Application of Lagrangian Receding Horizon Techniques to Resource Management in Ad Hoc Grid Environments

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Problem Description

- Ad hoc computing grids
  - Heterogeneous collection of computing and communication resources without fixed infrastructure
- Challenges
  - Assets can appear/disappear without warning
  - Communication links prone to failure, noise
- Required
  - Resource manager capable of rapid response to changing conditions

Approach

- Lagrangian objective function
  - Combine constraints into objective function using time-dependent parameters (Lagrangian multipliers)
- Receding horizon
  - Optimal control method
  - Predict evolution of system for limited time into future
  - Control based on prediction until next measurement of system state
- Initial experiment
  - Determine performance under different conditions
  - Evaluate sensitivity of critical parameters

Simulation Environment

- Two types of machines – fast, slow
  - Differentiated by cpu speed, energy consumption rate, communication bandwidth
- Single application
  - 1024 inter-communicating subtasks connected in directed acyclic graph (DAG)
  - Two versions of each subtask: 100% and 10%
  - Estimated time to compute provided for each subtask/machine/version triplet
  - 100 ETC/DAG combinations
- Three Cases
  - A: 2 fast, 2 slow
  - B: 2 fast, 1 slow
  - C: 1 fast, 2 slow

Objective

- Maximize number of 100% subtasks completed (T_{100})
  - Within specified time, energy constraints
  - Must complete all subtasks
- Objective function

$$ObjFn(\alpha,\beta,\gamma) = \alpha\frac{T_{100}}{T} - \beta\frac{TEC}{TSE} - \gamma\frac{AET}{\tau}$$

TEC = Total Energy Consumed
TSE = Total System Energy
AET = Application Execution Time
α,β,γ = Lagrangian multipliers [0,1], $\alpha+\beta+\gamma=1$
τ = time constraint

Heuristics: Max-Max (static)

- Provide performance baseline
  - Static heuristic – not suited to dynamic environment
- Two step process
  - For each machine, pick subtask/version pair that maximizes ObjFn
  - From that set, select machine/subtask/version triplet that maximizes ObjFn
- No receding horizon
  - Considered all subtasks, entire mapping simultaneously
  - Selected triplet could be scheduled for any time provided adequate "hole" in existing schedule can be found

Heuristics: SLRH* (dynamic)

- At each time step
  - For each machine, if available…
    - Collect set of all subtasks U whose
      - Precedence constraints are met
      - Adequate energy to execute at least 10% version
      - Meet worst-case communications
    - Evaluate ObjFn for each subtask in U, both versions
    - Order U based on ObjFn
    - Find first subtask/version pair that can be scheduled to start within time horizon H – map it
  - Increment time by time step ΔT

*Simplified Lagrangian Receding Horizon

Two Additional Variants

- SLRH-2
  - Assign all subtask/version pairs until
    - All pairs assigned
    - No additional pairs can be started within time horizon
  - Unable to successfully map all subtasks – dropped
- SLRH-3
  - Re-create, re-evaluate U after each assignment
    - Catch new subtasks that meet precedence constraint
  - Continue assigning pairs until no additional pairs can be stated within time horizon

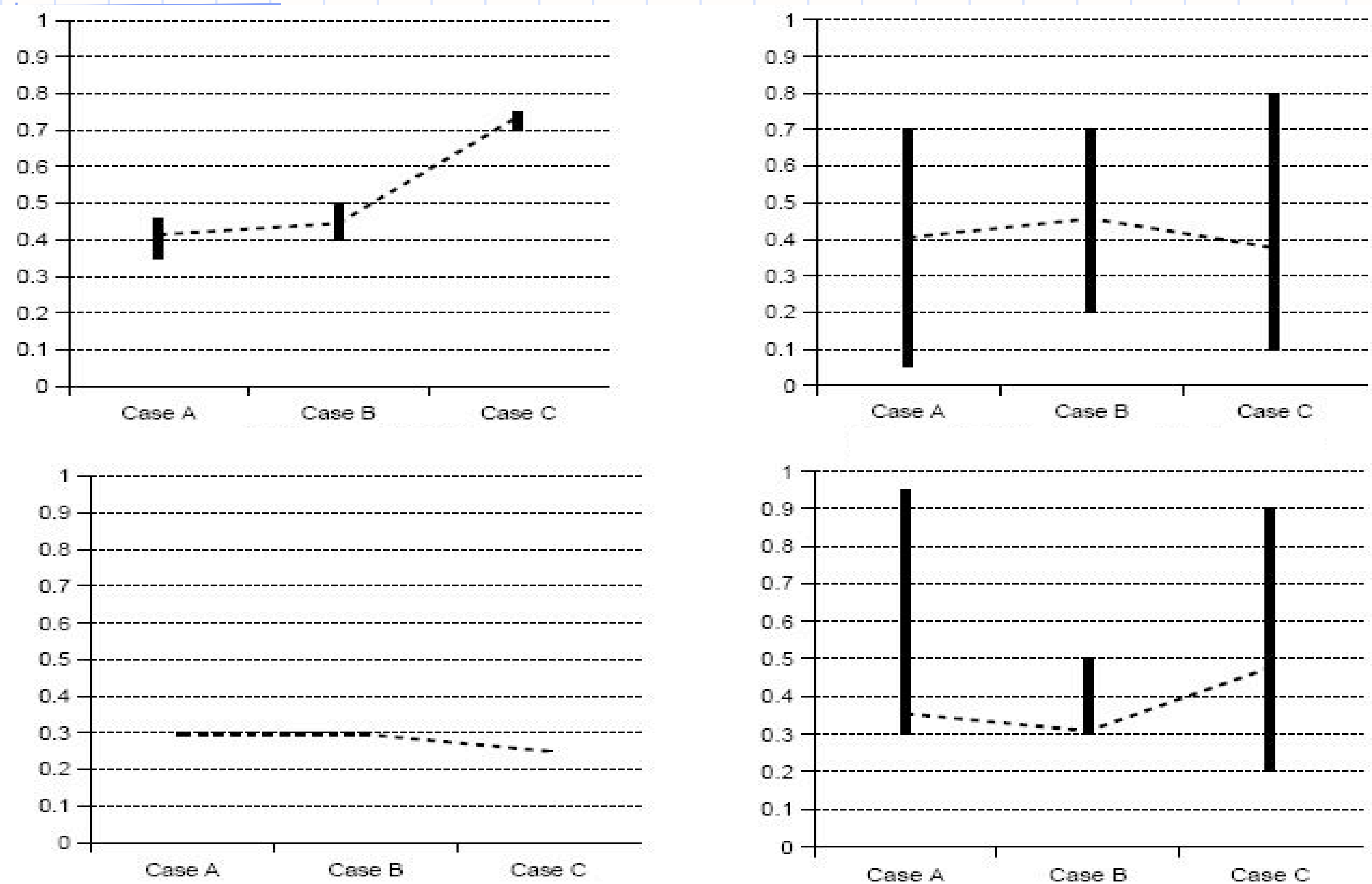
SLRH: Closer Look

- Simplified Lagrangian
  - No dynamic adjustment of α, β, γ
  - Acceptable for this experiment
- No guaranteed non-violation of constraints
  - Explicitly checked execution time constraint, energy constraint
- Setting ΔT & H
  - Experimentally determined
  - ΔT = 10 clock cycles
  - H = 100 clock cycles

ObjFn Parameters: α, β

α

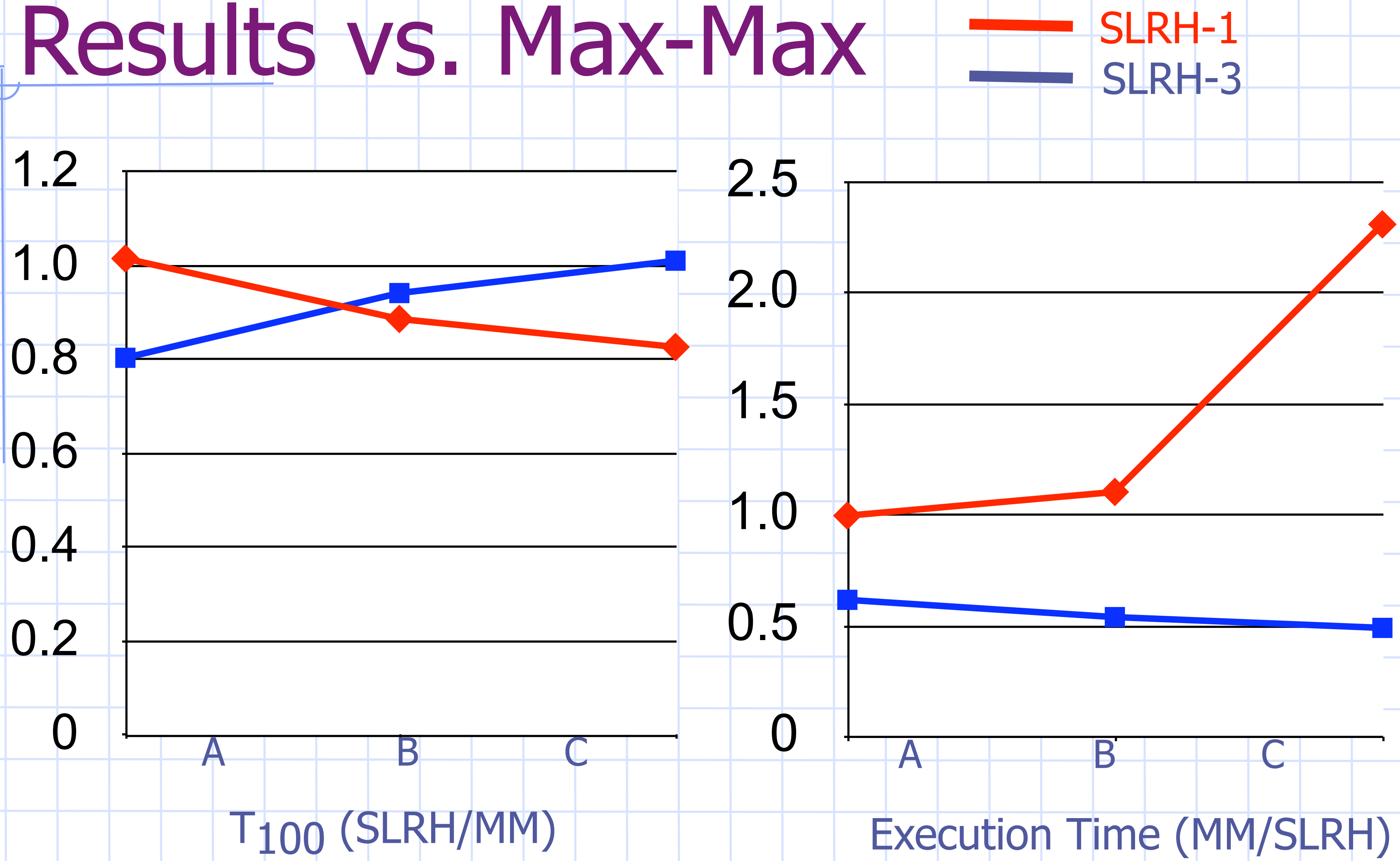
β



SLRH

Max-Max

Results vs. Max-Max



*Averaged over 100 ETC/DAG combinations

Summary

- SLRH performance
  - Comparable to static baseline
  - Appears relatively insensitive to characteristics of application
  - May require dynamic adjustment of the T_{100} Lagrangian multiplier to reflect changes in machine availability
- Speed needs improvement
  - Non-optimized scripting language used
  - Convert and optimize
- Questions