ExPERT: Pareto-efficient task replication on grids and a cloud

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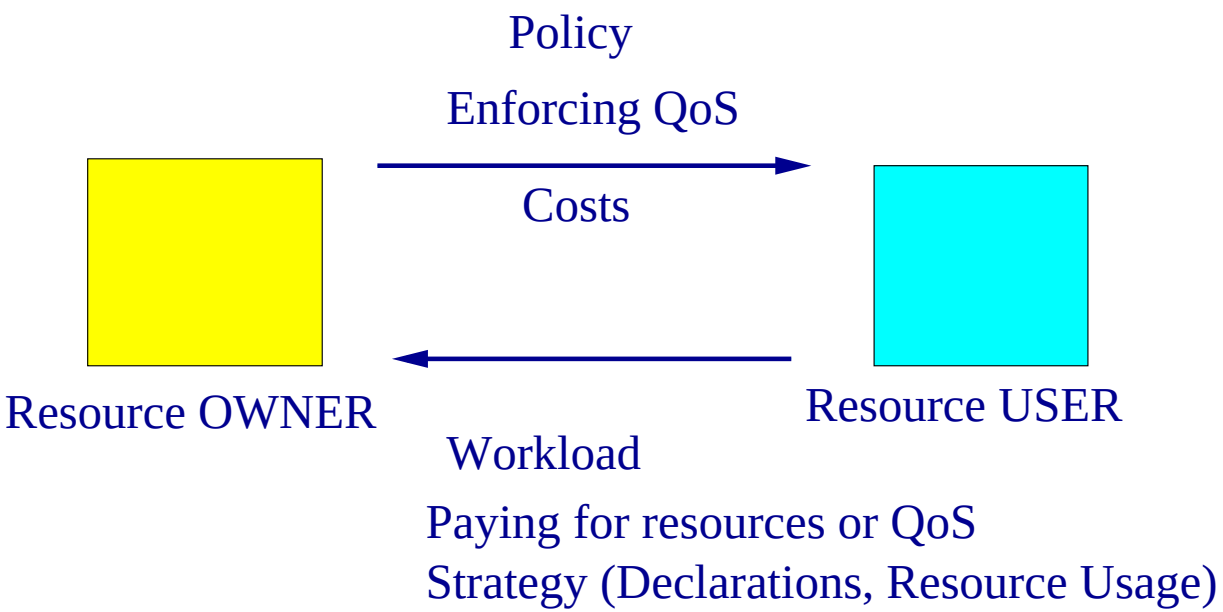
The Shared Resource Game — Players and Goals

Owner goals − minimize:
*Operational costs (energy)
*Effective load

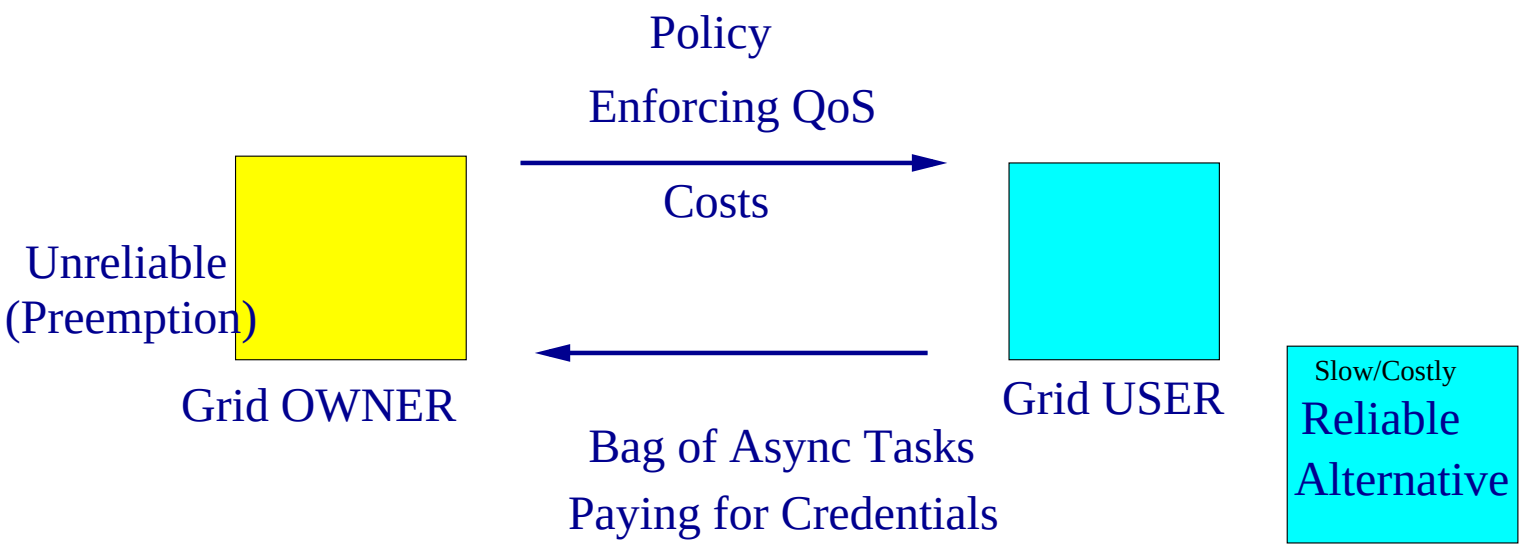
User goals − minimize:
*Makespan
*Cost



The Unreliable Shared Resource Game

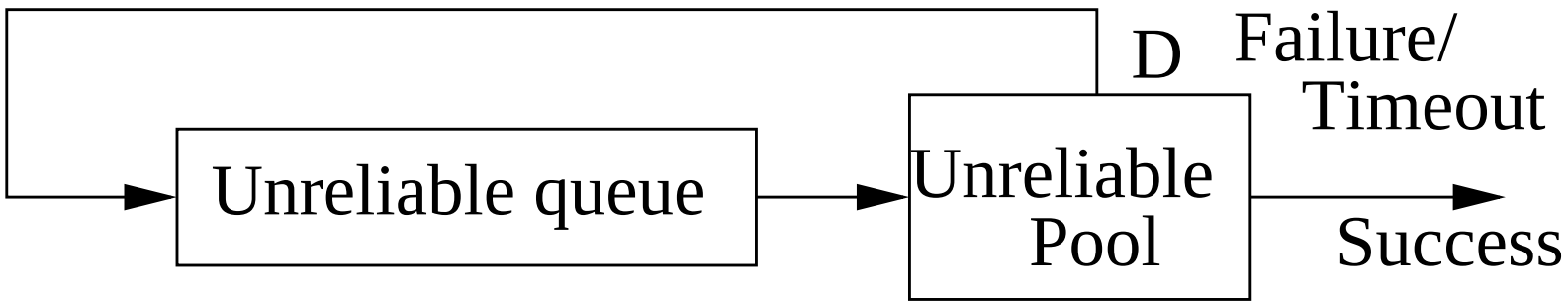
Owner goals − minimize:
*operational costs (energy)
*effective load

User goals − minimize:
*Makespan
*Cost



An environment of uncertainty: Will the task fail on the unreliable resource? Which system to use?

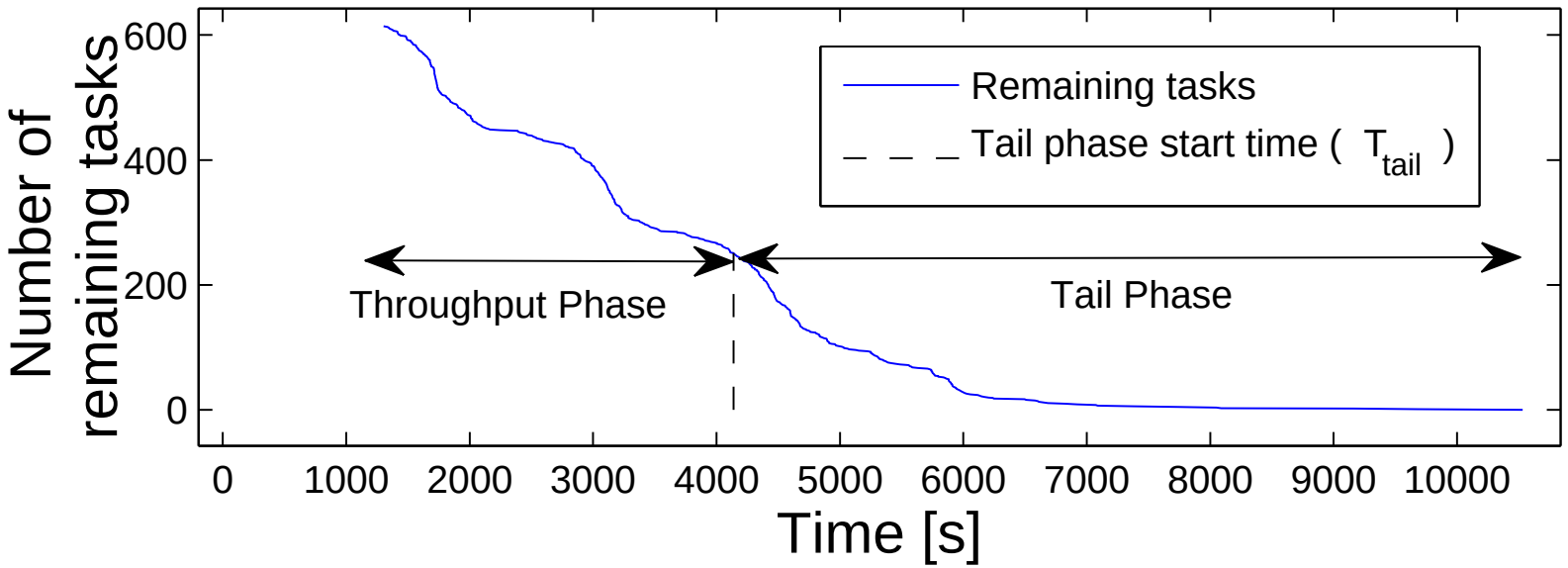
In the Beginning...



- #machines $<$ #unfinished tasks.
- *D* - instance deadline.
- No replication (replication is inefficient).

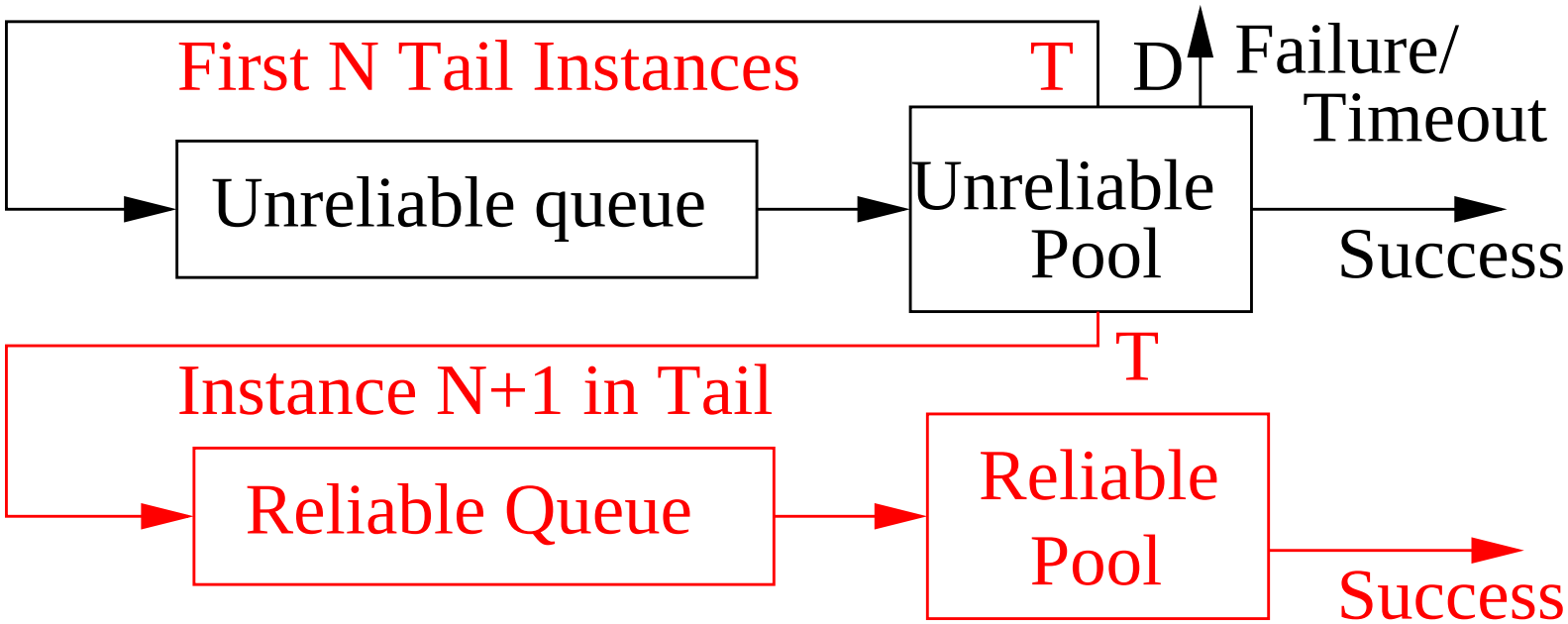
Using the Same Strategy After the Tail Starts

#machines > #unfinished tasks



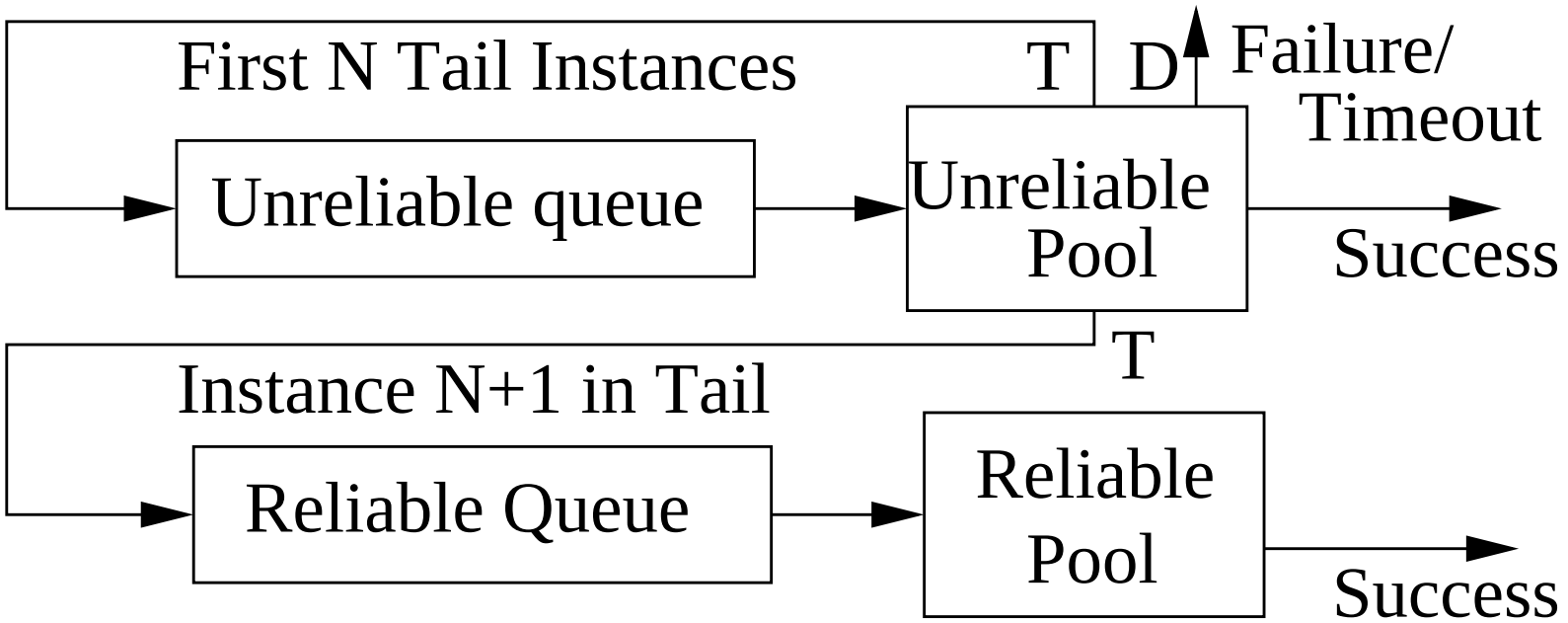
The tail is wagging the dog...

Replication - the User's Bank of $NTDM_r$ Strategies



- D - instance deadline, T - replication time
- Reliable machine used to ensure task completion
- N tail instances at most on unreliable resources
- M_r - max ratio of reliable to unreliable resources

Replication - the User's Bank of $NTDM_r$ Strategies



- D - instance deadline, T - replication time
- Reliable machine used to ensure task completion
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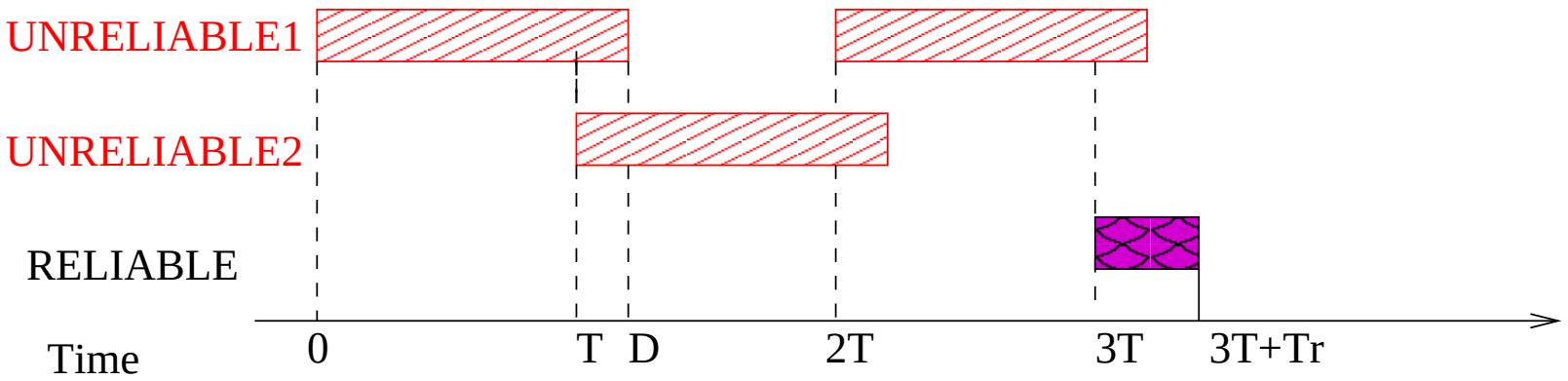
Replication - the User's Bank of $NTDM_r$ Strategies

- Example: Number of unreliable instances $N = 3$



- Replication wastes work!

The User's Problem: Optimization of...

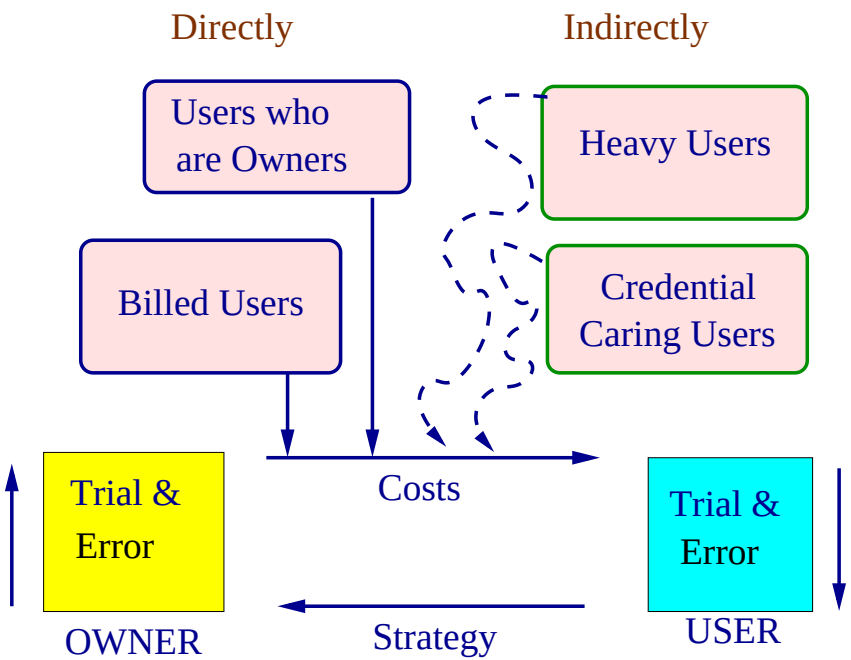
The user cares about multi-objective optimization:

- $\langle Cost \rangle$ - Mean $\frac{cost}{task}$ or $\frac{tail-cost}{tail-task}$
- $\langle MS \rangle$ - Mean makespan or tail makespan.

Each user may have her own objective, pending on those values:

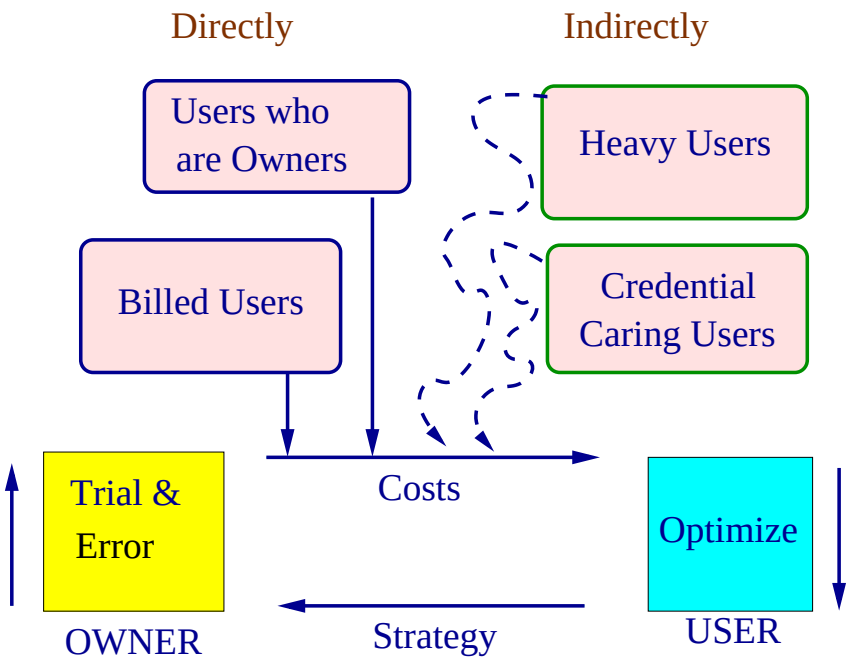
- Below minimal makespan: $\langle MS \rangle < Const$
- As fast as possible: $\min \langle MS \rangle$
- Below max budget: $\langle Cost \rangle < Const$
- As cheap as possible: $\min \langle Cost \rangle$
- Best price for the goods: $\min \langle Cost \rangle \langle MS \rangle$
- Any other function of means: $\langle Cost \rangle$, $\langle MS \rangle \ldots$

The Feedback Loop



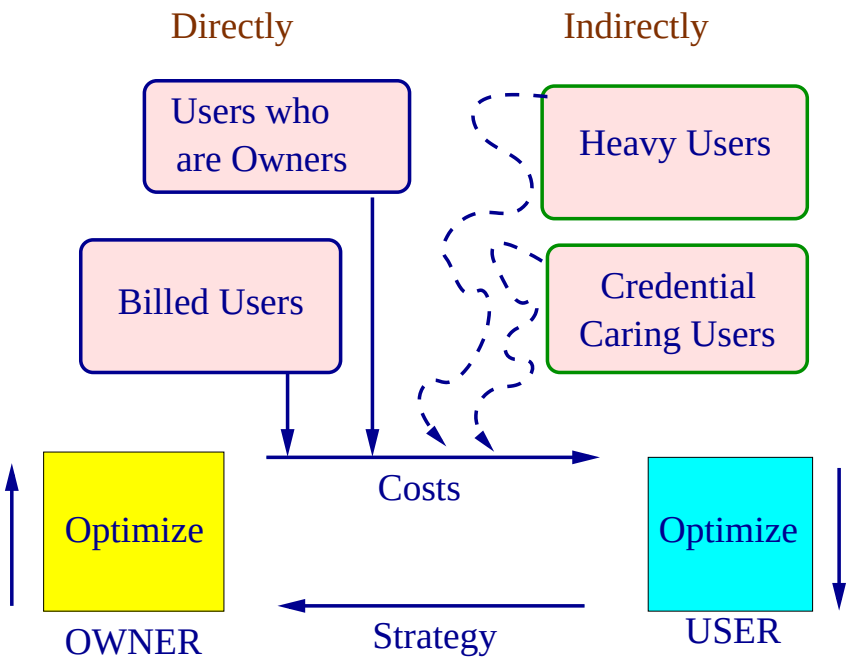
Users who do not optimize well behave irrationally and are hard to predict.

The Feedback Loop — Our Contribution



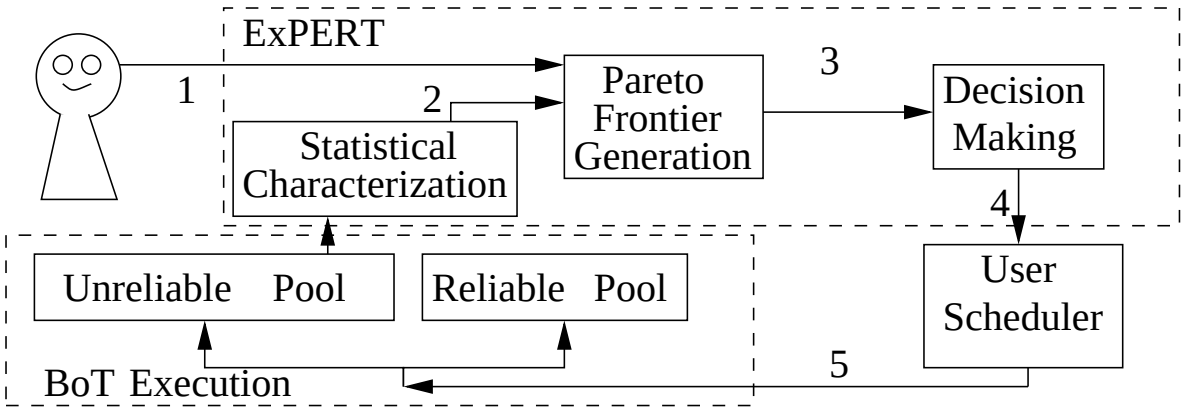
Rational users can optimize general utility function.

The Feedback Loop - Lookout



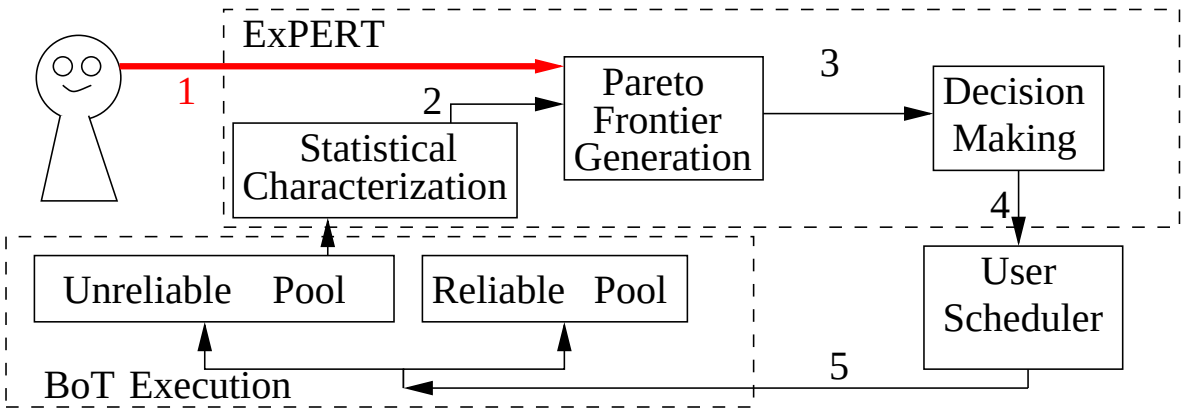
Towards the final goal of manipulating users to save energy

Solution Concept



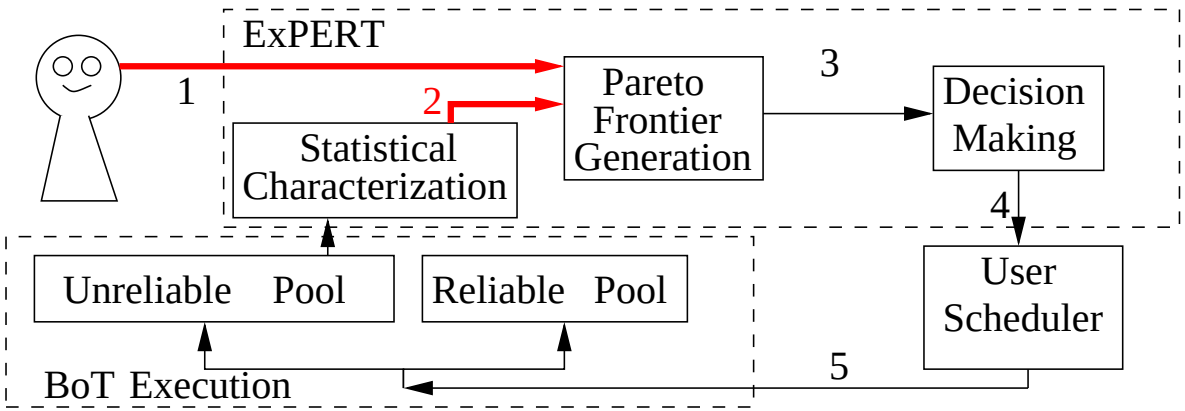
Solution Concept - Step 1

Get user additional data (costs, reliable pool times).



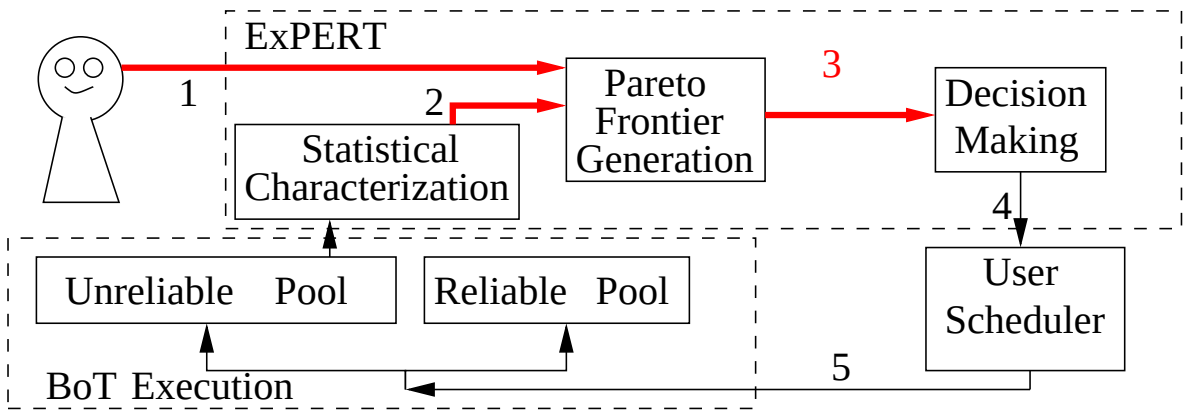
Solution Concept - Step 2

Get unreliable resource statistics (trace analysis).



Solution Concept - Step 3

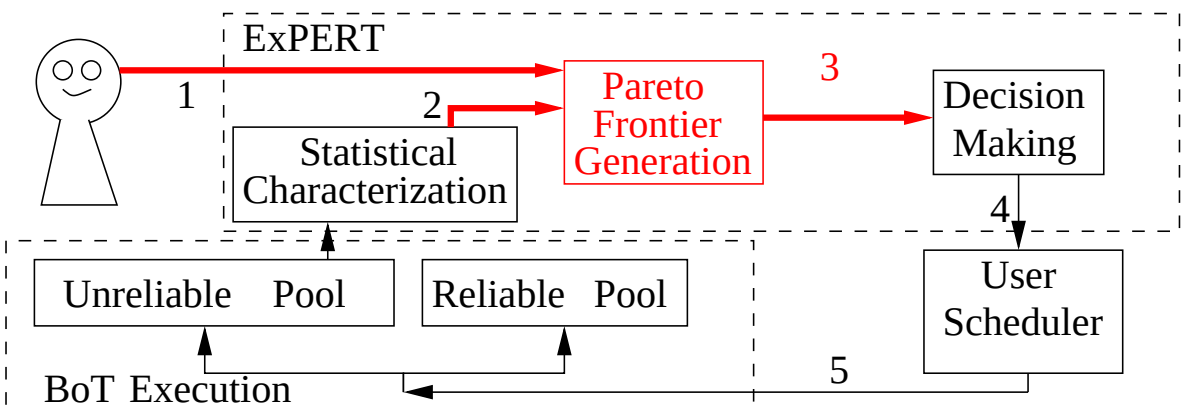
Compute a Pareto frontier for $\langle Cost \rangle, \langle MS \rangle$.



Solution Concept - Step 3

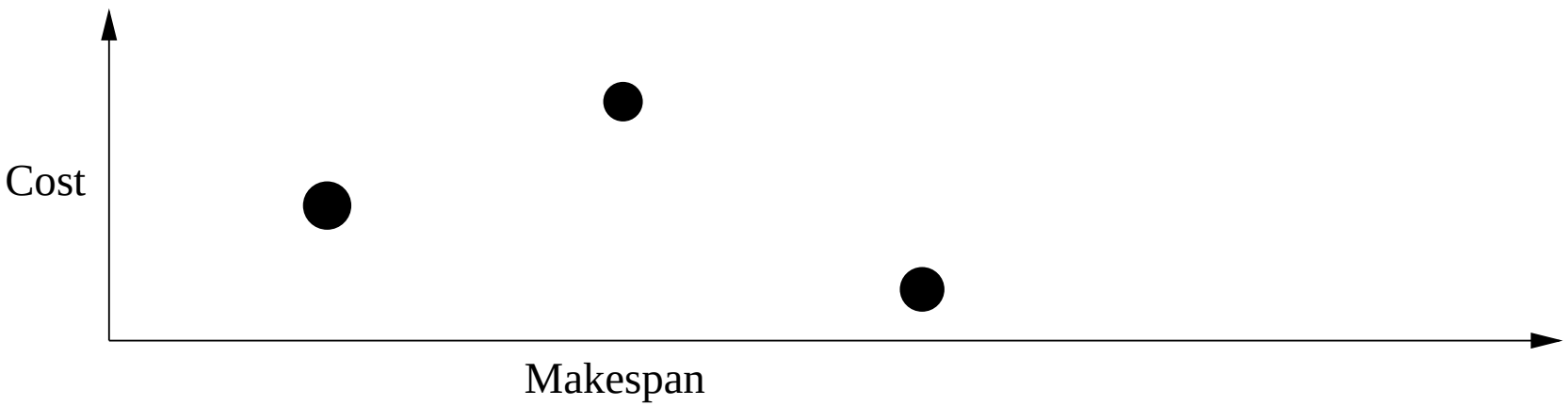
Estimate $\langle Cost \rangle, \langle MS \rangle$ for each strategy in the search space:

- For every working point, the *ExPERT Estimator* computes several random realizations on the basis of the statistic characterization.
- The average maksespan and cost over these realizations are used as the expectation values $\langle Cost \rangle, \langle MS \rangle$.



Solution Concept - Step 3

- Estimate $\langle Cost \rangle, \langle MS \rangle$ for each strategy in the search space.
- Filter out dominated strategies.
- Keep frontier composed of non-dominated strategies.



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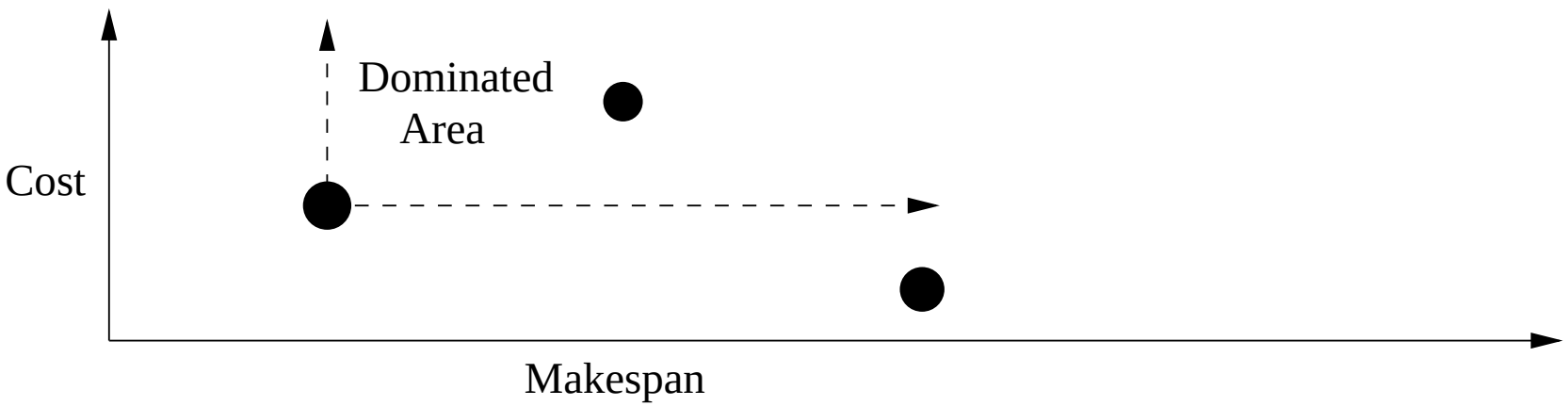

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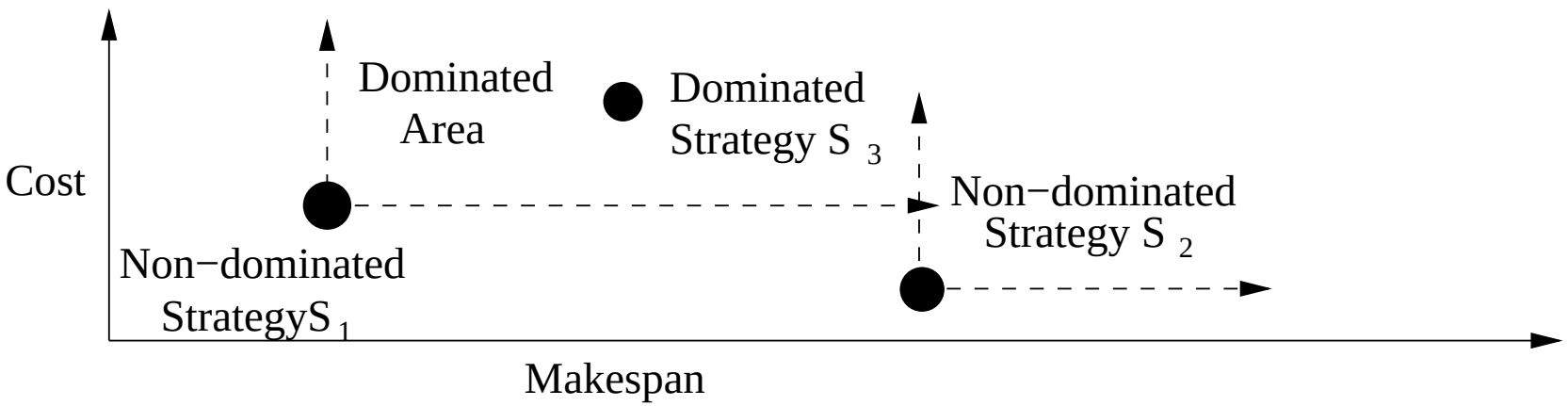

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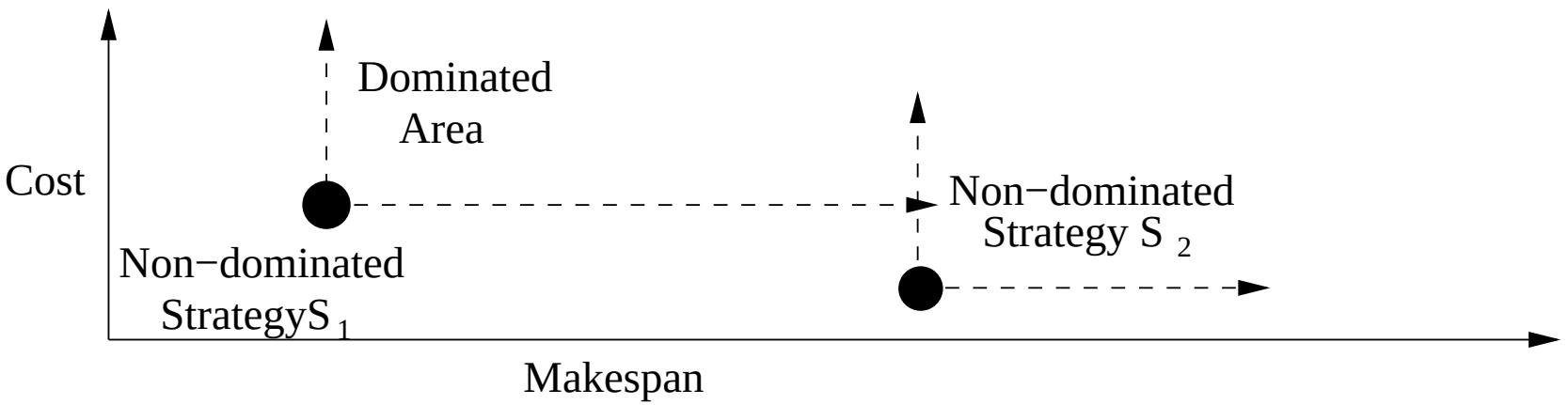

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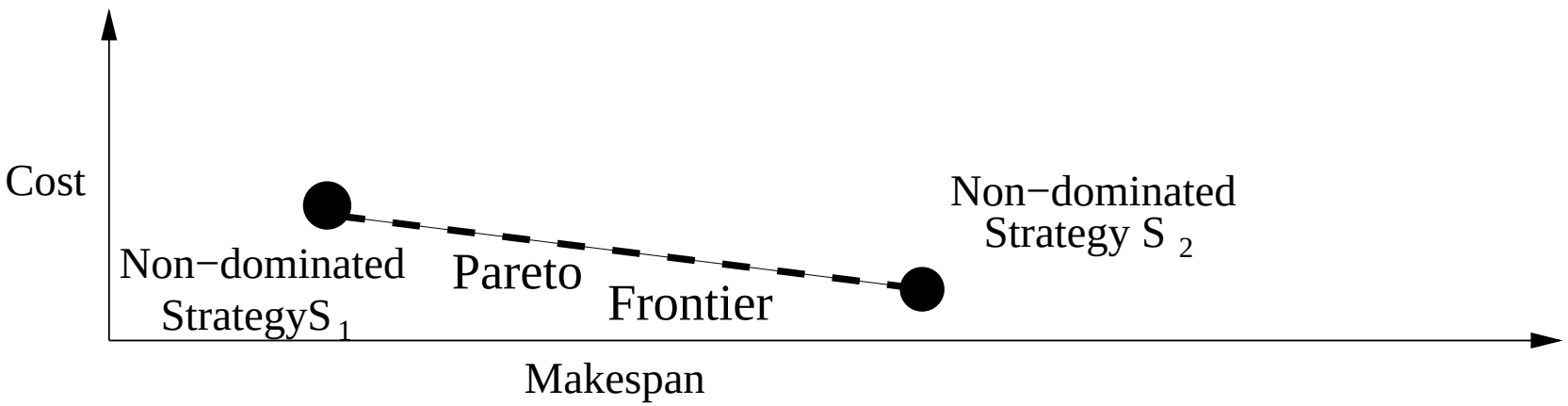
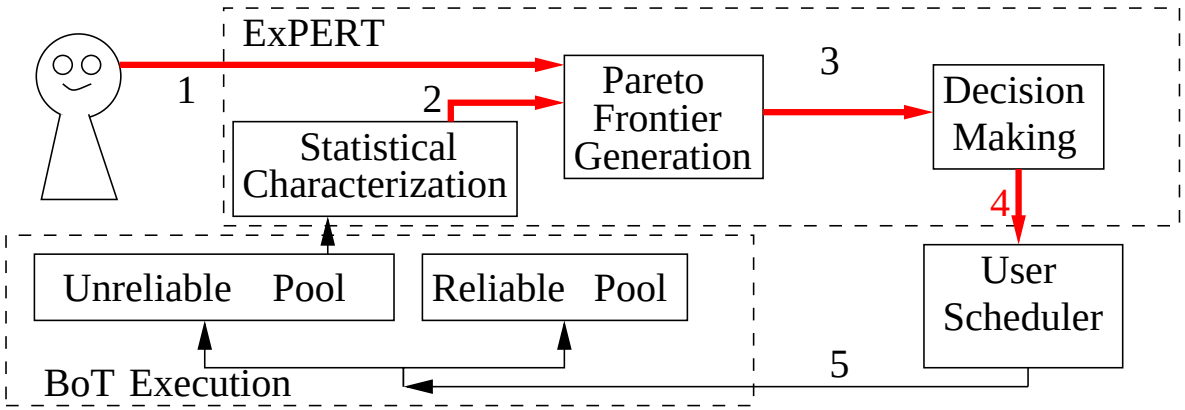


Solution Concept - Step 4

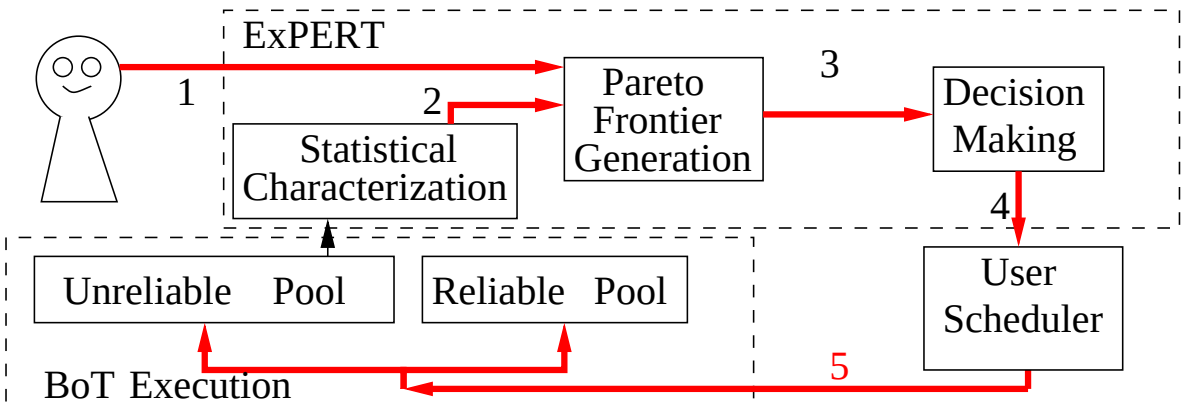
Choose optimal strategy according to user utility (by **expectation value**).



Get N, T, D, M_r params for the desired strategy.

Solution Concept - Step 5

Apply strategy: Feed N, T, D, M_r params as input to the user scheduler and deploy tasks on the resource pools.



Example - Based on a GridBoT Trace on UW-M

GridBoT:

- Supplies a unified front-end to multiple grids and clouds using their local resource management infrastructure.
- Employs dynamic run-time scheduling and replication strategies to execute BoTs in multiple environments simultaneously.

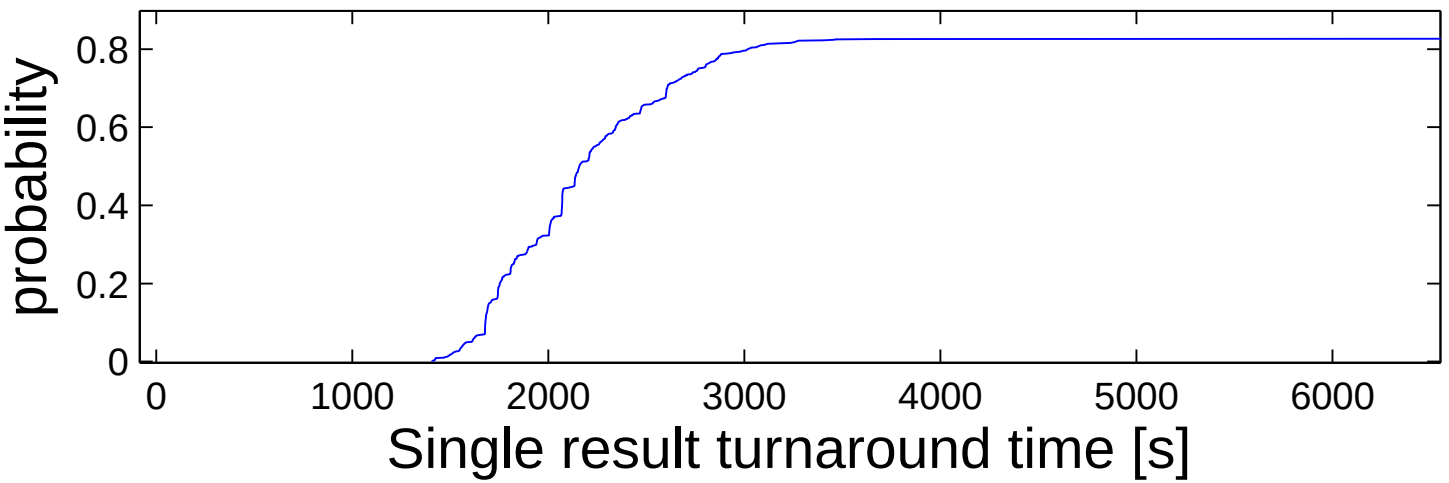
A BoT trace holds a line per task with the following fields:

- Status (failed/succeeded)
- Runtime : only for successful tasks.
- Wait time : from submitting to starting running. May be unavailable for failed tasks.

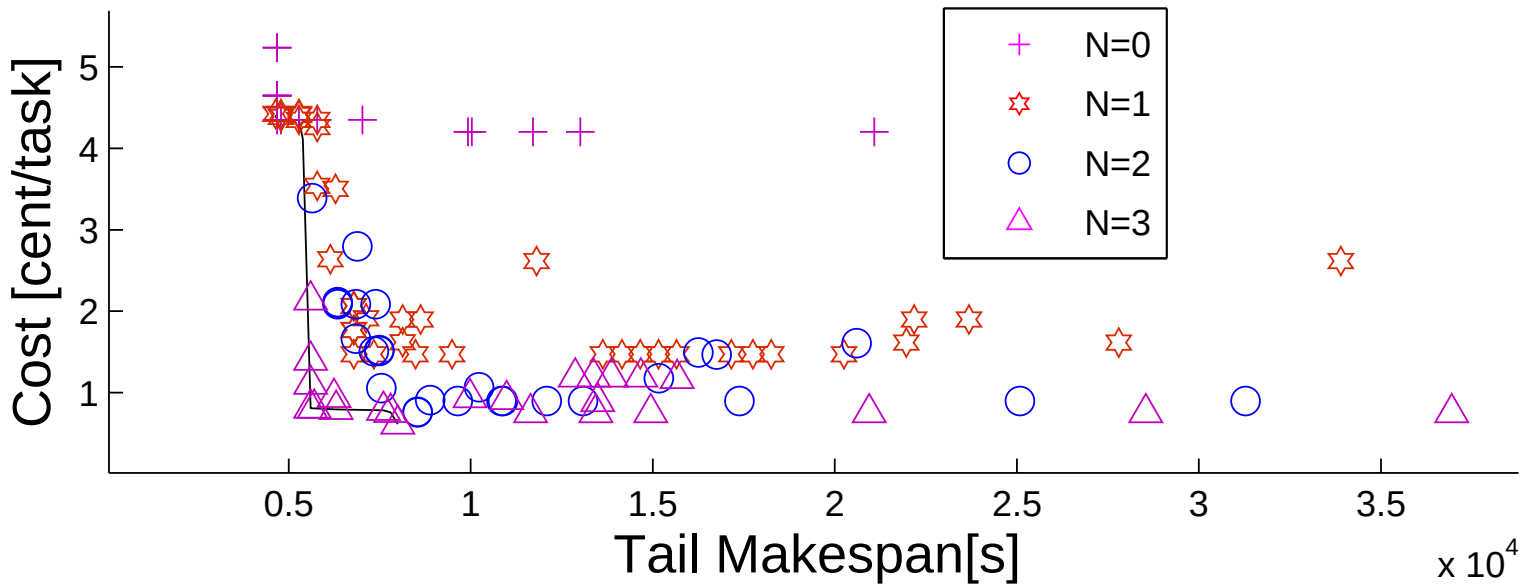
Result time= Runtime+Wait time
UW-M: Condor cluster of University of Wisconsin-Madison.

Characterize the Unreliable Resource

- $\sharp ur$: the *effective* size of the unreliable pool.
- $F(t, t') = reliability(t') \cdot F_s(t)$, CDF of result turnaround time, on the basis of:
  - $F_s(t)$: the measured CDF of result turnaround time (t)of *successful* tasks.
  - $reliability(t')$: the fraction of successful tasks as a function of the time since the BoT started t'.

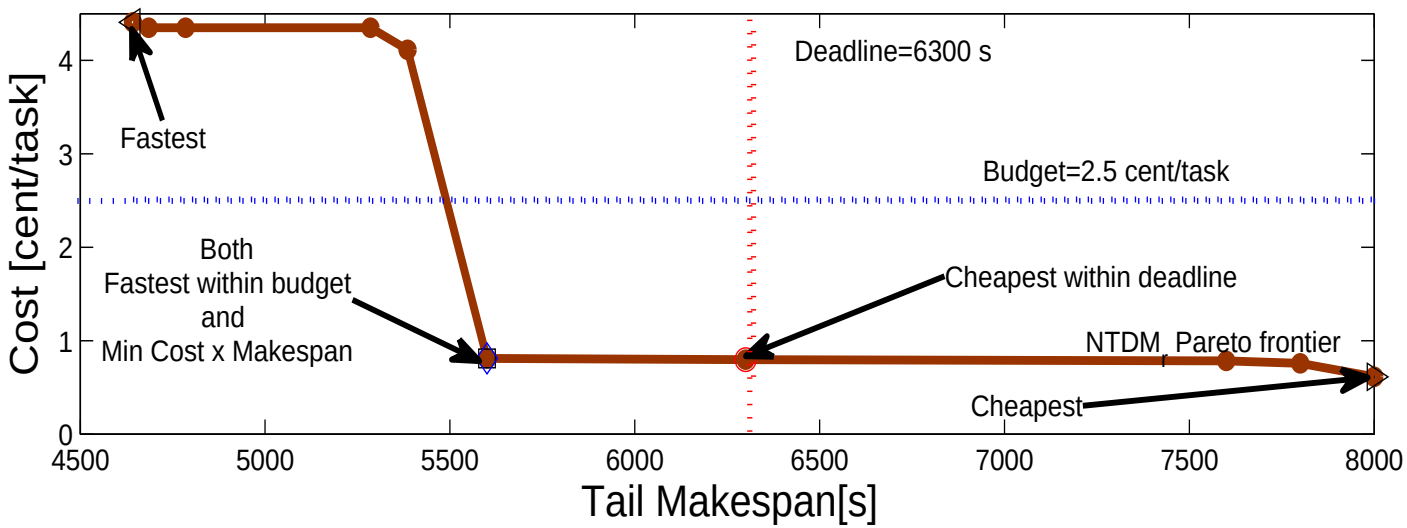


Pareto Frontier and Working Points



- Local optimization is not trivial.
- Unoptimized strategies are wasteful.

Optimizing a General User Utility Function along the Pareto Frontier

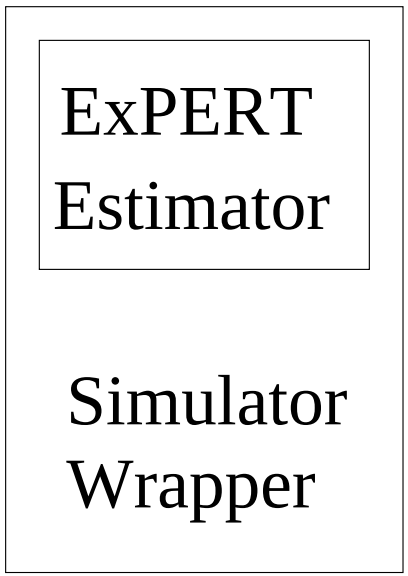


Utility function choice can be postponed till the user is aware of the cost-makespan tradeoff.
It does not have to be expressed.

Validation and Evaluation

ExPERT Estimator

Validation and Evaluation



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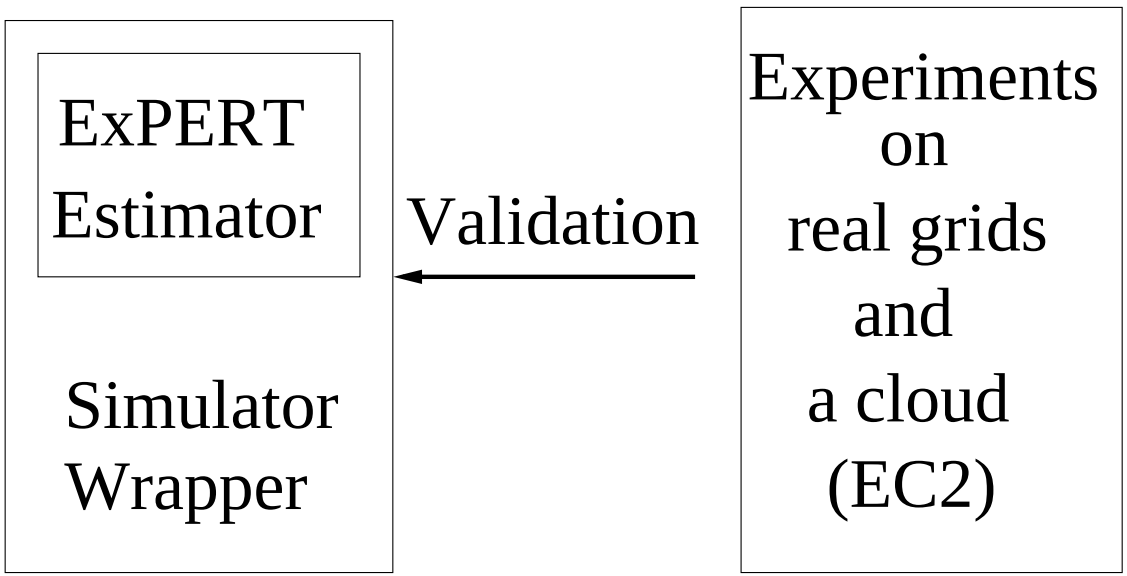

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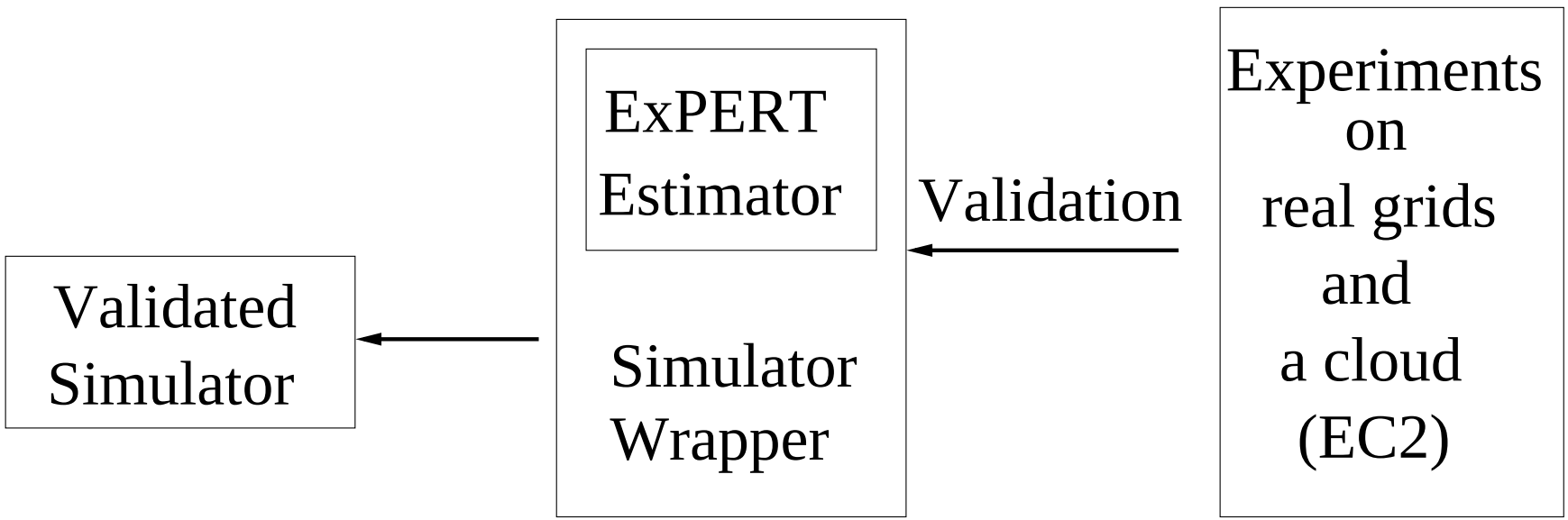

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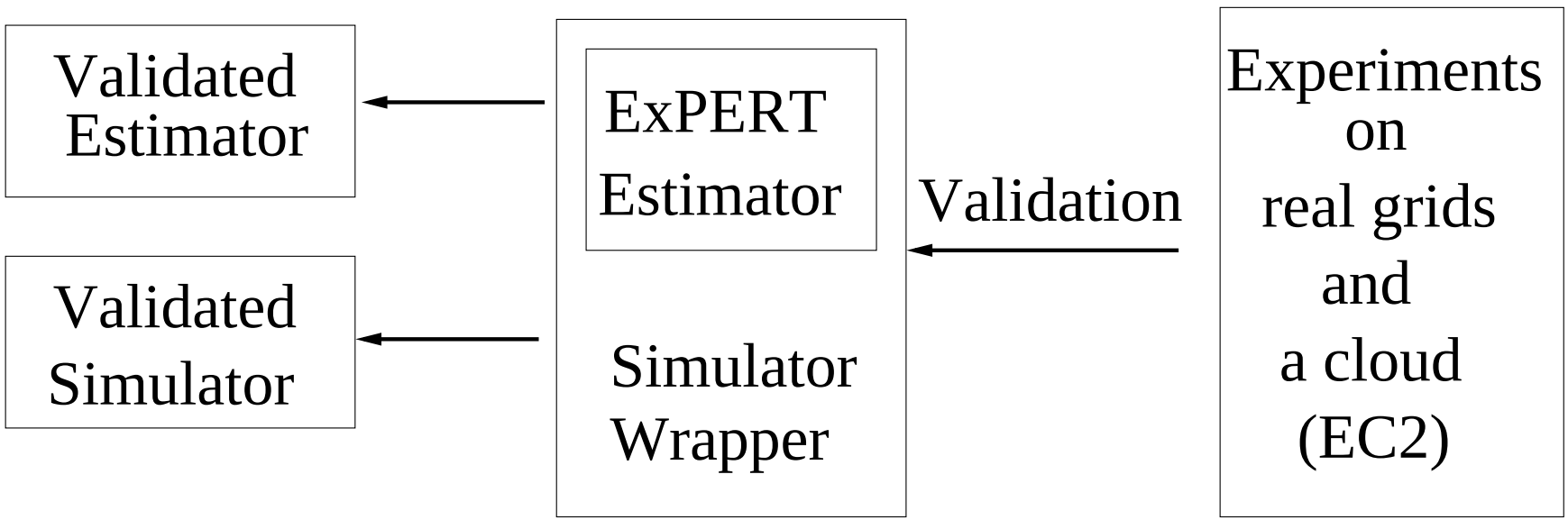

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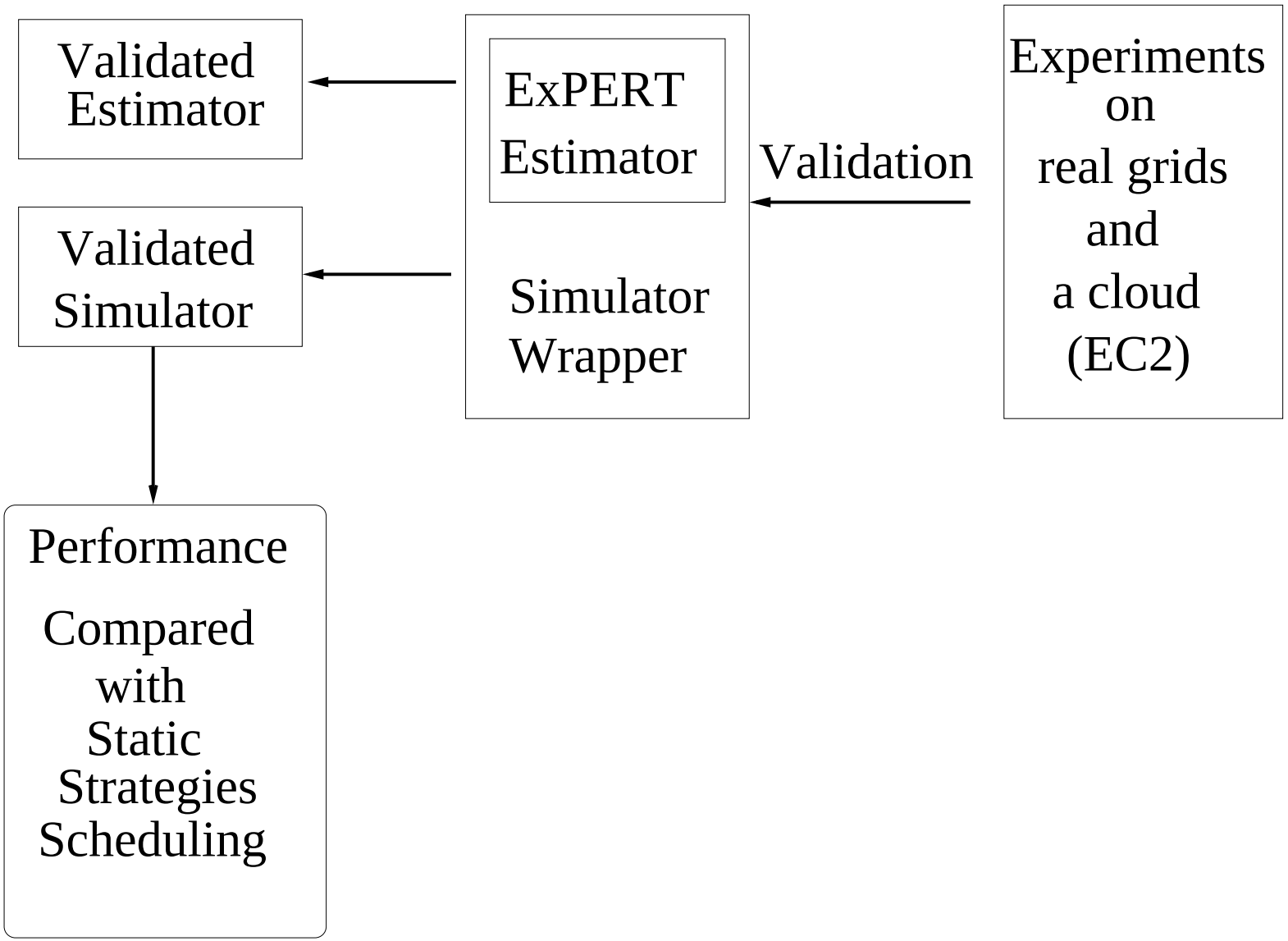

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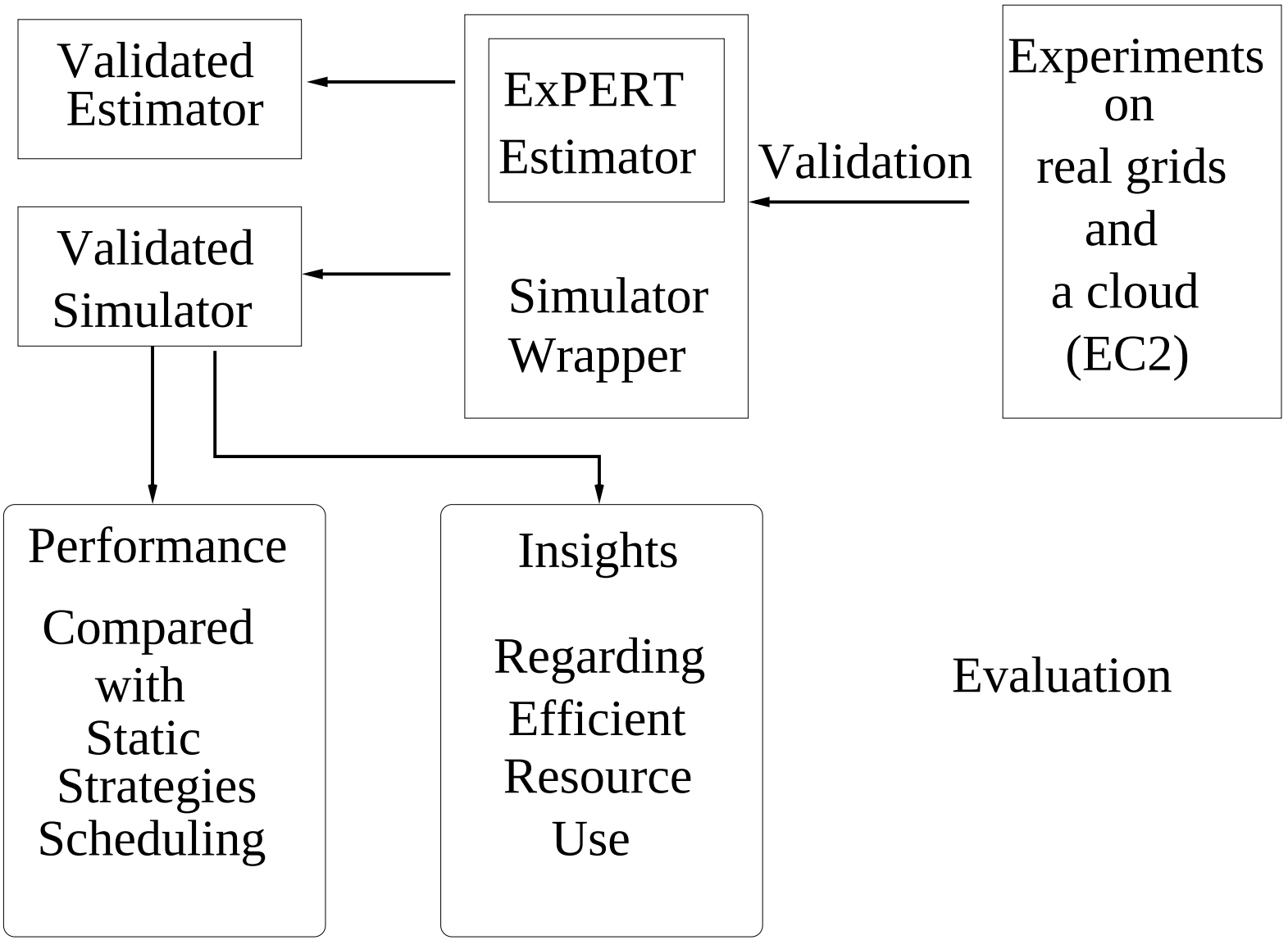
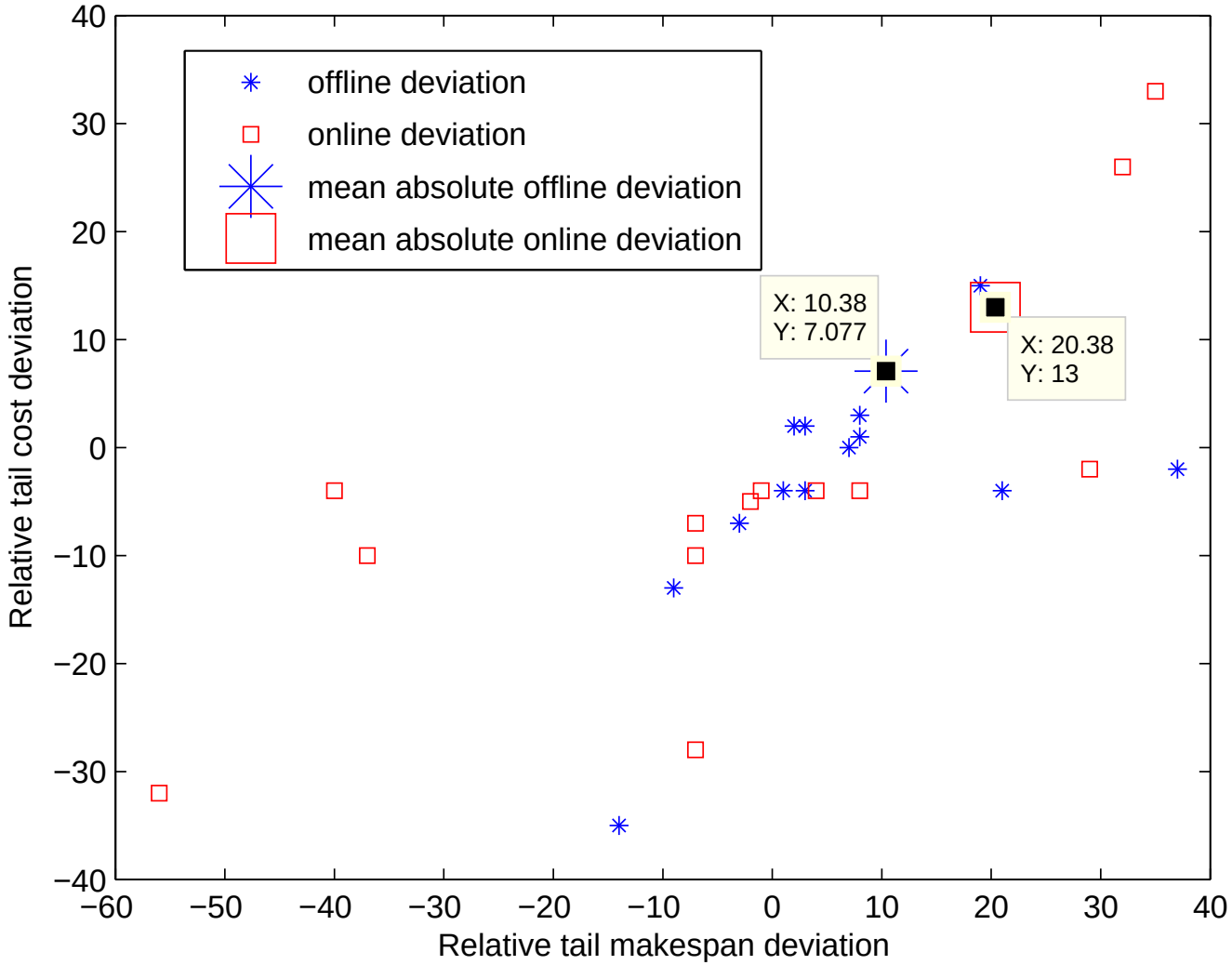


Resource Pools

Table: Resource Pools

Reliable Pool	Properties
Technion	20 self-owned CPUs in the Technion.
EC2	20 large EC2 cloud instances.
Unreliable Pool	**Properties**
UW-M	UW-Madison Condor pool (preempts).
OSG	Open Science Grid (no preemption).
UW-M + OSG	Combined: half $\sharp ur$ from each pool.
UW-M + EC2	Combined: 200 UW-M, 20 EC2.
UW-M + Technion	Combined: 200 UW-M, 20 Technion.

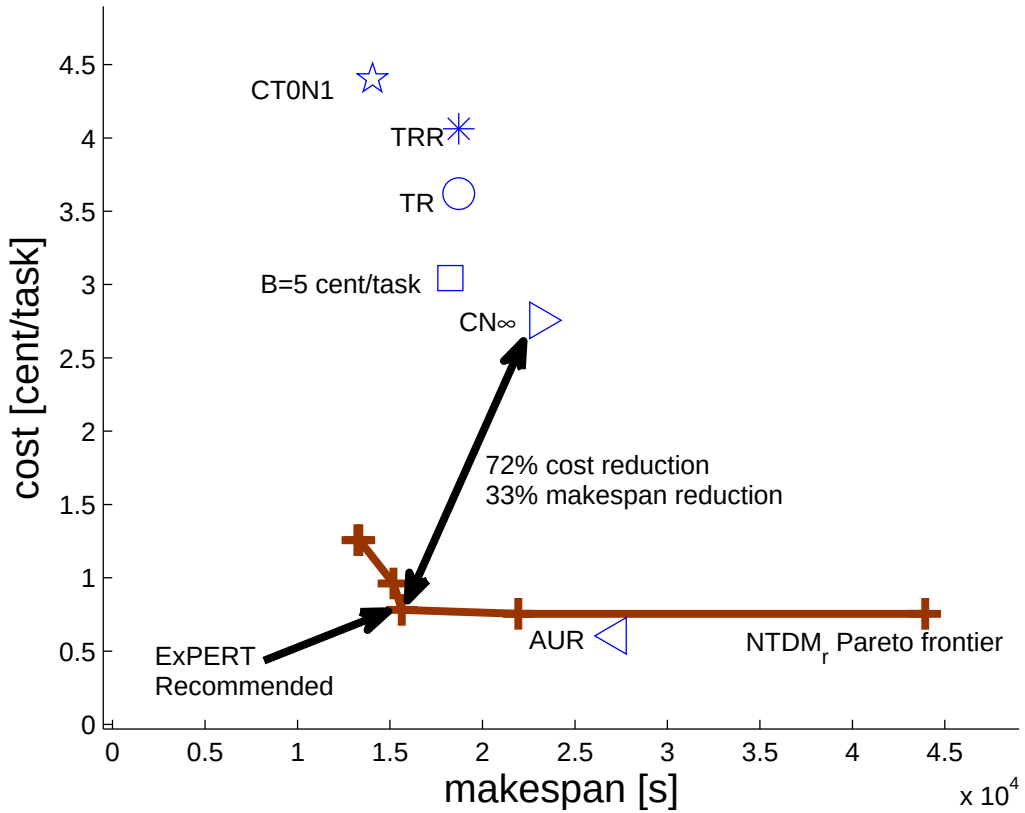
Validation: Prediction Deviation



Augmenting the Estimator with Static Strategies

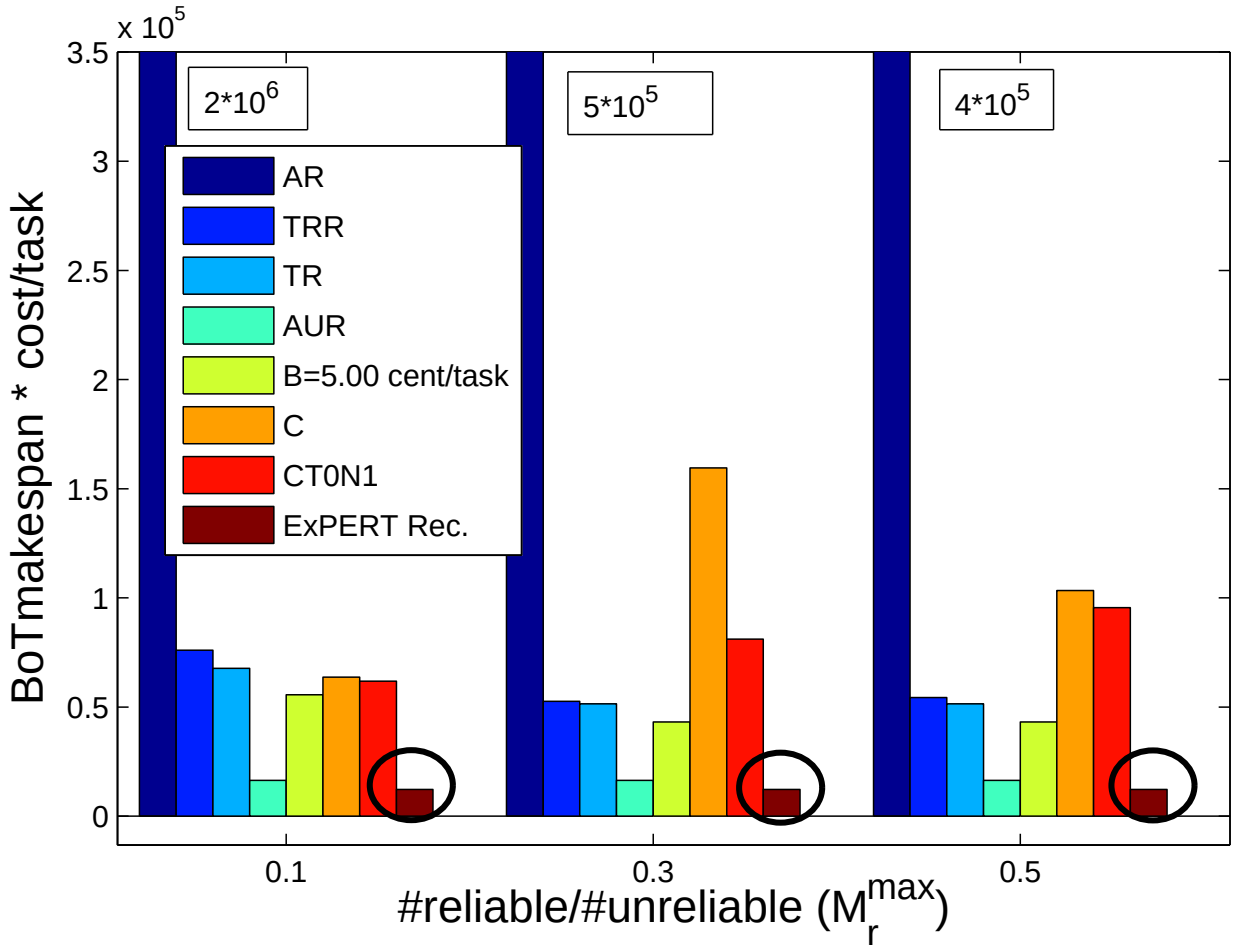
1. *AR: All to Reliable*
2. *TRR: all Tail Replicated to Reliable* (N=0,T=0)
3. *TR: all Tail to Reliable* ($N = 0, T = D$)
4. *AUR: All to UnReliable, no replication*
5. *B: Budget of 1$ for a BoT of 150 tasks (on average,* $\frac{2}{3}\frac{cent}{BoTtask}$*)*
6. *CN∞: Combine resources, no replication*
7. *CT0N1: Combine resources, replicate at tail with* $N = 1$, $T = 0$

Bi-Objective Performance, $M_r^{max} = 0.1$



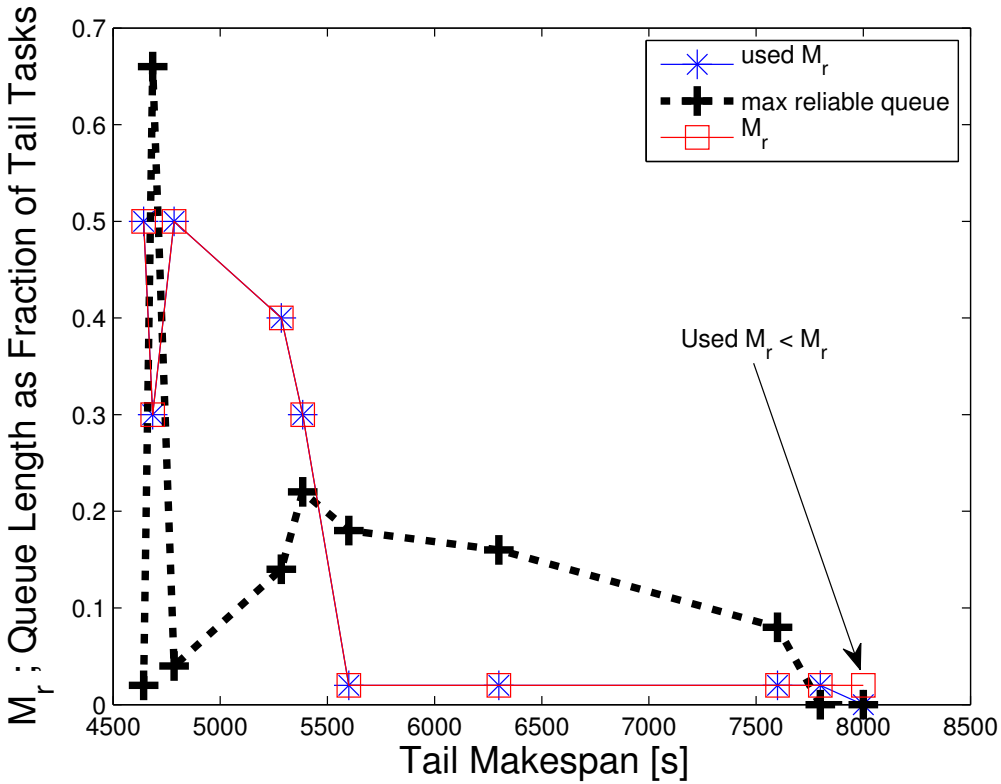
ExPert's Pareto frontier dominates most static strategies.

Performance: makespan $\times$ cost, 3 M_r^{max} values



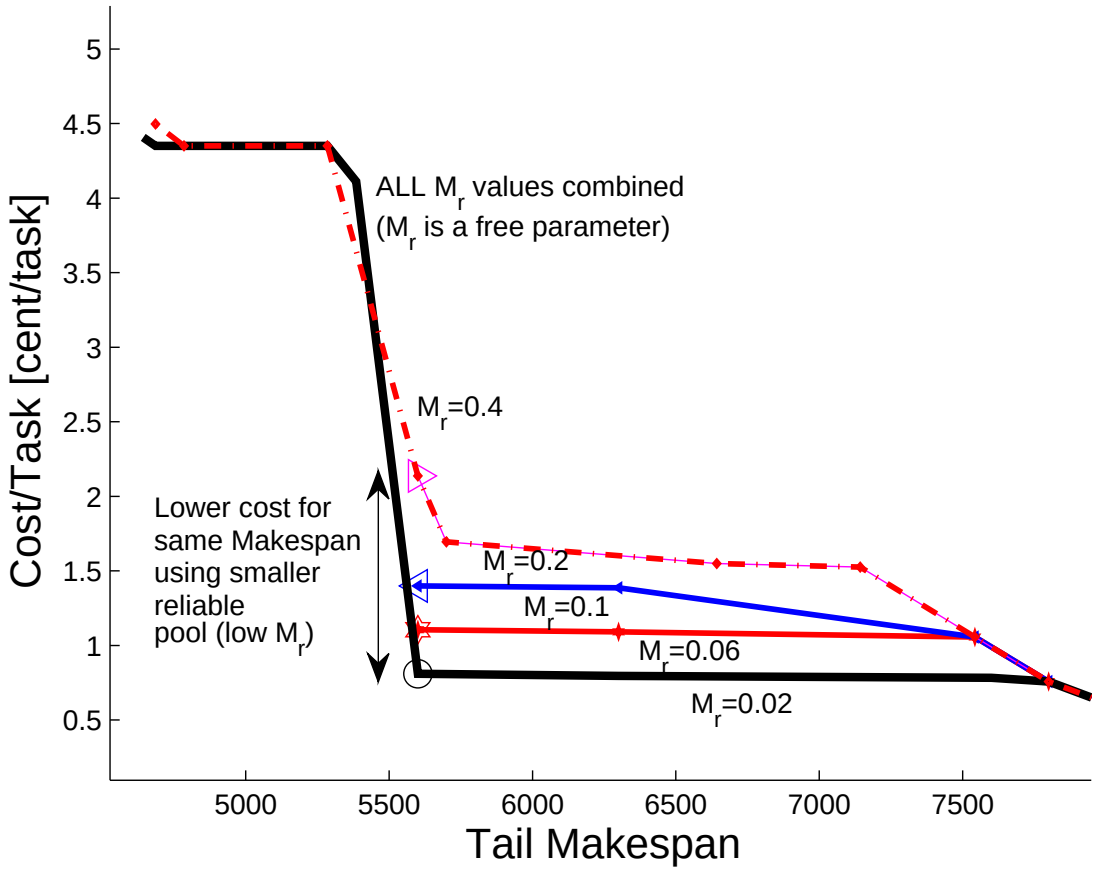
Smaller is better. Cost $\times$ makespan ExPert's recommended strategy is 25% lower than second-best and at least 72% lower than third -best.

Insight: Efficient Reliable Resource Use Includes a Queue



On the Pareto frontier, usually all reliable resources are used at some point, and a significant queue is built for them.

Insight: the Importance of M_r as a Free Parameter



The free parameter M_r enables efficient strategies with lower costs for the same makespan. It makes tasks wait in a queue, where they may be canceled.

Conclusion

- The NTM_r strategy space is vast enough to provide user preference flexibility.
- ExPERT-recommended strategies finish in two-thirds of the time and cost a quarter of commonly used static strategies.
- Using ExPERT means you do not waste time or money, and you optimize your own utility function.

Questions?

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Thank You!

夫人杉木