raises (ObjectNotActive, WrongPolicy);
readonly attribute CORBA::OctetSeq id;
```

POACurrent

- Current objects: Thread-local
- Initial reference: "POACurrent"
- Determines object reference of current operation

```
local interface Current : CORBA::Current {
 exception NoContext { };
 POA        get_POA()        raises (NoContext);
 ObjectId   get_object_id()      raises (NoContext);
 Object     get_reference()      raises(NoContext);
 Servant    get_servant()        raises(NoContext);
};
```

- ...

Factory

- Gamma et.al.: Design Patterns
- Allow creation of an object without having to specify what specific class that object should have
- Examples discussed so far:
  - POA: ServantActivator, AdapterActivator
  - Others?

CosNaming::NamingContext

```
interface NamingContext{
    NamingContext new_context();
    NamingContext bind_new_context(in Name n) raises(...);
    NamingContext destroy() raises(...);
    //...
};
```

- issues: location transparency, life cycle, federation

Interceptor

- Schmidt et.al.: Pattern-Oriented Software Architecture
- allows services to be added transparently to a framework and triggered automatically when certain events occur
- components: dispatcher, interceptor, framework, context
- multiple interception points, e.g. pre-marshal-request, post-marshal-request, pre-unmarshal-reply, post-unmarshal-reply, shutdown
- example: CORBA Portable Interceptors

Other relevant patterns

- master-slave (farmer-worker)
- client-dispatcher-server
- publisher-subscriber