SIMULATING MULTIPLE SYSTEMS OF SYSTEMS USING THE HIGH LEVEL ARCHITECTURE

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Abstract

Simulation provides the ability to obtain results from, and analyse, a system without physically building the system. These results can be used to inform the actual construction of the physical system, how best to use a system, how best to integrate a system with another system, and so on. A simulation can also be used to train and educate the end-users of a system either before the system is actually produced or when the availability of the actual system is limited.

Most end systems are in some way composed of subsystems. The subsystems themselves may be composed of subsystems. This type of architecture is generically referred to as a system of systems. For example, a ship is composed of a hull, engines, sensors, etc. The engine system may be composed of the fuel and cooling subsystems, for example. Systems constructed this way have numerous benefits including allowing subsystems to be built independently of each other (after creating well defined interfaces), and allowing for subsystems to be replaced without affecting other subsystems. These same benefits are desirable in the construction of a simulation of a system. One simulation framework that supports these ideals is the High Level Architecture (HLA).

The HLA is an international modelling and simulation framework that specifically provides for distributed simulation. The HLA uses the term federate for component simulations that are then brought together in a distributed computing environment to form a federation. The HLA defines a data model for documenting the data interfaces of the federates and the application programming interface used by the federates to communicate data. A simulation of a systems of systems architecture can be implemented in the HLA by creating federates for each subsystem and defining the data communicated between subsystems in terms of HLA's data model.

HLA's default communication model defines publishers and subscribers of data classes. The HLA provides class based filtering, i.e., a federate only receives data for a data class to which it has subscribed. However, HLA's default communication model has no notion of direct 'wiring' between federates. Thus, it is not possible to have data sent to a specific federate. This creates a problem if multiple instances of a system of systems are simulated concurrently, which may be desirable so as to observe the interactions between systems. In this case, the data sent within one system is exposed to all other systems in the simulation.

This thesis explores this problem of simulating multiple systems of systems using the HLA. The problem is stated formally by introducing the concept of a message path and showing that a federation containing multiple systems of systems contains incorrect message paths which communicate intra-system data between systems. Three methods are presented and shown to solve the problem by either eliminating the incorrect message paths or allowing a receiving federate to determine whether intra-system data was delivered via an incorrect message path.

The three solutions are Local Data Filtering (LDF), Data Distribution Management (DDM), and Federation Communities (FC). The LDF solution marks all intra-system data with a system identifier, allowing receivers to distinguish whether they should process it. The DDM method uses a service defined by the HLA that essentially provides an automated version of the LDF solution. The FC method restricts one federation to simulating one system and requires a multiple system simulation to enable inter-federation communication, something that is not defined in the HLA.

These three methods are analysed both quantitatively and qualitatively. The quantitative analysis looks at performance overhead imposed by each method and how well each method reduces the number of incorrect intra-system messages communicated. The qualitative analysis is presented in terms of identifying the complexity of implementing each method for a specific systems of systems federation: the election process for the Australian federal government.

The thesis concludes that the LDF method is simple to understand but potentially finicky to implement and is wasteful of network resources. The DDM method is advantageous in that it is a service defined by the HLA standard. However, the implementation of the DDM services

by a Runtime Infrastructure (RTI) is not defined by the HLA. Thus, the performance of the DDM method is coupled to a specific RTI and its configurability. The FC method achieves an ideal of replicating the simulation of a single system without modification to achieve a multi-system simulation. However, it requires and inter-federation communication mechanism that is not defined by the HLA. The FC method introduces extra latency and reduced throughput to inter-system messages in a Local Area Network (LAN) environment.

Declaration

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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This thesis is dedicated to the memory of my sister Kellie. I am sorry I did not complete it in time.

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