Evaluation of Secure Distributed TLM-based Co-Simulation over Wide Area Networks

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Motivation and Approach

Mathematical models need to be distributed and simulated in a secure manner, because of:

- **Model protection.** Manufacturers and sub-contractors normally don’t share simulation models.
- **Local expertise.** Large companies often have departments spread over the world.
- **Resource sharing.** Expensive simulation environments may not be available in the same location where the simulation takes place.

Approach

Sub-models are distributed and simulated at different locations using a transmission line modeling (TLM) framework developed by SKF. SKF has earlier successfully tested meta-model based co-simulation for different application areas, such as spindles with rotordynamics problems, simulations of large medical scanners, and hub-unit simulations for cars.

Research Questions

- Is it practically feasible to co-simulate models over a WAN (e.g. the Internet) and still obtain the simulation result within reasonable time?
- Will the total simulation time increase significantly if the model to be co-simulated is scaled up with many distributed sub-models?
- Which parameters are affecting the total simulation time when a model is distributed and co-simulated?

Experiments

- **Pendulum with Bearings**
- **Deployment Structure**
- **WAN Simulator**

- Approximately 430 hours of simulation time using cluster environment and WAN simulator.
- Realtime experiment between Sweden and Australia via an encrypted tunnel.

Results and Analysis

- **Datacom Latency**
- **Datacom Bandwidth**
- **TLM Delay**
- **Number of TLM Interfaces**

- Bandwidth is currently not a bottleneck, but it grows linear to the number of TLM-interfaces.
- Approximately, the simulation time doubles when TLM is halved. Main reason that numerical solvers can take longer time steps when TLM is increased.
- Adding TLM interfaces have marginal impact when there are several interfaces.

Conclusions

- It is usable in practice to co-simulate over long distances over WANs on the globe. This is demonstrated by co-simulating between Sweden and Australia, with an increased total simulation time of ≈ 170% compared to a local environment without encryption.
- It is more resource efficient to increase the number of compute nodes in an external simulation environment if the network latency is lower than a specific bottleneck breakpoint. The method is scalable in regards to the number of connected simulation components.

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