COSSIM
An Integrated Solution to Address the Simulator Gap for Parallel Heterogeneous Systems

Andreas Brokalakis
Synelixis Solutions Ltd, Greece
brokalakis@synelixis.com

Nikolaos Tampouratzis
Telecommunication Systems Institute, Greece
ntampouratzis@mhl.tuc.gr

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Motivation

- Microprocessor and Systems designers cannot ignore **network interactions** when designing new system architectures, since networks are **an integral part** of all parallel systems
  - Too many **interactions**, too **complicated**
  - Major **optimization** opportunities

- Majority of the **existing simulation tools** can **handle efficiently only parts** of a system
  - either **only the processing part** or the **network**

- **Existing simulators** are typically single-threaded
  - A parallel approach is required for networked systems simulation if realistic simulation times have to expected
What is COSSIM?

• COSSIM is an open-source framework that can simulate Highly Parallel Systems or more generally Systems of Systems
  – Networking and the processing simulators are integrated into a single framework
    • Single notion of time, accurate processing and network interactions
  – Easy simulation set-up, execution and visualization of results through a Graphical User Interface (Eclipse-based)
  – IP-based so that simulation can be distributed
  – Power estimation tools are also integrated in order to account for the real processing - network interactions
  – Fully functional version open & free, commercial support and support for add-on packages by providing proper extensions
COSSIM Framework

- **Key concept:**
  - use **well-established processing and network simulators**
  - Retain **compatibility** to be able to readily take advantage of all related research and development work

- **COSSIM** is built on top of
  - **GEM5**, to simulate the components of each processing node in the simulated system
  - **OMNET++**, to simulate the real networking infrastructure
  - **McPAT / OMNET++ addons** to provide energy and power consumption estimations
  - **CERTI (IEEE1516 HLA)** to integrate all simulator packages together
Network Support on gem5

Current network model of gem5 is restrictive:

- Only two nodes
- Simple wire (no switch / router)
- Identical CPU systems
- Single-thread / simplistic synchronization
In the modified version of gem5 (cGEM5):

- Ethernet packets are captured and through a custom library are sent to an HLA server
- The packets are sent to a representation of the nodes in the network simulator implementing the communication topology
Extending gem5 for COSSIM (2)

By this process:
- An arbitrary number of nodes can be connected
- Sophisticated network topologies can be implemented
- Each node is independent and therefore heterogeneous systems can be composed
- IP-based (HLA) interconnection allows for parallel / distributed execution of each cGEM5 instance

Additionally:
- FS simulation only (NIC + OS drivers rq.)
- X86 + ARM fully supported
- New and most current linux kernel versions running
The Network Simulator Sub System

- We employ OMNeT++ network simulator
- Each cGEM5 system is reflected in an OMNET++ HLA-enabled node
- **Challenge**: Incompatible network stacks between OMNeT++ and cGEM5
- **Developed**: custom-fit functionality developed at user space
  - No modification to the OMNeT++ -INET code
  - Fully compatible with the OMNeT++ legacy
- Preserving OMNET++ functionality, any supported network topology can be used, including network devices and custom nodes (in the OMNET++ space – not simulated through cGEM5)
The Elephant in the Room
Integration and Synchronization (1)

• Synchronization issues arise
  – differences between gem5 and OMNET++ (event-based)
  – communication between different gem5 systems running independently
  – requirement of a common notion of time throughout the whole simulated system

• Two-stage solution through CERTI HLA
  – Synchronization per node (each cGEM5 node needs to synchronize with its counterpart network node)
  – Global Synchronization (sync all nodes simultaneously periodically as different types of CPUs with different clock cycles → Different simulation time)
The Elephant in the Room
Integration and Synchronization (2)

- Synchronization per node
- Exchange Data Packets
The Elephant in the Room
Integration and Synchronization (2)

- Synchronization per node
- Exchange Data Packets
- Global Synchronization
  - All cGEM5 nodes
  - cOMNET++ SynchNode

Global Federation
Performance

- ARM / x86 systems while booting Linux OS
- One cGEM5 instance per physical core
- Machine 1 (Quad-core)
- Machine 2 (12-core connected to Machine 1 through LAN)
Performance vs Accuracy

- Global Synchronization Interval introduces a potential performance bottleneck
  - Restricts how long a cGEM5 instance can run freely before pausing for synchronization
  - Affects accuracy of results (application dependent – user settable)
- Example: 4-node ARM systems while booting Linux OS
Thank you!