High Performance Network Modeling in the US Army MNMI (Mobile Network Modeling Institute)

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The Mobile Network Modeling Institute (MNMI) at the Army Research Laboratory (ARL) has been established to apply High Performance Computing (HPC) tools and techniques to improve the Army's ability to study large-scale, mobile, ad-hoc networks. Current modeling technologies offer a wide range of radio models, but fail to provide scaling and performance at an acceptable level of fidelity. Due to the complexity of the military waveforms involved, it is critical to accurately model the entire network stack with specific attention to the ad-hoc routing protocols and RF-propagation effects of the environment. This involves significant computational load that can exploit parallelism of supercomputers to achieve a sufficient scaling and performance improvements over current serial methods.

The Army wishes to study the performance of networks for a variety of reasons including for research, deployment planning, procurement, and to improve "Network-Centric Warfare". This involves a combination of pure simulation, as well as emulation and live experimentation. Abstract models usually associated with simulation can be replaced with high fidelity implementations of network protocols and applications which sometimes share a code base with real systems. Constructed environments are used to combine live systems with network simulation and emulation providing scaling to live tests that maintain a true user experience while enabling the network and attached devices to experience a more complete exercise.

The MNMI has been working with the ns-3 open source network simulator to exercise its scaling and performance capabilities at the ARL DoD Supercomputing Resource Center (DSRC) [http://www.arl.hpc.mil]. Experiments on cluster platforms have demonstrated scaling of simple network simulations to the order of 300 million simulated nodes. Performance analysis of various network configurations with ns-3 has produced promising results on the order of 400,000 packet receive events per wall-clock time using hundreds of processors. Other novel techniques are being researched such as using co-simulation via distributed shared memory (coupling of orthogonally-decomposed codes), a real-time distributed scheduler, and off-loading computationally expensive operations to Data Parallel Processors (e.g. GPUs). The MNMI continues to work with its partners and the ns-3 community to evaluate, improve, and extend the capabilities and performance of the simulator.

Network emulation work in the MNMI is centered on the Extendable Mobile Ad-hoc Network Emulator (EMANE) software which is developed by Cengen [http://labs.cengen.com/emane] and funded by the Army Research Lab and Naval Research Lab. With EMANE, the physical and link layers are modeled in software while the rest of the network stack is executed natively in live systems. This is usually instantiated as virtual machines running on top of simulated network interfaces in a cluster. Unmodified applications and operating systems can be run over network models allowing user interaction and traditional network measurement tools to be used. With recently-acquired, dedicated hardware, emulations of more than 5000 nodes are anticipated while maintaining real-time RF propagation calculations.

Both ns-3 and EMANE have been used to stimulate live exercises aimed at evaluating emerging communications technologies. The C4ISR-Network Modernization exercises held at Ft. Dix, NJ offer a "sand box" to test individual communications technologies and Systems-of-Systems network architectures. Limited resources are available for live asset testing, so virtualization plays a key role in developing a realistic environment for product evaluation. OneSAF (semi-automated force modeling software) is traditionally used to populate the battlefield with virtual entities but has limited fidelity in its communications modeling. The MNMI has used its resources and capabilities to augment the OneSAF presence to construct an interactive virtual network environment, giving the systems under test a more realistic network and application loading. This work has led to the development of a real-time distributed scheduler for ns-3 which allows live simulations such as these to scale using distributed computing resources.

Future plans for the MNMI include the porting of additional military radio waveforms to the simulation and emulation platforms of choice as well as additional performance enhancements. We are currently pursuing the coupling of multiple simulation engines which will allow each to decompose large problem sets independently to take advantage of parallelism inherit to their roles. For example, a forces modeling code may decompose a large simulation along organizational boundaries for parallel processing, while an RF propagation code will benefit from decomposing the problem geographically. The engines will be coupled together via Distributed Shared Memory for sharing data and an RTI for coordinating time.

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