AMR Dependency Analysis and Network Simulation Tool

November 17, 2013
IA^3 at Supercomputing

Cy Chan, Joseph Kenny, Gilbert Hendry,
Vincent Beckner, John Bell, and John Shalf

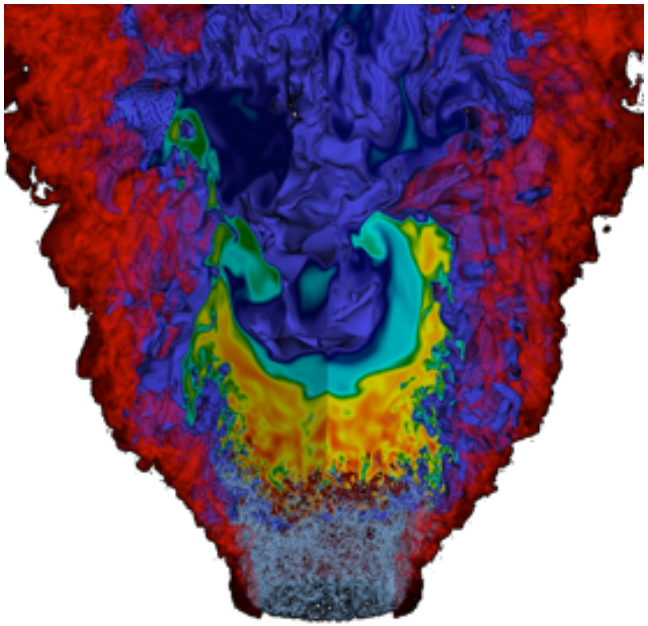
BERKELEY LAB

U.S. DEPARTMENT OF ENERGY | Office of Science

Sandia National Laboratories

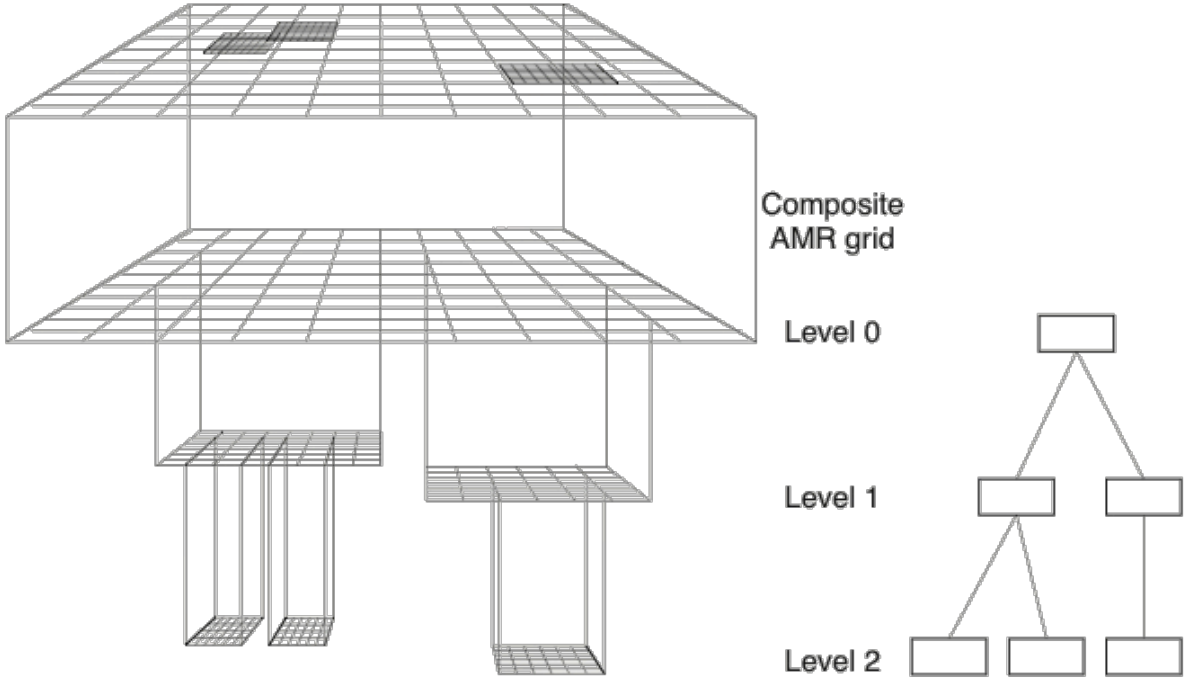
ExaCT: Combustion Co-Design

- **Exascale Center for Combustion in Turbulence (ExaCT) is one of three exascale co-design centers**
- **Highly efficient combustion systems will help us meet the 80% reduction target of greenhouse gas emissions by 2050**
- **Need performance models for combustion simulation co-design**



Source: John Bell (LBNL)

Adaptive Mesh Refinement (AMR)



- Multiple levels
- Set of boxes at each level
- Fine boxes enhance resolution at areas of interest
- Boxes exchange data within and across levels
- Irregular communication and unbalanced computation

AMR Analysis and Simulation Goals

- **On-node performance modeling with ExaSAT**
  - Compiler-driven static analysis and modeling
- **Need network simulation capability**
  - Leverage SST/macro software simulator
- **Asynchronous execution model**
- **Simulate performance on many potential exascale machine configurations**
- **Analyze the effects of:**
  - Data distribution
  - Network topology

Analysis Toolchain and Methodology

Problem Specification: CASTRO

BoxLib AMR Library

Box List

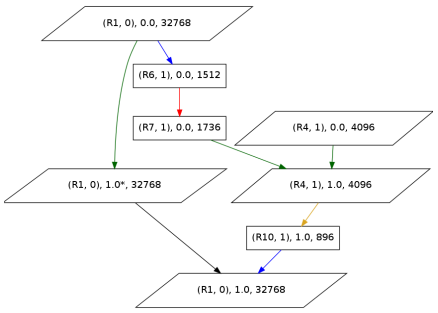
Level 0
0: ((0, 0, 0) (15,31,15)) 16 32 16 :: 3
0: ((16, 0, 0) (39,31,15)) 24 32 16 :: 1
Level 1
1: ((30, 0, 0) (47,31,31)) 18 32 32 :: 2
1: ((48,14,10) (67,29,29)) 20 16 20 :: 3
...
Level 2
2: ((72, 0,34) (83,19,59)) 12 20 26 :: 1
2: ((72, 0,60) (83,15,75)) 12 16 16 :: 2
...

AMR Dependency Analysis Tool

XML

```
<boxes>
<box id="R1" loc="0" />
<box id="R4" loc="1" />
</boxes>

<events>
<comp id="E10" dep="E5,E11" time="0.0676" />
<comm id="E12" dep="E2" from="R1" to="R4"
size="1512" />
...
</events>
```

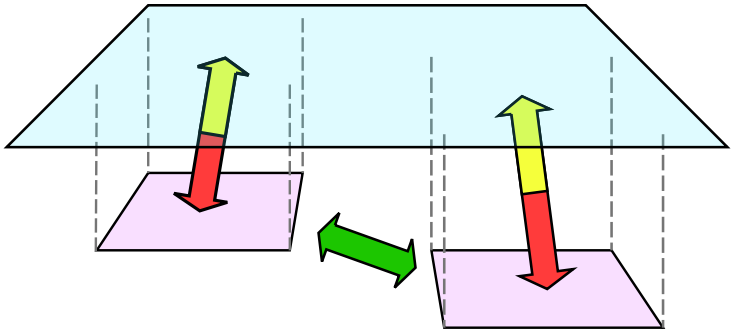


Dependency Graph

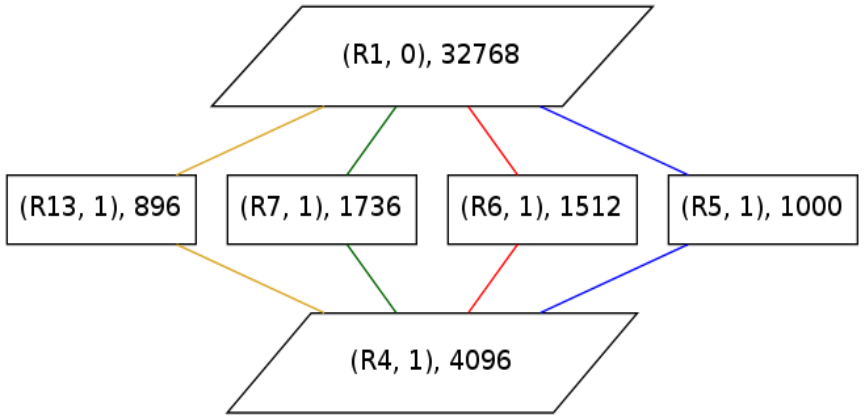
SST/macro Network Simulation

Performance Estimates

AMR Box Dependency Analysis Tool



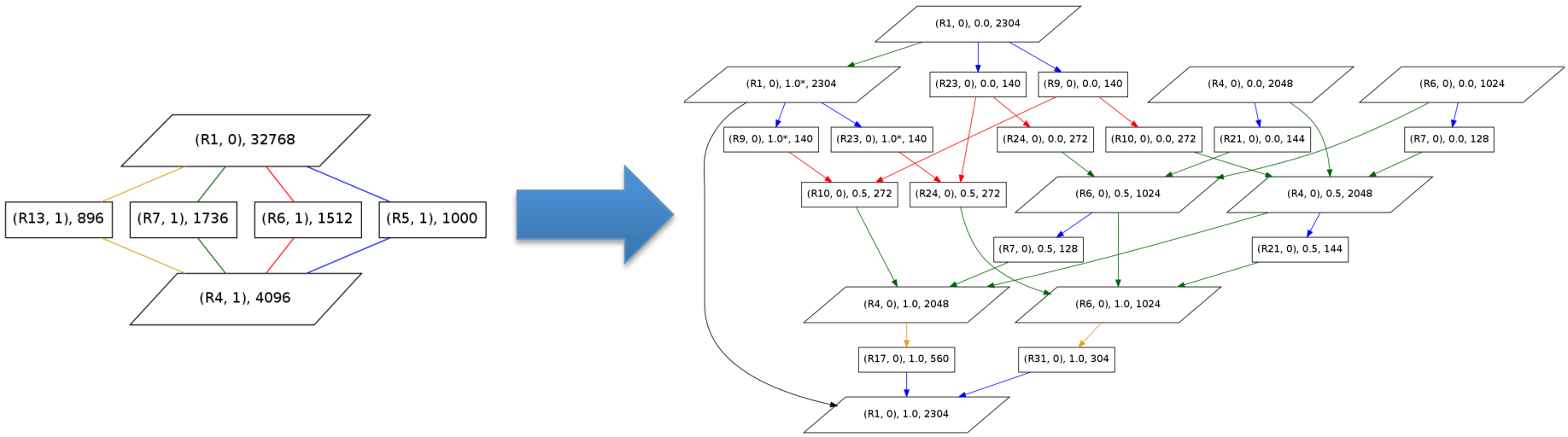
Box Geometry



Compact Graph Representation

- **Use box operations to determine required data exchange**
  - Box intersection, union, set difference, ghost halos
- **Different operation types have different input regions**
  - Examples: time stepping, interpolation, averaging, etc.

AMR Box Dependency Analysis Tool

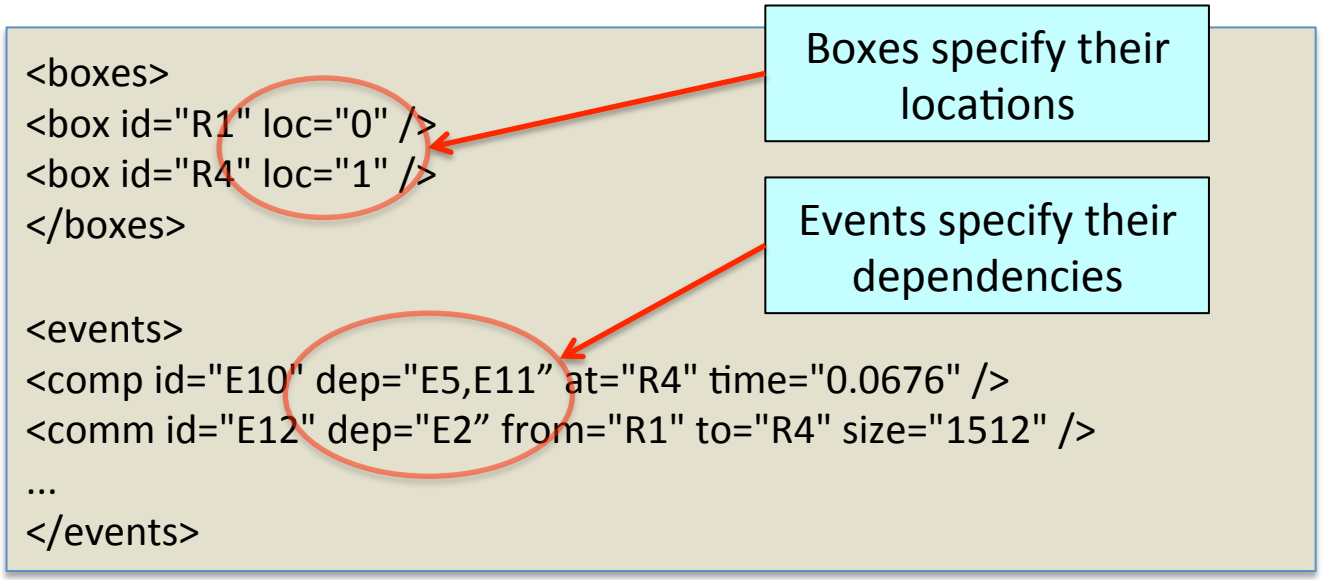


Compact Graph

Unfurled Dependency Graph

- **"Unfurl" compact graph representation to a full dependency graph representing execution**
  - Parameterized refinement ratio and time steps
  - Graph can be unfurled on "as-needed" basis to conserve memory

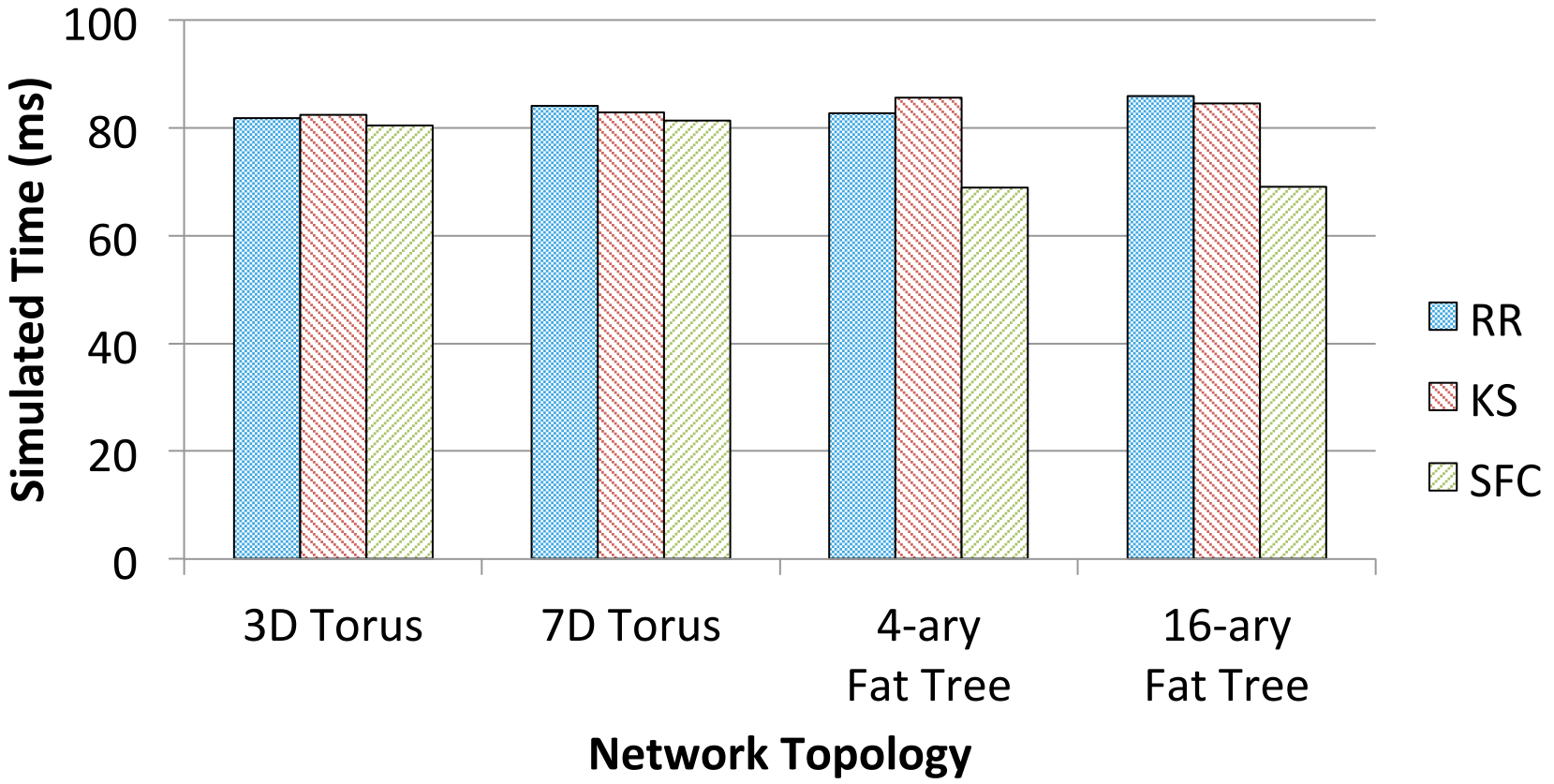
XML Specification



- **List of boxes and events to drive simulator**
  - Boxes can be re-assigned to different locations
  - Computation events have execution time estimates
  - Communication events have source, destination, and size

SST/macro Simulation Results

967 Boxes distributed across 480 Nodes



- Topology and data distribution expected to have greater impact for larger problem sizes

Work in Progress

- **Enhance on-node execution time estimates for compute events**
  - Leverage ExaSAT analysis on CCSE's CASTRO code
- **Make graph analysis and simulation more scalable (memory and execution time)**
  - Goal: scale up to 1 million boxes / 100k nodes
- **Examine more data distribution algorithms and network topologies and parameters**
  - Graph partitioning algorithms and online distribution
  - Mesh, ring, dragonfly, hypercube, etc.