Model Driven Quality Assurance Techniques for DRE Applications

Arvind S. Krishna & Emre Turkay
Andy Gokhale, Douglas C. Schmidt
Institute for Software Integrated Systems (ISIS)
Vanderbilt University
Nashville, TN 37203

Adam Porter, Cemal Yilmaz
Atif Memon

University of Maryland
College Park

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Context: Deployment & Configuration Spec

Packaging

- bundling a suite of software binary modules and metadata representing application components

Installation

- populating a repository with the packages required by the application

Configuration

- configuring the packages with the appropriate parameters to satisfy the functional and systemic requirements of application without constraining to any physical resources

Planning

- making appropriate deployment decisions including identifying the entities, such as CPUs, of the target environment where the packages will be deployed

Preparation

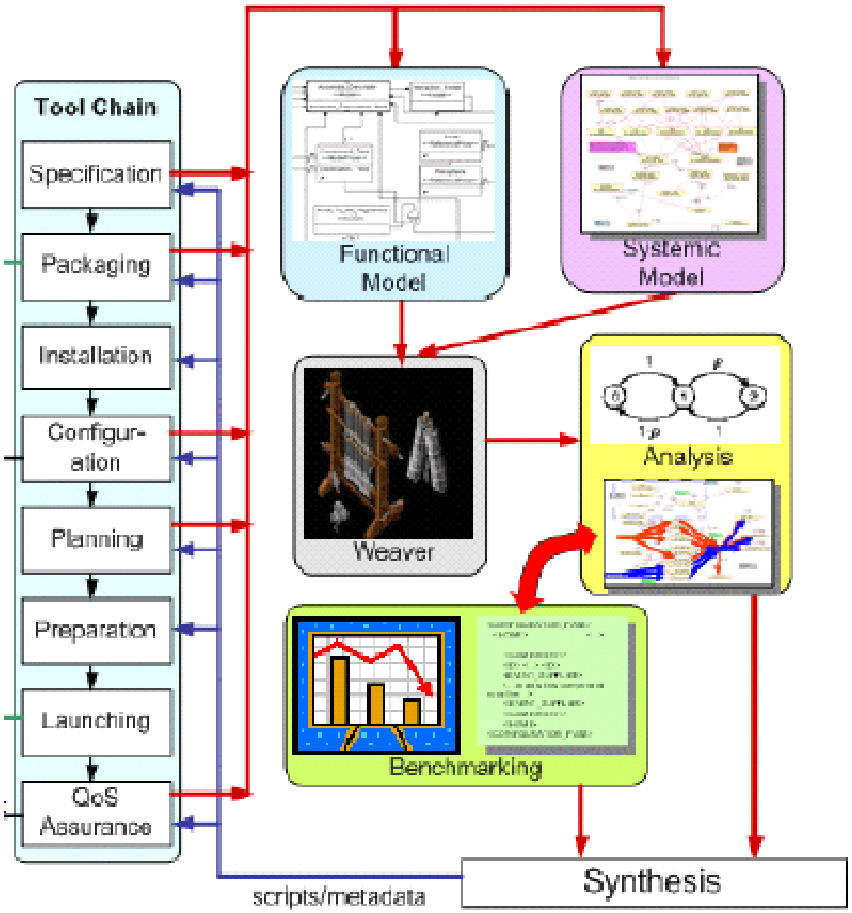
- moving the binaries to the identified entities of the target environment

Launching

- triggering the installed binaries and bringing the application to a ready state

Adaptation

- Runtime reconfiguration & resource management to maintain end-to-end QoS

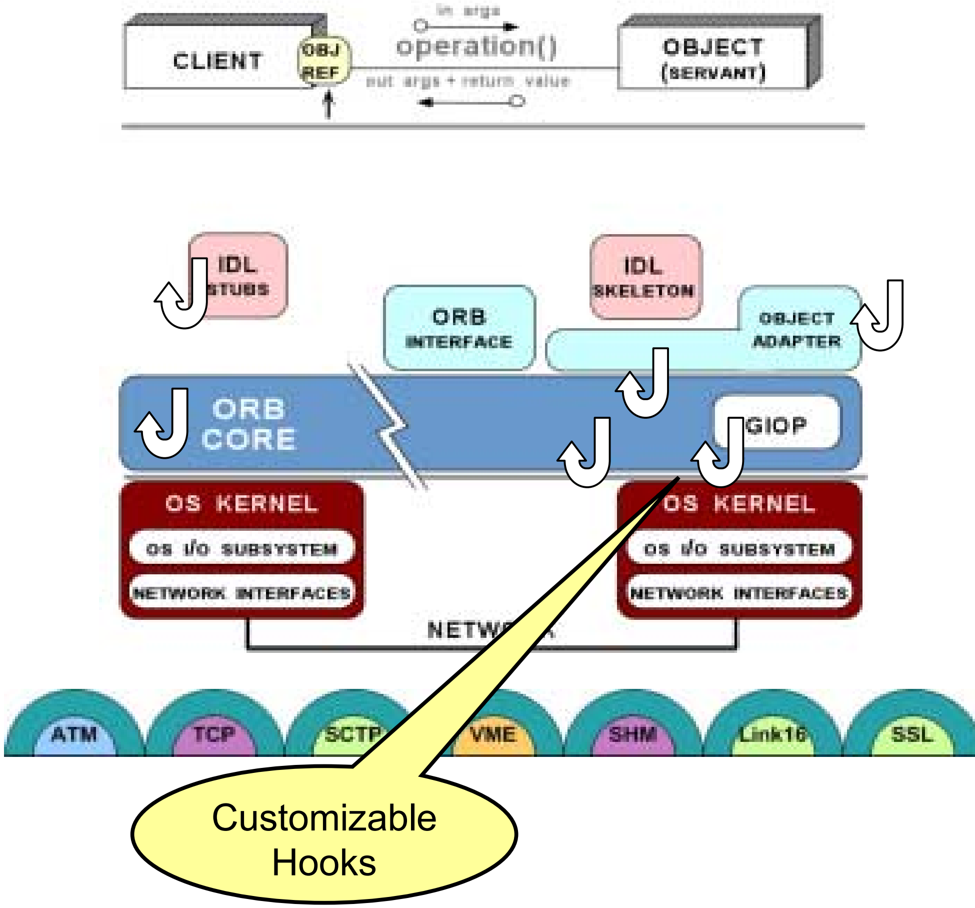


Configuring QoS Enabled Middleware

Various strategies in CIAO can be configured at initialization time

CIAO ORB is configured with service configuration files

```
ests/Latency/Thread_Per_Connection/svc.conf
ACE_Svc_Conf>
 <!--      -->
 <!--   $Id: svc.conf.xml,v 1.1 2002/08/23
 22:23:04 nanbor Exp $   -->
 <!--      -->
 <static id="Advanced_Resource_Factory"
   params="-ORBReactorType select_mt -
   ORBReactorMaskSignals 0 -
   ORBFlushingStrategy blocking" />
 <static id="Client_Strategy_Factory"
   params="-ORBTransportMuxStrategy
   EXCLUSIVE -ORBClientConnectionHandler
   RW" />
 <static id="Server_Strategy_Factory"
   params="-ORBConcurrency thread-per-
   connection" />
/ACE_Svc_Conf>
```



Configuration and Customization Patterns

Definition

- Several different ways to configure the underlying middleware
- Several domains have common characteristics. For example:
  - Avionics Domain and Enterprise Applications might share applications that have similar QoS requirements
  - Both might share similar concurrency, latency and jitter requirements
- If we can codify these recurring configurations then these are patterns that can be reused across these domains for the same middleware application

Identification

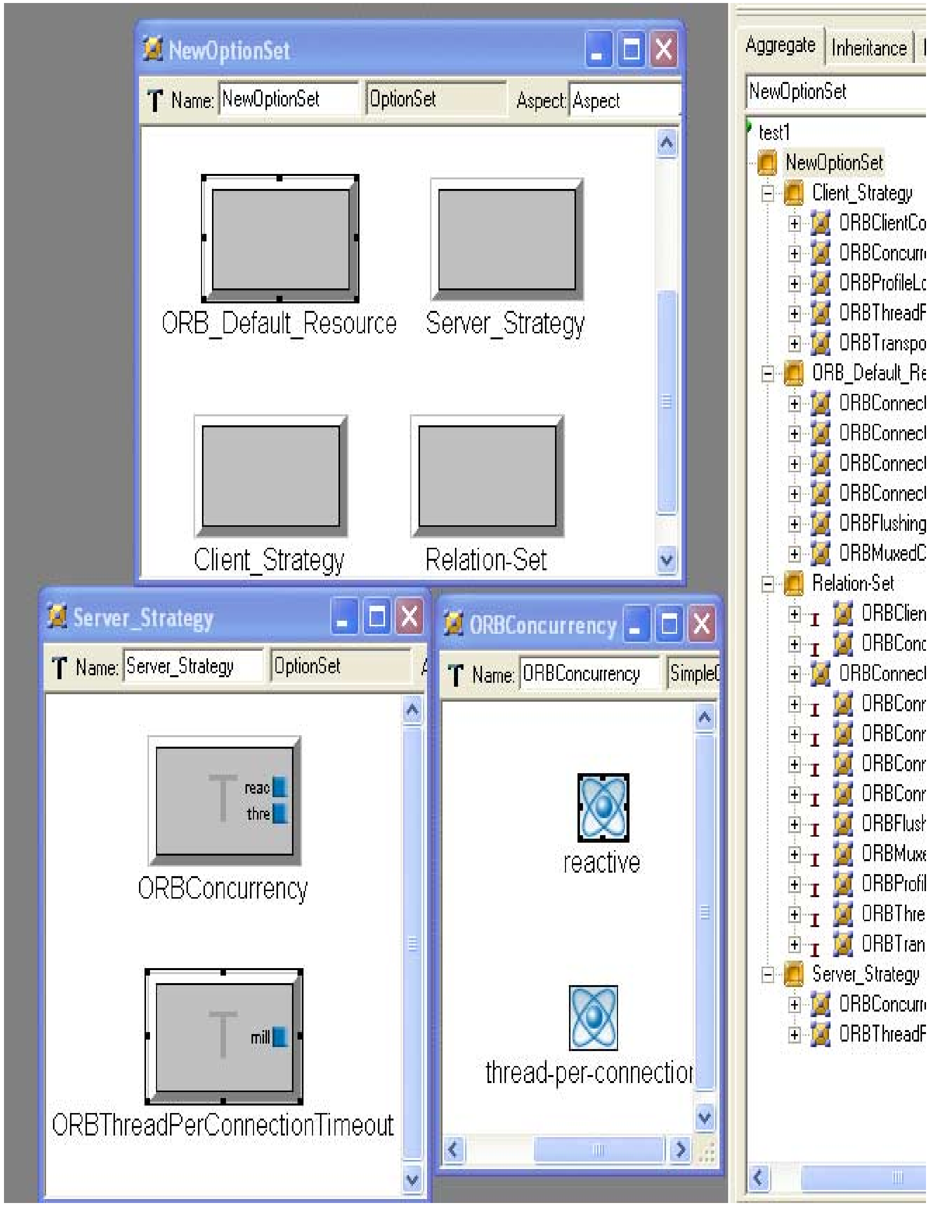
- To reduce the cost for identification of these patterns we have followed a three pronged approach
  1. Developed Configuration tools that allow end-users to model and generate semantically correct configuration options
  2. Developed Empirical evaluation tools to benchmark and run experiments on components configured using the configuration options
  3. Developed Distributed Continuous Quality Assurance techniques to iteratively run these configurations on varied hardware/OS/compiler platforms to identify recurring solutions to resolving QoS requirements.

Representation

- These patterns are represented as set of tuples {(x, value(x)} where x is the configuration option and value (x) is the configuration setting for x

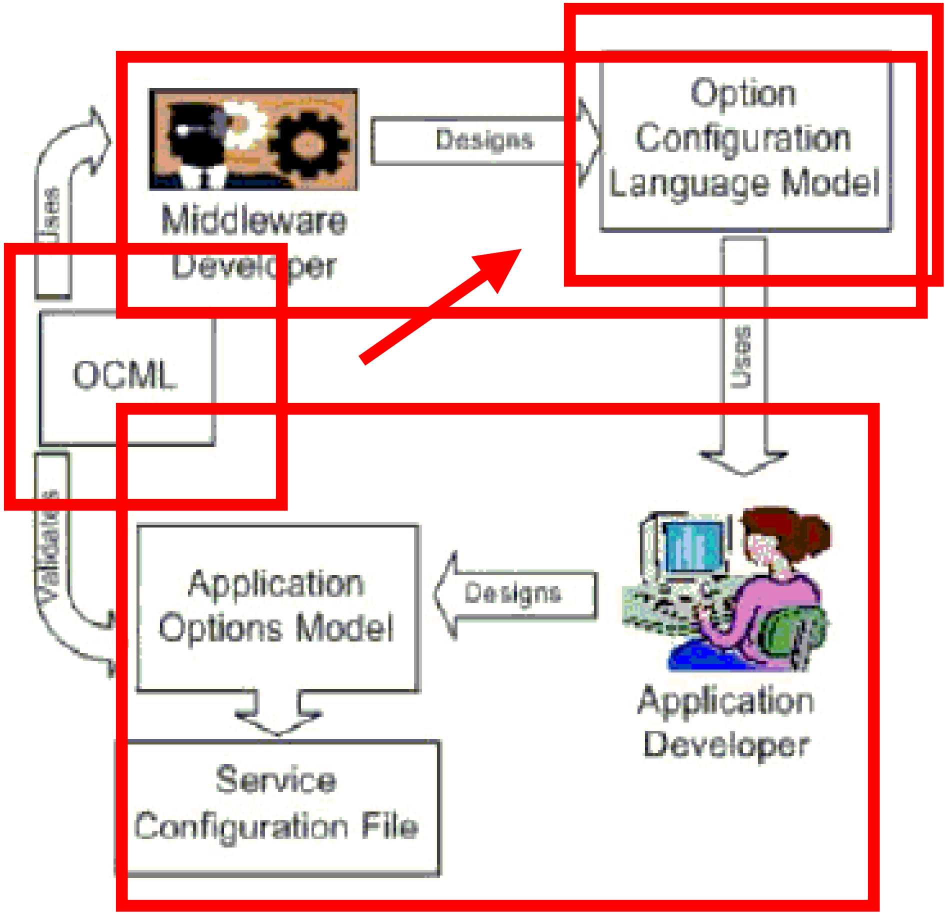
Model Based Solution → OCML

- Developed a domain-specific modeling language for TAO/CIAO called Options Configuration Modeling Language (OCML) using GME
- User provides a model of desired options & their values e.g.,
  - Middleware bus resources
  - Concurrency & connection management strategies
- Constraint checker flags incompatible options
- Synthesizes XML descriptors for middleware configuration
- Generates the documentation for the middleware configuration
- Online validation of the configurations



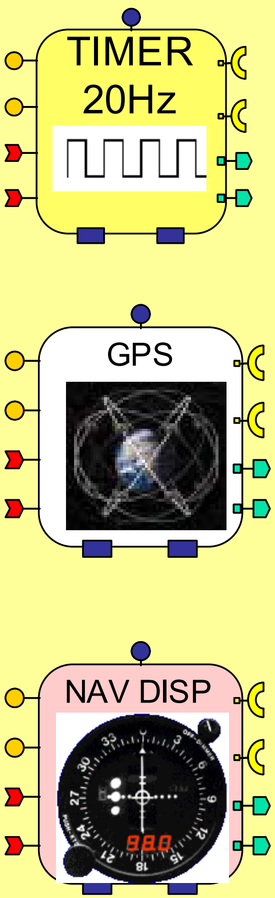
OCML Workflow

- OCML is used by
  - **Middleware developer** To design the Configuration Model
  - **Application Developer** To configure the Middleware for a Specific Application
- OCML metamodel is platform independent
- OCML models are platform specific

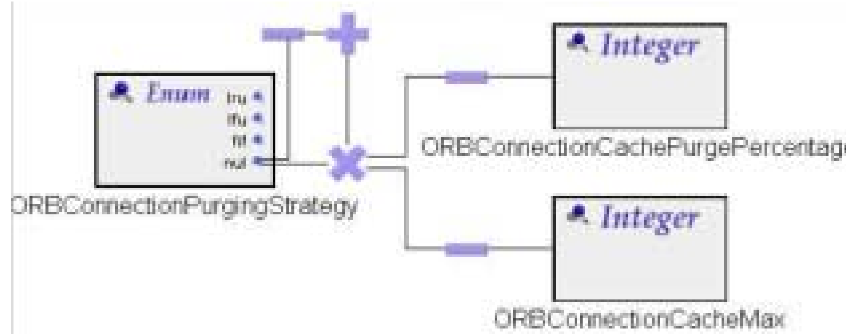


Configuration Aspect : Challenge #1

High priority



1: Users define the application QoS requirements such as pulse rate for the timer



2: Design model transformers to synthesize platforms-specific configurations for achieving QoS. Currently done with the OCML modeling paradigm

```
ests/Latency/Thread_Per_Connection/svc.conf
ACE_Svc_Conf>
 <!--      -->
 <!--   $Id: svc.conf.xml,v 1.1 2002/08/23
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   params="-ORBReactorType select_mt -
   ORBReactorMaskSignals 0 -
   ORBFlushingStrategy blocking" />
 <static id="Client_Strategy_Factory"
   params="-ORBTransportMuxStrategy
   EXCLUSIVE -ORBClientConnectionHandler
   RW" />
 <static id="Server_Strategy_Factory"
   params="-ORBConcurrency thread-per-
   connection" />
/ACE_Svc_Conf>
```
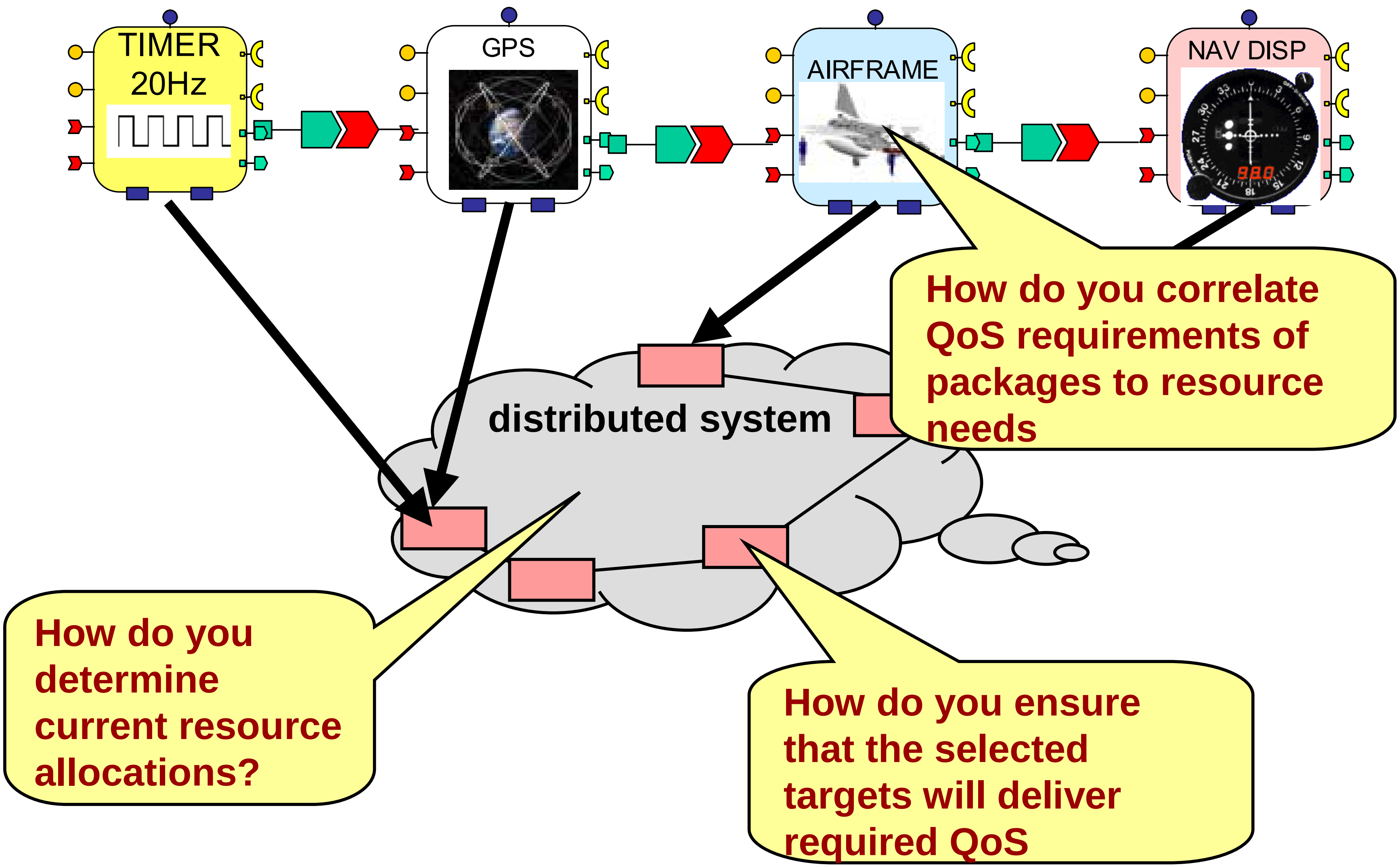

How do you ensure this configuration maximizes the QoS?

Planning Aspect : Challenge #2



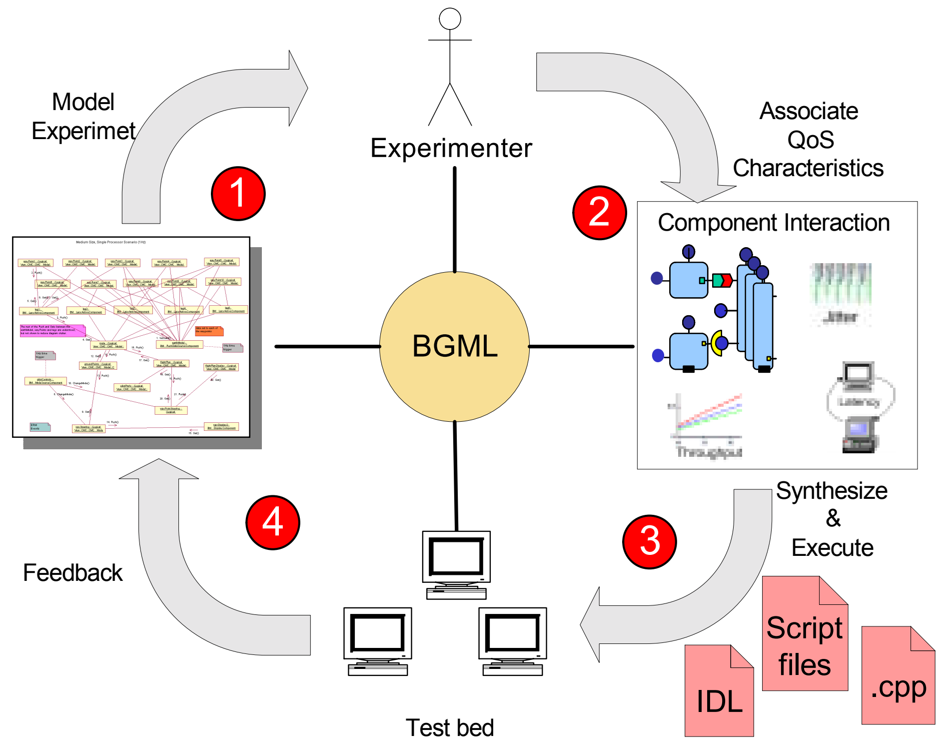
Solution – *BGML*

BGML Motivation

- Provide a model-driven tool-suite to empirically evaluate and refine configurations to maximize application QoS

BGML Workflow

1. End-user composes the scenario in the BGML modeling paradigm
2. Associate QoS properties with this scenario, such as latency, throughput or jitter
3. Synthesize the appropriate test code to run the experiment and measure the QoS
4. Feed-back metrics into models to verify if system meets appropriate QoS at design time



- The tool enables synthesis of all the scaffolding code required to set up, run, and tear-down the experiment.
- Using BGML tool it is possible to synthesize :
  - Benchmarking code
  - Component Implementation code
  - IDL and Component IDL files

Resolving Config & Planning Challenges

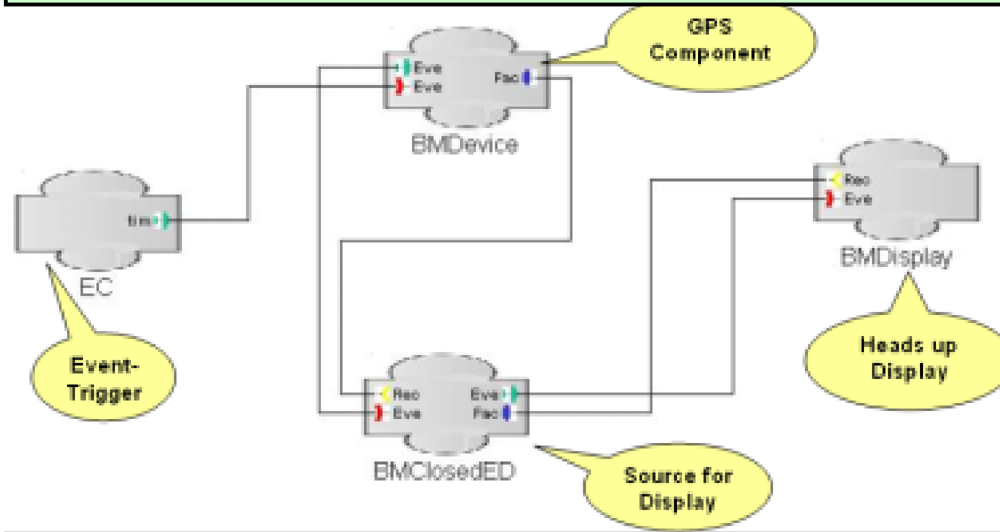
Resolving Challenge #1

- How to determine the configuration settings for the individual components to achieve the QoS required for this scenario?

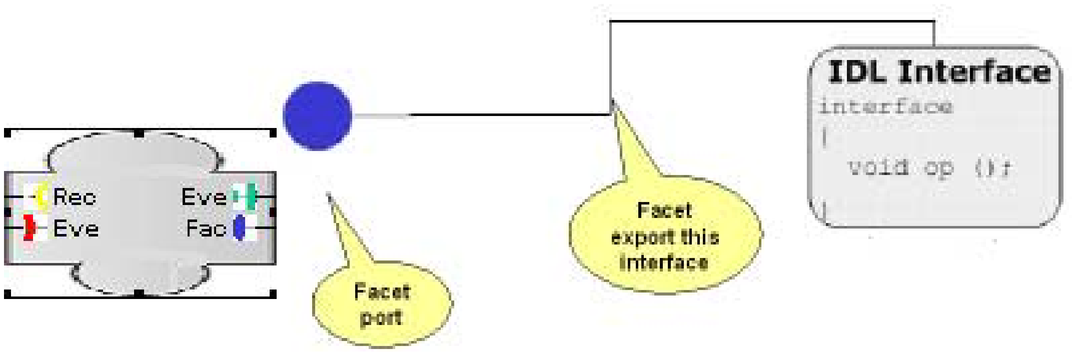
Boeing's BasicSP Scenario

- Navigation Display – displays GPS position updates
- GPS Component – generates periodic position updates
- Airframe Component – processes input from the GPS component and feeds to Navigation display
- Trigger Component – generates periodic refresh rates

Step1: Model Component Interaction using BGML Paradigm

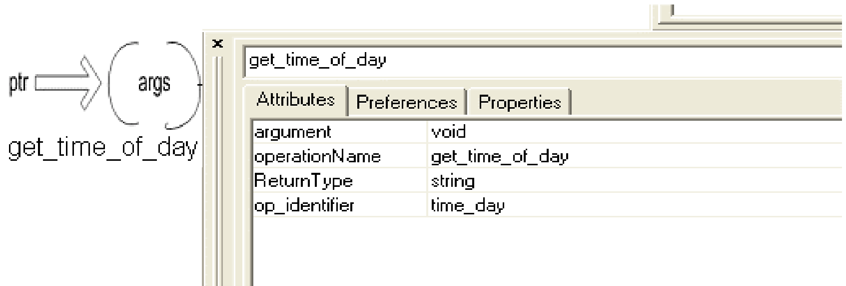


Step2: Configure each Component associating the appropriate IDL interfaces



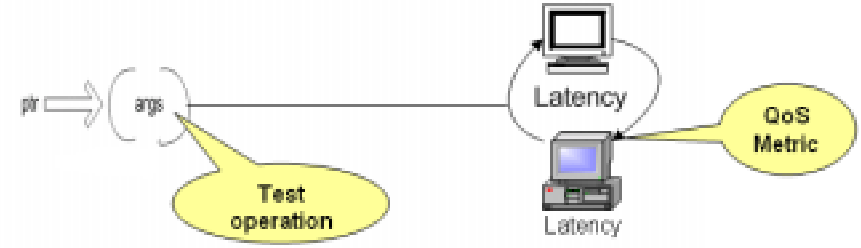
Modeling Avionics Scenario

Step3: Associate Operations with the Component Ports




```
void start_time_probe ()
{
  if (!timer_count)
      test_start = ACE_OS::gethrtime ();

     start_timer_probe = ACE_OS::gethrtime ();
}

void stop_time_probe ()
{
  finish_timer_probe = ACE_OS::gethrtime ();
  history.sample (finish_timer_probe - start_timer_probe);

  if (++ timer_count == niterations)
   {
     test_end = ACE_OS::gethrtime ();
     ACE_DEBUG ((LM_DEBUG, "test finished\n"));
        ACE_Throughput_Stats::dump_throughput ("Total", gsf,
                                   test_end - test_start,
                                   stats.samples_count ());
   }
}
```

Step4: Associate QoS metrics to measure in the scenario



- BGML Paradigm allows actual composition of the target interaction scenario, auto-generates benchmarking code
- Each configuration option can then be tested to identify the configuration that maximizes the QoS for the scenario
- These empirically refined configurations can be reused across applications that have similar/same application domains
- These configurations are configuration patterns – Configuration and Customization (C&C) patterns

BGML Metrics

Code Generation Metrics

- BGML allows generation of ~ 80% of all the required files to enact the scenario.

Files	Number	Source Lines of Code (SLOC)
IDL (*.idl)	5	125
Executor IDL (*E.idl)	4	40
Comp. IDL (*.cidl)	4	56
Source (.cpp)	4	525
Header (.h)	4	230
Config (svc.conf)	4	28
Benchmark (.cpp)	2	90

Identification of C&C Patterns

- For each component arrive at the configuration space i.e. all possible configuration parameters to tune QoS.
  - Nav Display component plays role of client with no requirements for concurrency
- Using each option permutation arrive at the option that optimizes QoS, e.g. latency for the application
- Set of configuration options along with the values represents a reusable configuration pattern

Notation	Option Name	Option Settings
o1	ORBProfileLock	{Thread, Null}
o2	ORBClientConnectionHandler	{RW, ST}
o3	ORBTransportMuxStrategy	{EXCLUSIVE, MUXED}
o4	ORBConnectStrategy	{reactive, LF}

Option Configuration	Latency QoS (msecs)
(o12 o22 o31 o42)	**35.58**
(o12 o22 o31 o41)	77.13
(o11 o22 o32 o41)	173.03
(o11 o21 o32 o41)	214.6
(o12 o21 o31 o41)	280.18
(o12 o21 o31 o42)	559.0
(o11 o21 o31 o42)	585.003
(o11 o21 o32 o42)	597.5
(o12 o21 o32 o42)	684.7
(o12 o21 o32 o41)	771.047
(o12 o22 o32 o42)	833.6
(o12 o22 o32 o41)	1077.725
(o11 o22 o32 o42)	1217.3
(o12 o21 o31 o41)	1258.8
(o11 o22 o31 o42)	1506.4
(o11 o22 o31 o41)	1589.4

For pure clients the following settings represents a reusable C&C pattern:
{(ORBProfile = null), (ORBClientConnectionHandler = RW), (ORBTransportMuxStrategy = Exclusive), (ORBConnectStrategy = Reactive)}

Distributed Continuous QA – Motivation

Persistent Challenges

- Scale
  - Massive configuration & optimization space
- Time to market pressure
  - Rapid updates, frequent releases
- Heterogeneity
  - Scattered resources & distributed developers
- Incomplete information
  - Unobservable usage context

Emerging Opportunities

- Leverage remote computing resources and network ubiquity for distributed, continuous QA

Existing Quality Assurance Processes:

- Auto-build scoreboard systems
  - e.g. Mozilla's Tinderbox
- Error reporting based on prepackaged installation tests
  - e.g. GNU GCC and ACE & TAO
- Online crash reporting
  - e.g. Netscape's QFA and Microsoft's Watson
- Shortcomings: inadequate, opaque, inefficient and inflexible QA processes
  - Scope: Generally restricted to functional testing and often incomplete
  - Documentation: No knowledge of what has or hasn't undergone QA
  - Control: Developers have no control over the QA processes
  - Adaptation: Can't learning from the earlier test results

Skoll Project

- Vision: QA processes conducted around-the-world, around-the-clock on powerful, virtual computing grid provided by thousands of user machines during off-peak hours
- Generic Skoll DCQA Process
  - Distributed
    - Identify QA task (e.g., testing, profiling, anomaly detection of program family)
    - Divide goal into subtasks each of which can be performed on a single processing node (i.e., user machines)
  - Opportunistic
    - When a node becomes available allocate one or more subtasks to it
    - Distribute subtasks to node and collect results when available
  - Adaptive
    - Use data-driven feedback to schedule and coordinate subtask allocation
- We are currently building an infrastructure, tools and algorithms for developing and executing thorough, transparent, managed, adaptive DCQA processes

The Skoll System

Configuration Model

Option	Settings	Interpretation
Compiler	{gcc2.96, SUNCC5_1}	Compiler
AMI	{1 = Yes, 0 = NO}	Enable Feature
CORBA_MSG	{1 = Yes, 0 = NO}	Enable Feature
CALLBACK	{1 = Yes, 0 = NO}	Enable Feature
POLLER	{1 = Yes, 0 = NO}	Enable Feature
run(T)	{1 = Yes, 0 = NO}	Test T runnable
Constraints		
AMI = 1 → CORBA_MSG = 1		
run(Multiple/run_test) = 1 → (Compiler = SUNCC5_1)		

Visualization

e.g., scoreboard

AIX

Build Name	Last Finished	Config	Setup	Compile	Tests	Failures	Status	Build Sponsor
AIX 5.1 VA6 Debug	[illegible]	[Config]	[Full]	[illegible]	[illegible]		Compile	Riverace
AIX 5.2 VA6-64 Debug	May 11, 2004 - 17:23	[Config]	[Full] [Brief]	[illegible]	[illegible]		Inactive	Riverace
AIX 5.2 VA6 Debug	May 12, 2004 - 14:37	[Config]	[Full] [Brief]	[illegible]	[illegible]	[illegible]	Inactive	Riverace
AIX 5.2 gcc3 Debug	May 11, 2004 - 16:06	[Config]	[Full] [Brief]	[Full] [Brief]	[illegible]	[illegible]	Compile	Riverace

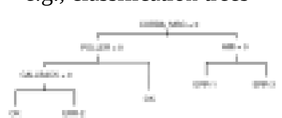
HP-UX

Build Name	Last Finished	Config	Setup	Compile	Tests	Failures	Status	Build Sponsor
HP-UX 11.00 aC++ Debug	May 12, 2004 - 14:12	[Config]	[Full]	[Full] [Brief]	[illegible]		Inactive	Riverace
HP-UX 11.00 gcc3 Debug	May 11, 2004 - 15:41	[Config]	[Full]	[Full]	[illegible]	[illegible]	Compile	Riverace

<version>v5.2.3</version>
</download>
…
</subtask>

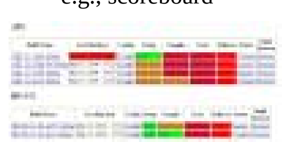
Automatic characterization

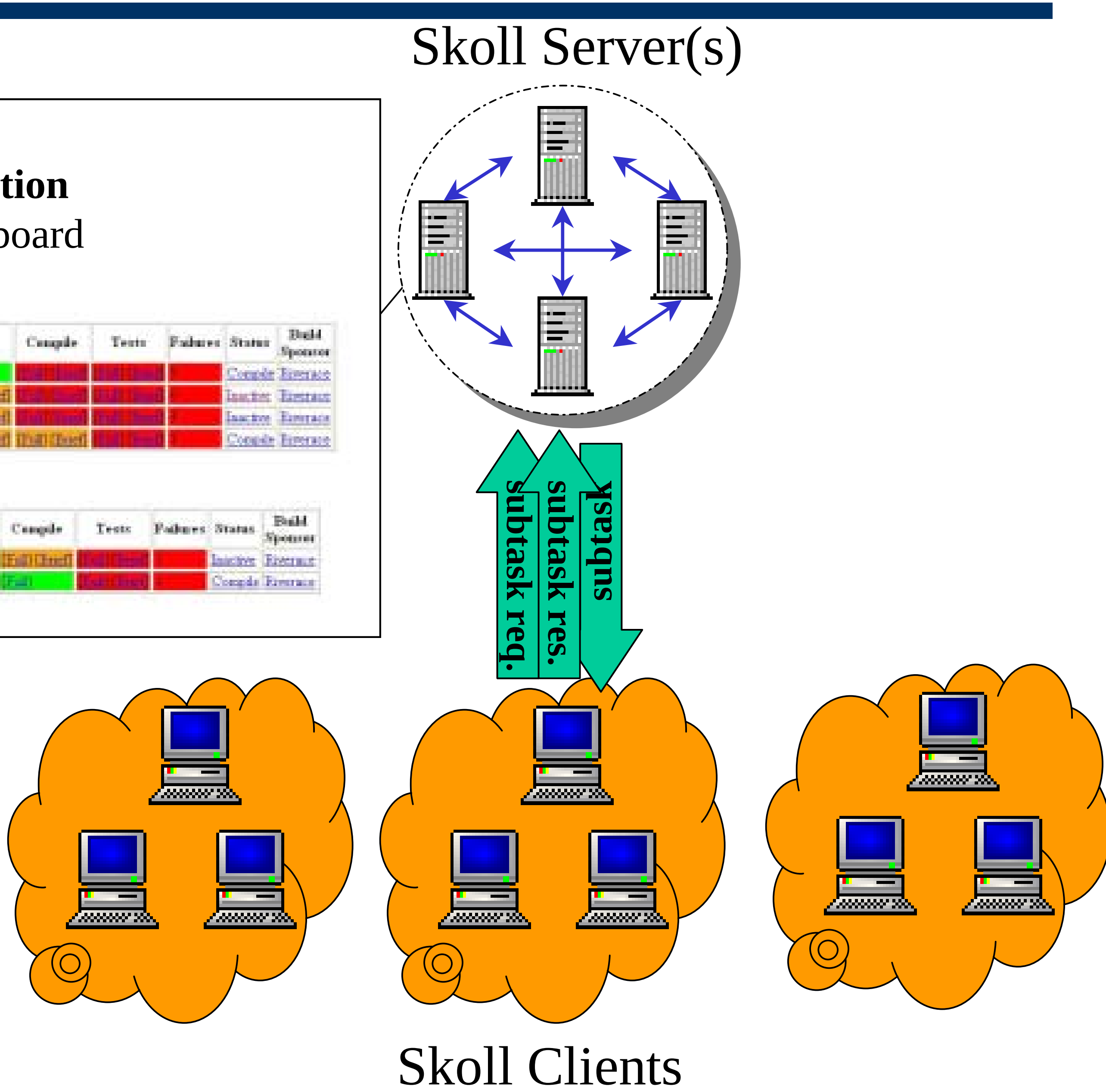
e.g., classification trees



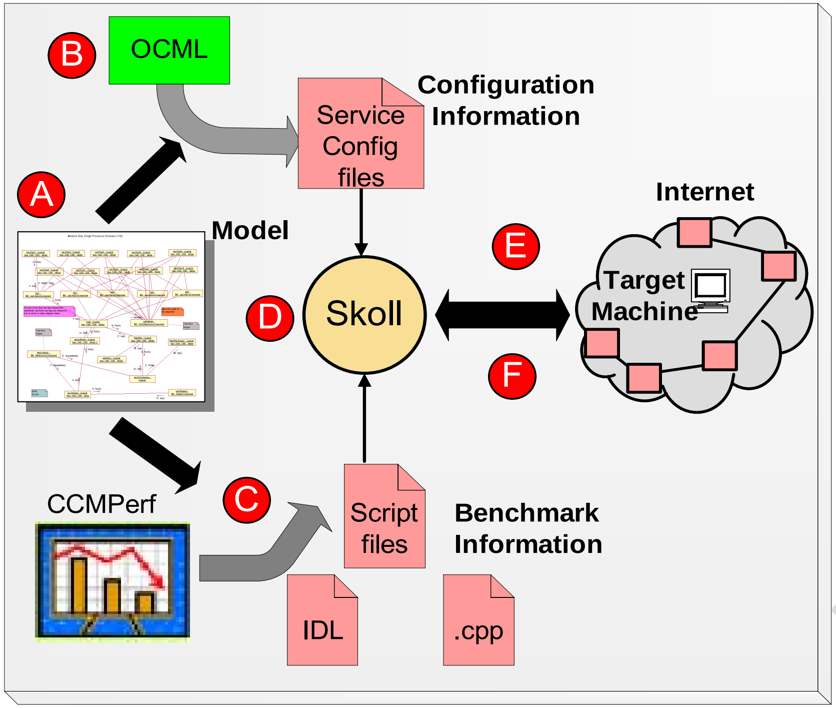
Visualization

e.g., scoreboard





Discovery & Classification of C&C patterns



A: Model test-application

B: Synthesize required configuration parameters using OCML

C: Synthesize benchmarking code using BGML

D: Feed test code to Skoll framework

E: Run on varied platforms to measure QoS variations

F: Maintain database of results from which C&C patterns can be identified

Context

- Identifying C&C patterns allows reusable best configurations to be readily applied to similar QoS requirements in various domains.

Problem

- Identification hard as we need to explore the entire configuration space. These keep growing at a great pace.
  - Leads to configuration space explosion.
  - No time to run tests for each combination for lack of resources.

Solution → Distributed Continuous Quality Assurance (DCQA)

- Framework for running tasks on user donated machines around the word, around the clock.
- Uses spare CPU cycles on user machines, like SETI@home project
- Enables identification and validation of C&C patterns on range of hardware, OS and compiler platforms

Downloading the Middleware & Tools

- Beta and Stable release can be accessed from **http://www.dre.vanderbilt.edu/Download.html**

OCML & BGML are part of the CoSMIC MDM tool suite

CoSMIC

- **http://www.dre.vanderbilt.edu/cosmic**