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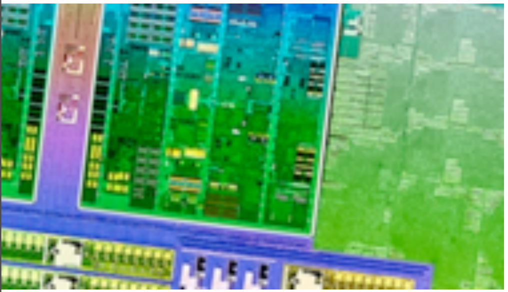

Proxy and Proto miniApps for Exascale Co-design

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Our Exascale Efforts Focus on Co-design

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- Key Co-Design capabilities
  - *SST* Architectural Simulation Framework
  - Pre-production, First-of-a-kind Testbeds
  - Scalable R&D System Software
  - *Mantevo* miniApplications

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  - *SST* Architectural Simulation Framework
  - Pre-production, First-of-a-kind Testbeds
  - Scalable R&D System Software
  - *Mantevo* miniApplications
- Exascale Implications
  - Sustained commitment of significant funding
  - Requires the Long View >5 years out

    —> time to *influence* Hardware Architectures

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- Conventional Wisdom
  - Hardware is difficult to change
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- Conventional Wisdom
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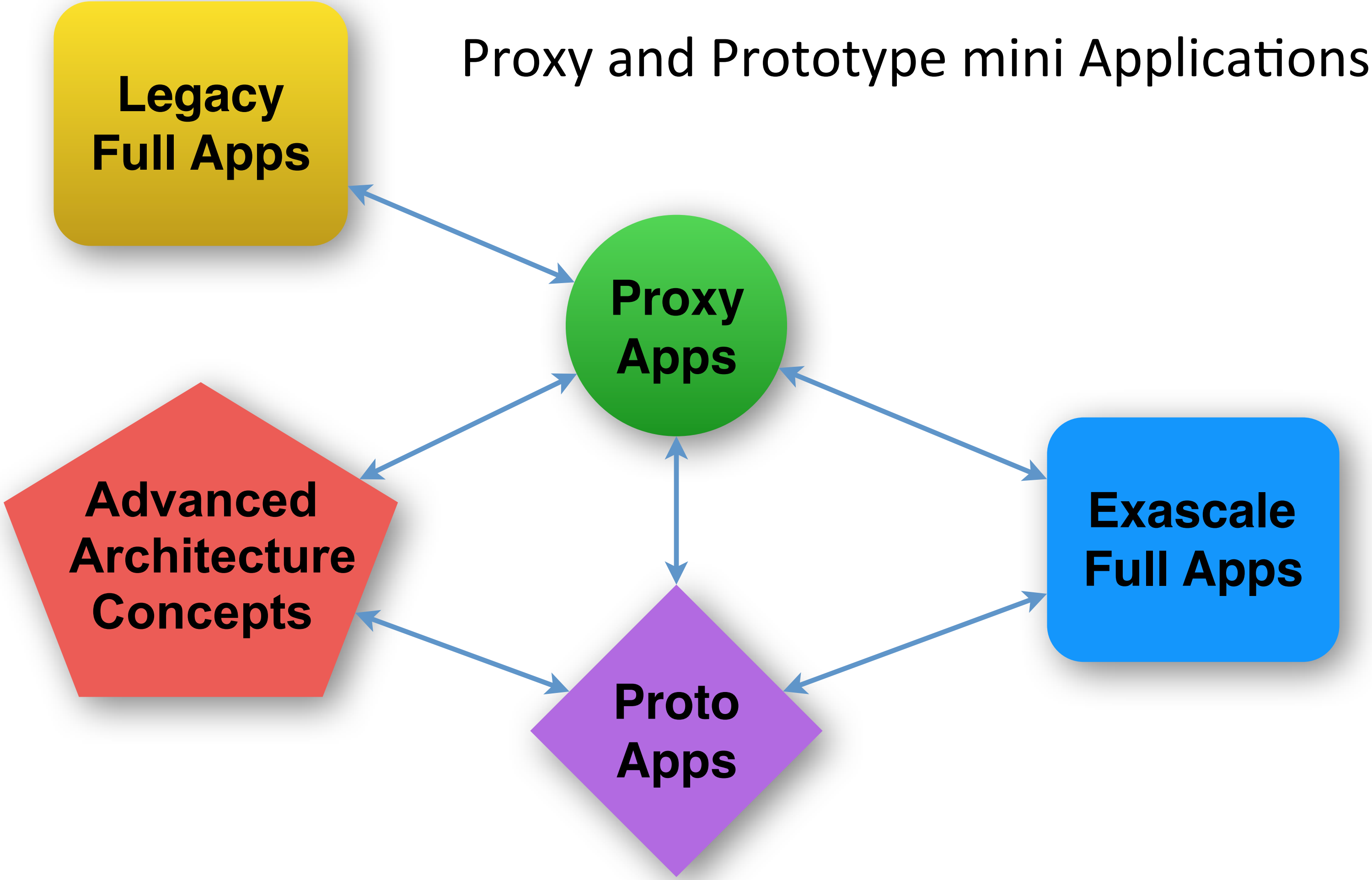
- For the Long View,

  Conventional Wisdom is wrong!

MiniApps: Proxy and Proto

- Relationship among Full Applications

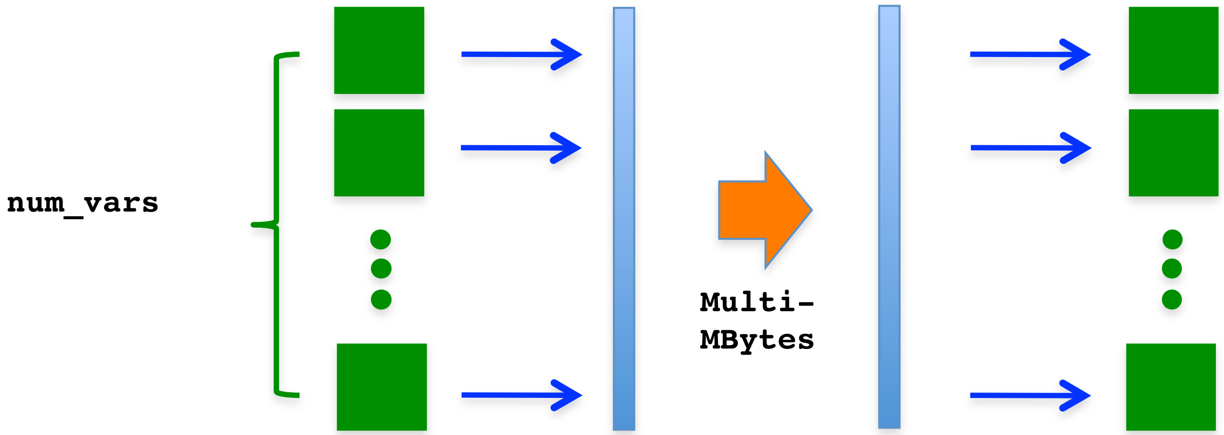
Proxy and Prototype mini Applications



Representative Legacy app: CTH

- Eulerian multi-material modeling application
- 3D, finite volume stencil computation
- BSP with message aggregation (BSPMA)

```
do i = 1, num_tsteps
```



```
    do j = 1, num_vars
        compute
    end do
end do
```

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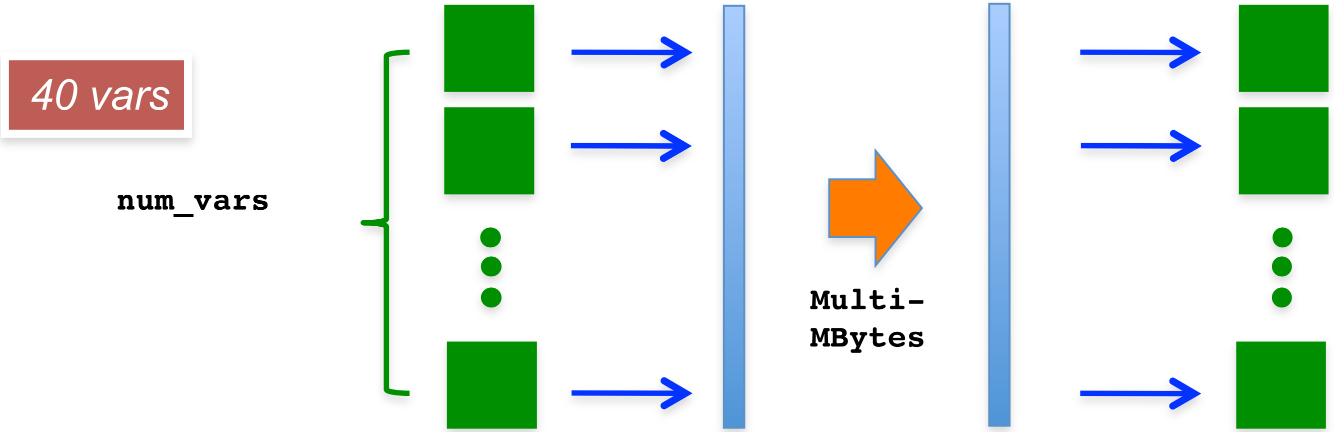

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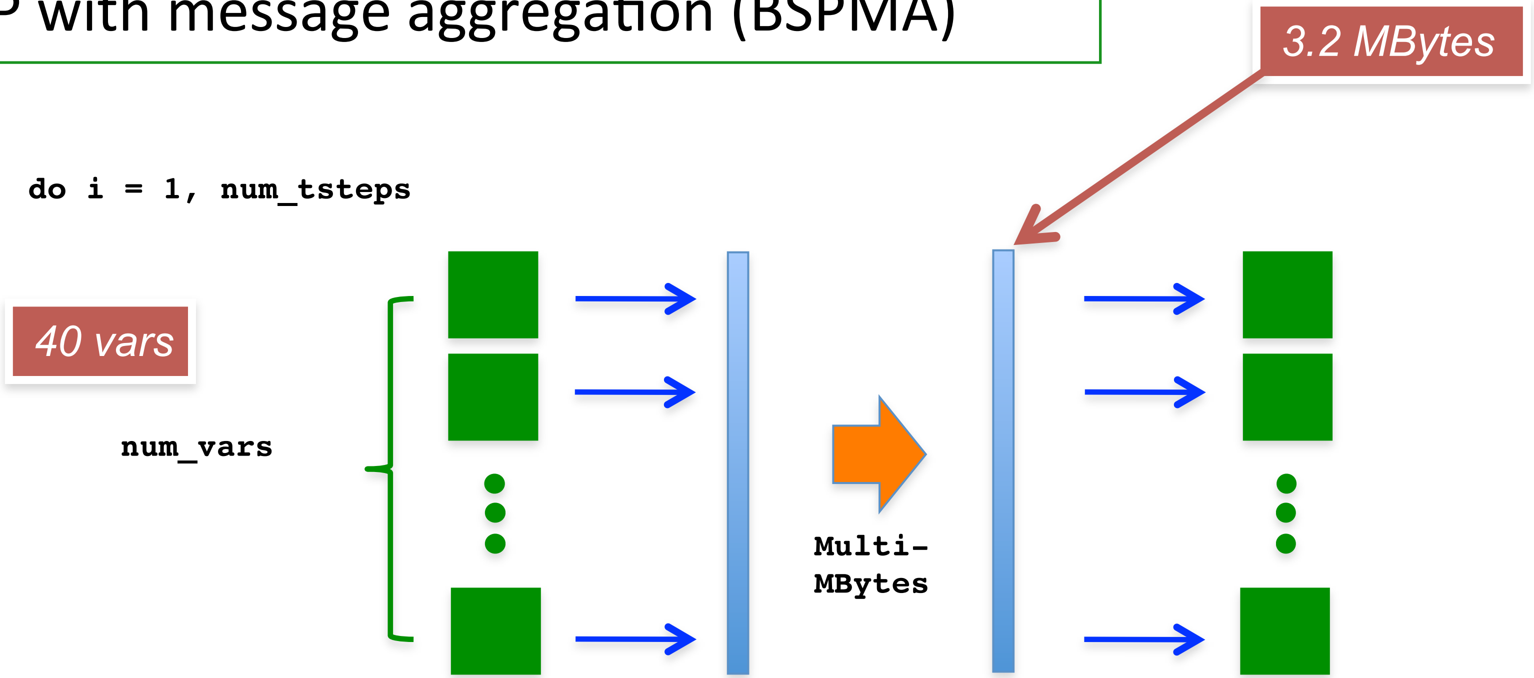
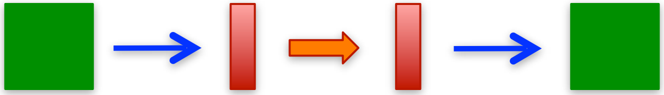


Alternative inter-node strategy: Single Variable Aggregated Faces (SVAF)

```
do i = 1, num_tsteps

  do j = 1, num_vars

     compute
```



```
  end do

end do
```

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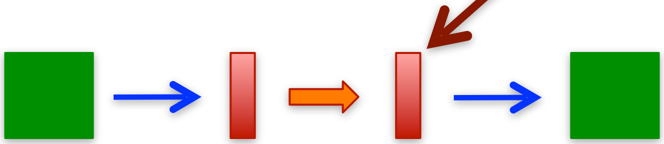
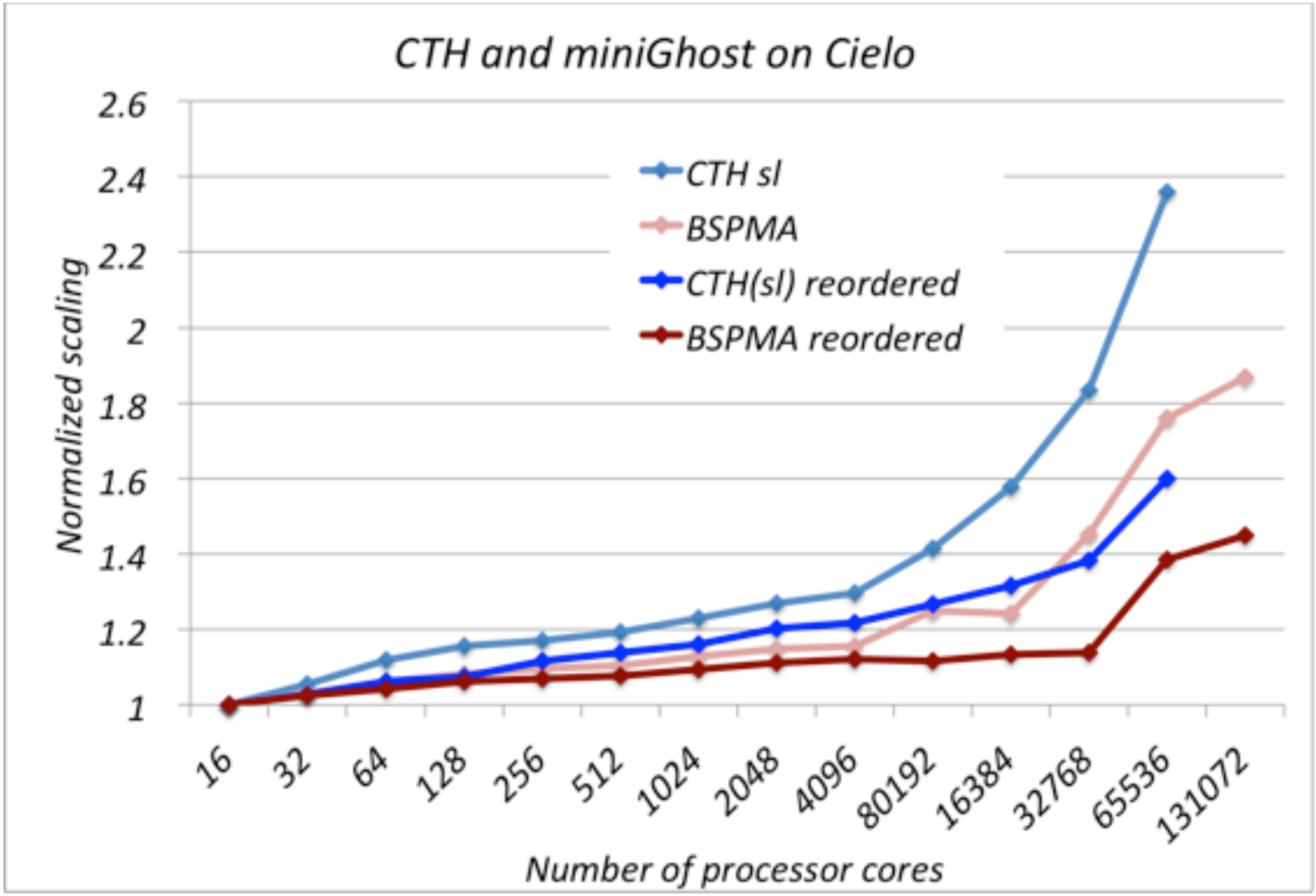


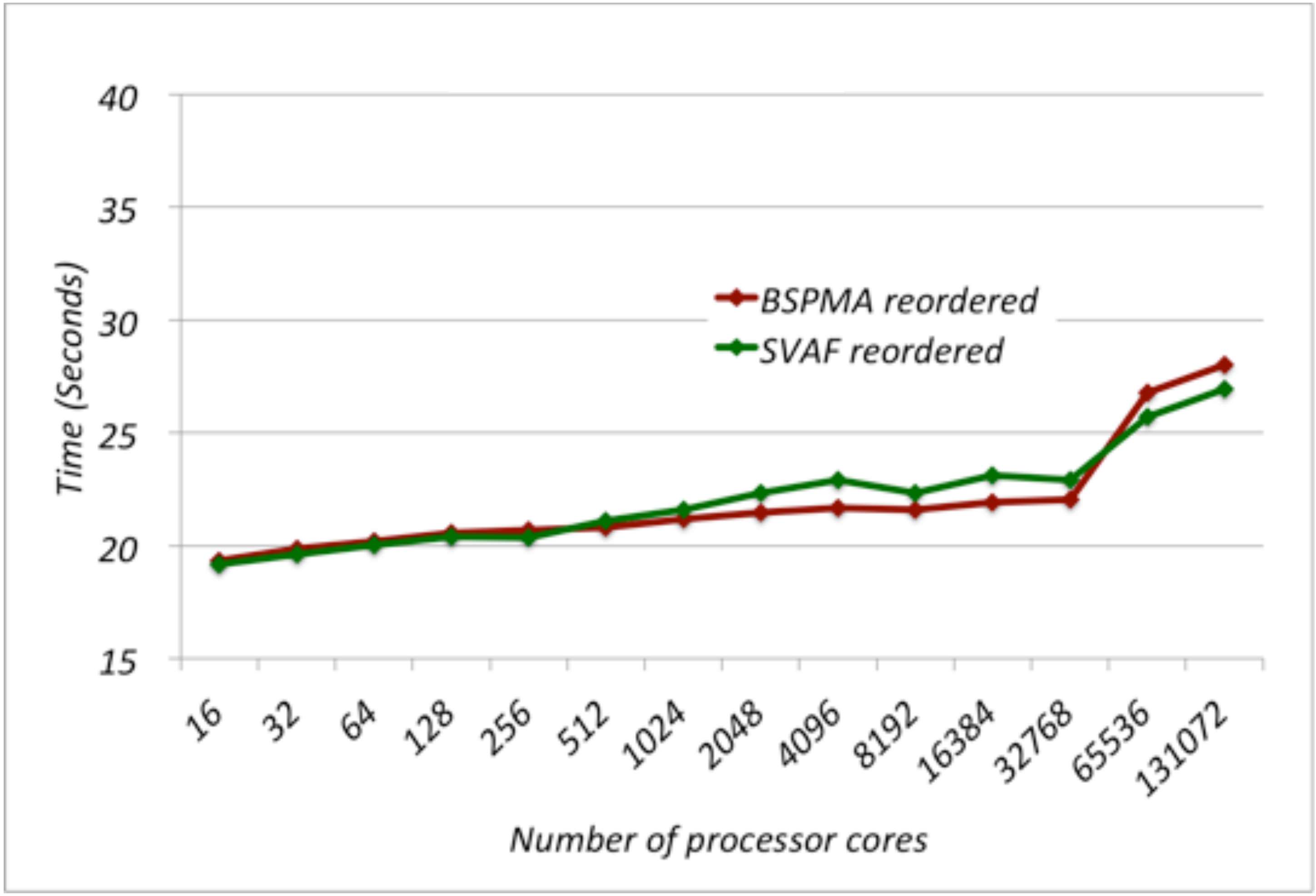
3.2 Mbytes / 40 = 80kbytes

```
 end do
end do
```

Physical ordering of MPI ranks



miniGhost on Cielo: BSPMA and SVAF



Implications for Co-design at a System Architecture Level

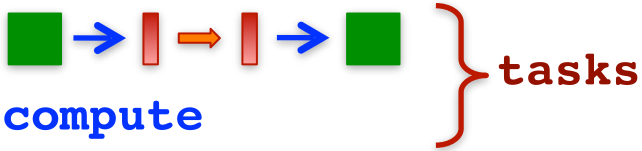
- We know that BSPMA applications create congestion problems for high radix topologies

- Hypothesis: If applications are task parallel, supported with asynchronous runtime software, and multithreaded processors, then congestion issues dissipate

- Focus area for our R&D with *Proto* miniApps
  - Application – Task parallel implementation
  - System Software – Support for asynchronous, adaptive threads
  - Node Architecture – Support for light-weight threading
  - System Architecture – Interconnect Fabric with high radix routers and high injection message rate

miniGhost task parallel

```
do i = 1, num_tsteps
 do j = 1, num_vars
   do iblk, jblk, kblk
```



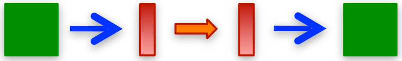
compute

tasks

```
   end do
 end do
end do
```

miniGhost task parallel

```
do i = 1, num_tsteps
  do j = 1, num_vars
     do iblk, jblk, kblk
```



```
        compute                 tasks
     end do
  end do
end do
```

Compute *after* comm due to workspace usage model

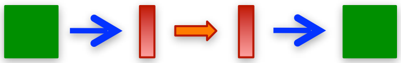
miniGhost task parallel

Needs abstraction (DAG)

```
do i = 1, num_tsteps

  do j = 1, num_vars

     do iblk, jblk, kblk
```



tasks

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        compute

     end do

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```

Compute *after* comm
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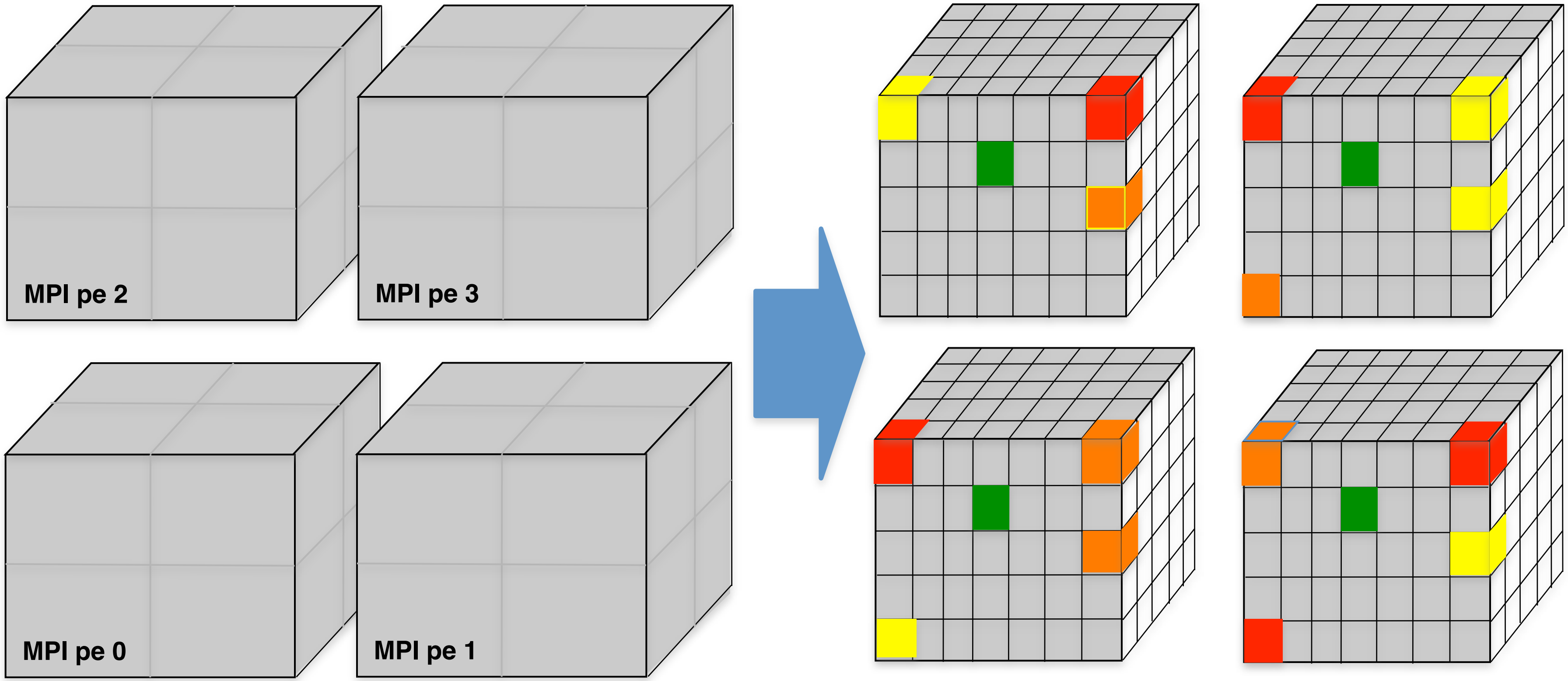
miniGhost: over-decomposition task parallel implementation



Data parallel

⬜ thread

Task parallel: some representative task workloads

🟩 Computation

🟧 Computation + MPI

🟨 Computation + BC

🟥 Computation + BC + MPI

miniGhost tp: Adding AMR

- Diffusion over the 3D domain with random initial conditions and reflective boundary conditions
  - Refinement based on the boundary or volume of an object being moved through the mesh and changing size. So, for example, a shock front can be simulated by refining based on a sphere which starts small and grows in size as the problem advances.

- Refinement within blocks
  - A block is refined into 8 blocks
  - Neighbors must be within one level of refinement
  - Computation is self-contained within a block

- Communication aggregated to BSP model
  - Excellent candidate for task parallelism version

Concluding Thoughts

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- Multiple Dimensions of Co-Design
  - HW: Node and System architecture
  - SW: Application and System Software

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- Multiple Dimensions of Co-Design
  - HW: Node and System architecture
  - SW: Application and System Software
- Examine *Conventional Wisdoms* on COTS and system balance
  - Component performance
  - Investment
    - Platform costs
    - R&D investments