Dynamic Load Balancing in Charm++

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Outline

- Dynamic Load Balancing framework in Charm++
- Measurement Based Load Balancing
- Examples:
  - Hybrid Load Balancers
  - Topology-aware Load Balancers
- User Control and Flexibility
- Future Work

Dynamic Load-Balancing

- Task of load balancing (LB)
  - Given a collection of migratable objects and a set of processors
  - Find a mapping of objects to processors
    - Almost same amount of computation on each processor
  - Additional constraints
    - Ensure communication between processors is minimum
    - Take topology of the machine into consideration
- Dynamic mapping of chares to processors
  - Load on processors keeps changing during the actual execution

Load-Balancing Approaches

- A rich set of strategies in Charm++
- Two main ideas
  - No correlation between successive iterations
    - Fully dynamic
    - Seed load balancers
  - Load varies slightly over iterations
    - CSE, Molecular Dynamics simulations
    - Measurement-based load balancers

Principle of Persistence

- Object communication patterns and computational loads tend to persist over time
  - In spite of dynamic behavior
    - Abrupt and large, but infrequent changes (e.g. AMR)
    - Slow and small changes (e.g. particle migration)
- Parallel analog of principle of locality
  - Heuristics, that hold for most CSE applications

Measurement Based Load Balancing

- Based on principle of persistence
- Runtime instrumentation (LB Database)
  - communication volume and computation time
- Measurement based load balancers
  - Use the database periodically to make new decisions
  - Many alternative strategies can use the database
    - Centralized vs. distributed
    - Greedy improvements vs. complete reassignment
    - Topology-aware

Load Balancer Strategies

- Centralized
  - Object load data are sent to processor 0
  - Integrate to a complete object graph
  - Migration decision is broadcasted from processor 0
  - Global barrier

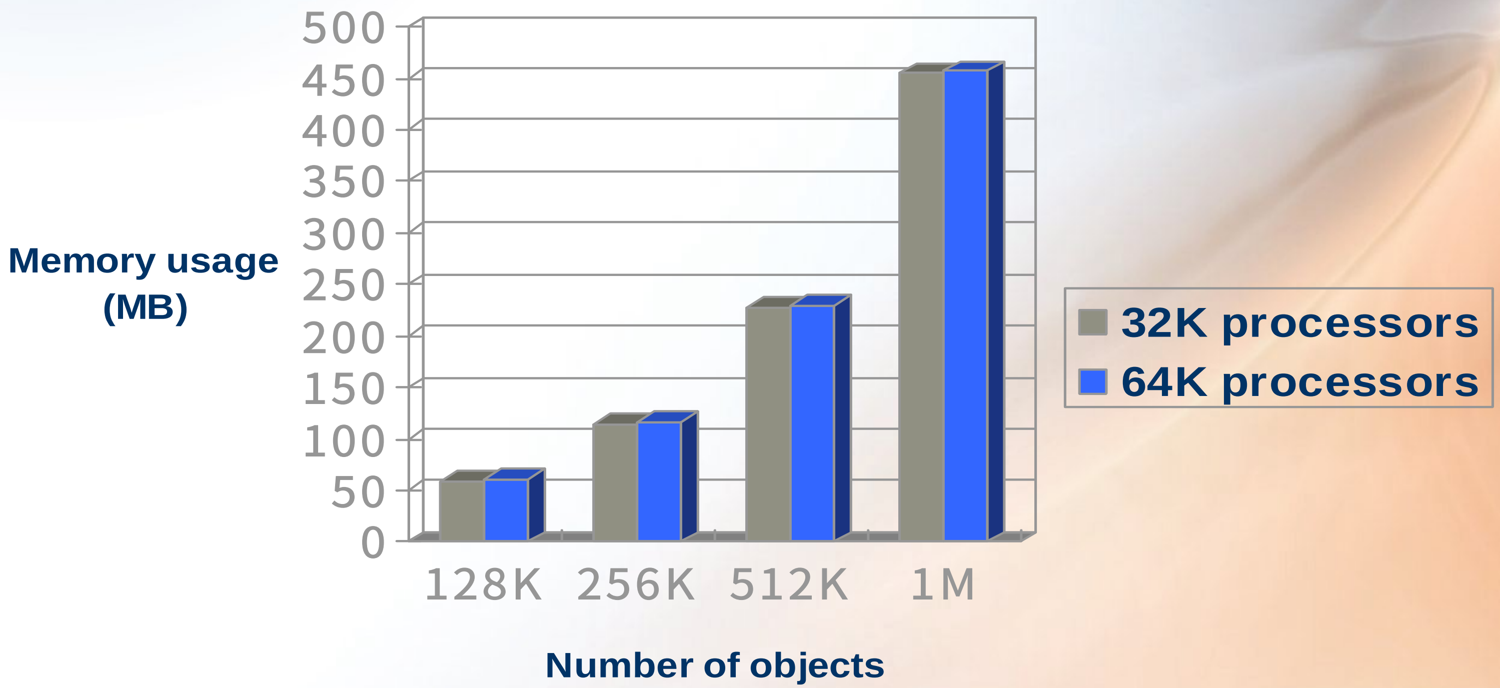
- Distributed
  - Load balancing among neighboring processors
  - Build partial object graph
  - Migration decision is sent to its neighbors
  - No global barrier

Load Balancing on Large Machines

- Existing load balancing strategies don’t scale on extremely large machines
- Limitations of centralized strategies:
  - Central node: memory/communication bottleneck
  - Decision-making algorithms tend to be very slow
- Limitations of distributed strategies:
  - Difficult to achieve well-informed load balancing decisions

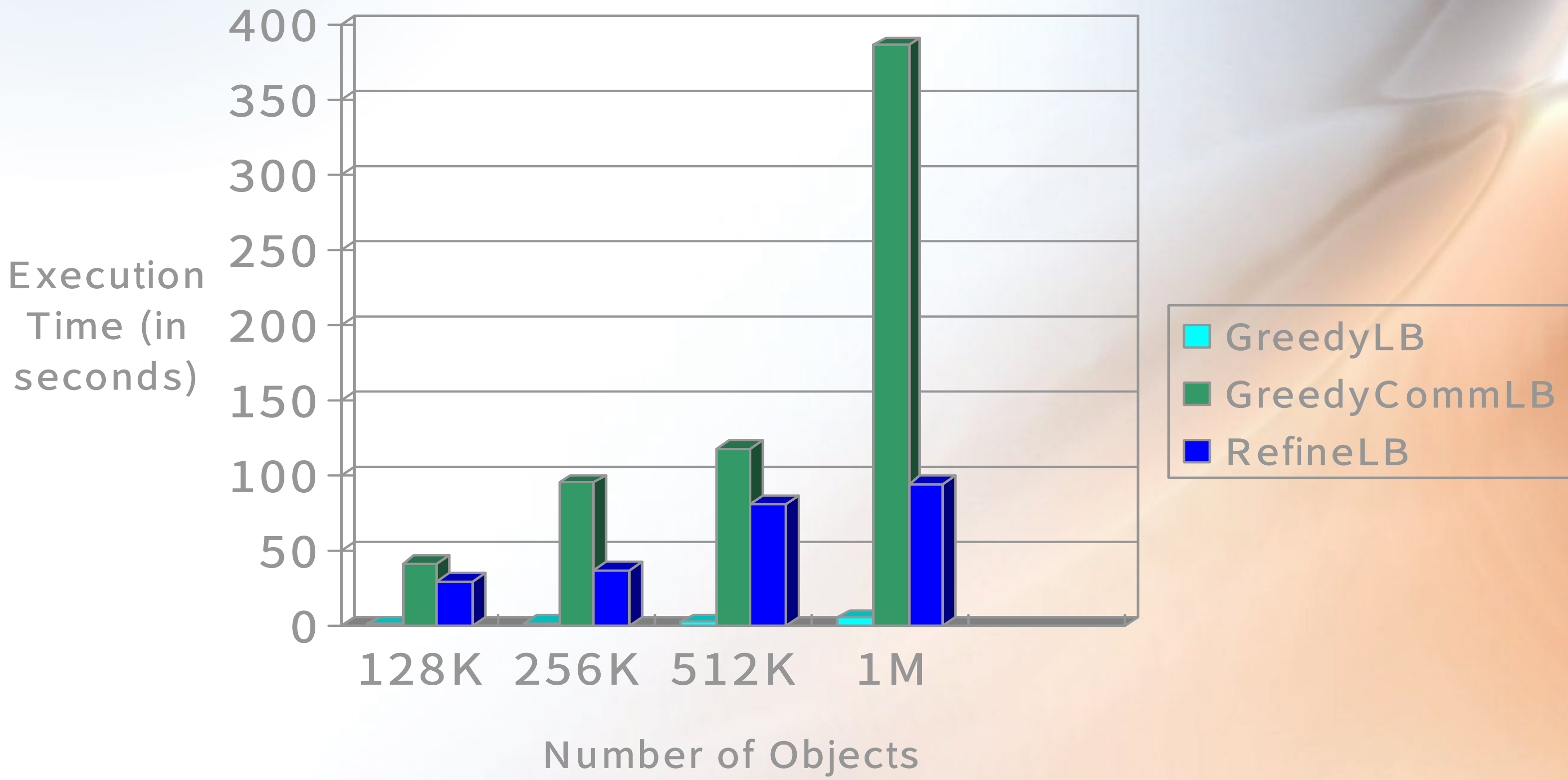
Simulation Study - Memory Overhead

Simulation performed with the performance simulator BigSim



lb_test benchmark is a parameterized program that creates a specified number of communicating objects in 2D-mesh.

Load Balancing Execution Time



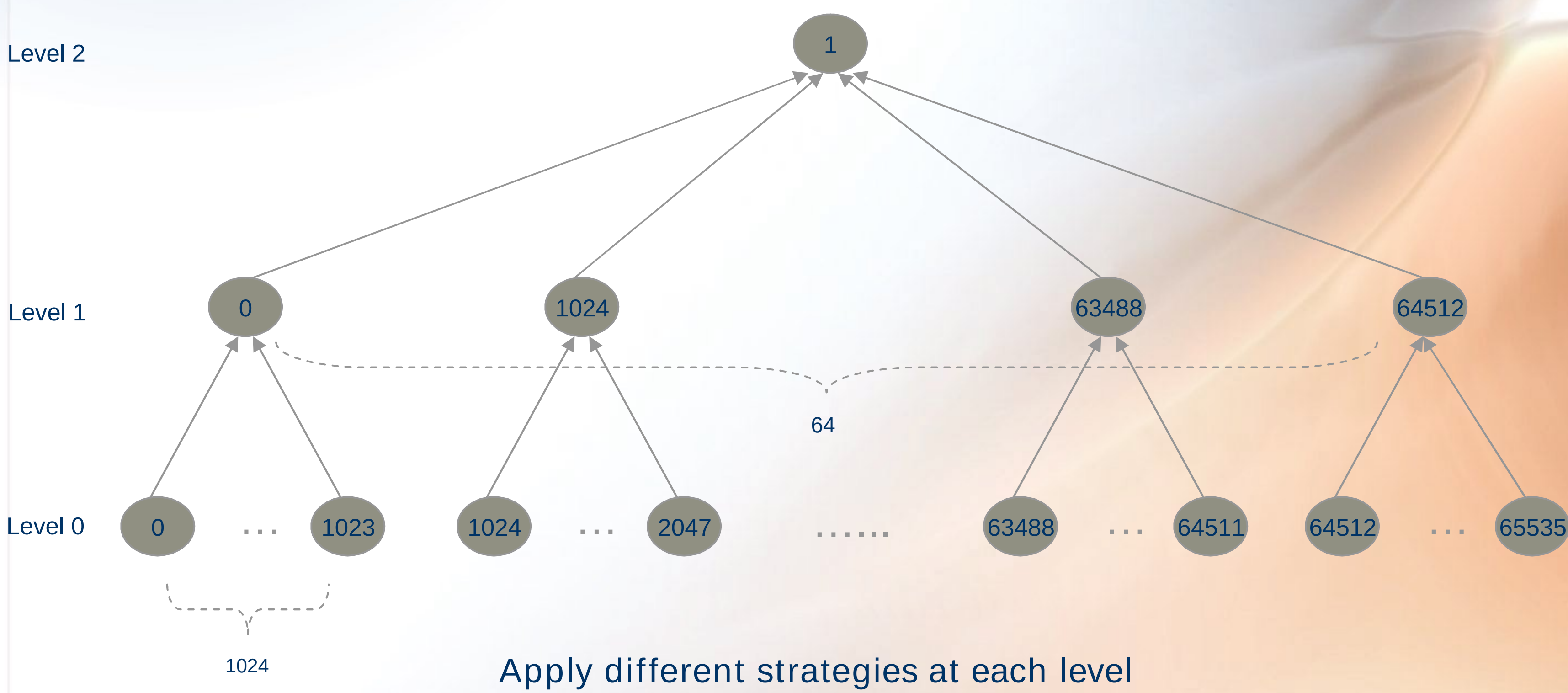
Execution time of load balancing algorithms on a 64K processor simulation

Hierarchical Load Balancers

- Hierarchical distributed load balancers
  - Divide into processor groups
  - Apply different strategies at each level
  - Scalable to a large number of processors

Hierarchical Tree (an example)

64K processor hierarchical tree



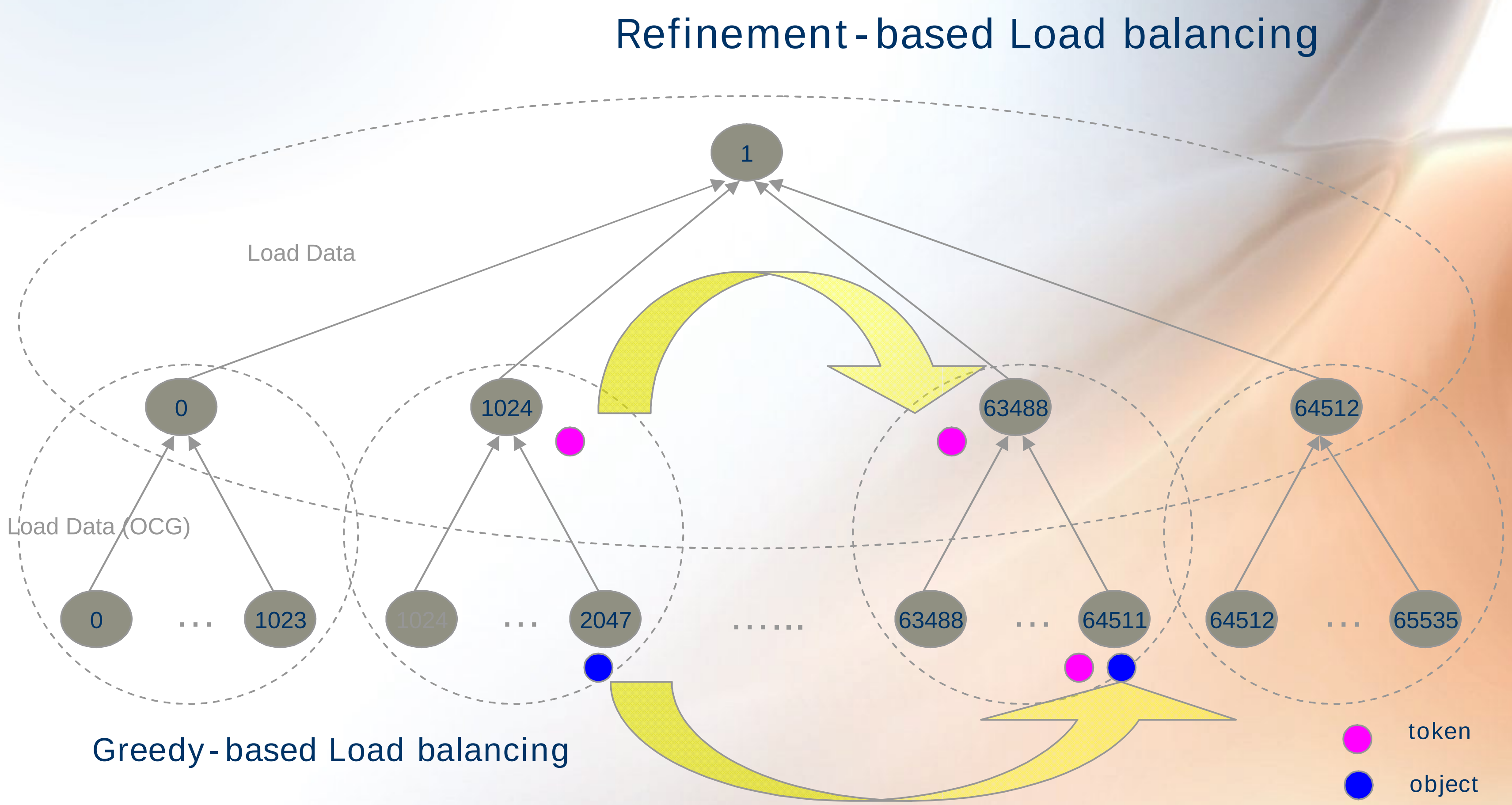
Apply different strategies at each level

An Example: Hybrid LB

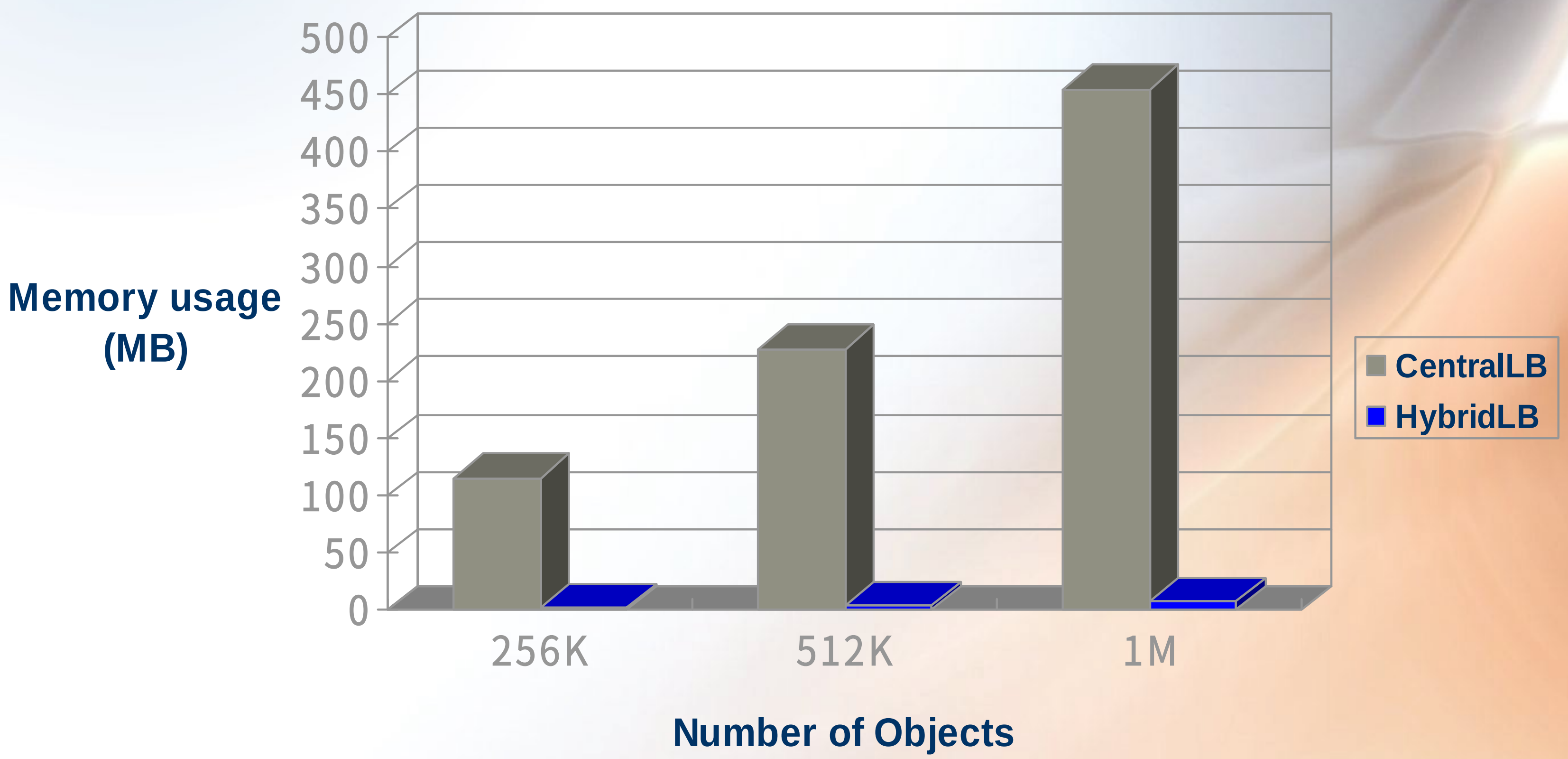
- Dividing processors into independent sets of groups, and groups are organized in hierarchies (decentralized)
- Each group has a leader (the central node) which performs centralized load balancing
- A particular hybrid strategy that works well

Gengbin Zheng, PhD Thesis, 2005

Our HybridLB Scheme

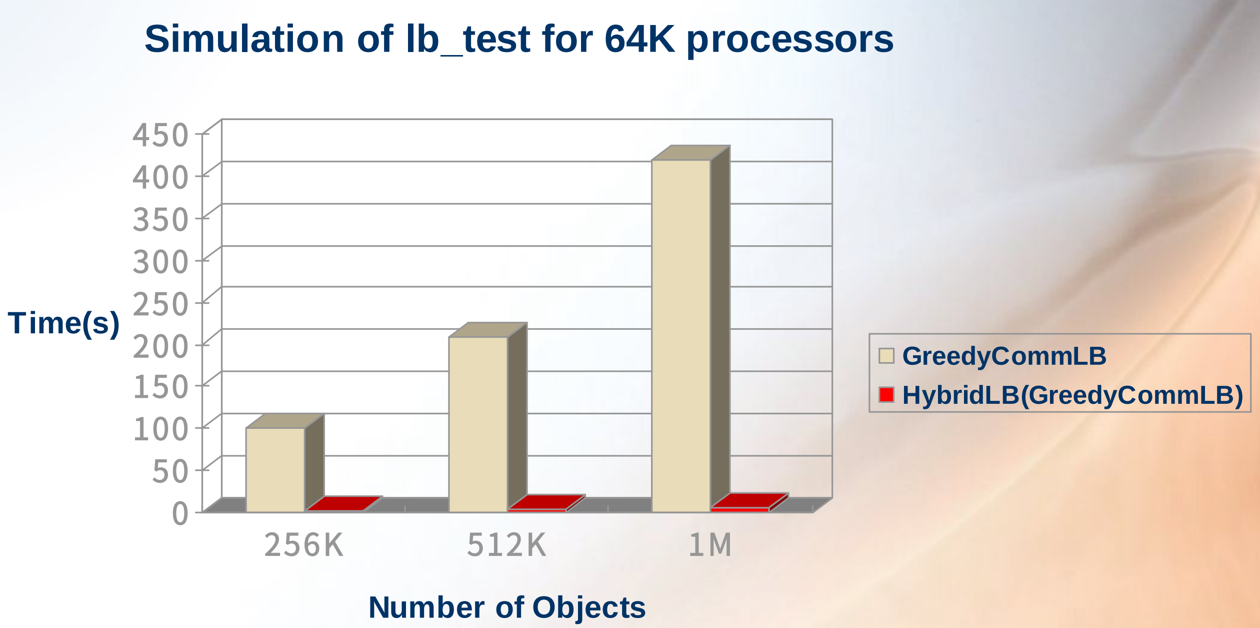


Memory Overhead



Simulation of lb_test (for 64k processors)

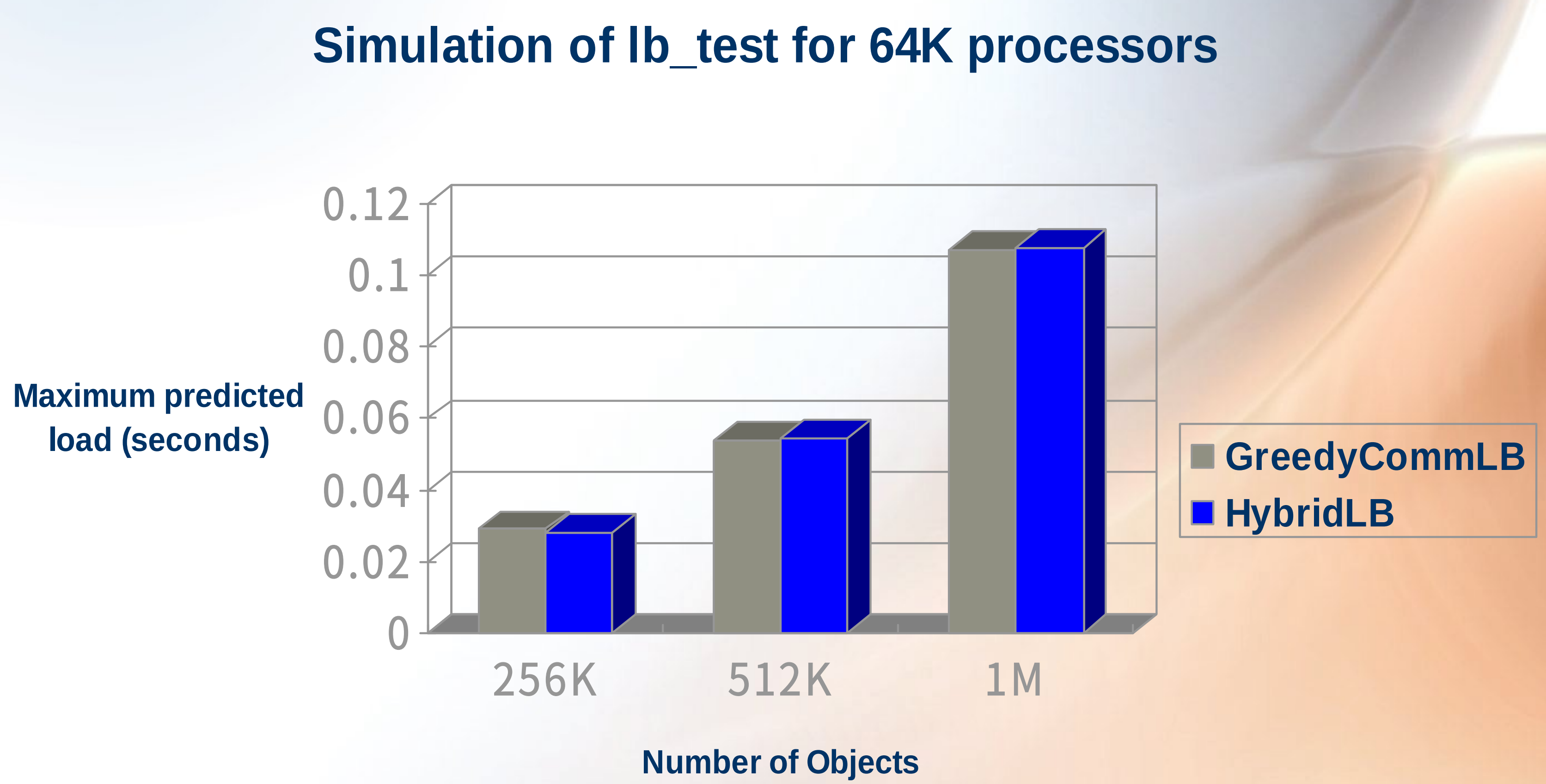
Total Load Balancing Time



N procs	4096	8192	16384
Memory	6.8MB	22.57MB	22.63MB

lb_test benchmark's actual run on BG/L at IBM (512K objects)

Load Balancing Quality



Topology-aware mapping of tasks

- Problem
  - Map tasks to processors connected in a topology, such that:
    - Compute load on processors is balanced
    - Communicating chares (objects) are placed on nearby processors.

Mapping Model

- Task Graph :
  - $G_t = (V_t , E_t)$
  - Weighted graph, undirected edges
  - Nodes ⇔ chares, $w(v_a)$ ⇔ computation
  - Edges ⇔ communication, c_{ab} ⇔ bytes between v_a and v_b
- Topology-graph :
  - $G_p = (V_p , E_p)$
  - Nodes ⇔ processors
  - Edges ⇔ Direct Network Links
  - Ex: 3D-Torus, 2D-Mesh, Hypercube

Model (Contd.)

- Task Mapping
  - Assigns tasks to processors
  - $P : V_t \rightarrow V_p$
- Hop-Bytes
  - Hop-Bytes ⇔ Communication cost
  - The cost imposed on the network is more if more links are used
  - Weigh inter-processor communication by distance on the network

Load Balancing Framework in Charm++

- Issues of mapping and decomposition separated
- User had full control over mapping
- Many choices
  - Initial static mapping
  - Mapping at run-time as newer objects created
  - Write a new load balancing strategy: inherit from BaseLB

Future Work

- Hybrid Model-based Load Balancers
  - User gives a model to the LB
  - Combine it with measurement based load balancer
- Multicast aware Load Balancers
  - Try and place targets of multicast on the same processor

Conclusions

- Measurement based LBs are good for most cases
- Need scalable LBs in the future due to large machines like BG/L
  - Hybrid Load Balancers
  - Communication sensitive LBs
  - Topology aware LBs