TOPAZ: An Open-Source Interconnection Network Simulator for Chip Multiprocessors and Supercomputers

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Interconnects Research: Simulation Tool

What makes a Simulation Tool better than others?

Flexibility

-Heterogeneous field, from supercomputers to CMP.

- Highly Configurable

Accuracy Vs. Comp. Effort

- Avoid slow simulations for first stages of research process.
- But provide accurate enough results at last stages.

Ease-of-Use

-Fast learning is essential.

- MAX: 1-day delay for user-mode

TOPAZ

- **Interfaz to Full-System Simulation.**
- **Multithreaded simulation for massive number of routers.**
- **Simple & Complex models.**
- **Dynamic accuracy simulation.**
- **Many out-of-the-box components.**
- **Very modular code, easy to understand.**

Outline

- Simulator Description
- Out-of-the-Box
- Utilization Examples
- Support & Collaboration

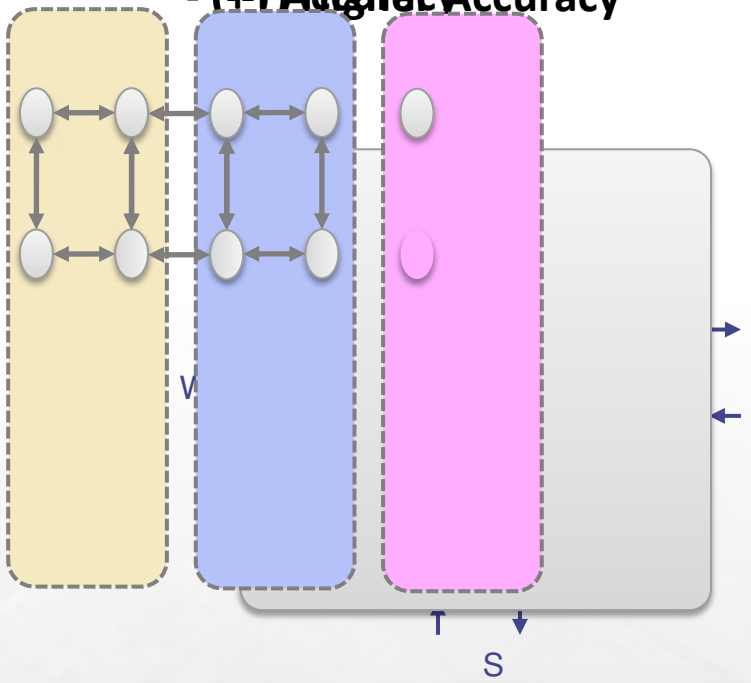
Main Features

- Evolution of SICOSYS
- Object-oriented Design
  - **Implemented in C++**
  - **100 classes / 50,000 lines of code**
  - **High portability (C++ standard compiler)**
- Different levels of detail
- Support for multiple applications

[REF] V.Puente, J.A. Gregorio, R. Beivide, SICOSYS: an integrated framework for studying interconnection network performance in multiprocessor systems. IEEE Comput. Soc, 2000.

Main Features

- Evolution of SICOSYS
- Object-oriented Design
- **Different levels of detail**
- Support for multiple scenarios



Using TOPAZ (Building)

```
>./TPZSimul -s SIMUL_DETAILED
```

TPZSimul.ini

```
<RouterFile      id="../sgm/Router.sgm" >
<NetworkFile   id="../sgm/Network.sgm" >
<SimulationFile  id="../sgm/Simula.sgm" >
```

Simula.sgm

```
<Simulation id="SIMUL_DETAILED">
  <Network
  <SimulationCycles id=
  <DiscardTraffic
  <TrafficPattern
  <Load
  <PacketLength
</Simulation>
```

Network.sgm

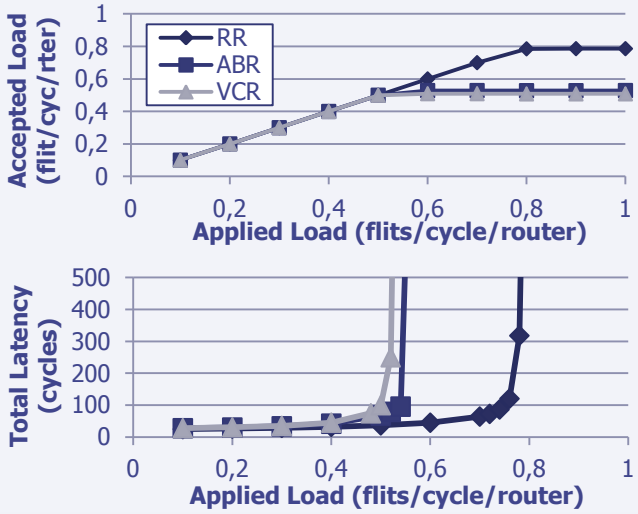
```
<TorusNetwor id="TORUS" siz X=8 sizeY=8 route ="DETAILED" d lay=1>
<MeshNetwork id= MESH  sizeX=8 sizeY=8 router= DETAILED  delay=1>
```

Router.sgm

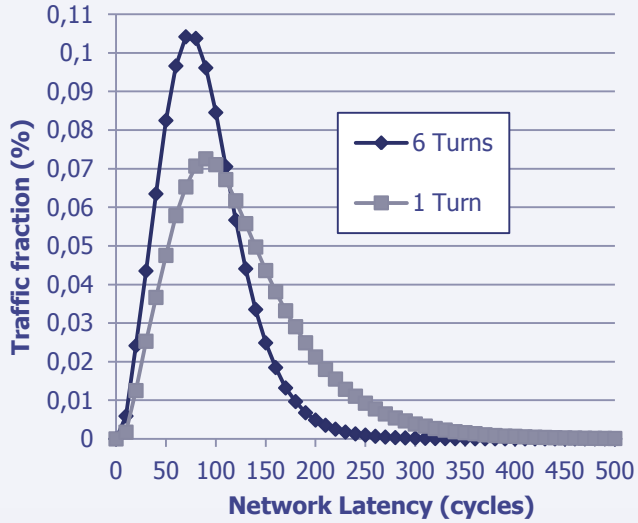
```
<Route d="DETAILED" i puts=5 outputs=5 bufferSize=64
bufferCont gControl="ROUTING_ALG">
  <Injector id= NJ">
  <Consume d="CONS">
  <Buffer i ="BUF1" type="X+" headerDelay=2>
  <Buffe d="BUF2" type="X-" headerDelay=2>
  . . . . . .
  <B fer id="BUF5" type="Node" headerDelay=2>
  < outing id="RTG1" type="X+" headerDelay=1>
  . . . . . .
  <Routing id="RTG5" type="Node" headerDelay=1>
  <Crossbar id="XBAR" inputs="5" outputs="5" type="CT">
    <Input id=1 type="X+">
    . . . . . .
    <Output id=5 type="Node">
  </Crossbar>

  <Connection id="C01" source="INJ" destination="BUF5">
  . . . . . .
  <Connection id="C20" source="RTG.1" destination="XBAR.1">
  . . . . . .
</Router>
```

Using TOPAZ (Printing)

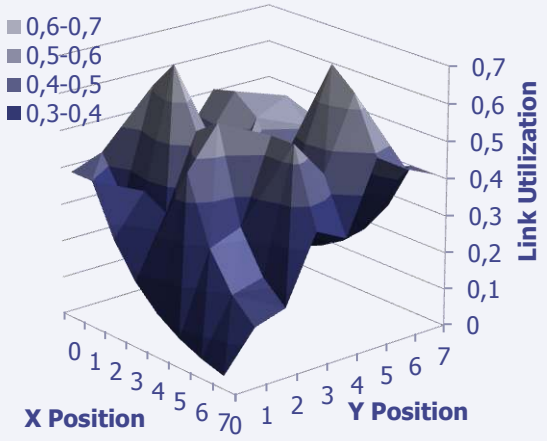
Standalone



Throughput/Latency curves

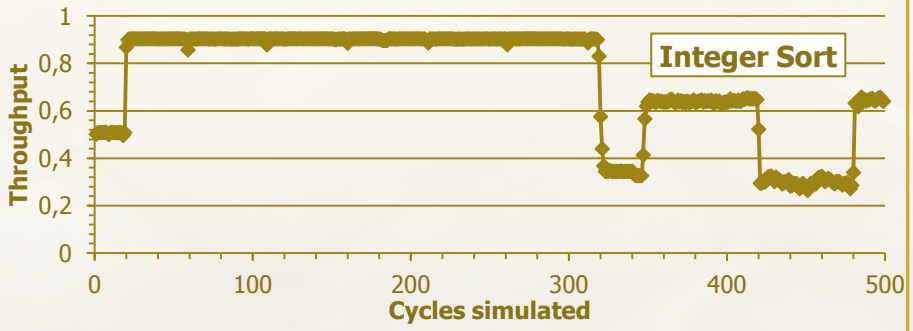


Latency Histogram



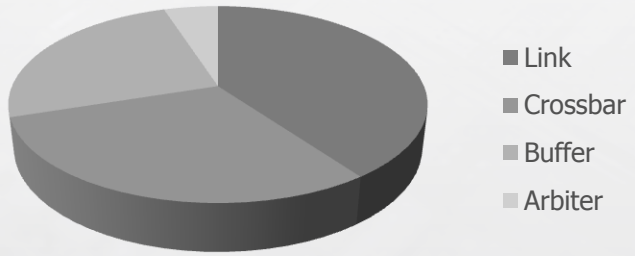
Injection/Consumption/Link map

+ Gems (or Gem5)



Throughput/Latency evolution

+ Orion



Power Breakdown

Outline

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- **Out-of-the-Box**
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Out of the Box

1. Configuration Parameters

Router	Flow Control	Topology	Traffic
Buffer Size	Virtual Cut Through	Ring	Random
Buffer Delay			Bit-Reversal
Packet Size	Bubble Flow Control	Mesh (2D & 3D)	Perfect-Shuffle
# Virtual Channels		Torus (2D & 3D)	Transpose Matrix
#Physical networks	Wormhole		Tornado
Message Types		Midimew (2D)	Hot-Spot
Router Pipeline	Virtual Channel flow Control	Square Midimew (2D)	Local
Link Delay			Trace-Based

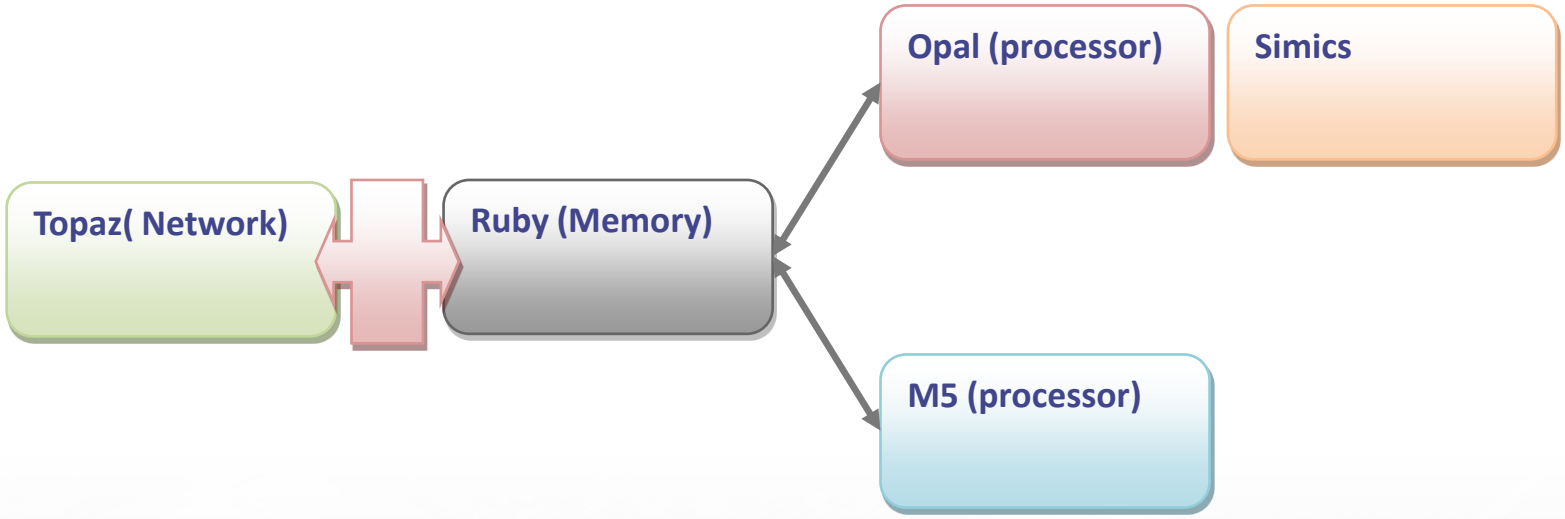
Out of the Box

2. Available Routers

Router	REF	Year	Level of Detail
Adaptive Bubble Router	[14]	2001	Complex & simple
Deterministic Bubble Router	[15]	1998	Complex & simple
Deterministic with VC (Dally)	[16][17]	2001	Complex & simple
VCTM (Dally + MC Support)	[18]	2008	Complex & simple
Pipeline Optimized	[24]	2008	Complex & simple
Rotary Router	[19]	2007	Complex
Bufferless Router	[21]	2010	Simple
Bidirectional Router	[22]	2009	Simple
Buffered Crossbar	[23]	1987	Complex

Out of the Box

3. Integration with Full-System Simulation Tools



Wisconsin Multifacet Gems: http://research.cs.wisc.edu/gems/

Gem5 simulator system: http://gem5.org/Main_Page

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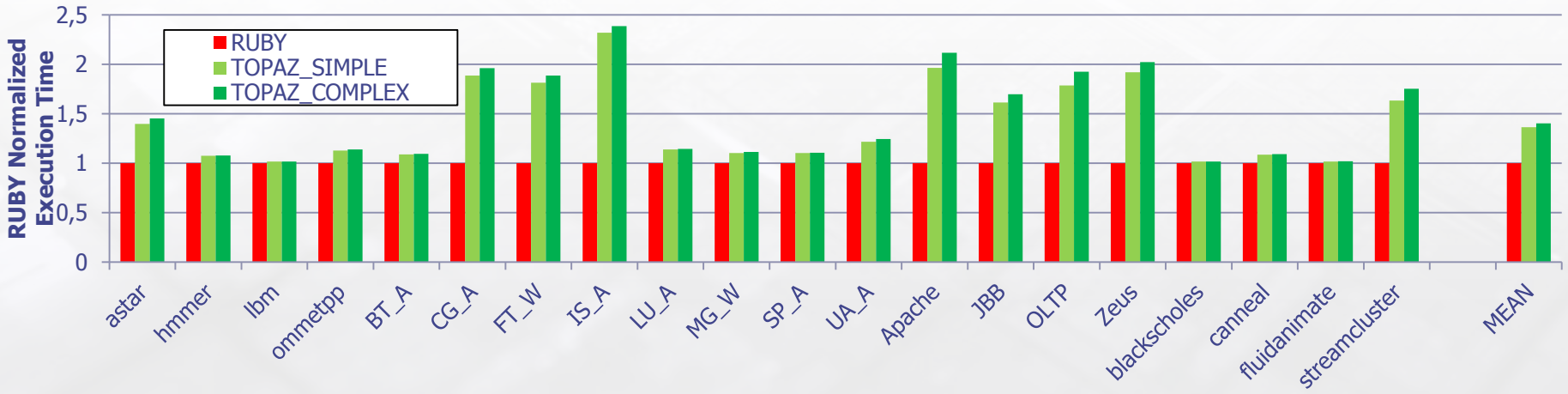
Increasing Full-System simulation accuracy

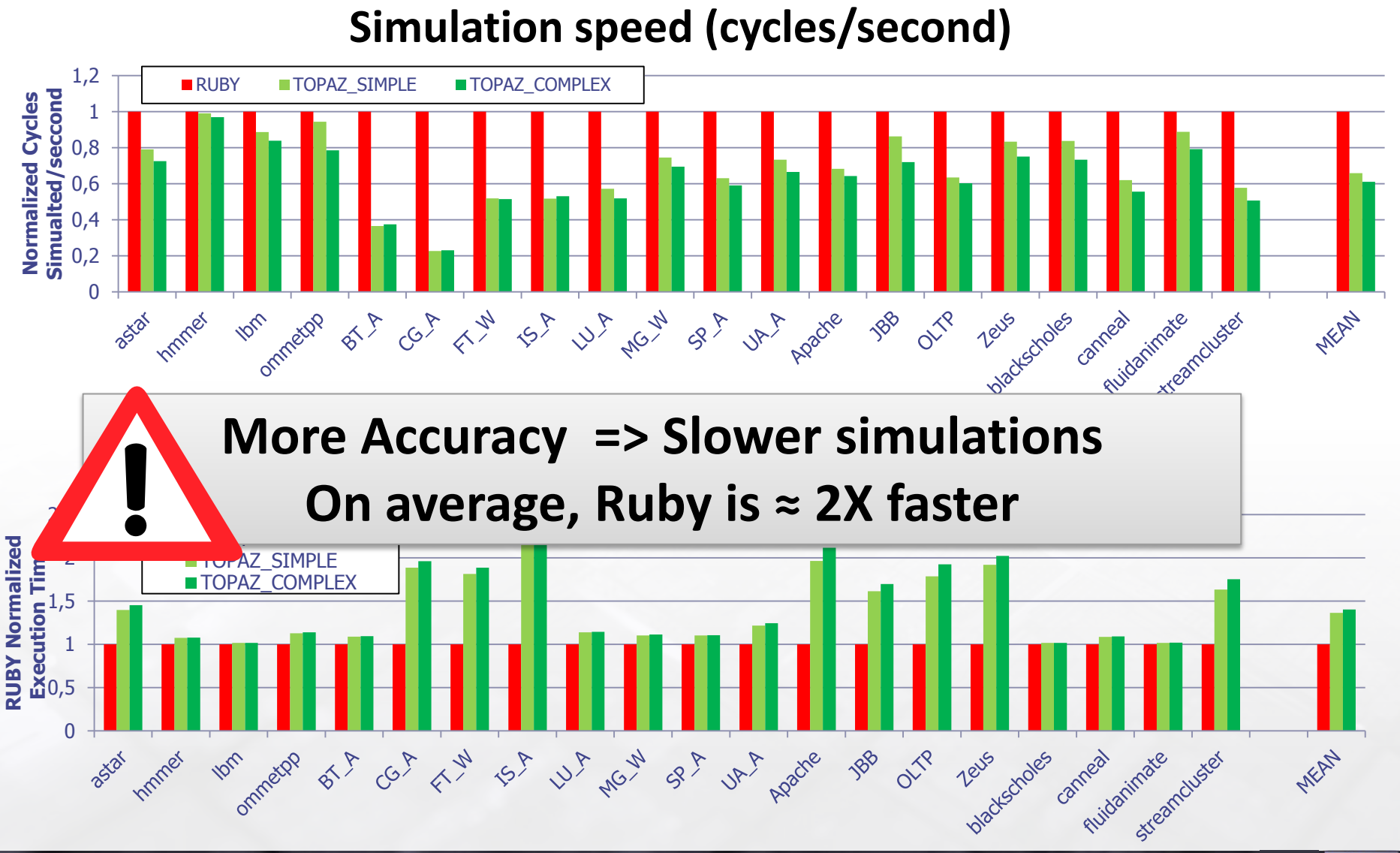
Main System Parameters

System				Network	
Cores	16 Cores, @4GHz, OOO, 4-wide issue, 64-entry IW, 16 outstanding Mem. Req	L2	16 MB, SNUCA, Token(B) coherence protocol, 6 msg. dependence chain	Topology	4x4 Mesh
L1	Independent I/D caches, 32KB, 4-way, 1 cycles	L2 Bank	1MB, 16-way, 5 cycles, pseudo LRU	Links	1 cycle, 128bits wide
Memory	4GB, 320GB/s, 260 cycles	OS	Solaris 10		

Broadcast Coherence Protocol (Execution Time)

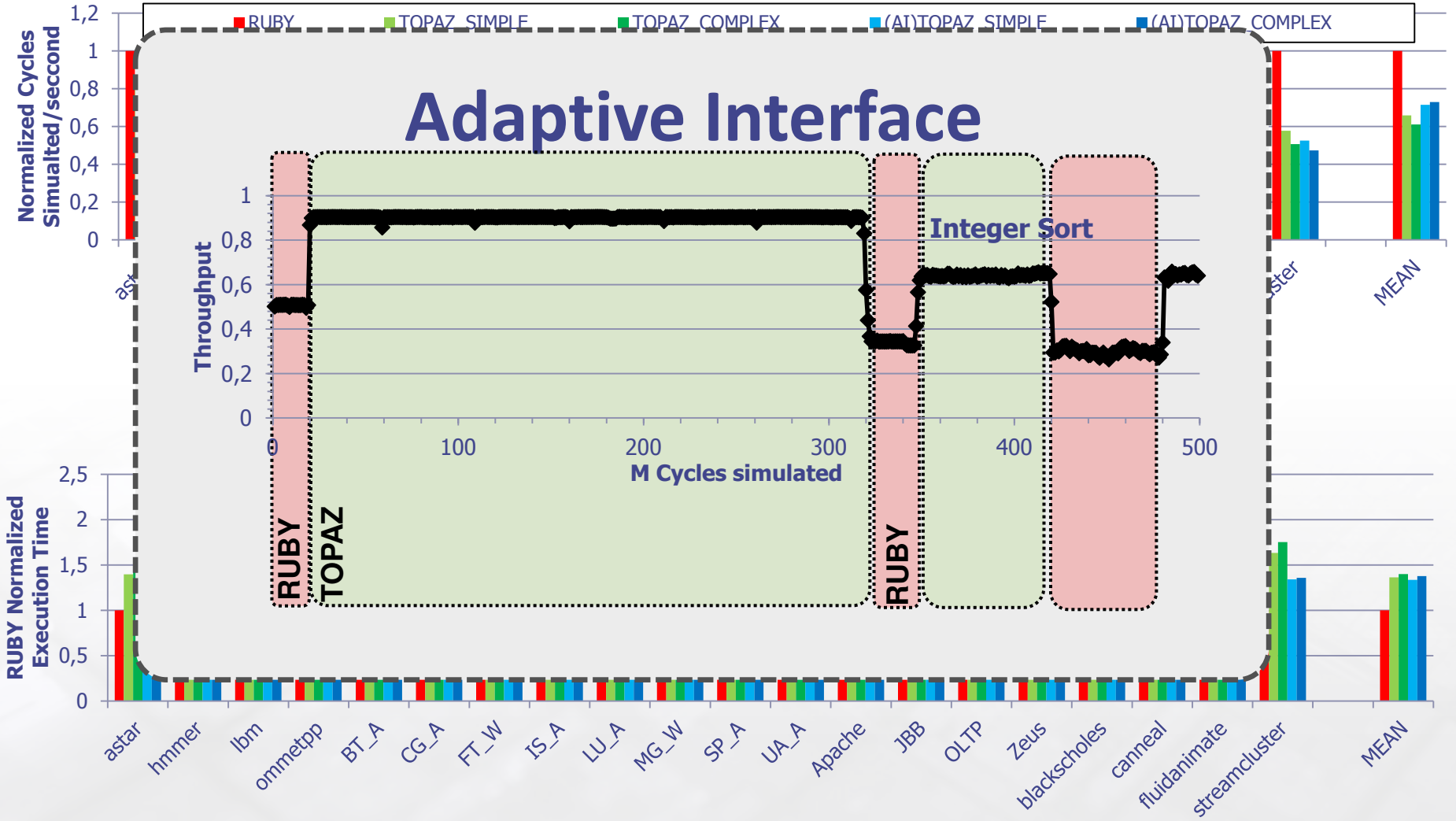


Increasing Full-System simulation accuracy

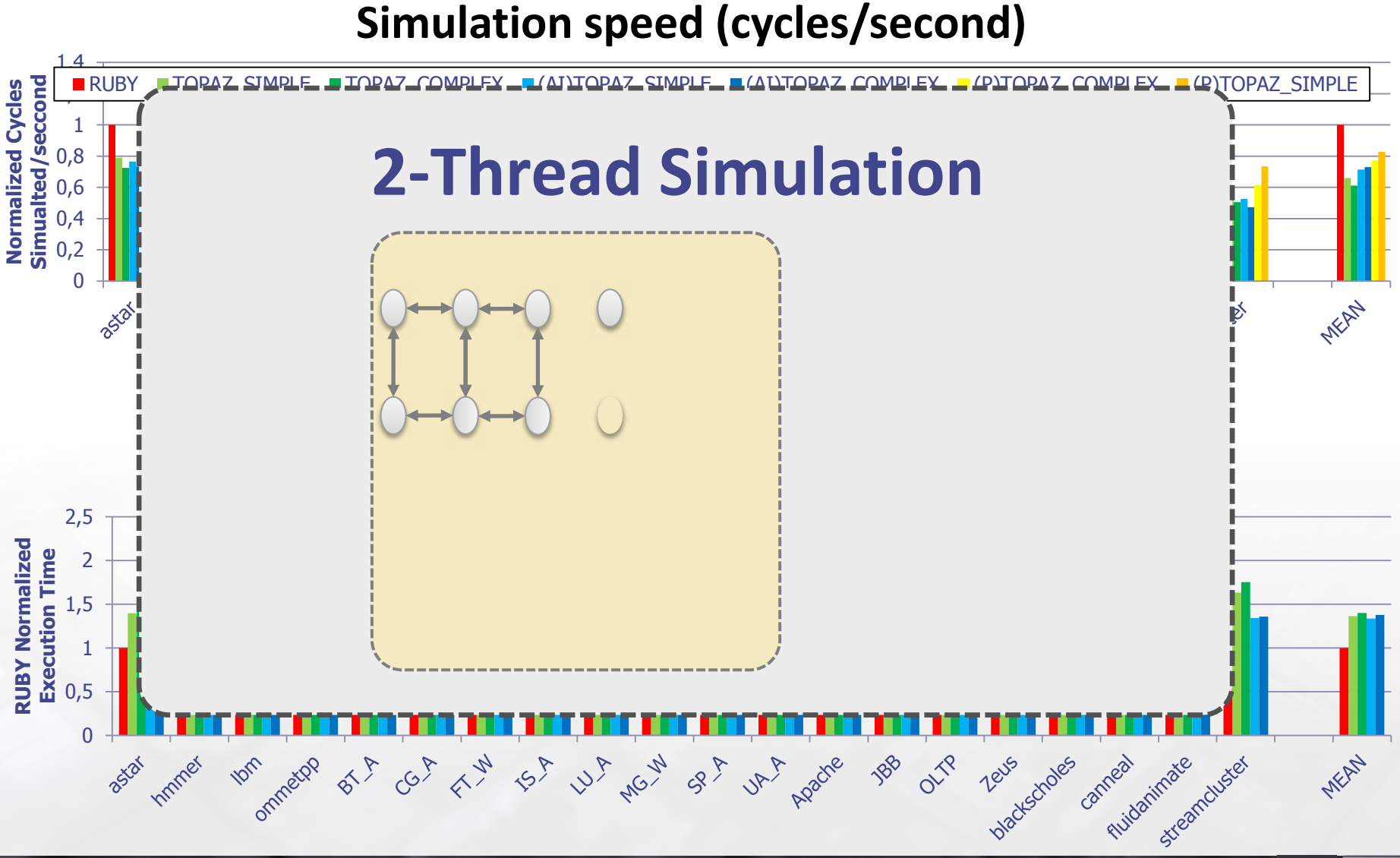


Improving Simulation Speed (I)

Simulation speed (cycles/second)

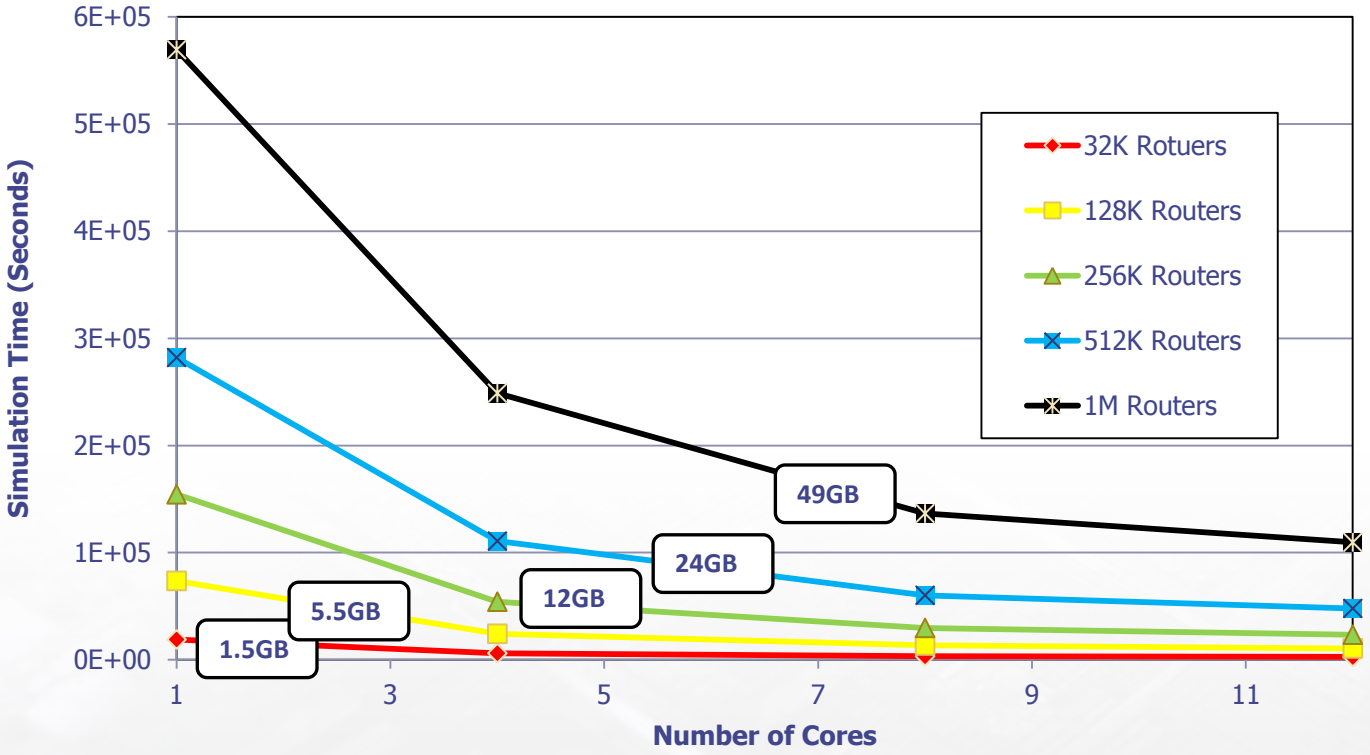


Improving Simulation Speed (II)



Simulating thousand-node Networks

12-Core (Xeon E5645) server with 54GBytes of main memory.



- 3D Torus, Bubble Router (simple), similar to IBM Blue Gene.
- Multithreaded implementation takes advantage of multicore server
- Good speedup for 1 Million routers

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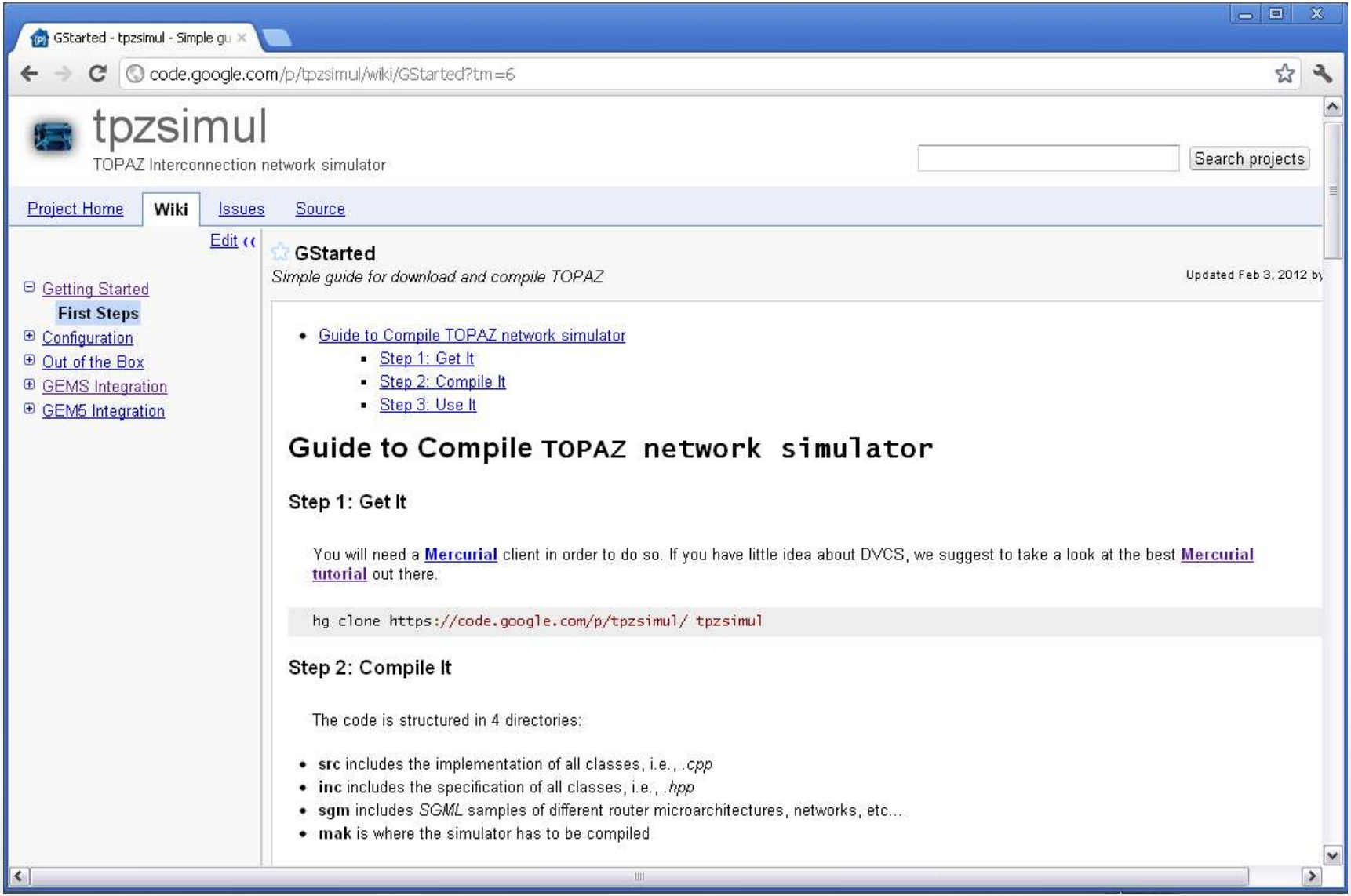
Support & Collaboration

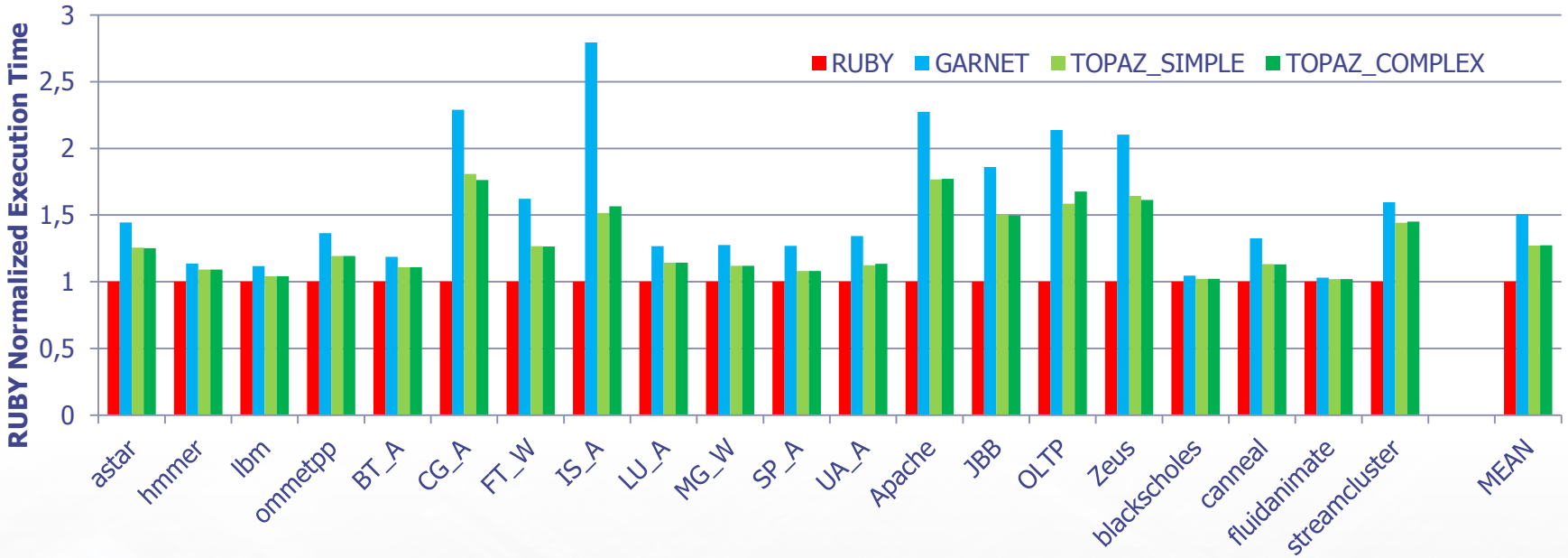
Support & Collaboration

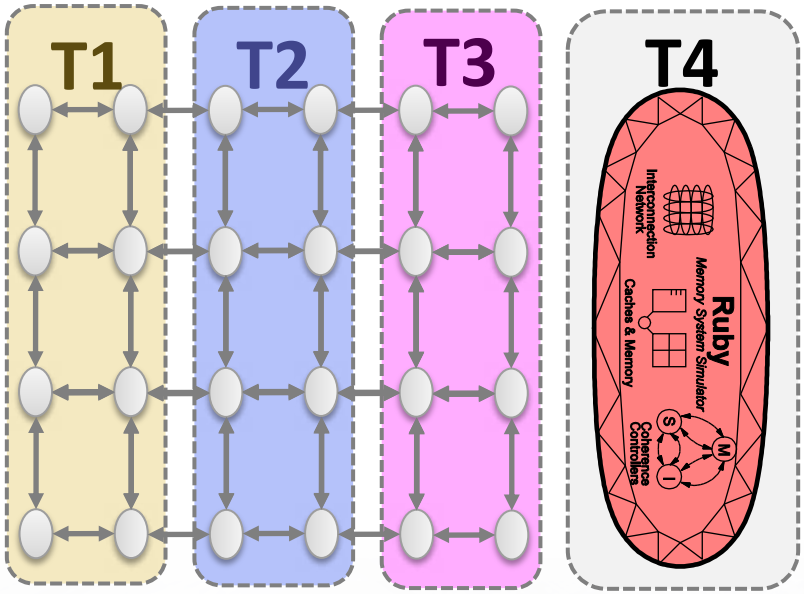


Thanks for your attention

Questions?

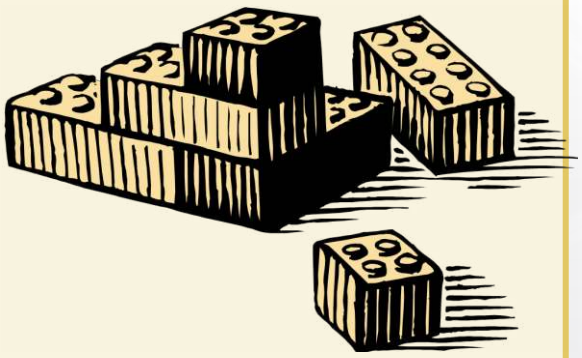
GARNET


RUBY Normalized Execution Time
3
2,5
2
1,5
1
0,5
0
RUBY
GARNET
TOPAZ_SIMPLE
TOPAZ_COMPLEX
astar
hmmer
lbm
ommetpp
BT_A
CG_A
FT_W
IS_A
LU_A
MG_W
SP_A
UA_A
Apache
JBB
OLTP
Zeus
blackscholes
canneal
fluidanimate
streamcluster
MEAN

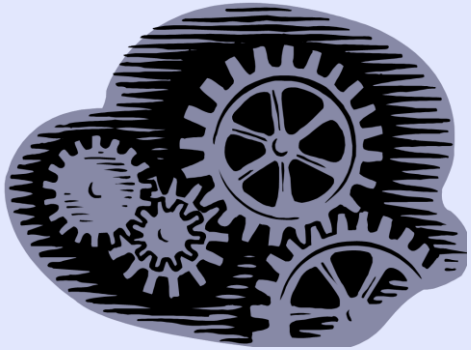

T1
T2
T3
T4
Interconnection Network
Ruby
Memory System Simulator
Caches & Memory
S
M
I
Coherence Controllers

Using TOPAZ

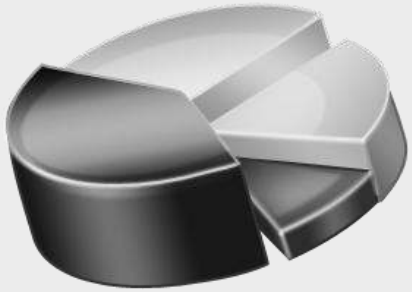
BUILDING



RUNNING



PRINTING

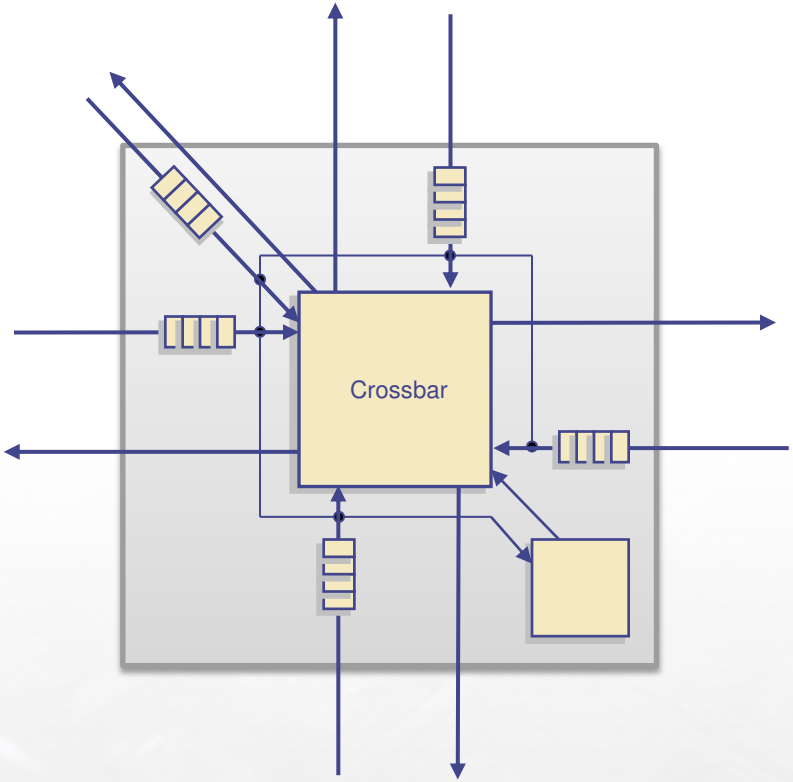


Using TOPAZ (Building)

Router.sgm

-Router & Crossbar Ports
- Buffer Size
- Routing & Flow Control Policies

Network.sgm



Using TOPAZ (Building)

Router.sgm

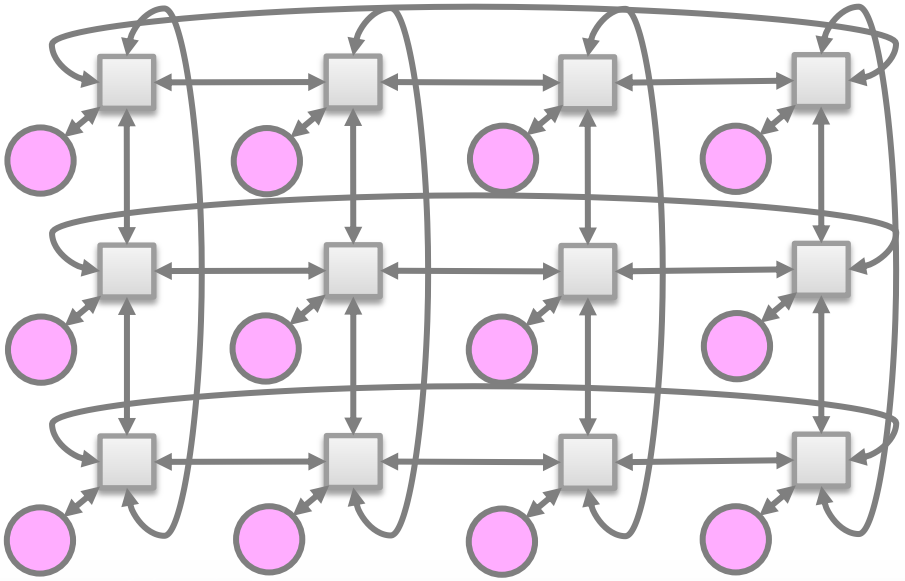
-Router & Crossbar Ports
- Buffer Size
- Routing & Flow Control Policies

Network.sgm

-Network Size
- Network Topology
- Link Delay

Simula.sgm

-Traffic Pattern
- Message Size
- Simulation Cycles



Using TOPAZ (Running)

No need to re-compile

- Only need to add new configutations at **sgml files**.
- Each configuration identified by a tag at **Simula.sgm**. Option **–s** at command line to choose a specific configuration.

Different Execution Modes:

- Run your simulation for **XXX Cycles.**
- Run your simulation until **YYY Messages** reach their destination.

Command Line Options:

- Many sgml parameters can be overwritten through command line options.
- Example:
- Useful for **scripting.**