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# High Level Architecture for Distributed Simulations



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# Introduction



- Parallel/Distributed Systems – composed of multiple interconnected computers
- Difference between Parallel & Distributed Systems
- Benefits of P/D Simulation System:
  - Reduced execution time
  - Geographical distribution
  - Integrating multiple computer architectures
  - Fault tolerance
- Usage: high-performance computing (queuing systems), defense community (SIMNET, DIS, HLA), entertainment (VR, gaming, training systems)

# Hardware Platforms



- Shared-Memory Multiprocessors
  - Shared variables via [UMA](#) and [NUMA](#)
  - High-speed interconnection network between CPU/cache modules and memory banks, I/O devices
- Distributed-Memory Multicomputers
  - All communication via message passing
  - CPU/cache/memory modules interconnected via network
- SIMD Machines
  - Instructions broadcast by control unit to each processing element (PE)
  - All PEs are network-interconnected

# Current Cluster Architecture



- SCEROLA Cluster Multicomputer (shared):
  - 65-node cluster, each node containing:
    - AMD T-Bird 900MHz processor, 256MB RAM (133MHz)
    - 9GB Hard Disk (NFS, emulating shared-disk)
    - Fast Ethernet 100Mbps interconnection network
    - System clock synchronized via message-passing
    - Linux RedHat 7 OS (individual copy on each processor)
    - MPICH 1.2.1
- Issues:
  - Shared system with multiple users
  - May produce biased simulation results

# Computer Simulation - Introduction

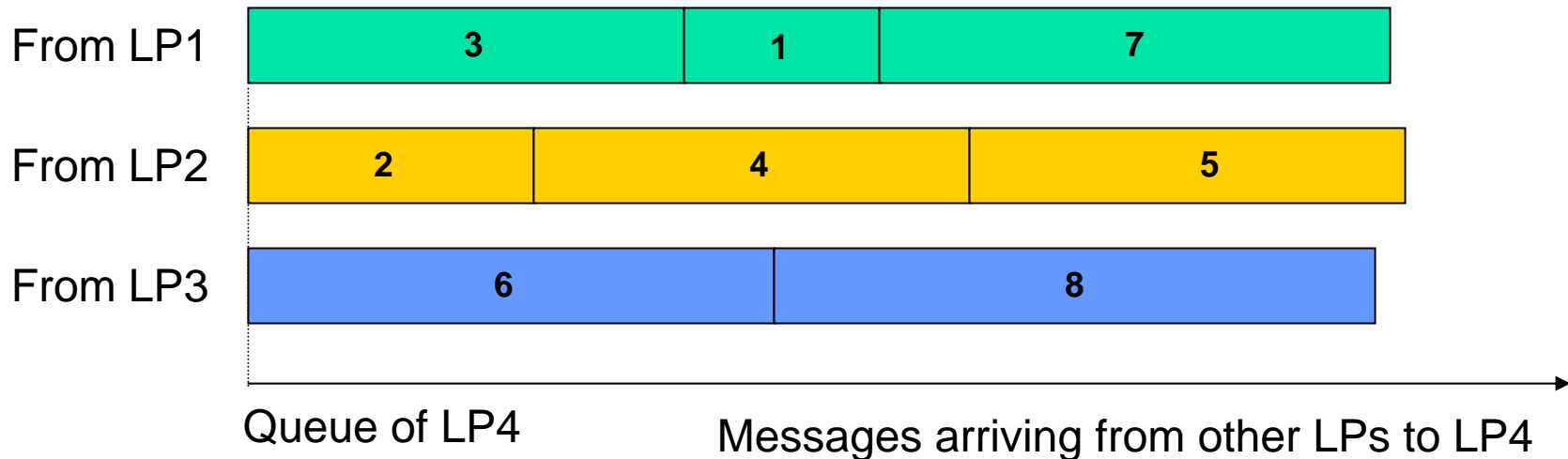


- Simulation execution:
  - Real-time
  - Scaled real-time
  - As-fast-as-possible
- Time flow mechanism:
  - Continuous
  - Discrete:
    - Time-stepped
    - Event-driven
- Object-oriented and object-based simulations

# Parallel and Distributed Simulation




- Synchronization Problem
  - Local Causality Constraint (non-decreasing timestamps)
- Lookahead Principle (null messages):




Process event 1, set  $t_0$  to  $\text{size}(1)$ , then send null message to LP1-3 with timestamp of  $\text{size}(2) - \text{size}(1) = \text{clock} + \text{lookahead}$ .

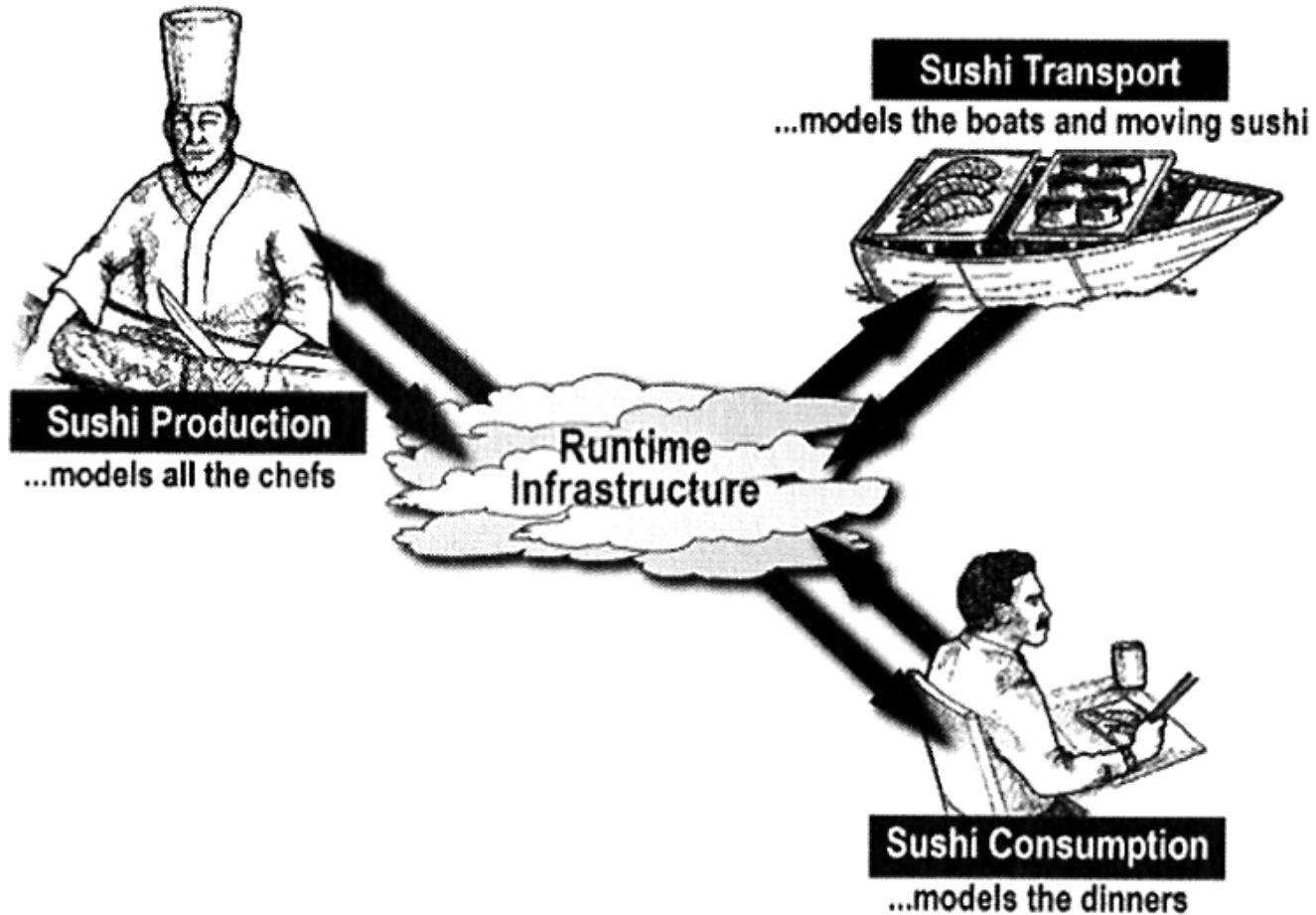
# Why Parallel Simulation?

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- In our intrusion detection framework for wireless ad hoc networks was initially implemented for a single workstation
  - With increase in number of nodes comprising the simulation, processing time and memory usage increased proportionally
  - Most computation-intensive tasks are performed on each node, and communication subsystem requires much smaller amount of system resources
  - Distributing nodes among multiple processors promises good scalability results

# HLA Introduction

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- HLA - High Level Architecture
  - A framework for distributed systems implementation
  - A software architecture for large scale distributed simulations
  - Adopted by DoD for all modeling and simulation activities

# Example – Sushi Restaurant Federation



# Terminology

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- HLA
- Federation
- Federate
- Federation Execution
- RTI


# Federation




*Consists of:*

- Runtime Infrastructure (RTI)
- Federation Object Model (FOM)
- Federates


# Federate

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- Member of the federation
  - May consist of a single process or several processes
  - Granularity depends on the implementation
  - Has strict guidelines for defining data and methods

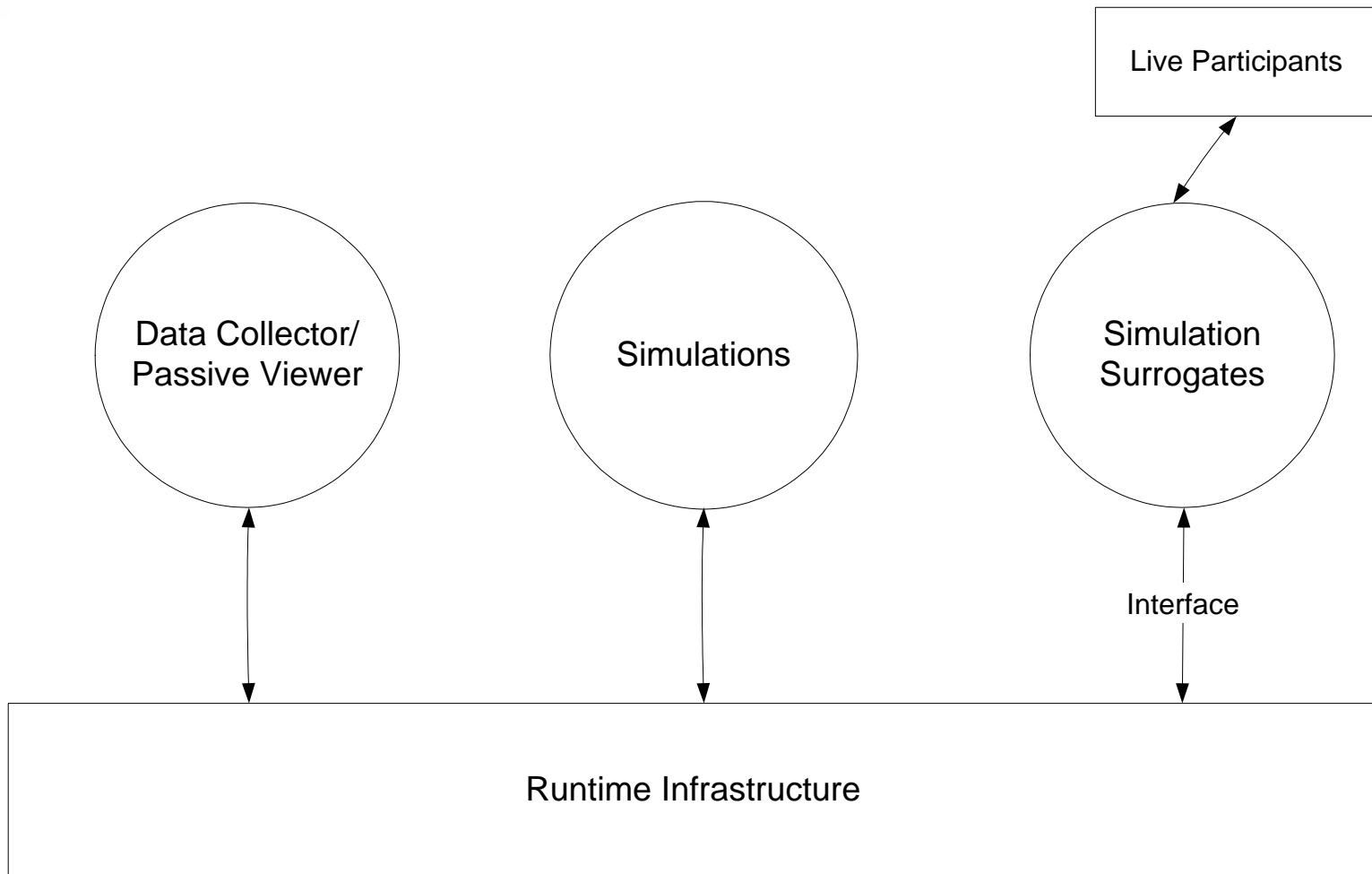
# Federation Object Model (FOM)

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- Data component of HLA
  - Contains the data types
  - Specifies data type rules
  - Helps a structured communication among federates
  - Furnished to the RTI during federation execution


# HLA as Software Architecture

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- HLA is a layered architecture
    - Distributed nature is hidden from federates
  - HLA is a data abstraction architecture
    - All federates inherit the same interface
    - All communication is done via RTI
  - HLA is an event-based architecture


# Software Components of HLA



# Information Model

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- Object Model Template (OMT) prescribes the structures for all FOMs
  - FOM is the *vocabulary of data* exchanged through the RTI
  - FOM describes only *shared* data with other federates
  - FOM is a parameter to the RTI at the beginning of an execution
  - RTI does not change when FOM is changed

# Federation Rules

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- Federations shall have an HLA FOM in accordance with HLA OMT
  - In a federation, all simulation-associated object instances are in the federates
  - All exchanges of FOM data among federates occur via RTI
  - Federates shall interact with the RTI in accordance with the HLA Interface Specification
  - An instance attribute shall be owned by at most one federate at any time

# Federate Rules



- All federates have an HLA Simulation Object Model (SOM)
- Federates shall be able to update attributes and manage interactions, as specified in their SOMs
- Federates shall be able to transfer ownership of attributes dynamically, as specified in their SOMs
- Federates shall be able to manage local time

# HLA Services



- Federation Management
  - by defining a federation execution and membership
  - by accomplishing federation-wide operations
- Declaration Management
  - Federates declare their intent to produce/publish and consume/subscribe to data
- Object Management
  - Send and receive interactions
  - Register new instances of an object class and update its attributes

# HLA Services (Continued)



- Ownership Management
  - This service in the RTI implements the HLA's notion of security while simulating an entity
- Time Management
  - Allow each federate to advance its logical time in coordination with other federates
  - Control the synchronized delivery of time-stamped events
- Data Distribution Management
  - Control the producer-consumer relationships among federates
  - Manages relationships in terms of object instances and routing spaces

# Demo 1 – Chat System



- Objective: to develop personal network communication system using HLA
- Tasks:
  - Work in groups of 2 people (1 per workstation)
  - Start RTI on one workstation (run rti2.bat file in HLA folder)
  - Start Chat federate on each workstation from Examples\Chat folder:  

```
java -classpath prti.jar;jgl3.1.0.jar;"%classpath%" Chat <IP Address>
```
  - Type any text in the window at the prompt
- Result: Each workstation sends data via RTI communication bus, and results are displayed at another workstation.
  - Note: Corresponding IP address will be displayed at each workstation

# Demo 1 - Code Details



Java file: Chat.java

1. Try to create a federation. If it exists already, then join it:

```
_rtiAmbassador = RTI.getRTIAmbassador(rtiHost, 8989);
    try {
        _rtiAmbassador.createFederationExecution(
            "ChatRoom", new URL("file:chat.fed"));
    }
catch (FederationExecutionAlreadyExists ignored) { }
_rtiAmbassador.joinFederationExecution("Chat", "ChatRoom", this);
```

# Demo 1 - Continued



2. Create point of interaction from FOM specifications:

```
_messageId = _rtiAmbassador.getInteractionClassHandle(  
    "Communication");  
_parameterIdText = _rtiAmbassador.getParameterHandle(  
    "Message", _messageId);  
  
_rtiAmbassador.subscribeInteractionClass(_messageId);  
  
_rtiAmbassador.publishInteractionClass(_messageId);
```

# Demo 1 - Continued



3. Create a parameter for communication and send an HLA interaction via federate's RTI Ambassador:

```
SuppliedParameters parameters =  
    RTI.suppliedParametersFactory().create(1);
```

```
byte[] value = cmdline.getBytes();
```

```
parameters.add(_parameterIdText, value);
```

```
_rtiAmbassador.sendInteraction(_messageId, parameters,  
    null);
```

# Demo 2 – Sorting Server



- Objective: to develop a client - server system using HLA
- Tasks: <http://www.cs.ucf.edu/courses/cda4932.spr02/assign2.html>
  - Work in groups of 2 people (1 per workstation)
  - Start RTI on one workstation (run rti2.bat file in HLA folder)
  - Start Sorting Server federate on one workstation from Examples\Sort folder:  
`java -classpath prti.jar;jgl3.1.0.jar;"%classpath%" Server <IP Address>`
  - Start Client federate on another workstation from Examples\Sort folder:  
`java -classpath prti.jar;jgl3.1.0.jar;"%classpath%" Client <IP Address>`
  - Repeat running client for a few iterations
- Result: Client workstation sends unsorted data to a Server via RTI, and the Server returns sorted data to the client.

# Demo 3 – Distributed Database System



- Objective: to develop a distributed database query system using HLA
- Tasks: <http://www.cs.ucf.edu/courses/cda4932.spr02/assign3.html>
  - Work individually (1 or 2 people per workstation)
  - Open 4 DOS windows
  - Start RTI on a workstation (run rti2.bat file in HLA folder)
  - Start Sorting Server federate 3 on a workstation from Examples\Query folder, one command per each DOS window:

```
java -classpath prt.jar;jgl3.1.0.jar;"%classpath%" Server1
java -classpath prt.jar;jgl3.1.0.jar;"%classpath%" Server2
java -classpath prt.jar;jgl3.1.0.jar;"%classpath%" Server3
```

# Demo 3 (cont.-d)



- Start Client federate on a workstation from Examples\Query folder:  
`java -classpath prt.jar;jgl3.1.0.jar;"%classpath%" Client`
- Issue a query in the format (any of the following):  
`age=24`  
`fname=Wendy`  
`lname=Arthurs`
- Server will return the search results
- Repeat running client for a few iterations
- Result: Client workstation sends a query to each Database Server via RTI, and each Server returns results of the query to the Client. Each server processes user query (database search operation) in parallel.

# References



- “Creating Computer Simulation Systems: an Introduction to the High Level Architecture”, Frederick Kuhl, Richard Weatherly, Judith Dahmann, Prentice Hall PTR. ISBN 0-13-022511-8
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- DMSO Software Distribution Center: <https://sdc.dmsso.mil/>
- Pitch pRTI (free implementation 1.3):  
<http://www.pitch.se/>
- Oleg Kachirski – HLA website:  
<http://www-ece2.engr.ucf.edu/~oka/eel6885/>
- CDA4932 Distributed Systems course website:  
<http://www.cs.ucf.edu/courses/cda4932.spr02/index.html>