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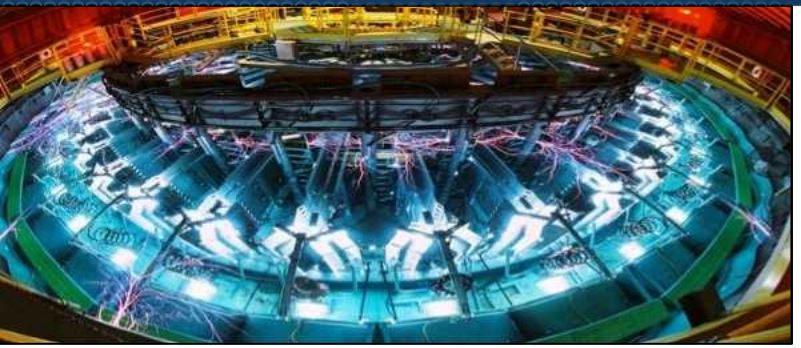

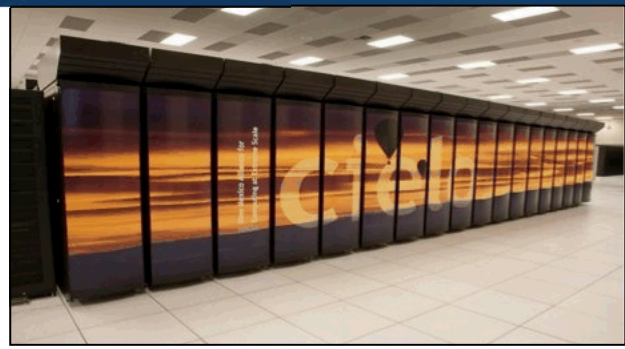

Overview of the Structural Simulation Toolkit (SST)

Jeremiah Wilke
Scalable Modeling and Analysis, Sandia National Labs, Livermore CA
Simulation BOF, Supercomputing 2017, Denver, CO
Unclassified Unlimited Release (UUR)

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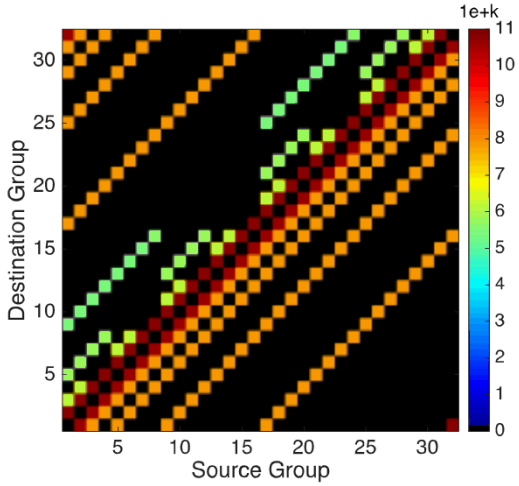
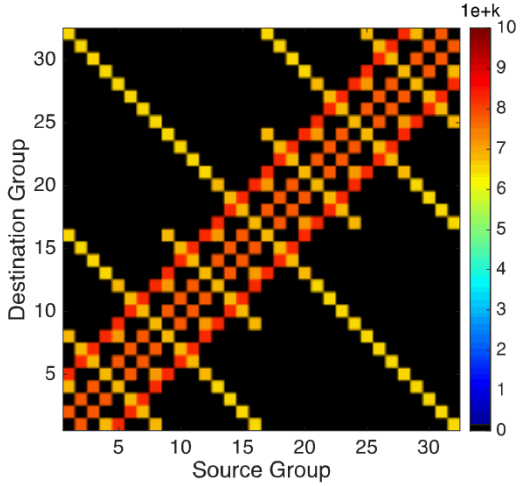
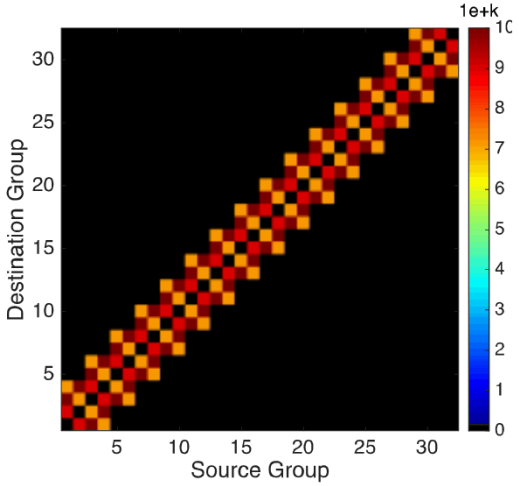
Is network simulation anything more than just injecting a known traffic pattern?



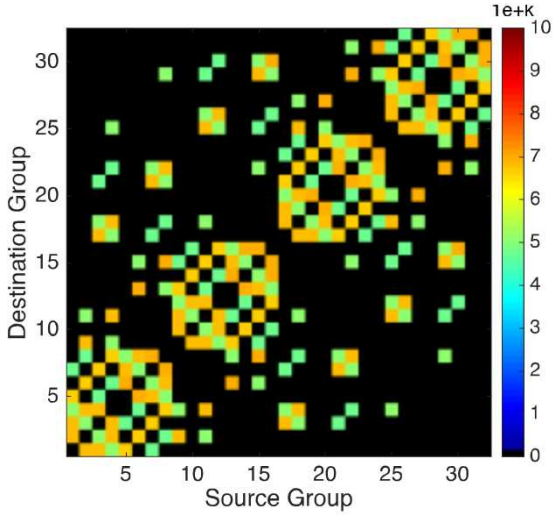
GTC



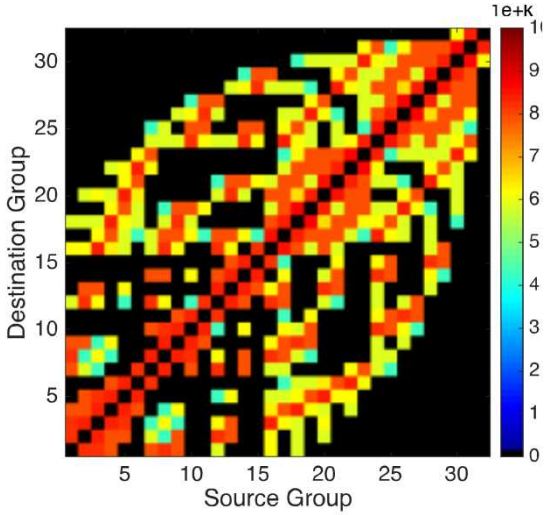
Nekbone



Lulesh

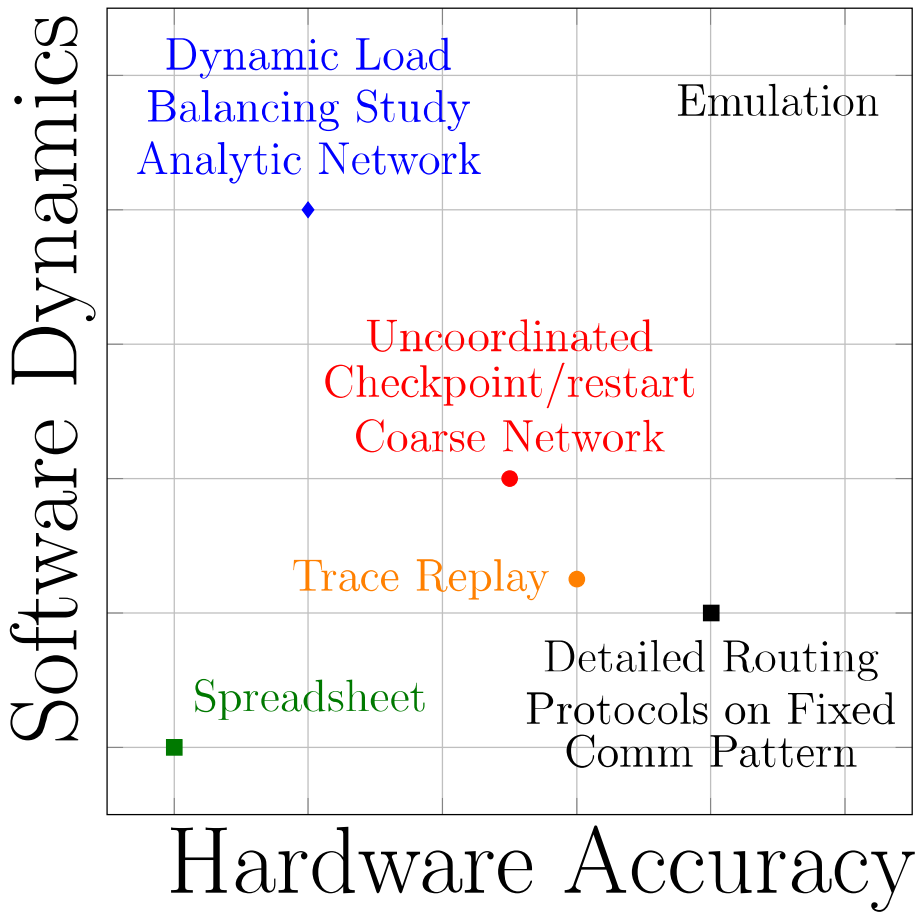


MiniFE



FillBoundary

Selection of endpoint/hardware model depends on the experiment you want to perform

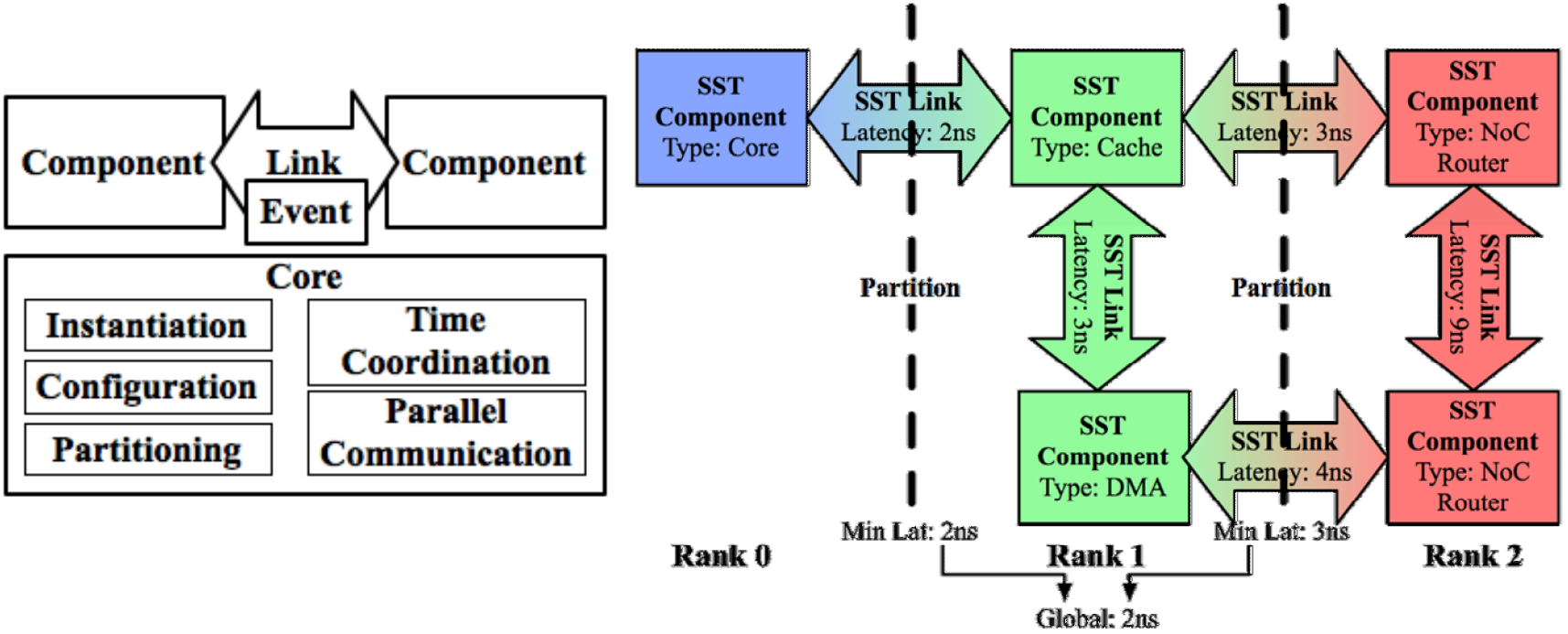


Tools available in SST span spectrum ease of use/flexibility/efficiency

- Trace replay
  - (+) Easy to setup, reasonable accuracy
  - (-) Not flexible, need large compute resources to collect trace
- Ember motif: state-machine generating compute/comm calls
  - (+) Computationally efficient, flexible
  - (-) Work to setup, data-dependent control flow difficult
- Skeleton app: compile and link MPI codes directly into simulation
  - (+) No interface to learn (just MPI code), most flexible
  - ( ) If auto-skeletonizing compiler, not difficult to generate
  - (-) Work to write from scratch, work to skeletonize existing code

Method	Human setup difficulty	Flexibility	Computational efficiency
Traces	Lowest	Lowest	Lowest
Motifs	Medium	Medium-High	Highest
Skeleton	Medium	High	High
Dynamic Skeleton/Motif	High	Highest	Medium-High

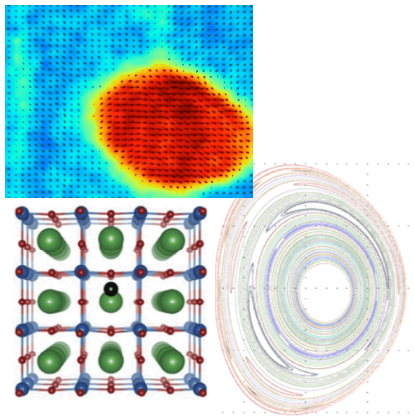
SST is designed from ground-up to enable parallel simulation of interchangeable components



- PDES is a challenging problem – no need to repeat it for every problem domain
  - Partitioning
  - Lookahead optimization/computation
  - Synchronization/event delivery
- SST aims for optimal balance of human time versus computer time
  - Focus on conservative (easier model development) over massively parallel (optimistic)
  - Python input file that builds components and connects them with links

Model for industry/academic collaboration with SST has interchangeable components

Workload models:



Endpoint Interface

SST Core

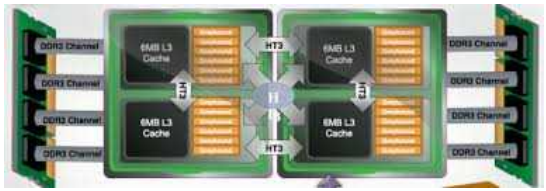
Component | Link / Event | Component

Core

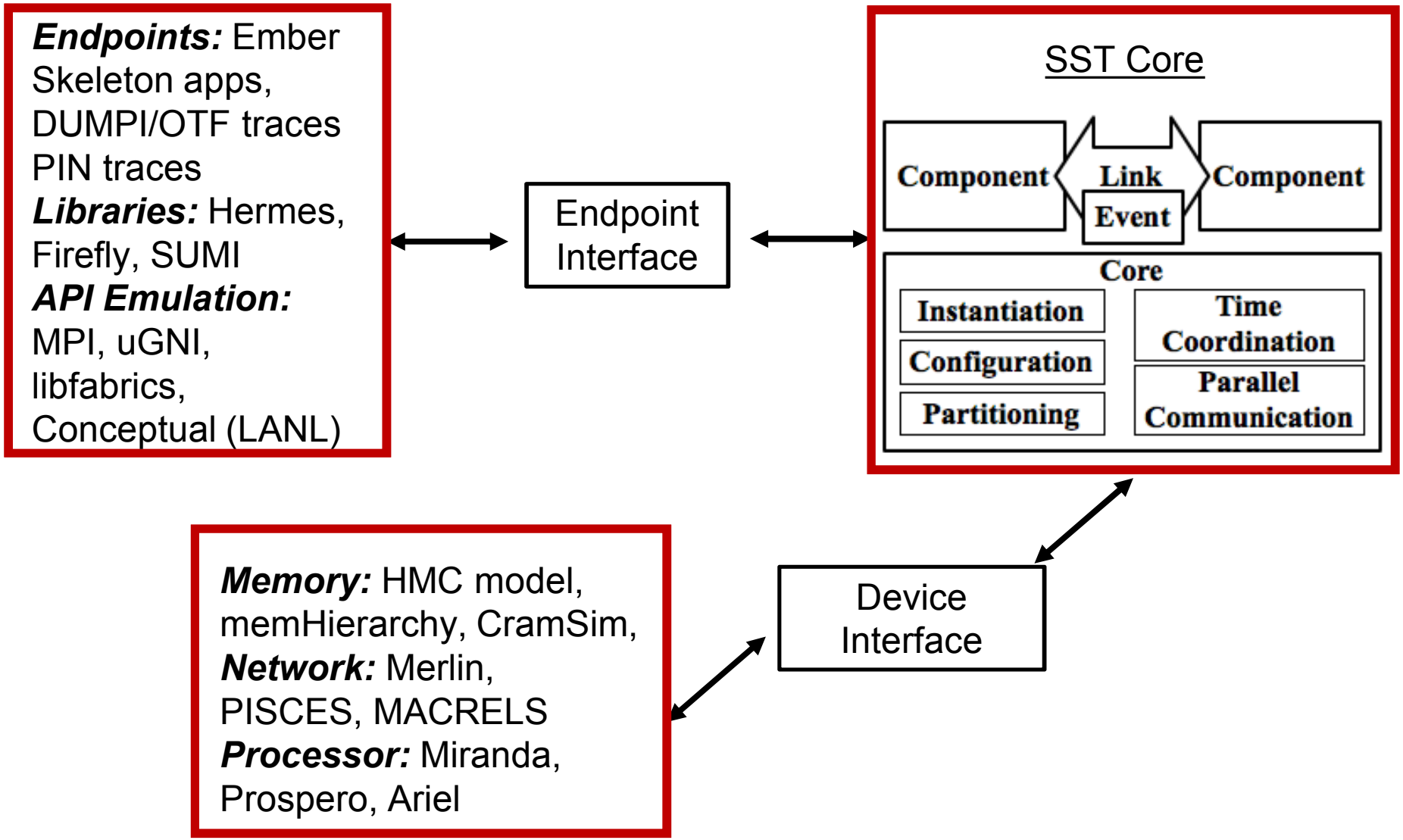
Instantiation | Time Coordination | Configuration | Parallel Communication | Partitioning

Device Interface

Device Models:



Many models with varying accuracy/cost in SST element libraries



The basics of skeleton apps in SST/macro

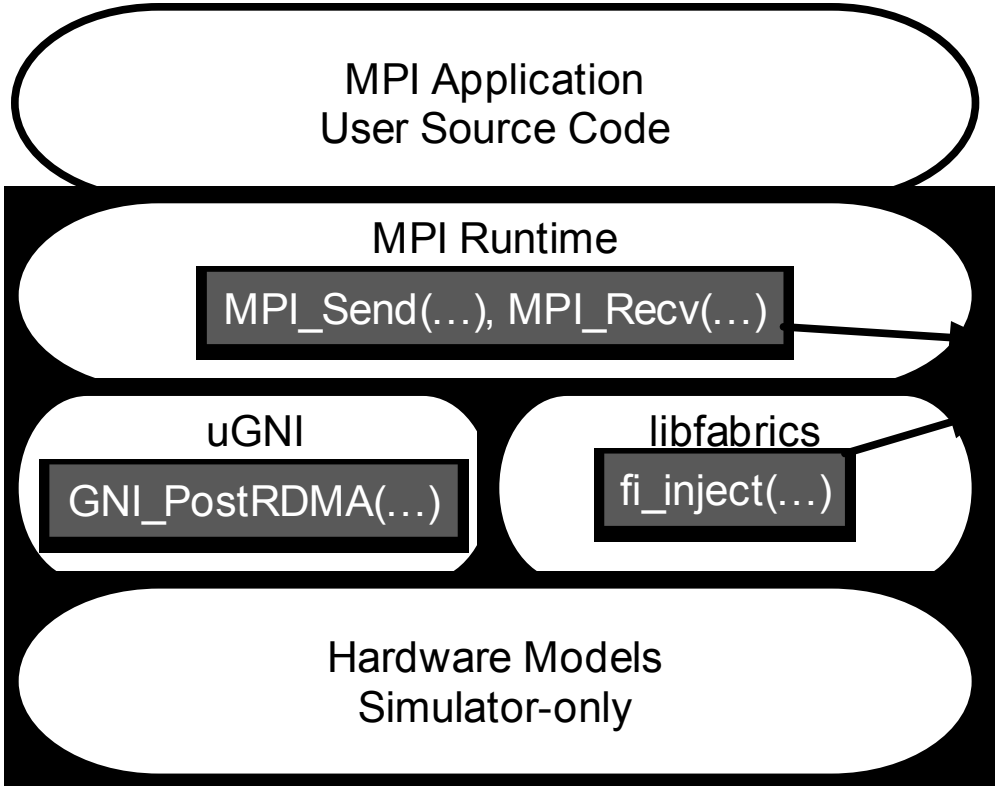
Sample from Lulesh code

```
if (planeMax) {
   /* contiguous memory */
   int fromRank = myRank + domain.tp()*domain.tp() ;
   int recvCount = dx * dy * xferFields ;
   MPI_Irecv(&domain.commDataRecv[pmsg * maxPlaneComm],
             recvCount, baseType, fromRank, msgType,
             MPI_COMM_WORLD, &domain.recvRequest[pmsg]) ;
   ++pmsg ;
}
if (rowMin && doRecv) {
   /* semi-contiguous memory */
   int fromRank = myRank - domain.tp() ;
   int recvCount = dx * dz * xferFields ;
   MPI_Irecv(&domain.commDataRecv[pmsg * maxPlaneComm],
             recvCount, baseType, fromRank, msgType,
             MPI_COMM_WORLD, &domain.recvRequest[pmsg]) ;
   ++pmsg ;
}
```

Intercept MPI calls via compiler wrapper

$>sst++ lulesh-comm.cc –c –o lulesh-comm.o

Software stack simulation leverages low-cost context switching to provide ”virtual” development environment

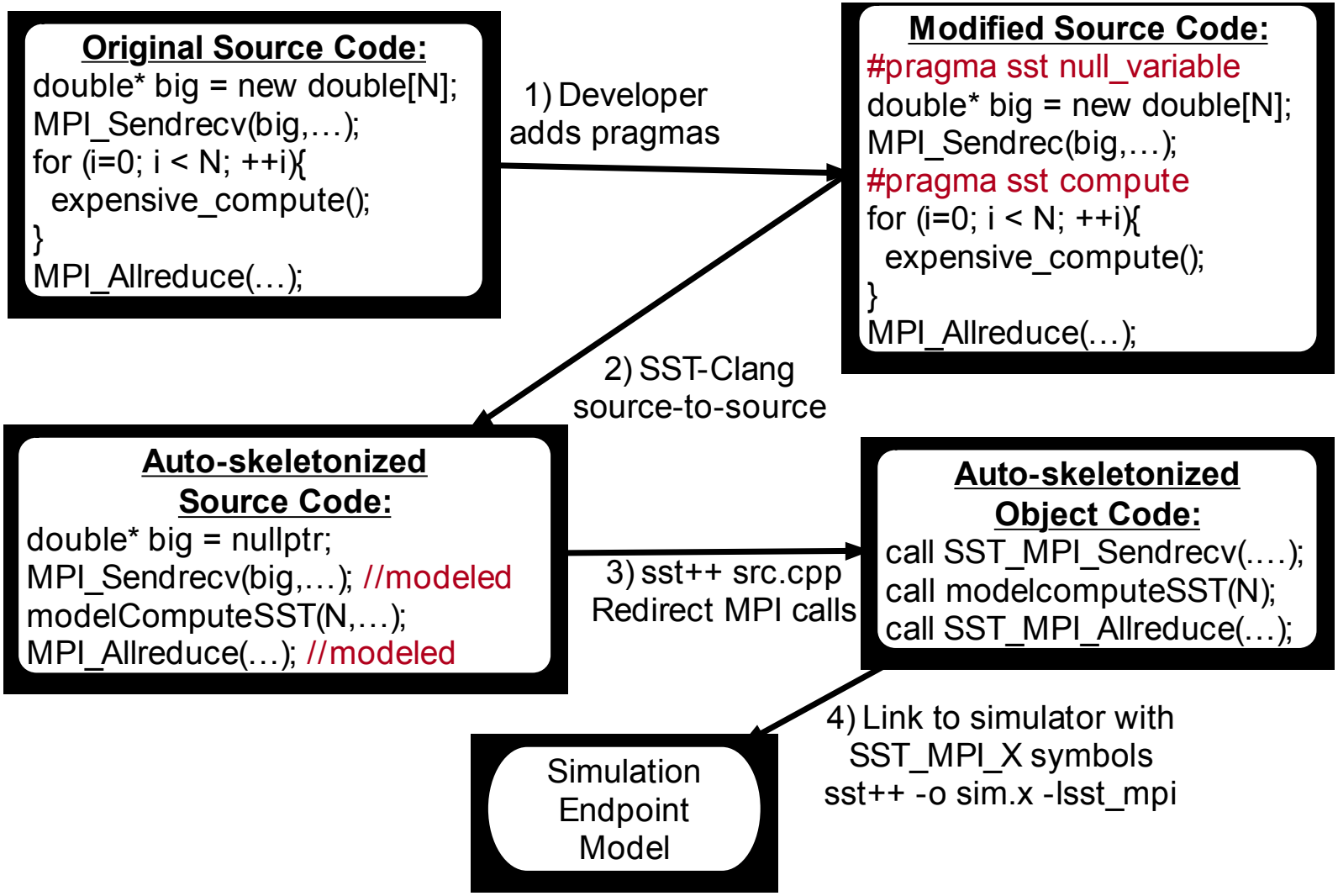


(Mostly) unmodified application code

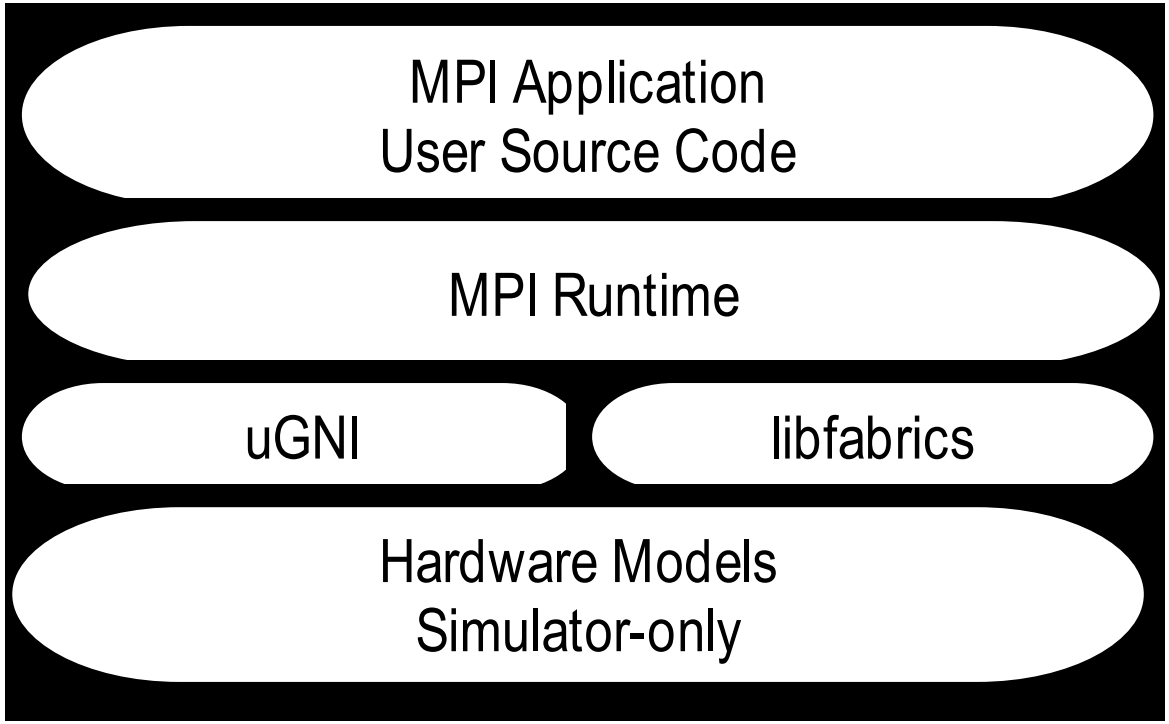
Symbols to intercept with SST/macro

SST middleware and and hardware models

Auto-skeletonizing SST compiler (mostly auto)



Enables experimentation, direct software development of different layers of network stack



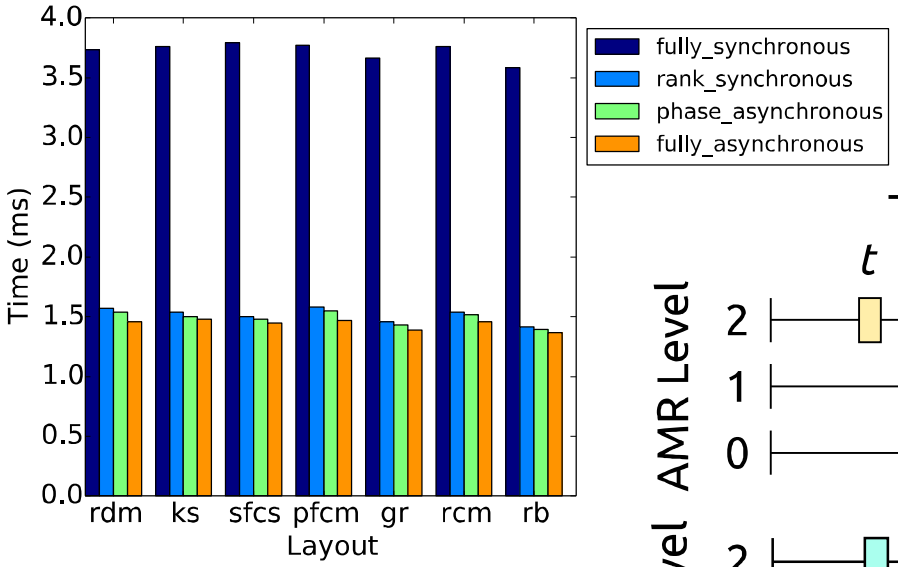
Applications/algorithms

Message order, higher-level semantics

Session layer, message-transfer layer (MTL

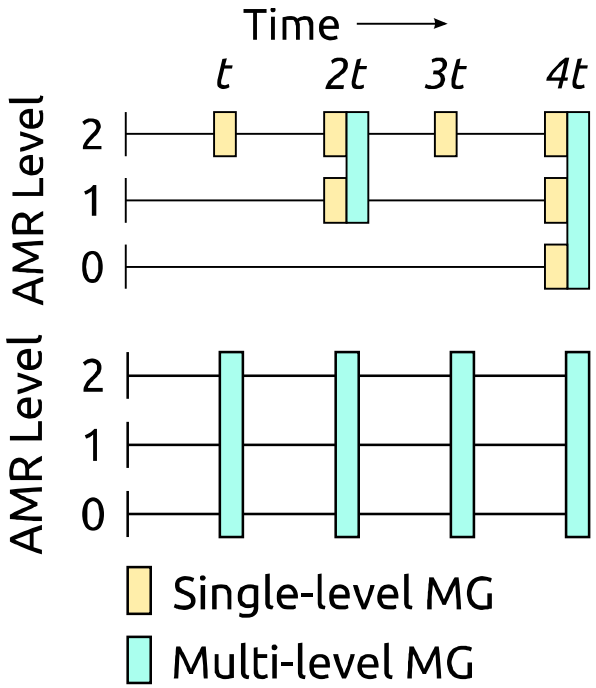
Packetization, byte-transfer layer (BTL), physical network

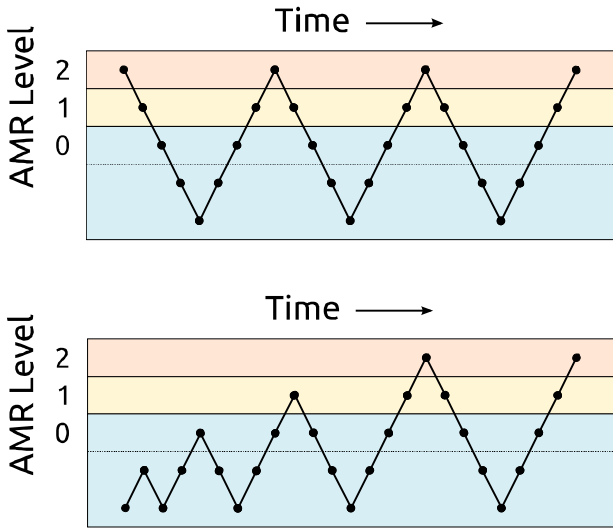
Assesses algorithmic refactoring without needing to overhaul/debug code



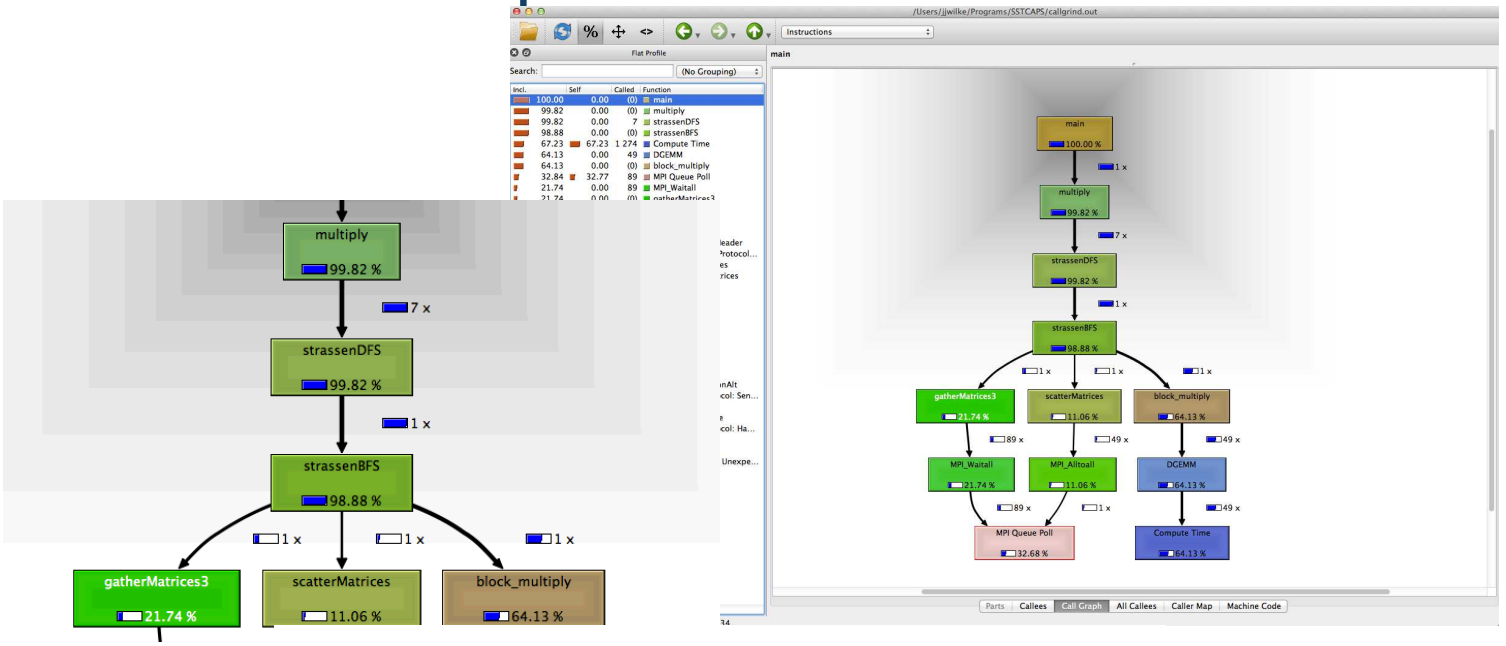
Allreduce → Iallreduce
Waitall → Waitany

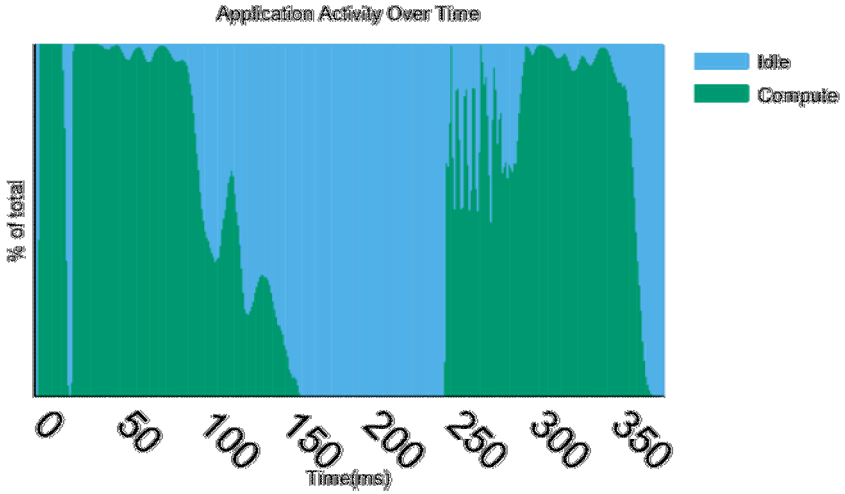
Removing blocking collectives drastically reduces times, other levels of asynchrony give limited performance gains





Extract statistics from virtual software stacks just as done in real performance tools

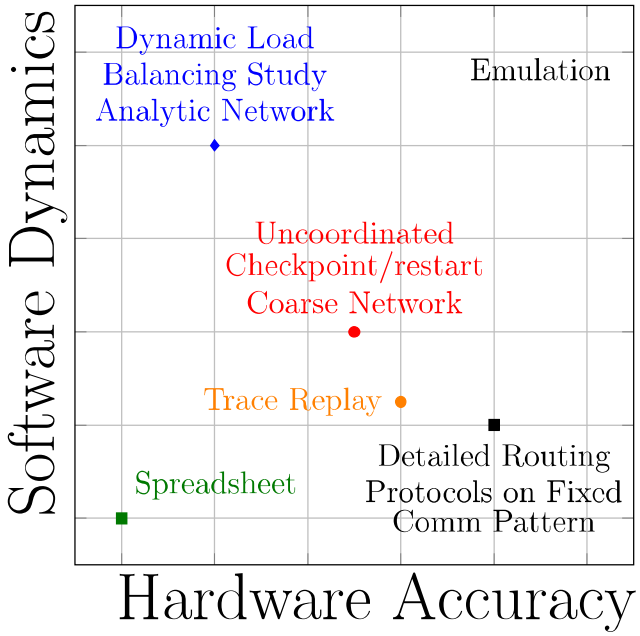




Conclusions

- Large hardware/software design space available to simulation
- Choice of endpoint model/network model depends on research focus/system scale/human time available

Method	Human setup difficulty	Flexibility	Computational efficiency
Traces	Lowest	Lowest	Lowest
Motifs	Medium	Medium-High	Highest
Deterministic Skeleton	Medium	High	High
Dynamic Skeleton	High	Highest	Medium-High



Acknowledgments

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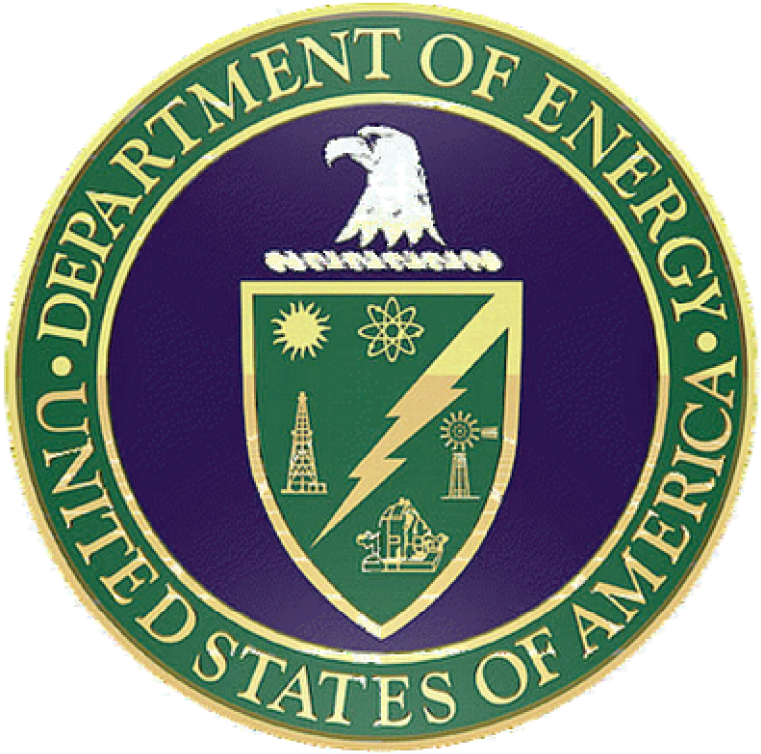

National Nuclear Security Administration

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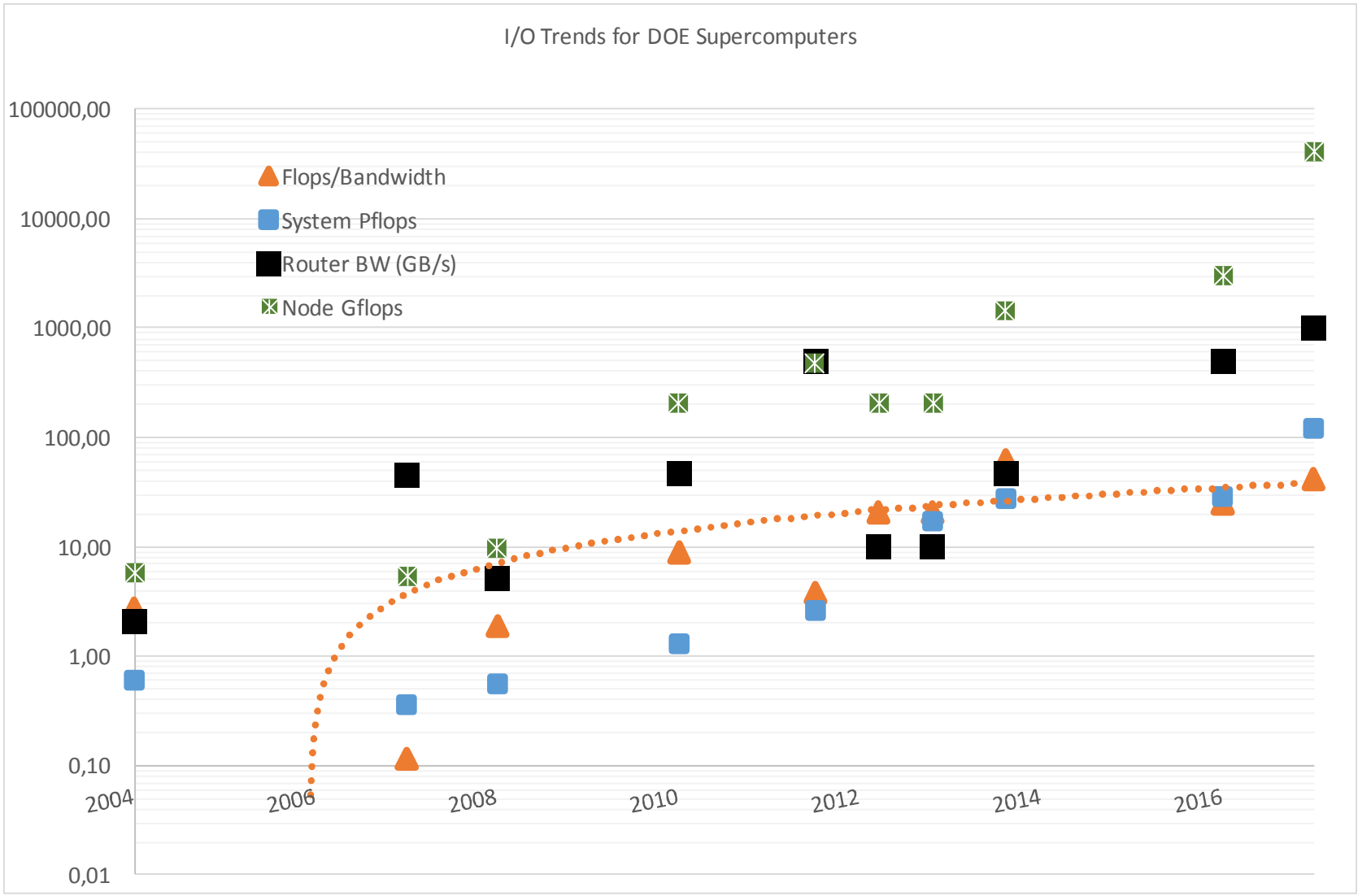
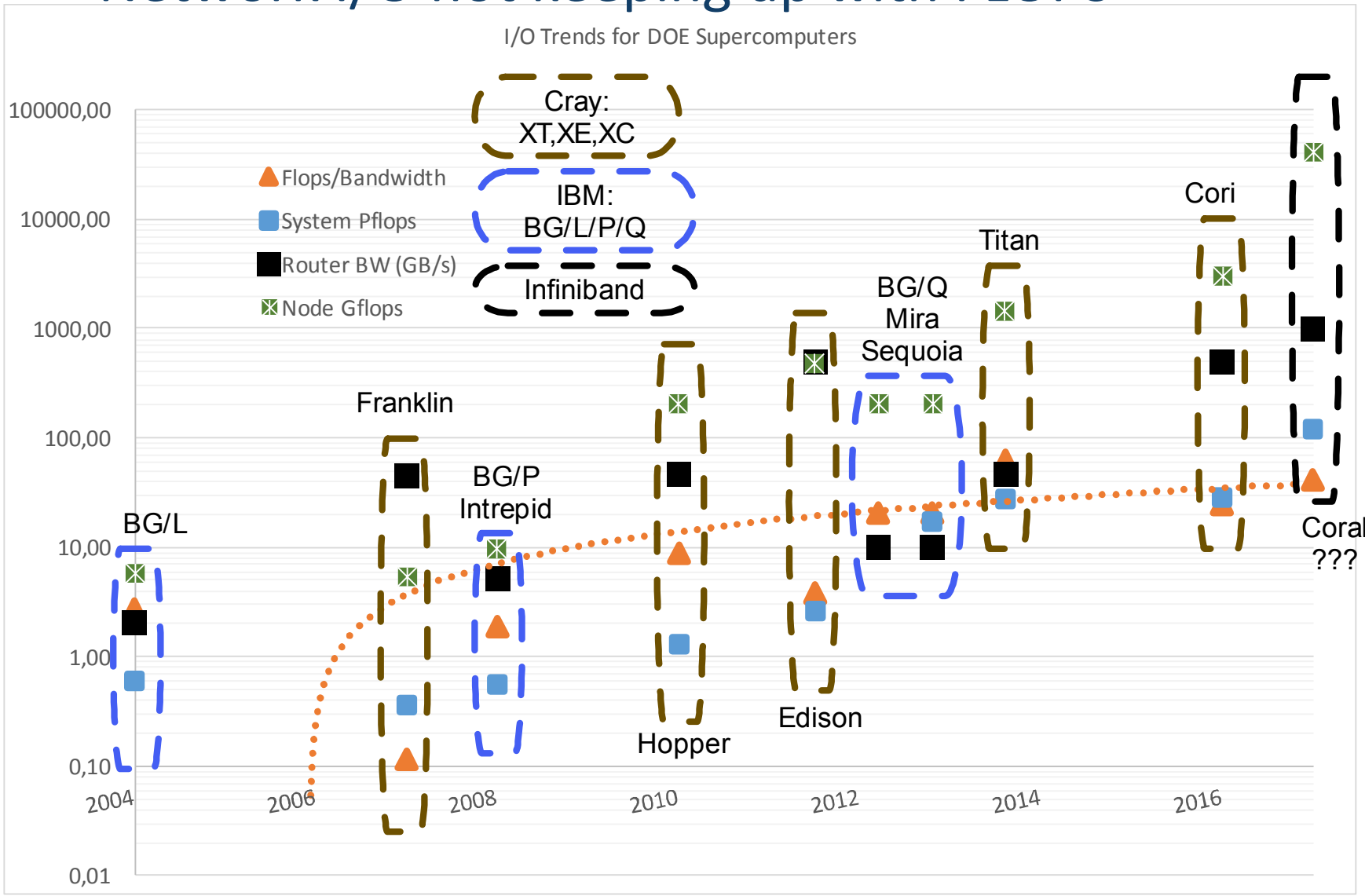
System-level problems that need simulation: Network I/O not keeping up with FLOPS



System-level problems that need simulation: Network I/O not keeping up with FLOPS



System level problems that need simulation: File I/O not keeping up with FLOPS