MetaBalancer: An automatic load balancer based on application characteristics

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Outline

1 Motivation

2 Meta-Balancer: Overview

3 Load Balancer: Existing Framework

4 Meta-Balancer
- Statistics Collection
- Ideal LB Period
- Strategy Selection

5 Conclusion

6 Future Work

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- Load balancing decisions depend on application
  - Multiple runs required to observe and decide
  - Tough to judge the correct load balancing parameters

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- Load balancing decisions depend on application
  - Multiple runs required to observe and decide
  - Tough to judge the correct load balancing parameters
- Dynamic applications require dynamic load balancing decisions
  - Some phases may need frequent load balancing, others may be static
  - Computation to communication ratio may change

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Meta-Balancer

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  - RTS maintains and controls the placement of chares

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  - Computation and communication per chare is maintained
  - RTS maintains and controls the placement of chares
- Charm++ RTS is aware of the system characteristics
- Offload the load balancing related decision making to Charm++ RTS
- Meta-Balancer makes load balancing decisions without any user involvement

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- Adaptive triggering of load balancing
- Strategy Selection
  - Communication vs Computation strategy
  - Comprehensive vs Refinement strategy

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- Control flow
  1. AtSync called whenever load balancing is to be performed in the application
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  3. Global barrier to collect statistics
  4. Execute load balancing strategy and perform migration
  5. Application resumes

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Lifecycle

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  2. Based on the statistics collected, the central processor (root)
     - Finds the ideal LB period and informs other processors
     - If immediate LB required, informs other processors
  3. During load balancing, root decides the LB strategy

Asynchronous Collection of Stats via Reduction

- Statistics are collected via reduction periodically and frequently
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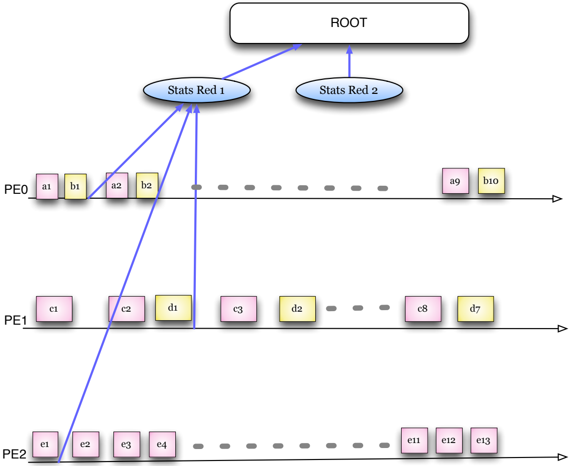
- Statistics are collected via reduction periodically and frequently
- Collection has to be asynchronous - presence of a frequent local and global barrier results in substantial overheads
- Only minimal statistics are collected via custom reduction in Charm++
  - Maximum load - *max* reducer over all processor's load
  - Average load - *sum* reducer over all processor's load
  - Minimum Utilization - *min* reducer over all processor's utilization (ratio of busy time and total time)

Asynchronous Collection of Stats via Reduction



Ideal LB Period

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- Load balancing removes load imbalance, but causes following overheads:
  - Data collection and strategy cost
  - Migration cost
- Optimal performance obtained if load balancing is performed at an ideal period
- Gains obtained from load balancing is maximized despite the incurred overheads.

Ideal LB Period

Assuming,

τ - ideal LB period, γ - total iterations

Γ - execution time, θ - cost of LB

$y = ax + c_a$ - average load line equation

$y = mx + c_m$ - maximum load w.r.t average load

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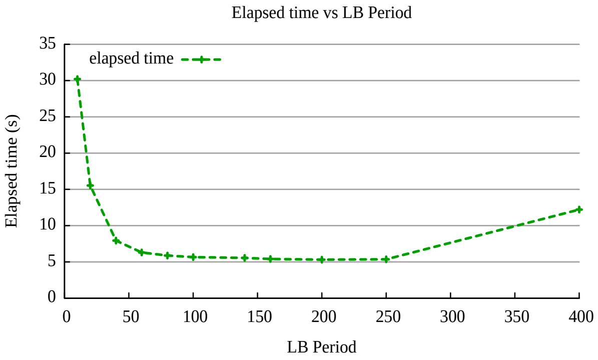
Differentiating the above, following LB period is obtained for minimum execution time
$\tau = \sqrt{\frac{2\theta}{m}}$

Results: Jacobi2D



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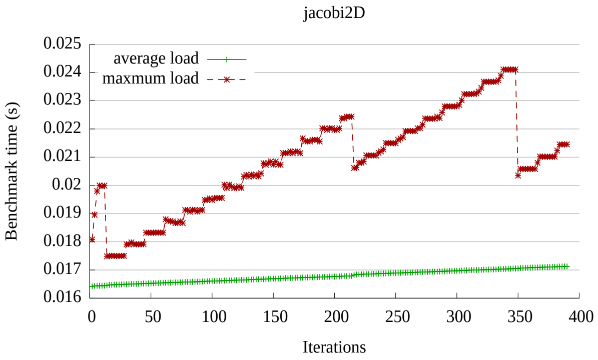

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- As application characteristic changes, LB period may change
  - Capability to refine (expand and contract) LB period if possible
- If prediction and statistics collected do not match, immediate trigger if required

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- Meta-Balancer uses $\alpha\beta$ cost of an application to identify if it is communication intensive, which consist of two components:

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- Meta-Balancer uses $\alpha\beta$ cost of an application to identify if it is communication intensive, which consist of two components:

  1. α cost - start up cost of the messages sent
  2. β cost - bandwidth cost of bytes sent

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- Thereafter, refinement strategies are invoked unless history shows poor quality of refinement based strategies

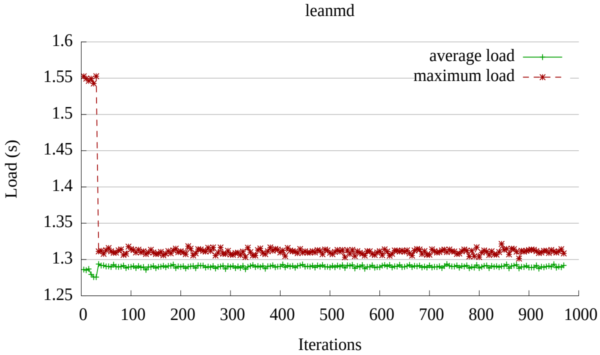


Figure: *leanmd* mini-application

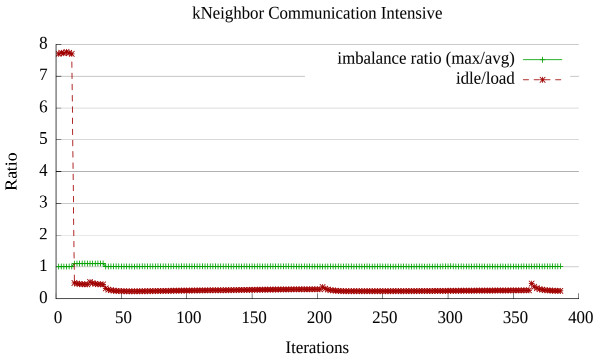


Figure: *kNeighbor* with high communication

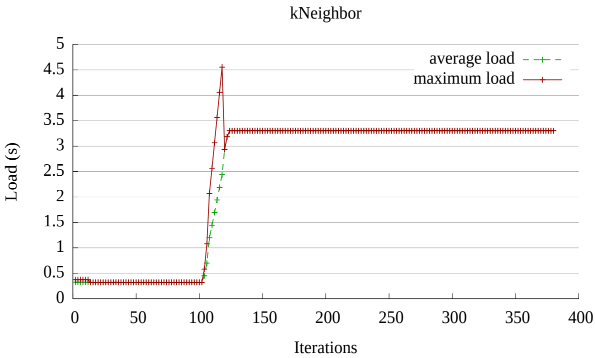
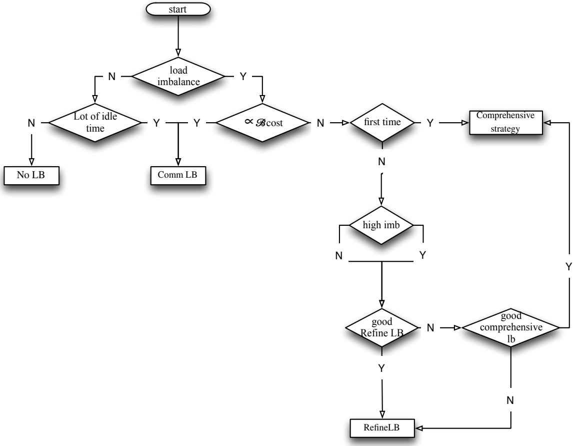


Figure: Dynamic triggering of LB for *kNeighbor*

Overall Scheme

LB Strategy Selection



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- Load imbalance affects performance and scalability of an application
- Leaving it to the application programmer to manually handle this imbalance in a dynamic application is unreasonable and inefficient
- Meta-Balancer relieves the user from load balancing decisions by
  - Frequently collecting minimal statistics about the application
  - Controlling the load balancing decision based on the application characteristics

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- Expand strategy selection
  - Hierarchical vs Centralized
  - Topology-aware vs topology oblivious

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  - Topology-aware vs topology oblivious
- More accurate prediction of load - higher order curves

Thank You!