# Multi-scale Modeling in Neuroscience

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Multiple sub-models at differing abstractions and time-scales can be combined into a single heterogeneous multi-scale model using both synchronous and asynchronous approaches. In the traditional synchronous approach, components are directly coupled in time and operate in parallel as a single system. The communication is termed implicit, in that each message is conditioned on the internal state of the sender which is implicitly synchronized with that of the receiver. Component frameworks are mature tools to support the necessary systems integration and parallelization. The Network Model Interface (NMI) is a simplification of the Common Component Architecture (CCA) and is a basis for implementing component frameworks to support synchronous multi-scale modeling in neuroscience. As with the CCA, NMI abstracts the interface between a generic component and a generic framework and the provision of primary services. The cost of integration scales linearly with the total number of components and frameworks which promotes the use of multiple frameworks. Communication and synchronization strategies as well as load-balancing mechanisms are implemented in compliant frameworks. When communicating spikes, the axonal delays can be used to hide the latency in the communication with the computation. For coarsely granular architectures such as clusters of workstations where the number of neurons per compute node is large, the traditional Bulk Synchronous Parallel (BSP) strategy with a set of synchronized channels with local communications can be replaced with a set of non-local asynchronous channels. This results in significant reduction in contention, in particular for machines without specialized hardware interconnects. Graph partitioning algorithms, where the edge cost is inversely proportional to the axonal delay, can be used to maximize the allowable latencies whilst balancing the load in the system.

In asynchronous multi-scale modeling, components are indirectly coupled through the joint probability over inputs, outputs, internal states and assumptions that each model defines. The components exist as an ensemble of inter-related models or meta-model. Each communication takes the form of a question initiated by the receiver and answered by the sender. This communication is explicit in that the answer is conditioned only on the (explicit well-formed) question with no implicit assumption of synchronized internal states. In the online approach the receiver initiates a new instance of the sender to answer the question. In the offline approach, the sender can be run independently to build up a permanent offline store of answers over the space of possible questions. The Virtual Instrument (VI) is a user-level grid middleware project that can support the complex workflows required for setting up and running an ensemble of models in parallel. It provides the programmer with abstractions for exploring very large parameter spaces involving billions of simulations running over years. A backend database supports guaranteed fulfillment, auditing and reproduction. Resource management is delegated to underlying grid middleware layers such as APST.