Using Real-time CORBA Effectively
Patterns & Principles

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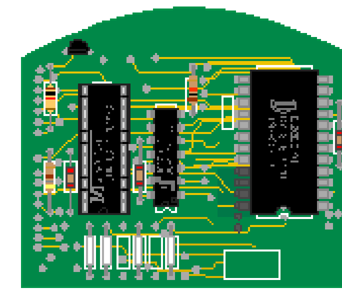
This talk is based on material based on Doug Schmidt, Irfan Pyarali, and Carlos O’Ryan

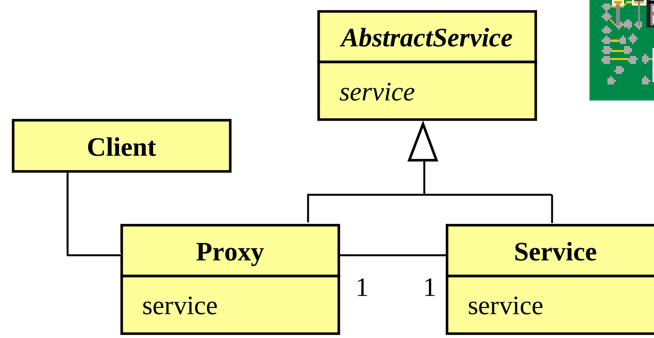
Saturday, May 12, 2001

Motivation for QoS-enabled Middleware

Trends



- Hardware keeps getting smaller, faster, & cheaper
- Software keeps getting larger, slower, & more expensive



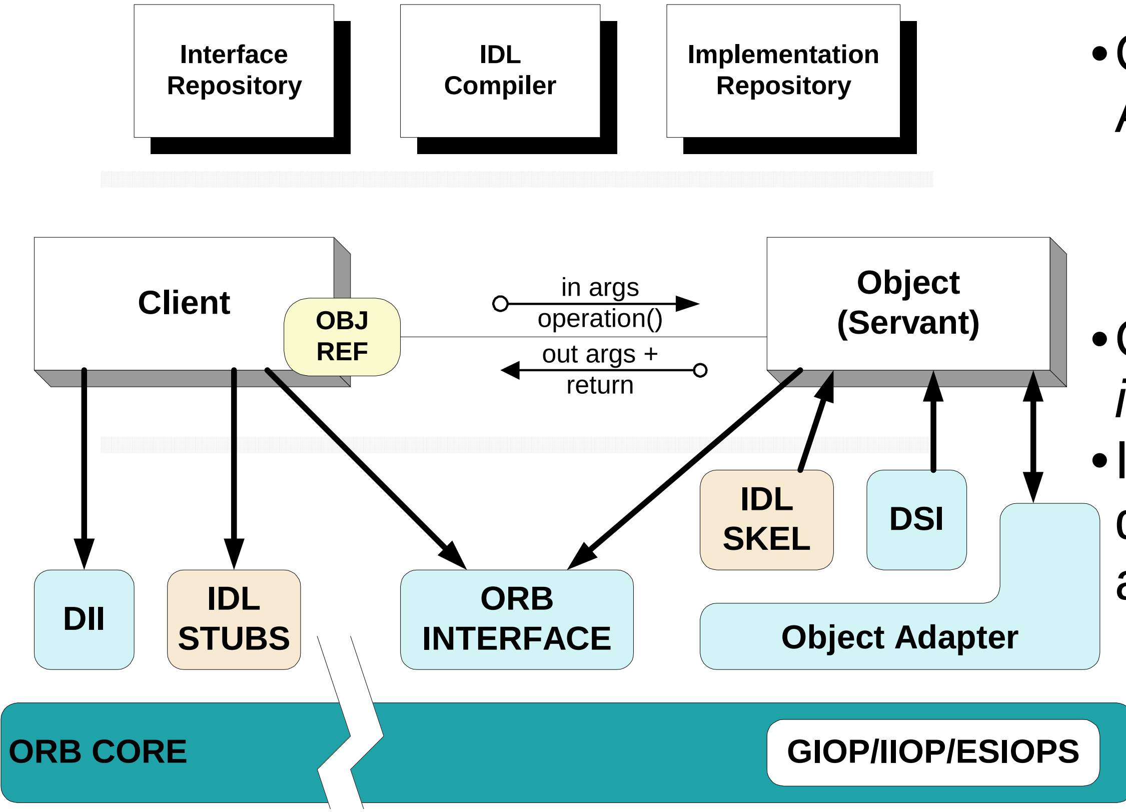
Historical Challenges

- Building distributed systems is hard
- Building them on-time & under budget is even harder

New Challenges

- Many mission-critical distributed applications require real-time QoS guarantees
  - e.g., combat systems, online trading, telecom
- Building QoS-enabled applications manually is tedious, error-prone, & expensive
- Conventional middleware does not support real-time QoS requirements effectively

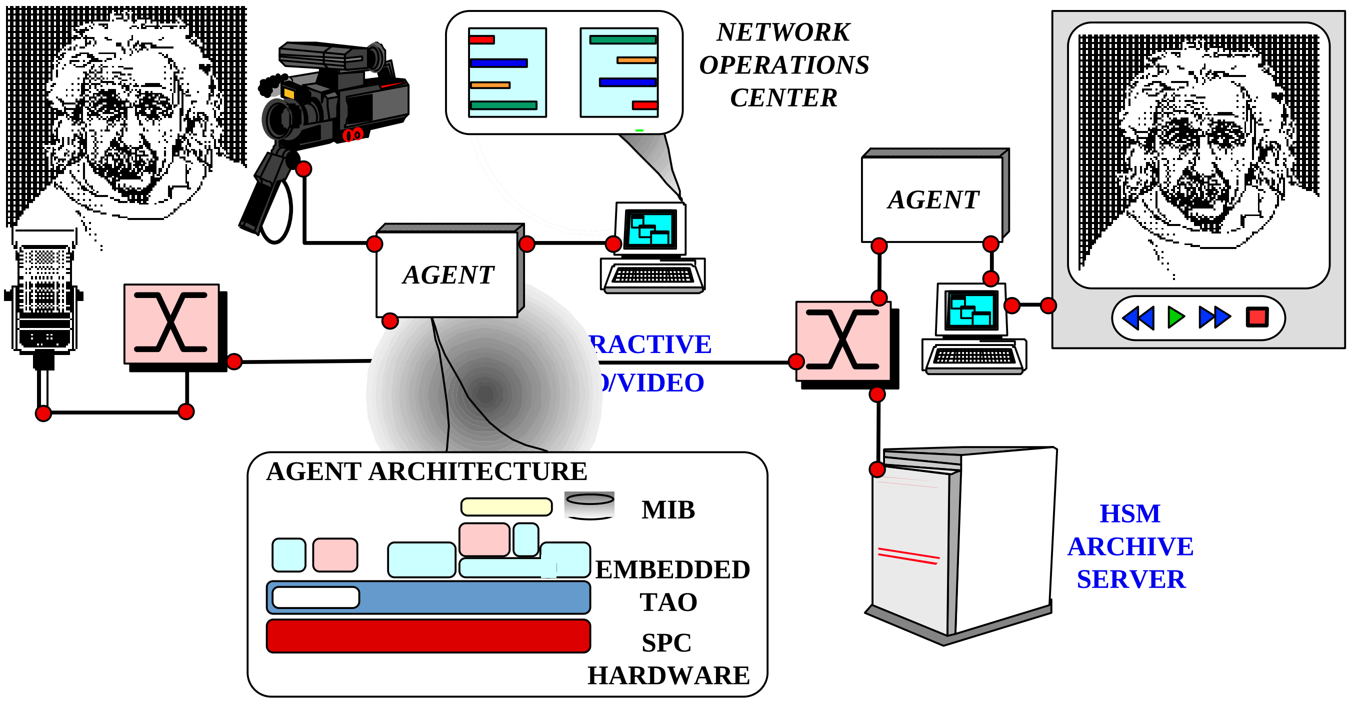
Overview of CORBA



- CORBA shields applications from heterogeneous platform *dependencies*
  - *e.g.*, languages, operating systems, networking protocols, hardware

- Common Object Request Broker Architecture (CORBA)
  - A family of specifications
  - OMG is the standards body
  - Over 800 companies
- CORBA defines *interfaces*, not *implementations*
- It simplifies development of distributed applications by automating/encapsulating
  - Object location
  - Connection & memory mgmt.
  - Parameter (de)marshaling
  - Event & request demultiplexing
  - Error handling & fault tolerance
  - Object/server activation
  - Concurrency
  - Security

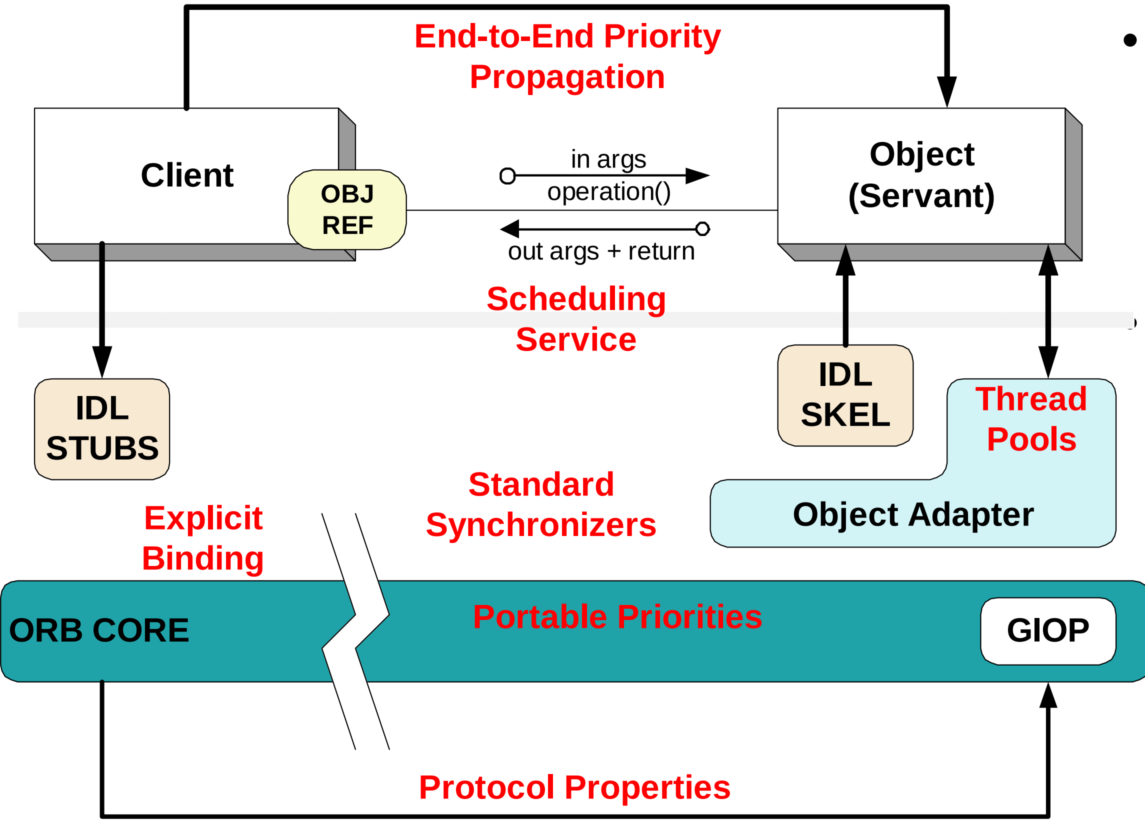
Caveat: Requirements & Historical Limitations of CORBA for Real-time Systems



Requirements
- Location transparency
- Performance transparency
- Predictability transparency
- Reliability transparency

Historical Limitations
- Lack of QoS specifications
- Lack of QoS enforcement
- Lack of real-time programming features
- Lack of performance optimizations

Real-Time CORBA Overview

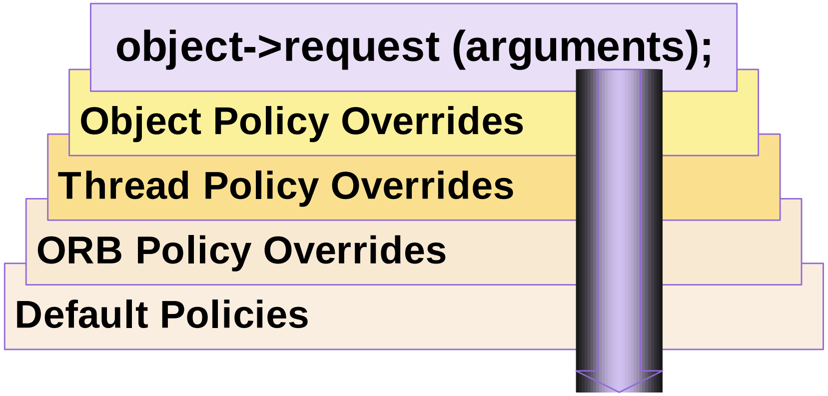


Real-time CORBA leverages the CORBA Messaging QoS Policy framework

- RT CORBA adds QoS control to regular CORBA improve the application *predictability*, *e.g.*,
  - Bounding priority inversions &
  - Managing resources end-to-end
- Policies & mechanisms for resource configuration/control in RT-CORBA include:
  1. **Processor Resources**
     - Thread pools
     - Priority models
     - Portable priorities
  2. **Communication Resources**
     - Protocol policies
     - Explicit binding
  3. **Memory Resources**
     - Request buffering
- These capabilities address some important real-time application development challenges

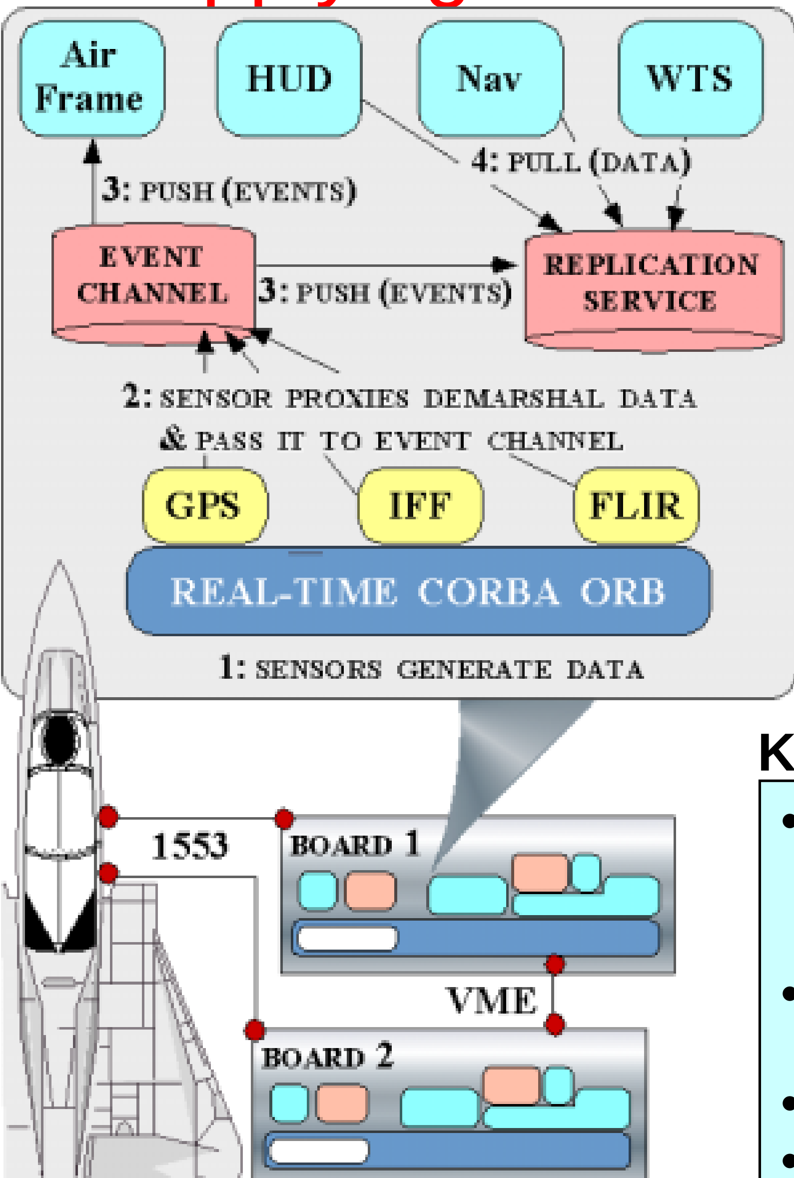
Overview of the CORBA QoS Policy Framework

- CORBA defines a QoS framework that includes policy management for *request priority, queueing, message delivery quality, timeouts, etc*.
- QoS is managed through interfaces derived from `CORBA::Policy`
  - Each QoS Policy has an associated `PolicyType` that can be queried
- A `PolicyList` is sequence of policies
- Client-side policies are specified at 3 “overriding levels”:
  1. ORB-level through `PolicyManager`
  2. Thread-level through `PolicyCurrent`
  3. Object-level through overrides in an *object reference*



- Server-side policies are specified by associating QoS policy objects with a POA
  - *i.e.*, can be passed as arguments to `POA::create_POA()`
- Client-side QoS policies & overrides can be established & validated via calls to `Object::validate_connection()` & other CORBA APIs

Applying RT CORBA to Real-time Avionics



Goals

- Apply COTS & open systems to mission-critical real-time avionics

Key System Characteristics

- Deterministic & statistical deadlines
  - ~20 Hz
- Low latency & jitter
  - ~250 *u*secs
- Periodic & aperiodic processing
- Complex dependencies
- Continuous platform upgrades

Key Results

- Test flown at China Lake NAWS by Boeing OSAT II '98, funded by OS-JTF
  - www.cs.wustl.edu/~schmidt/TAO-boeing.html
- Also used on SOFIA project by Raytheon
  - sofia.arc.nasa.gov
- First use of RT CORBA in mission computing
- Drove Real-time CORBA standardization

Applying RT CORBA to Hot Rolling Mills

Goals

- Control the processing of molten steel moving through a hot rolling mill in real-time

System Characteristics

- Hard real-time process automation requirements
  - *i.e.*, 250 ms real-time cycles
- System acquires values representing plant's current state, tracks material flow, calculates new settings for the rolls & devices, & submits new settings back to plant

www.siroll.de

Key Software Solution Characteristics

- Affordable, flexible, & COTS
  - Product-line architecture
  - Design guided by patterns & frameworks
  - Windows NT/2000
  - Real-time CORBA

Applying RT CORBA to Image Processing

Goals

- Examine glass bottles for defects in real-time

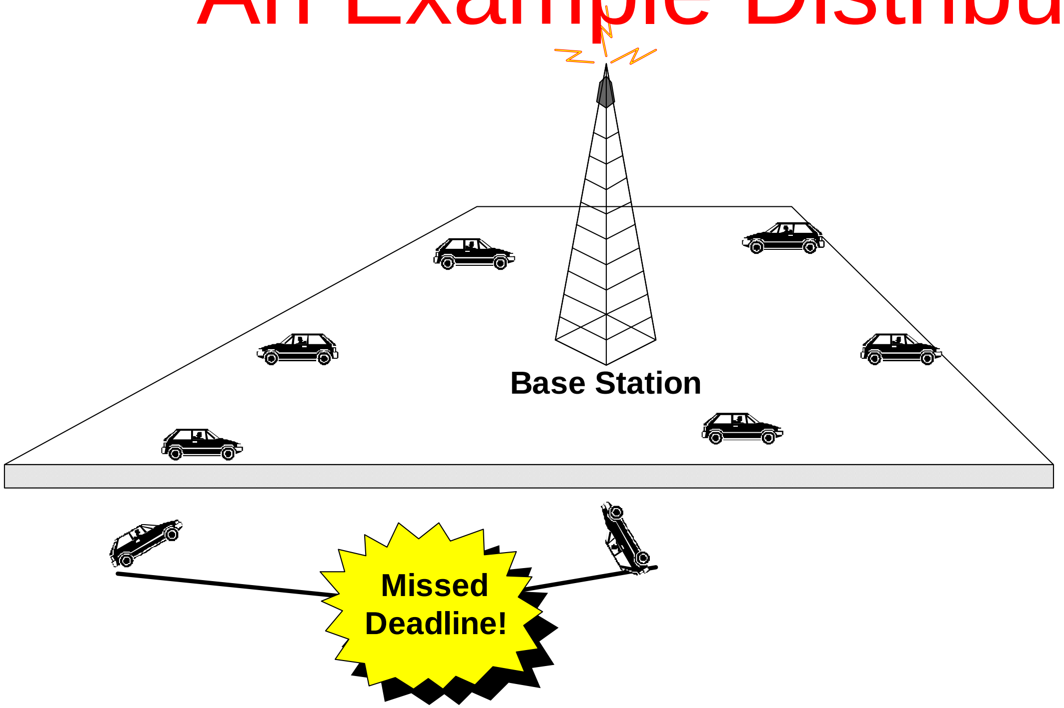
System Characteristics

- Process 20 bottles per sec
  - *i.e.*, ~50 msec per bottle
- Networked configuration
- ~10 cameras

Key Software Solution Characteristics

- Affordable, flexible, & COTS
  - Embedded Linux (Lem)
  - Compact PCI bus + Celeron processors
  - Remote booted by DHCP/TFTP
  - Real-time CORBA

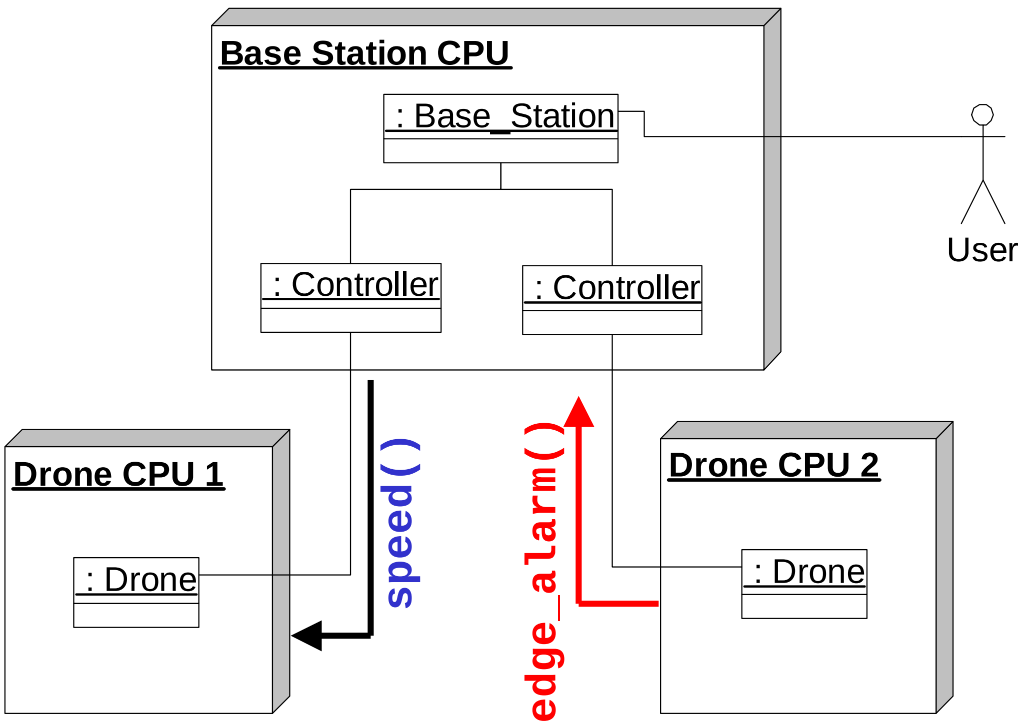
An Example Distributed Application



- Consider an application where cooperating *drones* explore a surface & report its properties periodically
  - *e.g.*, color, texture, etc.
- This is a simplification of various autonomous vehicle use-cases

- Drones aren't very "smart,"
  - *e.g.*, they can fall off the "edge" of the surface if not stopped
- Thus, a *controller* is used to coordinate their actions
  - *e.g.*, it can order them to a new position

Designing the Application



- End-users talk to a **`Base_Station`** object
  - *e.g.*, they define high-level exploration goals for the drones
- The **`Base_Station`** object controls the drones remotely using **`Drone`** objects
- **`Drone`** objects are proxies for the underlying drone vehicles
  - *e.g.*, they expose operations for controlling & monitoring individual drone behavior

- Each drone sends information obtained from its sensors back to the **`Base_Station`** via a **`Controller`** object
  - This interaction is an example of *Asynchronous Completion Token* & *Distributed Callback* patterns

Defining Application Interfaces with CORBA IDL

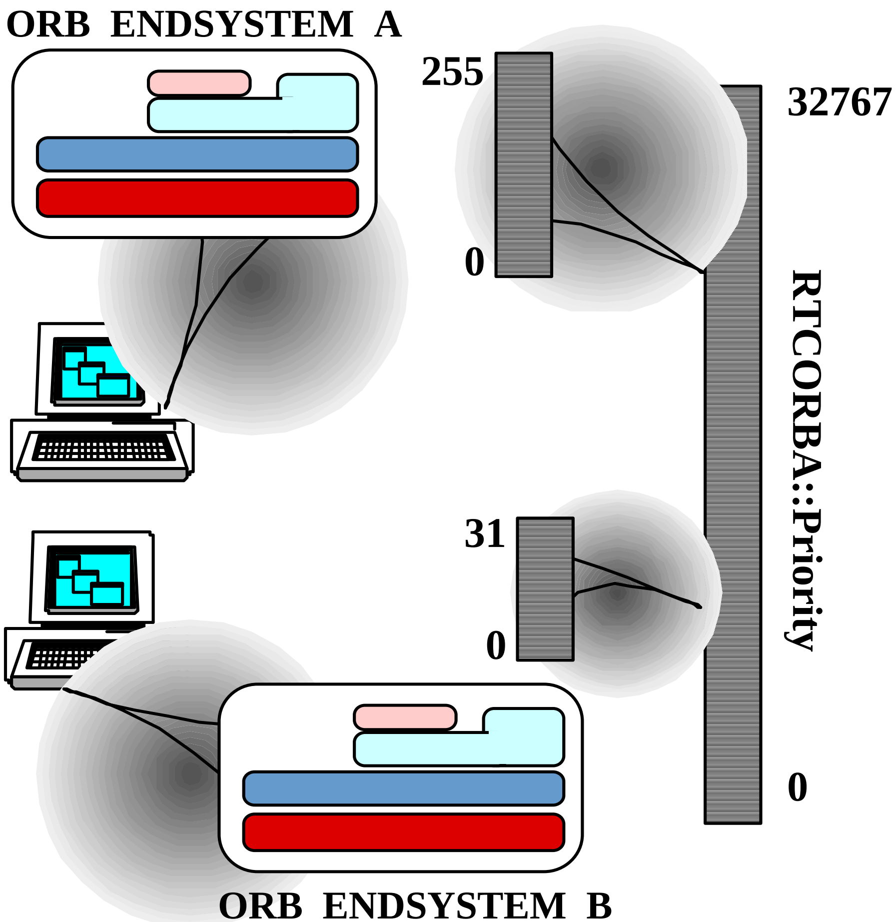
```
interface Drone {
  void turn (in float degrees);
  void speed (in short mph);
  void reset_odometer ();
  short odometer ();
  // …
};

interface Controller {
  void edge_alarm ();
  void turn_completed ();
};

exception Lack_Resources {};

interface Base_Station {
  Controller new_controller (in string name)
    raises (Lack_Resources);
  void set_new_target (in float x, in float y);
  //……
};
```

- Each **Drone** talks to one **Controller**
  - *e.g.*, **Drones** send hi-priority alarm messages when they detect an edge
- The **Controller** should take corrective action if a **Drone** detects it's about to fall off an edge!
- The **Base_Station** interface is a **Controller** factory
  - **Drones** use this interface to create their **Controllers** during power up
  - End-users use this interface to set high-level mobility targets

QoS-related Application Design Challenges

- Our example application contains the following QoS-related design challenges
  1. *Obtaining portable ORB end-system priorities*
  2. *Preserving priorities end-to-end*
  3. *Enforcing certain priorities at the server*
  4. *Changing CORBA priorities*
  5. *Supporting thread pools effectively*
  6. *Buffering client requests*
  7. *Synchronizing objects correctly*
  8. *Configuring custom protocols*
  9. *Controlling network & end-system resources to minimize priority inversion*
  10. *Avoiding dynamic connections*
  11. *Simplifying application scheduling*
  12. *Controlling request timeouts*
- The remainder of this tutorial illustrates how these challenges can be addressed by applying RT CORBA capabilities

Obtaining Portable ORB End-system Priorities



- **Problem**: How to communicate priorities having different native OS priority ranges
- **Solution**: Standard RT CORBA priority mapping interfaces
  - OS-independent design supports heterogeneous real-time platforms
  - CORBA priorities are "globally" unique values that range from 0 to 32767
  - Users can map CORBA priorities onto native OS priorities in custom ways
  - No silver bullet, but rather an ``enabling technique''
    - *i.e.*, can't magically turn a general-purpose OS into a real-time OS!

Priority Mapping Example

- Define a priority mapping class that always uses native priorities in the range 128-255
  - *e.g.*, this is the top half of LynxOS priorities

```
class MyPriorityMapping : public RTCORBA::PriorityMapping {
  CORBA::Boolean to_native (RTCORBA::Priority corba_prio,
                            RTCORBA::NativePriority &native_prio)
  {
    native_prio = 128 + (corba_prio / 256);
    // In the [128,256) range…
    return true;
  }

  // Similar for CORBA::Boolean to_CORBA ();
};
```

- **Problem**: How do we configure this new class?
- **Solution**: Use TAO's `PriorityMappingManager`

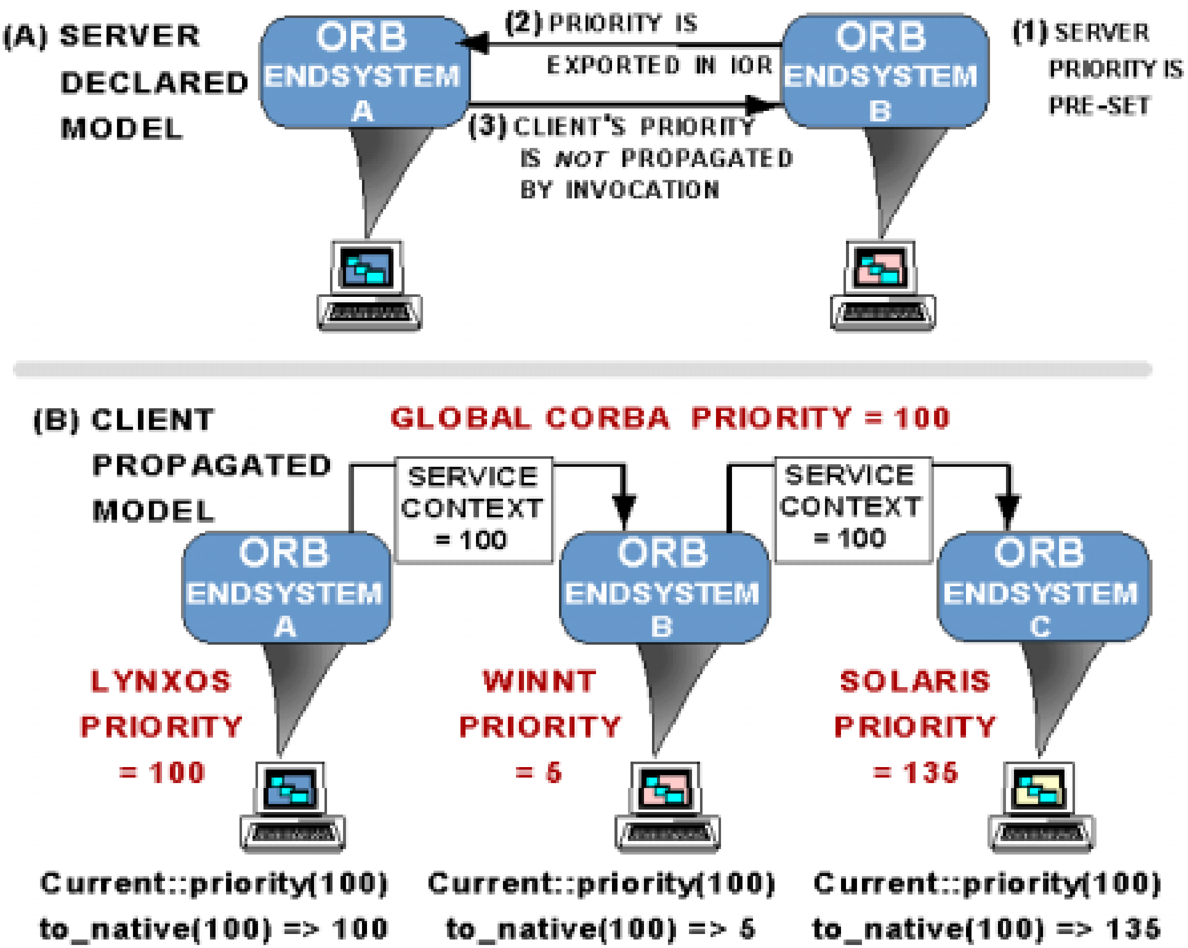
TAO's PriorityMappingManager

- TAO provides an extension that uses a *locality constrained* object to configure the priority mapping:

```
CORBA::ORB_var orb = CORBA::ORB_init (argc, argv); // The ORB

// Get the PriorityMappingManager
CORBA::Object_var obj =
   orb->resolve_initial_references (“PriorityMappingManager”);
TAO::PriorityMappingManager_var manager =
   TAO::PriorityMappingManager::_narrow (obj);

// Create an instance of your mapping
RTCORBA::PriorityMapping *my_mapping =
   new MyPriorityMapping;

// Install the new mapping
manager->mapping (my_mapping);
```

- It would be nice if this feature were standardized in RT CORBA…
  - The current specification doesn't standardize this in order to maximize ORB implementer options, *e.g.*, link-time vs. run-time bindings

Preserving Priorities End-to-End



- **Problem**: Requests could run at the wrong priority on the server
  - *e.g.*, this can cause major problems if `edge_alarm()` operations are processed too late!!
- **Solution**: Use RT CORBA priority model policies
  - **SERVER_DECLARED**
    - Server handles requests at the priority declared when object was created
  - **CLIENT_PROPAGATED**
    - Request is executed at the priority requested by client (priority encoded as part of client request)

Applying **CLIENT_PROPAGATED**

- Drones send critical messages to **Controllers** in the **Base_Station**
  - **edge_alarm()** runs at the highest priority in the system
  - **turn_completed()** runs at a lower priority in the system

```
CORBA::PolicyList policies (1); policies.length (1);
policies[0] = rtorb->create_priority_model_policy
   (RTCORBA::CLIENT_PROPAGATED,
    DEFAULT_PRIORITY /* For non-RT ORBs */);

// Create a POA with the correct policies
PortableServer::POA_var controller_poa =
   root_poa->create_POA ("Controller_POA",
                         PortableServer::POAManager::_nil (),
                         policies);

// Activate one Controller servant in <controller_poa>
controller_poa->activate_object (my_controller);
...
// Export object reference for <my_controller>
```

- Note how **CLIENT_PROPAGATED** policy is set on the server & exported to the client along with an object reference

Changing CORBA Priorities at the Client

- **Problem**: How can RT-CORBA client applications change the priority of operations?
- **Solution**: Use the `RTCurrent` to change the priority of the current thread explicitly
  - An `RTCurrent` can also be used to query the priority
  - Values are expressed in the *CORBA priority* range
  - Behavior of `RTCurrent` is *thread-specific*

```
// Get the ORB's RTCurrent object
obj = orb->resolve_initial_references ("RTCurrent");

RTCORBA::RTCurrent_var rt_current =
   RTCORBA::RTCurrent::_narrow (obj);

// Change the current CORBA priority
rt_current->the_priority (VERY_HIGH_PRIORITY);

// Invoke the request at <VERY_HIGH_PRIORITY> priority
// The priority is propagated (see previous page)
controller->edge_alarm ();
```

Design Interlude: The RTORB Interface

- **Problem:** How can the ORB be extended without changing the CORBA::ORB API?
- **Solution:** Use the *Extension Interface* pattern from POSA2
  - Use `resolve_initial_references()` interface to obtain the extension
  - Thus, non real-time ORBs and applications are not affected by RT CORBA enhancements!

```
CORBA::ORB_var orb = CORBA::ORB_init (argc, argv);

CORBA::Object_var obj =
   orb->resolve_initial_references ("RTORB");

RTCORBA::RTORB_var rtorb =
   RTCORBA::RTORB::_narrow (obj);
// Assuming this narrow succeeds we can henceforth use RT
// CORBA features
```

Applying **SERVER_DECLARED**

- **Problem**: Some operations must always be invoked at a fixed priority
  - *e.g.*, the **Base_Station** methods are not time-critical, so they should always run at lower priority than the **Controller** methods
- **Solution**: Use the RT CORBA **SERVER_DECLARED** priority model

```
CORBA::PolicyList policies (1); policies.length (1);
policies[0] = rtorb->create_priority_model_policy
   (RTCORBA::SERVER_DECLARED, LOW_PRIORITY);

// Create a POA with the correct policies
PortableServer::POA_var base_station_poa =
   root_poa->create_POA ("Base_Station_POA",
                         PortableServer::POAManager::_nil (),
                         policies);

// Activate the <Base_Station> servant in <base_station_poa>
base_station_poa->activate_object (base_station);
```

- By default, **SERVER_DECLARED** objects inherit the priority of their **RTPOA**
  - It's possible to override this priority on a per-object basis, however!

Extended RT POA Interface

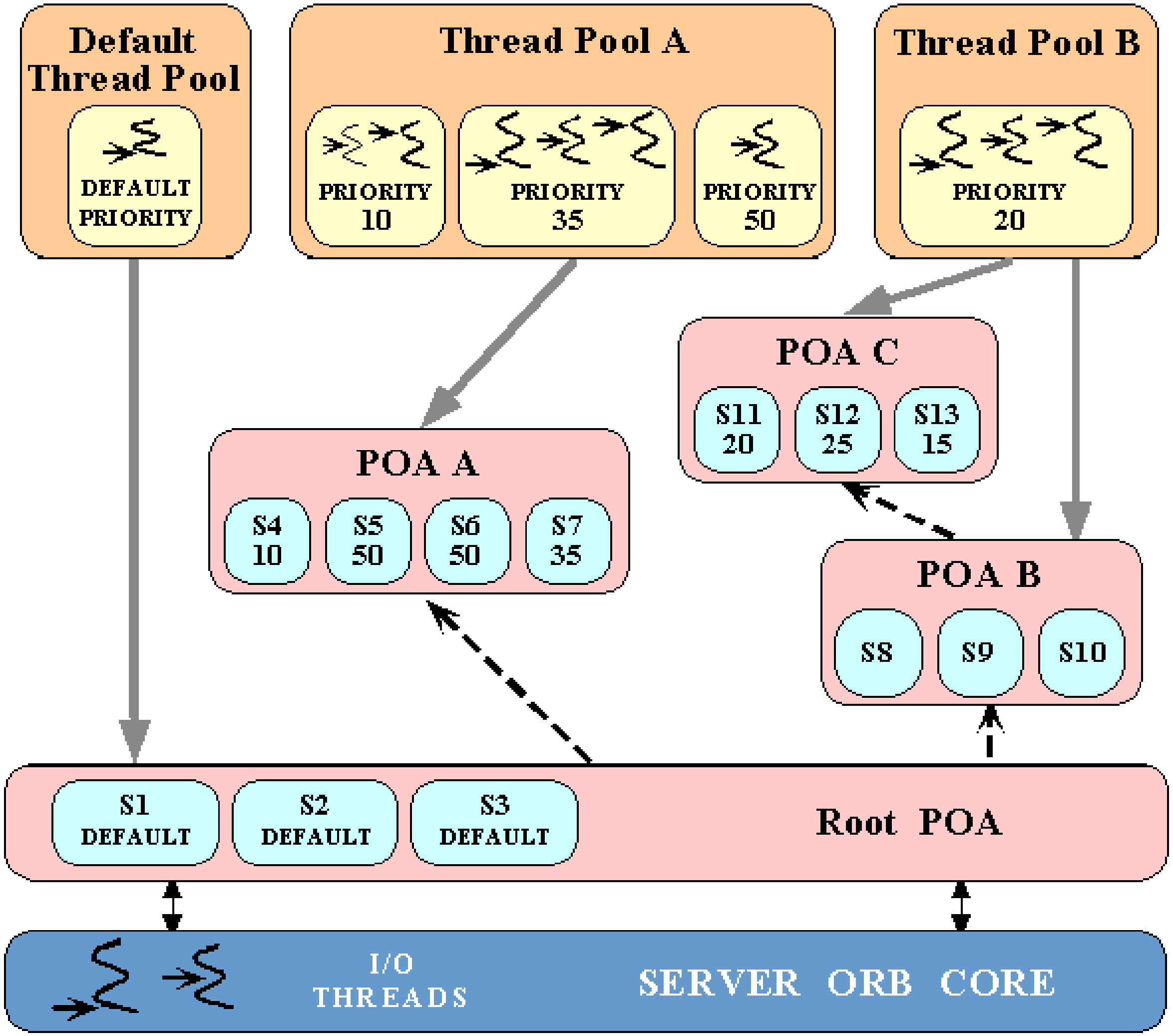
- RT CORBA extends the POA interface via inheritance

```
module RTPortableServer {
  local interface POA : PortableServer::POA {
    PortableServer::ObjectId activate_object_with_priority
     (in PortableServer::Servant servant_ptr,
      in RTCORBA::Priority priority)
    raises (ServantAlreadyActive, WrongPolicy);
  // ...
};
```

- Methods in this interface can override default **SERVER_DECLARED** priorities

```
// Activate object with default priority of RTPOA
MyBase_Station *station = new MyBase_Station;
base_station_poa->activate_object (station);

// Activate another object with a specific priority
RTPortableServer::POA_var rt_poa =
  RTPortableServer::POA::_narrow (base_station_poa);
rt_poa->activate_object_with_priority (another_servant,
                                       ANOTHER_PRIORITY);
```

Supporting Thread Pools Effectively



- **Problem**: Pre-allocating threading resources on the server *portably* & *efficiently*
  - *e.g.*, the **Base_Station** must have sufficient threads for all its priority levels
- **Solution**: Use RT CORBA thread pools to configure server POAs to support
  - Different levels of service
  - Overlapping of computation & I/O
  - Priority partitioning

Note that a thread pool can manage multiple POAs

Creating & Destroying Thread Pools

```
interface RTCORBA::RTORB {
  typedef unsigned long ThreadpoolId;

  ThreadpoolId create_threadpool (
     in unsigned long stacksize,
     in unsigned long static_threads,
     in unsigned long dynamic_threads,
     in Priority default_priority,
     in boolean allow_request_buffering,
     in unsigned long max_buffered_requests,
     in unsigned long max_request_buffer_size);

  void destroy_threadpool (in ThreadpoolId threadpool)
     raises (InvalidThreadpool);
};
```

There are factory methods for controlling the life-cycle of RT-CORBA thread pools

Creating Thread Pools with Lanes

- **Problem**: Exhaustion of threads by low priority requests
  - *e.g.,* many requests to the **`Base_Station`** methods use up all the threads in the thread pool so that no threads for high priority **`Controller`** methods are available
- **Solution**: Partition thread pool into subsets, which are called **`Lanes,`** each lane has a different priority

```
interface RTCORBA::RTORB {
   struct ThreadpoolLane {
      Priority lane_priority;
      unsigned long static_threads;
      unsigned long dynamic_threads;
   };
   ThreadpoolId create_threadpool_with_lanes (
      in unsigned long stacksize,
      in ThreadpoolLanes lanes,
      in boolean allow_borrowing
      in boolean allow_request_buffering,
      in unsigned long max_buffered_requests,
      in unsigned long max_request_buffer_size );
};
```

- It's possible to "borrow" threads from lanes with lower priorities

Configuring Thread Pool Lanes

```
// Define two lanes
RTCORBA::ThreadpoolLane high_priority =
{ 10 /* Priority */,
   3 /* Static Threads */,
   0 /* Dynamic Threads */ };

RTCORBA::ThreadpoolLane low_priority =
{  5 /* Priority */,
   7 /* Static Threads */,
   2 /* Dynamic Threads */};

RTCORBA::ThreadpoolLanes lanes(2); lanes.length(2);
lanes[0] = high_priority; lanes[1] = low_priority;

RTCORBA::ThreadpoolId pool_id =
  rt_orb->create_threadpool_with_lanes (
    1024 * 10, // Stacksize
    lanes, // Thread pool lanes
    false, // No thread borrowing
    false, 0, 0); // No request buffering
```

When a thread pool is created it's possible to control certain resource allocations

- *e.g.*, stacksize, request buffering, & whether or not to allow "borrowing" across lanes

Installing Thread Pools on a RT-POA

```
// From previous page
RTCORBA::ThreadpoolId pool_id = // ...

// Create Thread Pool Policy
RTCORBA::ThreadpoolPolicy_var tp_policy =
   rt_orb->create_threadpool_policy (pool_id);

// Create policy list for RT-POA
CORBA::PolicyList RTPOA_policies(1); RTPOA_policies.length (1);
RTPOA_policies[0] = tp_policy;

// Create POAs
PortableServer::POA_var rt_poa_1 =
   root_poa->create_POA (“RT-POA_1”, // POA name
                         PortableServer::POAManager::_nil (),
                         RTPOA_policies);  // POA policies
PortableServer::POA_var rt_poa_2 =
   root_poa->create_POA (“RT-POA_2”, // POA name
                         PortableServer::POAManager::_nil (),
                         RTPOA_policies);  // POA policies
```

Note how multiple RT POAs can share the same thread pools

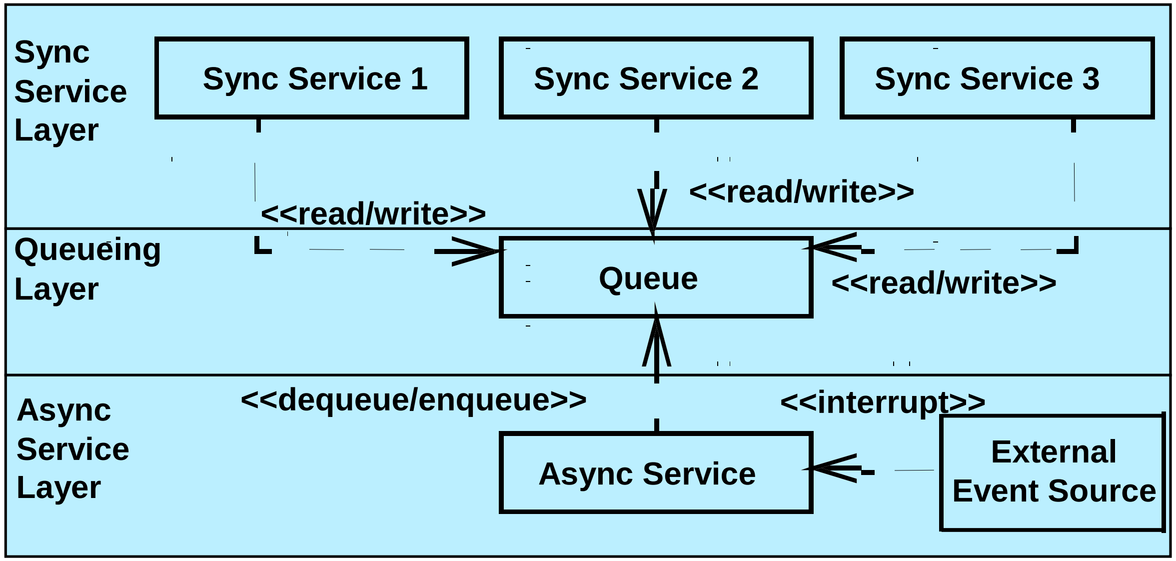
Thread Pools Implementation Strategies

- There are two general strategies to implement RT CORBA thread pools:
  1. Use the *Half-Sync/Half-Async* pattern to have I/O thread(s) buffer client requests in a queue & then have worker threads in the pool process the requests
  2. Use the *Leader/Followers* pattern to demultiplex I/O events into threads in the pool *without* requiring additional I/O threads
- Each strategy is appropriate for certain application domains
  - *e.g.,* certain hard-real time applications cannot incur the non-determinism & priority inversion of additional request queues
- To evaluate each approach we must understand their consequences
  - Their pattern descriptions capture this information
  - Good metrics to compare RT-CORBA implementations

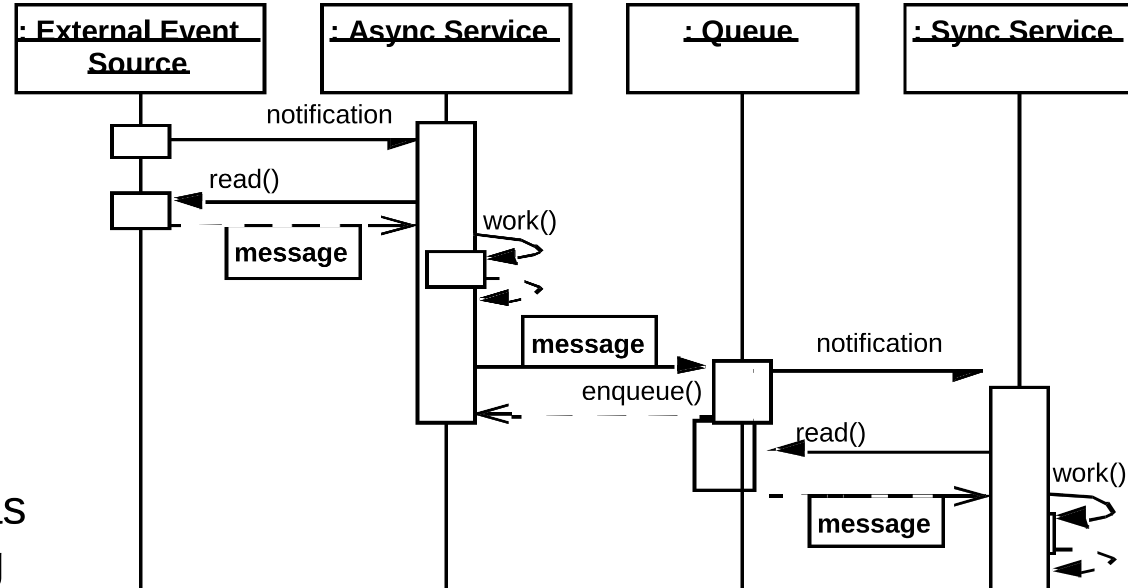
The Half-Sync/Half-Async Pattern

Intent

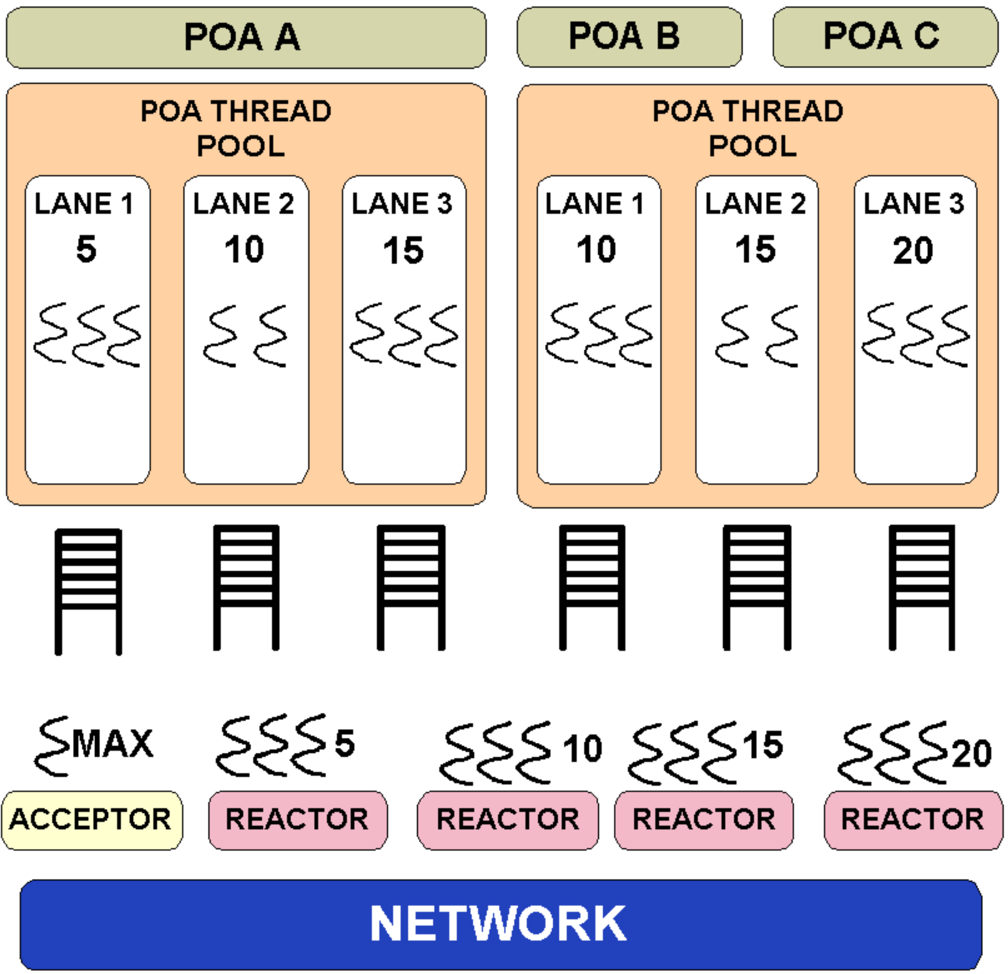
The *Half-Sync/Half-Async* architectural pattern decouples async & sync service processing in concurrent systems, to simplify programming without unduly reducing performance



- This pattern defines two service processing layers—one async and one sync—along with a queueing layer that allows services to exchange messages between the two layers
- The pattern allows sync services, such as servant processing, to run concurrently, relative both to each other and to async services, such as I/O handling & event demultiplexing



Queue-per-Lane Thread Pool Design



Design Overview

- Single acceptor endpoint
- One reactor for each priority level
- Each lane has a queue
- I/O & application-level request processing are in different threads

Pros

- Better feature support, *e.g.,*
  - Request buffering
  - Thread borrowing
- Better scalability, *e.g.,*
  - Single acceptor
  - Fewer reactors
  - Smaller IORs
- Easier piece-by-piece integration into the ORB

Cons

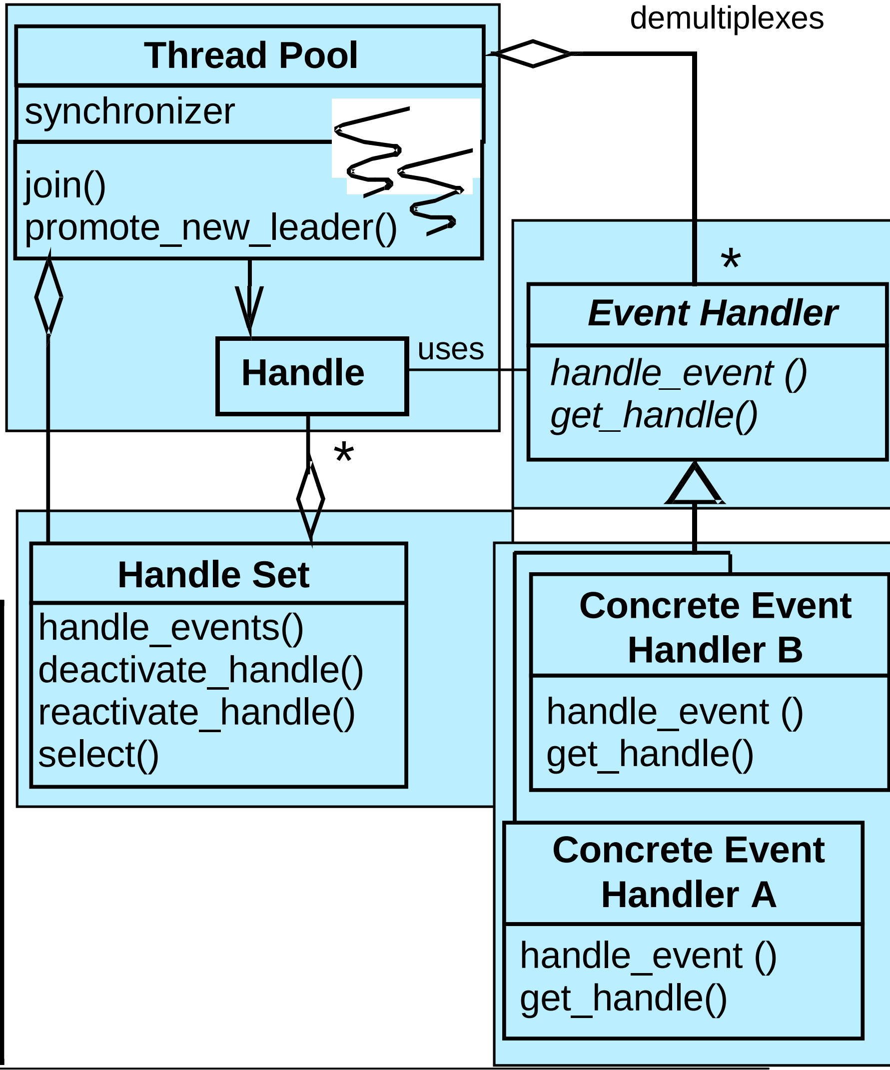
- Less efficient because of queuing
- Predictability reduced without _bind_priority_band() implicit operation

The Leader/Followers Pattern

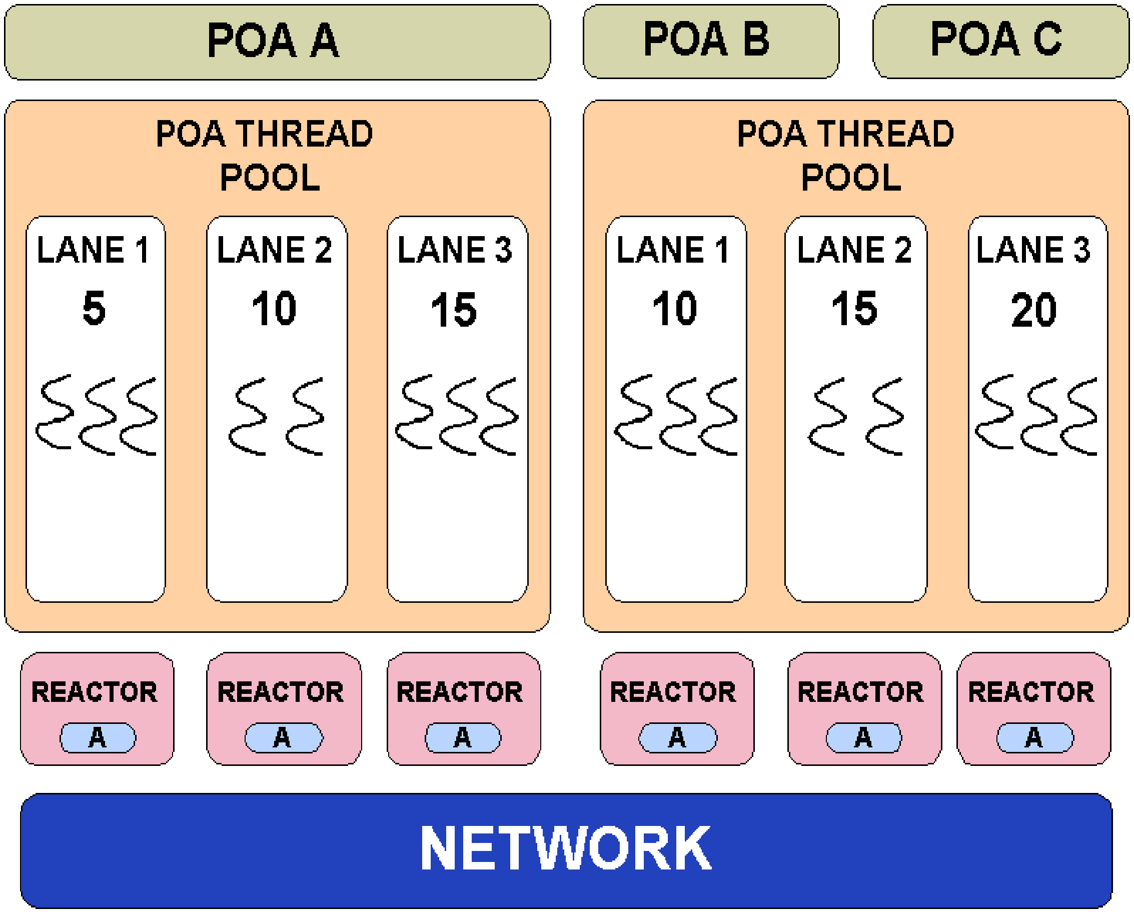
Intent

The Leader/Followers architectural pattern provides an efficient concurrency model where multiple threads take turns sharing event sources to detect, demux, dispatch, & process service requests that occur on the event sources

Handles / Handle Sets	Concurrent Handles	Iterative Handles
Concurrent Handle Sets	UDP Sockets + `WaitForMultiple Objects()`	TCP Sockets + `WaitForMultple Objects()`
Iterative Handle Sets	UDP Sockets + `select()/poll()`	TCP Sockets + `select()/poll()`



Reactor-per-Lane Thread Pool Design



Design Overview

- Each lane has its own set of resources
  - *i.e.*, reactor, acceptor endpoint, etc.
- I/O & application-level request processing are done in the same thread

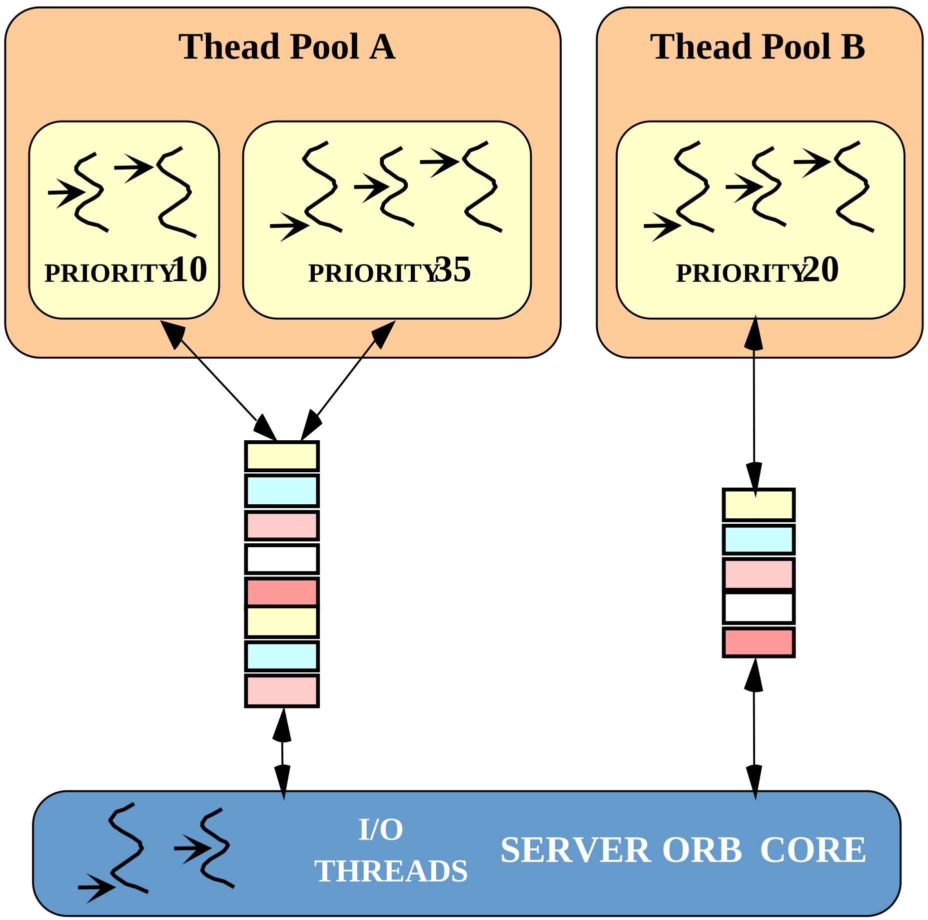
Pros

- Better performance
  - No context switches
  - Stack & TSS optimizations
- No priority inversions during connection establishment
- Control over ***all*** threads with standard thread pool API

Cons

- Harder ORB implementation
- Many endpoints = longer IORs

Buffering Client Requests



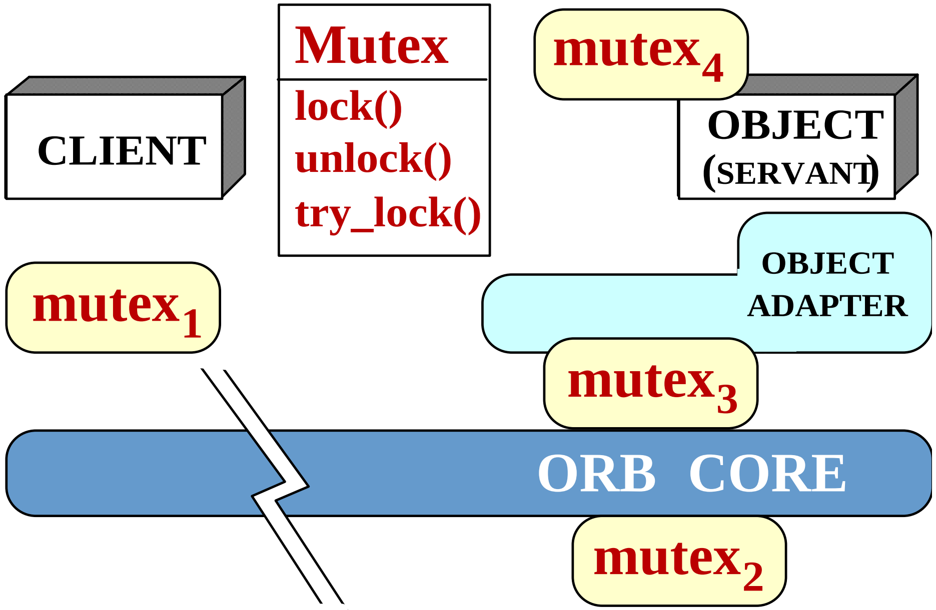
- **Problem**: Some types of applications need more buffering than is provided by the OS I/O subsystem
  - *e.g.*, to handle "bursty" client traffic
- **Solution**: Buffer client requests in ORB
- RT CORBA thread pool buffer capacities can be configured according to:
  1. Maximum number of bytes and/or
  2. Maximum number of requests

Configuring Request Buffering

```
// Create a thread pool with buffering
RTCORBA::ThreadpoolId pool_id =
   rt_orb->create_threadpool (1024 * 10,  // Stacksize
                              true,       // Enable buffering
                              128,        // Maximum messages
                              64 * 1024); // Maximum buffering

// Create Thread Pool Policy
RTCORBA::ThreadpoolPolicy_var tp_policy =
   rt_orb->create_threadpool_policy (pool_id);

// Use that policy to configure the RT-POA
```

- Since some RT ORBs don’t use queues to avoid priority inversions, an ORB can reject a request to create a thread pool with buffers
  - This design is still compliant, however, since the maximum buffer capacity is always 0
  - Moreover, queueing can be done within the I/O subsystem of the OS

Synchronizing Objects Consistently



- **Problem**: An ORB & application may need to use the same *type* of mutex to avoid priority inversions
  - *e.g.*, using priority ceiling or priority inheritance protocols
- **Solution**: Use the `RTCORBA::Mutex` interface to ensure that consistent mutex semantics are enforced across ORB & application domains

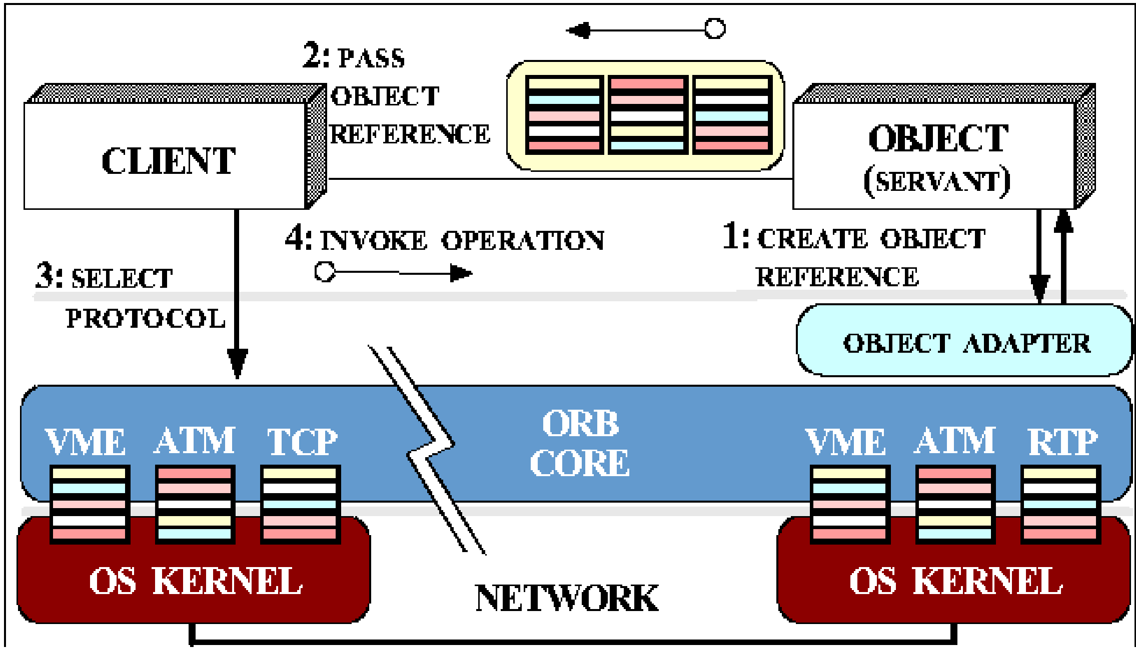
```
RTCORBA::Mutex_var mutex = rtorb->create_mutex ();
...
mutex->lock ();
// Critical section here…
mutex->unlock ();
...
rtorb->destroy_mutex (mutex);
```

`create_mutex()` is a factory method

Configuring Custom Protocols

- **Problems**: Selecting communication protocol(s) is crucial to obtaining QoS
  - TCP/IP is inadequate to provide end-to-end *real-time* response
  - Thus, communication between **`Base_Station`**, **`Controllers`**, & **`Drones`** must use a different protocol
    - *e.g.,* VME, 1553, shared memory, VIA, firewire, bluetooth, etc.
  - Moreover, communication between **`Drone`** & **`Controller`** cannot be queued

- **Solution**: Protocol selection policies
  - Both server-side & client-side policies are supported
  - Some policies control protocol selection, others configuration
  - Order of protocols indicates protocol preference
  - Some policies are exported to client in object reference



Ironically, RT-CORBA specifies only protocol properties for TCP!

Example: Configuring protocols

- First, we create the protocol properties

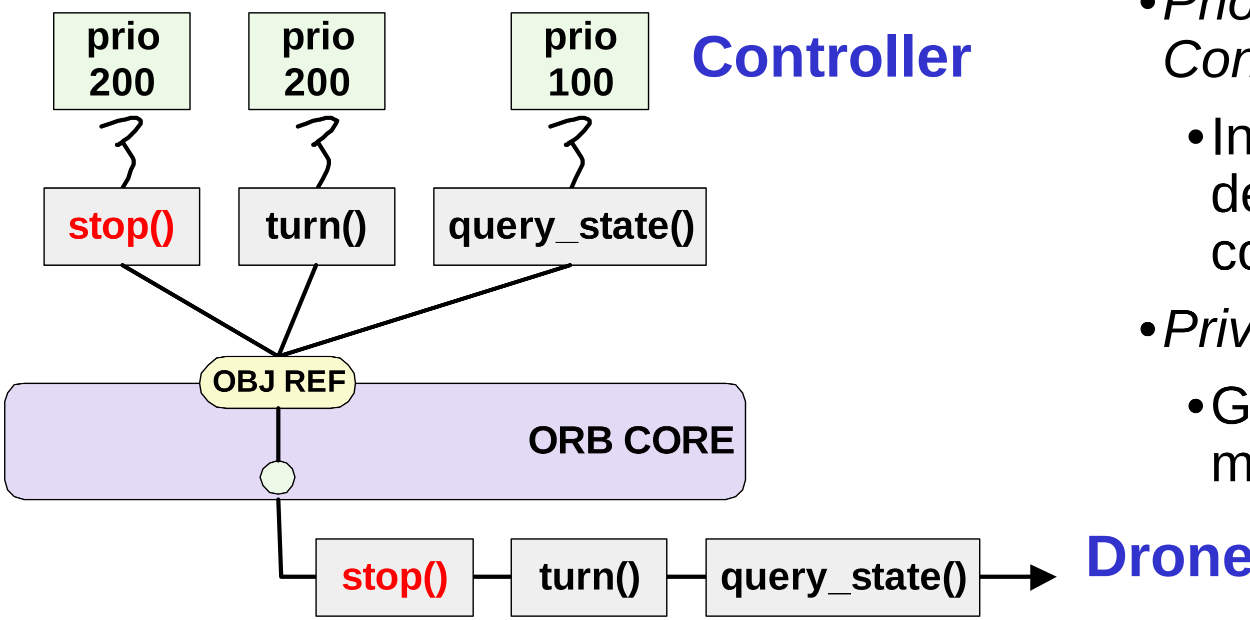
```
RTCORBA::ProtocolProperties_var tcp_properties =
   rtorb->create_tcp_protocol_properties (
        64 * 1024, /* send buffer */
        64 * 1024, /* recv buffer */
        false, /* keep alive */
        true, /* dont_route */
        true  /* no_delay */);
```

- Next, we configure the list of protocols to use

```
RTCORBA::ProtocolList plist; plist.length (2);
plist[0].protocol_type = MY_PROTOCOL_TAG;  // Custom protocol
plist[0].trans_protocol_props =
    /* Use ORB proprietary interface */
plist[1].protocol_type = IOP::TAG_INTERNET_IOP; // IIOP
plist[1].trans_protocol_props = tcp_properties;
RTCORBA::ClientProtocolPolicy_ptr policy =
   rtorb->create_client_protocol_policy (plist);
```

Controlling Network Resources

- **Problems**:
  - Avoiding request-level ("head-of-line") priority inversions
  - Minimizing thread-level priority inversions
  - Control jitter due to connection establishment



- **Solution**: Use explicit binding mechanisms, *e.g.*,
  - *Connection pre-allocation*
    - Eliminates a common source of operation jitter
  - *Priority Banded Connection Policy*
    - Invocation priority determines which connection is used
  - *Private Connection Policy*
    - Guarantees non-multiplexed connections

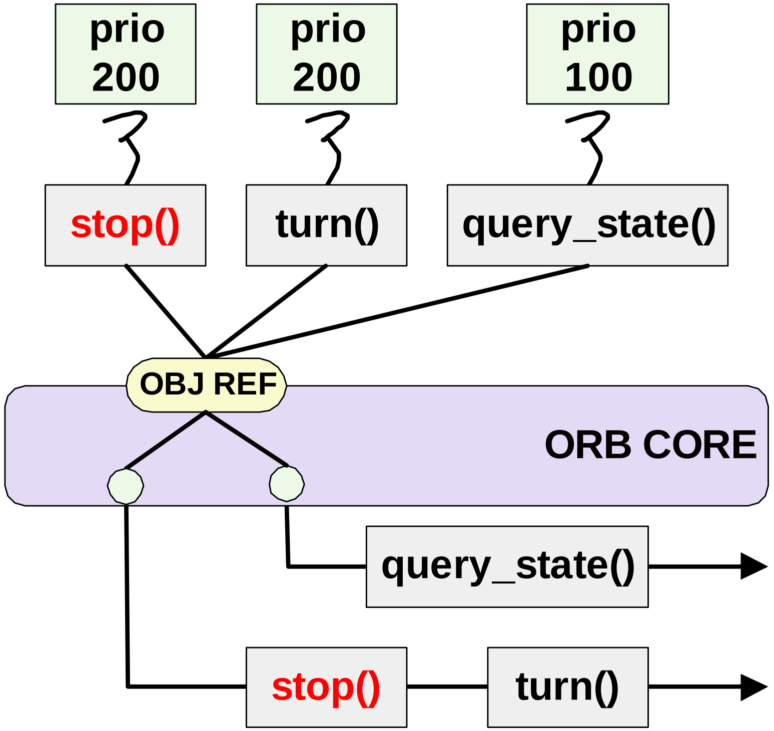
Pre-allocating Network Connections

- **Problem:** Dynamically establishing connections from the base station to/from the drones can result in unacceptable jitter, which can be detrimental to time-critical applications
- **Solution:** Pre-allocate one or more connections using the `Object::_validate_connection()` operation, which is defined in the CORBA Message specification

```
Drone_var drone = …; // Obtain reference to a drone

// Pre-establish connections using current policy overrides
CORBA::PolicyList_var inconsistent_policies;

// The following operation causes a _bind_priority_band()
// "implicit" request to be sent to the server
CORBA::Boolean successful =
   drone->_validate_connection (inconsistent_policies);
```

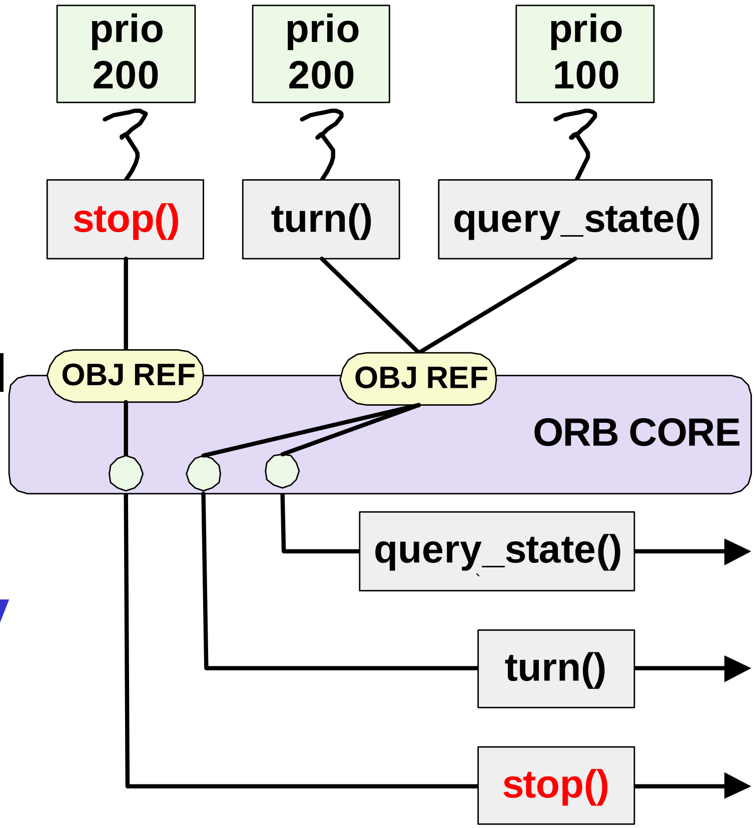
Priority Banded Connection Policy

- **Problem**: To minimize priority inversions, high-priority operations should not be queued behind low-priority operations
- **Solution**: Use different connections for different priority ranges via the RT CORBA `PriorityBandedConnectionPolicy`



Private Connection Policy

- **Problem**: To minimize priority inversions, some applications cannot share a connection between multiple objects
  - *e.g.*, sending a `stop()` request should use exclusive, pre-allocated resources



- **Solution**: Use the RT CORBA `PrivateConnectionPolicy` to guarantee non-multiplexed connections

Simplifying Application Scheduling

- **Problem**: Although RT-CORBA gives developers control over system resources it has two deficiencies:
  - It can be tedious to configure all the various policies
  - Application developer must select the right priority values
- **Solution**: Apply the RT-CORBA Scheduling Service to simplify application scheduling
  - Developers just declare the current *activity*
  - Properties of an activity are specified using an (unspecified) external tool
  - Note that the Scheduling Service is an optional part of the RT-CORBA 1.0 specification

```
// Find the scheduling service
RTCosScheduling::ClientScheduler_var scheduler = … ;

// Schedule the 'edge_alarm' activity
scheduler->schedule_activity ("edge_alarm");

controller->edge_alarm ();
```

The client-side programming model Is simple

Server-side Scheduling

```
// Obtain a reference to the scheduling service
RTCosScheduling::ServerScheduler_var scheduler = … ;

CORBA::PolicyList policies; // Set POA policies

// The scheduling service configures the RT policies
PortableServer::POA_var rt_poa = scheduler->create_POA
  (“ControllerPOA”,
   PortableServer::POAManager::_nil (),
   policies);

// Activate the servant, and obtain a reference to it.
rt_poa->activate_servant (my_controller);
CORBA::Object_var controller =
   rt_poa->servant_to_reference (my_controller);

// Configure the resources required for this object
// e.g., setup interceptors to control priorities
scheduler->schedule_object (controller, “CTRL_000”);
```

Servers can also be configured using the Scheduling Service

Other Relevant CORBA Features

- RT CORBA leverages other advanced CORBA features to provide a more comprehensive QoS-enabled ORB middleware solution, *e.g.:*
  - ***Timeouts***: CORBA Messaging provides policies to control roundtrip timeouts
  - ***Reliable oneways***: which are also part of CORBA Messaging
  - ***Asynchronous invocations***: CORBA Messaging includes support for type-safe asynchronous method invocation (AMI)
  - ***Real-time analysis & scheduling***: The RT CORBA 1.0 Scheduling Service is an optional compliance point for this purpose
    - However, most of the problem is left for an external tool
  - ***Enhanced views of time*****:** Defines interfaces to control & query "clocks" (orbos/1999-10-02)
  - ***RT Notification Service*****:** Currently in progress in the OMG (orbos/00-06-10), looks for RT-enhanced Notification Service
  - ***Dynamic Scheduling*****:** Currently in progress in the OMG (orbos/98-02-15) to address additional policies for dynamic & hybrid static/dynamic scheduling

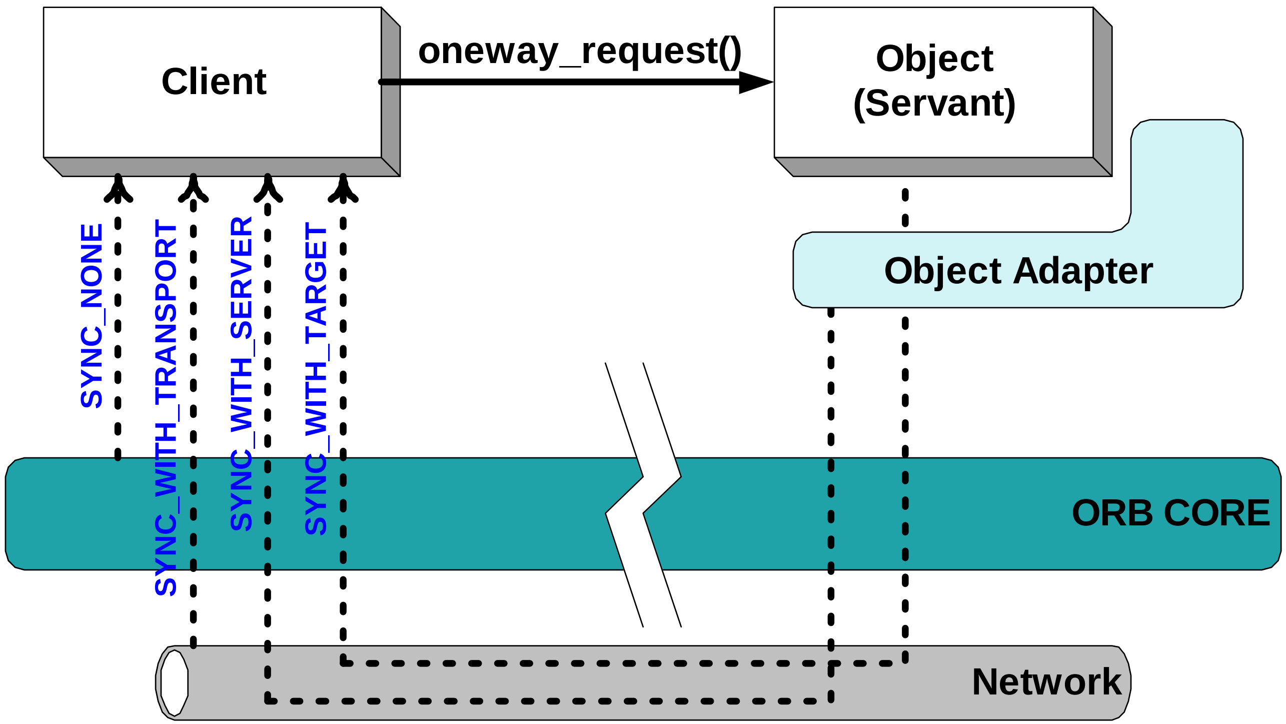
Controlling Request Timeouts

- **Problem**: Our **`Controller`** object should not block indefinitely when trying to stop a drone that's fallen off an edge!
- **Solution**: Override the timeout policy in the **`Drone`** object reference

```
// 10 milliseconds (base units are 100 nanosecs)
CORBA::Any val; val <<= TimeBase::TimeT (100000UL);

// Create the timeout policy
CORBA::PolicyList policies (1); policies.length (1);
policies[0] = orb->create_policy
   (Messaging::RELATIVE_RT_TIMEOUT_POLICY_TYPE, val);

// Override the policy in the drone
CORBA::Object_var obj = drone->_set_policy_overrides
   (policies, CORBA::ADD_OVERRIDE);

Drone_var drone_with_timeout = Drone::_narrow (obj);
try {  drone_with_timeout->speed (0); }
catch (CORBA::TIMEOUT e) { // Handle exception }
```

Reliable Oneways

- **Problem**: The **oneway** semantics are not precise enough for Real-time applications
- **Solution**: Use the **SyncScope** policy to control it.



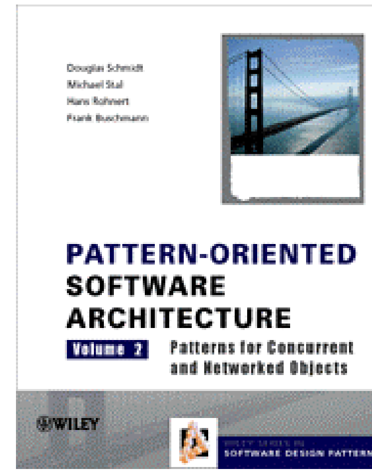
Open Issues with the Real-Time CORBA Specification

1. No standard APIs for setting & getting priority mappings & priority transforms
2. No compelling use-cases for server-set client protocol policies
3. Semantic ambiguities
   - Valid policy configurations & their semantics
     - *e.g.,* should a protocol property affect all endpoints or just some?
   - Resource definition & allocation
   - Mapping of threads to connection endpoints on the server
4. The bounds on priority inversions is a quality of implementation
   - No requirement for I/O threads to run at the same priority as request processing threads

Bottom-line: RT CORBA applications remain dependant on implementation details

Additional Information

- **CORBA 2.4 specification (includes RT-CORBA)**
  - **`www.omg.org/technology/documents/formal/corbaiiop.htm`**
- **Patterns for concurrent & networked objects**
  - **`www.posa.uci.edu`**

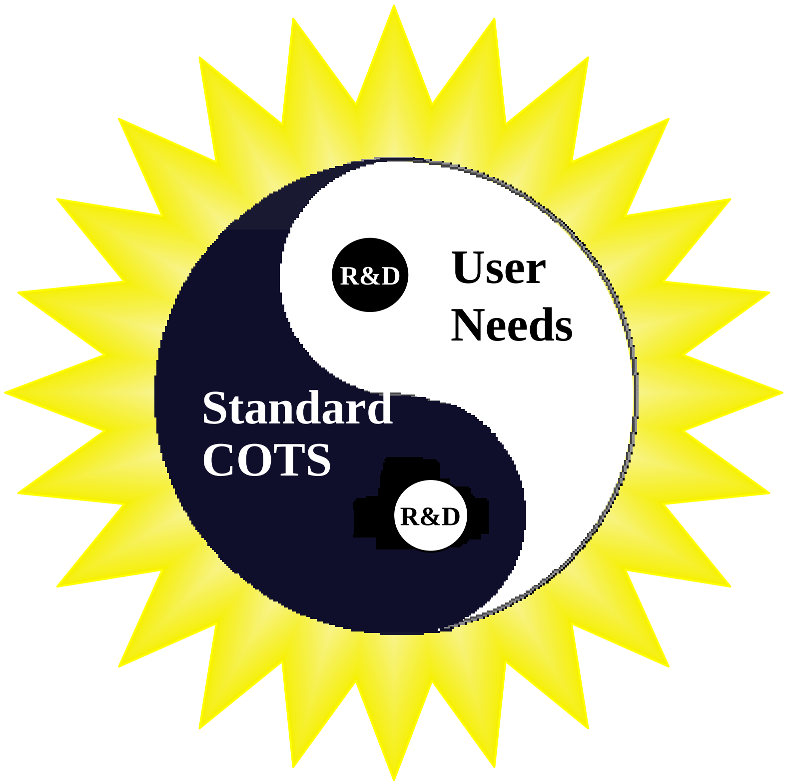


- **ACE & TAO open-source middleware**
  - **`www.cs.wustl.edu/~schmidt/ACE.html`**
  - **`www.cs.wustl.edu/~schmidt/TAO.html`**
- **CORBA research papers**
  - **`www.cs.wustl.edu/~schmidt/corba-research.html`**
- **CORBA tutorials**
  - **`www.cs.wustl.edu/~schmidt/tutorials-corba.html`**

Concluding Remarks

- RT CORBA 1.0 is a major step forward for QoS-enabled middleware
  - *e.g.,* it introduces important capabilities to manage key ORB end-system/network resources
- We expect that these new capabilities will increase interest in--and applicability of--CORBA for distributed real-time & embedded systems
- RT CORBA 1.0 doesn't solve *all* real-time development problems, however
  - It lacks important features:
    - Standard priority mapping manager
    - Dynamic scheduling
      - Addressed in RT CORBA 2.0
  - Portions of spec are under-specified
    - Thus, developers must be familiar with the implementation decisions made by their RT ORB

- Our work on TAO has helped advance middleware for distributed real-time & embedded systems by implementing RT CORBA in an open-source ORB & providing feedback to users & OMG



OOPSLA 2001 October 14th – October 18th

Workshop on

Towards Patterns and Pattern Languages for OO Distributed Real-time and Embedded Systems

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