Ozdagli, Ali Irmak Ph.D., Purdue University, May 2015. Distributed Real-time Hybrid Simulation: Modeling, Development and Experimental Validation. Major Professor: Shirley J. Dyke.

Real-time hybrid simulation (RTHS) has become a recognized methodology for isolating and evaluating performance of critical structural components under potentially catastrophic events such as earthquakes. Although RTHS is efficient in its utilization of equipment and space compared to traditional testing methods such as shake table testing, laboratory resources may not always be available in one location to conduct appropriate large-scale experiments. Consequently, distributed systems, capable of connecting multiple RTHS setups located at numerous geographically distributed facilities through information exchange, become essential. This dissertation focuses on the development, evaluation and validation of a new distributed RTHS (dRTHS) platform enabling integration of physical and numerical components of RTHS in geographically distributed locations over the Internet.

One significant challenge for conducting successful dRTHS over the Internet is sustaining real-time communication between test sites. The network is not consistent and variations in the Quality of Service (QoS) are expected. Since dRTHS is delay-sensitive by nature, a fixed transmission rate with minimum jitter and latency in the network traffic should be maintained during an experiment. A Smith predictor can compensate network delays, but requires use of a known deadtime for optimal operation. The platform proposed herein is developed to mitigate the aforementioned challenge. An easily programmable environment is provided based on Matlab/xPC. In this method, (i) a buffer is added to the simulation loop to minimize network jitter and stabilize the transmission rate, and (ii) a routine is implemented to estimate the network time delay on-the-fly for the optimal operation of the Smith predictor.

The performance of the proposed platform is validated through a series of numerical and experimental studies. An illustrative demonstration is conducted using a three story structure equipped with an MR damper. The structure is tested on the shake table and its global responses are compared to RTHS and dRTHS configurations where the physical MR damper and numerical structural model are tested in local and geographically distributed laboratories. The main contributions of this research are twofold: (1) dRTHS is validated as a feasible testing methodology, alternative to traditional and modern testing techniques such as shake table testing and RTHS, and (ii) the proposed platform serves as a viable environment for researcher to develop, evaluate and validate their own tools, investigate new methods to conduct dRTHS and advance the research in this area to the limits.