Design and Implementation Issues in the Dynamic Scheduling Real-Time CORBA 2.0 Specification

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Comparison of Static and Dynamic Scheduling

<table>
<thead>
<tr>
<th>Static Scheduling</th>
<th>Dynamic Scheduling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tasks in the system are known</td>
<td>Tasks in the system may or may not be known</td>
</tr>
<tr>
<td>Execution time and QoS requirements of tasks are fixed</td>
<td>Execution time and QoS requirements of tasks change dynamically</td>
</tr>
<tr>
<td>A priori scheduling analysis possible</td>
<td>A priori scheduling analysis may not be possible</td>
</tr>
</tbody>
</table>
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Real-Time CORBA (RTCORBA) 1.0 Overview

- RTCORBA 1.0 adds QoS control to regular CORBA to improve the application predictability
  - Bounding priority inversions
  - Managing resources end-to-end
- Policies & mechanisms for resource configuration/control in RTCORBA include:
  - **Processor Resources**
    - Thread pools
    - Priority models
    - Portable priorities
  - **Communication Resources**
    - Protocol policies
    - Explicit binding
  - **Memory Resources**
    - Request buffering
- These capabilities however address only static real-time systems
Challenges: Dynamic Scheduling in Distributed Systems

- Tasks span multiple heterogeneous hosts
- Tasks and hosts they span are not known a priori
- Propagate scheduling requirements of a task across hosts it spans
- Allow custom scheduling discipline plug-ins
- Fixed priorities for tasks insufficient for scheduling analysis
- Cancel a distributed task and reschedule accordingly on hosts it spans
- Local schedulers need to reschedule when tasks return from a remote invocation
- Collaboration of schedulers in the system to ensure global scheduling
Solution: RTCORBA 2.0

- **Scheduling Segment** is a sequence of code with specific scheduling requirements
- **Distributable Thread (DT)** a programming model abstraction for a distributed task
  - Loci of execution spans multiple nodes and scheduling segments
  - Identified by a unique system wide id GUID (Globally Unique Id)
  - DT scheduling information passed through GIOP Service Contexts across hosts it spans
- **Pluggable Scheduler** facilitates the use of custom scheduling disciplines
- **Scheduling Points** to interact with the scheduler at application and ORB level
Scheduling Segments

- BSS - begin_scheduling_segment
- ESS - end_scheduling_segment

- RTScheduler::Current has methods to begin, end and update scheduling segments and spawn a new DT
- Each segment’s scheduling characteristics is defined by its Scheduling Parameters
- Nested scheduling segments allow association of different scheduling parameters
- Begin and End of a scheduling segment should be on the same host

[Diagram of scheduling segments and tasks]

- ApplicationCall
- TaskExecution
Distributable Threads May Span Endsystems

- Distributable Thread traversing multiple hosts with two-way invocations
Distributable Thread Creation

- Distributable Thread making One-Way invocation
  - New DT created implicitly
  - With implicit scheduling parameters

- Distributable Thread Spawn
  - New native thread created
  - New DT created
  - With implicit scheduling parameters
Distributable Thread Cancellation

- RTSScheduling::DistributableThread::cancel() cancels the DT
- This operation raises the CORBA::Thread_Cancelled exception at the next scheduling point
- The exception is propagated to the start of the DT
- The exception is not propagated to the head of the DT
- DT can be cancelled on any host that it currently spans
Pluggable Scheduling

- **Scheduling/Dispatching**
  - Enforce predictable behavior in DRE systems

- **Alternative disciplines**
  - RMS, MUF, EDF, LLF
  - Custom scheduling disciplines dictated by system requirements
  - Queried via resolve_initial_references
    - “RTScheduler”

- **RTScheduling::Scheduler interface**
  - From which implementations are derived
  - Interactions with application and ORB

- **Scheduler Managers**
  - Install/manage schedulers in the ORB
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Scheduling Points

1. Begin scheduling segment or spawn
2. Update scheduling segment
3. End scheduling segment
4. Send request
5. Receive request
6. Send reply
7. Receive reply
### Dynamic Scheduling

#### Scheduling Points, Continued

<table>
<thead>
<tr>
<th>User / ORB</th>
<th>Scheduler Upcall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current::spawn()</td>
<td>begin_new_scheduling_segment()</td>
</tr>
<tr>
<td>Current::begin_scheduling_segment() [when creating DTs]</td>
<td>begin_new_scheduling_segment()</td>
</tr>
<tr>
<td>Current::begin_scheduling_segment() [when creating nested segments]</td>
<td>begin_nested_scheduling_segment()</td>
</tr>
<tr>
<td>Current::update_scheduling_segment()</td>
<td>update_scheduling_segment()</td>
</tr>
<tr>
<td>Current::end_scheduling_segment() [when ending scheduling nested segments]</td>
<td>end_nested_scheduling_segment()</td>
</tr>
<tr>
<td>Current::end_scheduling_segment() [when destroying DTs]</td>
<td>end_scheduling_segment()</td>
</tr>
<tr>
<td>DistributableThread::cancel()</td>
<td>cancel()</td>
</tr>
<tr>
<td>Outgoing request</td>
<td>send_request()</td>
</tr>
<tr>
<td>Incoming request</td>
<td>receive_request()</td>
</tr>
<tr>
<td>Outgoing reply</td>
<td>send_reply()</td>
</tr>
<tr>
<td>Incoming reply</td>
<td>receive_reply()</td>
</tr>
</tbody>
</table>
• DT identity (GUID) vs. OS thread identity (tid)
  – Mapping may be many-to-many and may evolve over time
  – Need GUID aware concurrency and synchronization mechanisms
    • ORB-level schedulers, but also lower-level mutexes, TSS, managers
  – DT cancellation semantics depends on ORB-level concurrency
    • *i.e.*, reactive vs. cooperative vs. preemptive
Dynamic Distributed Scheduling Service

- Distributed Scheduling Service works with ORB local scheduler to enforce global scheduling
- Set *end-to-end* Urgencies (MUF) or raw CORBA priorities for DTs
- Determine cancellation points for overload management
- Interact with future scheduling adaptation mechanisms

RT CORBA 2.0 Pluggable Scheduler (e.g. WashU/Avionics Kokyu)
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Dynamic Scheduling

Fixed Priority Scheduler

<table>
<thead>
<tr>
<th>DT GUID on Host2</th>
<th>Start Time T (secs)</th>
<th>Importance</th>
<th>Execution Time (secs)</th>
<th>Local</th>
<th>Dist</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>0</td>
<td>15</td>
<td>10</td>
<td>-</td>
<td></td>
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<td>13</td>
<td>5</td>
<td>2</td>
<td>15</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DT GUID on Host1</th>
<th>Start Time T (secs)</th>
<th>Importance</th>
<th>Execution Time (secs)</th>
<th>Local</th>
<th>Dist</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
<td>10</td>
<td>5</td>
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<tr>
<td>6</td>
<td>7</td>
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<td>5</td>
<td>-</td>
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</tr>
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</table>
Shortcomings of the RTCORBA 2.0 specification

- Redundant operations for querying DT id
  - `Current::get_current_id()` is redundant
  - Id accessed with readonly attribute `Id`

- Insufficient operation parameters for `Current::spawn()`
  - Name, scheduling parameters
  - CORBA::VoidData data required by `ThreadAction::do()` method called by `spawn`

- Insufficient operations in `RTScheduling::Scheduler` interface for user and ORB interaction with scheduler
Future Work

• Global Scheduling
  – System wide scheduling algorithm
  – Interacting schedulers

• Multi-Level scheduling
  – Meta scheduling
  – Global optimality
Conclusions

• RTCORBA 2.0 provides mechanisms for dynamic scheduling in DRE systems

• RTCORBA 2.0 provides interfaces for:
  – User interaction with scheduler to schedule the task
  – ORB interaction with scheduler when sending/receiving requests
  – Scheduler developer’s implementation and plug-in of specific scheduling disciplines

• Implementation experience has shown some shortcomings in the RTCORBA 2.0 standard, particularly for truly pluggable schedulers.

• RTCORBA 2.0 implementation in TAO

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