When Watts Meet Bits:
The Power -Computing Collaborative Scheduling

Team # IMMC25931815
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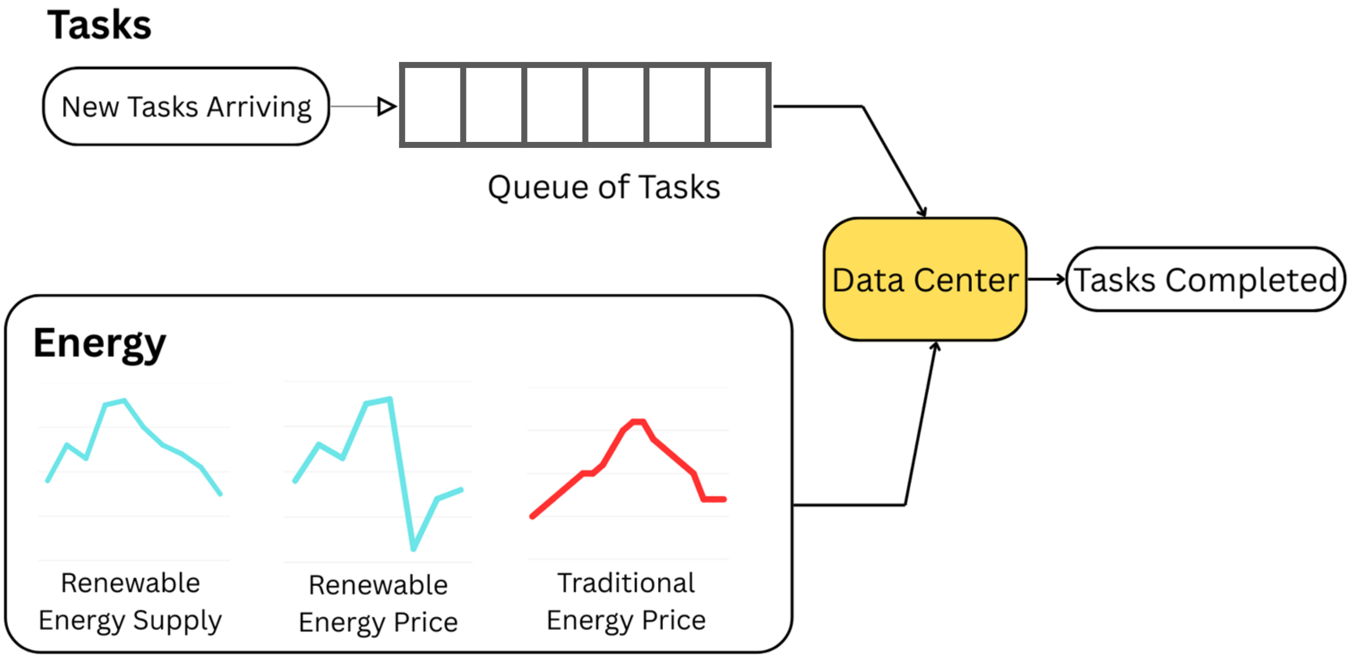
Background and Motivations

How does our data center operate?



Problem Formulation

Objectives	Constraints
Minimizing total **energy cost** Maximizing usage of **renewable energy**	- causality constraint - deadline constraint - server capacity constraint - renewable energy supply constraint

Offline Optimal Model

Offline Greedy Model

Online Greedy Model

Offline Optimal Model

- Knows **all future data** (e.g. task arrivals, renewable generation, price, etc.)
- Schedules tasks in the most efficient way possible, with **integer linear programming**

$$\text{Min} \quad \sum_{t=1}^{24} [c(t) - \lambda\, e_r(t)]$$

Subject to the previously mentioned constraints:

causality constraint
deadline constraint
server capacity constraint
renewable energy supply constraint

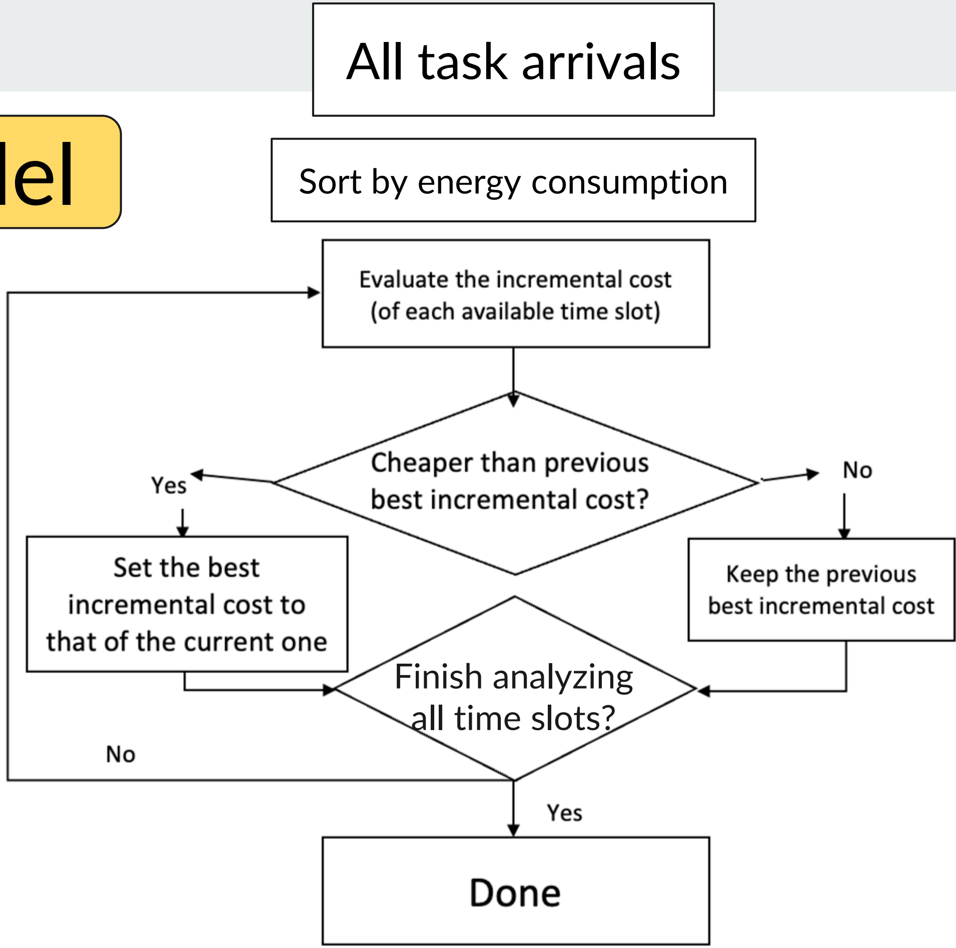
*$c(t)$ = the cost of energy in the t^{th} hour (in $)
$e_r(t)$ = the usage of renewable energy in the t^{th} hour (in kWh)
λ is the weighting factor, which will decide the priority of the objectives

Offline Greedy Model

The offline greedy algorithm:

- Knows **all future data**
  (e.g. task arrivals, renewable generation, energy price, etc.)

- Greedily assigns tasks with the largest **energy consumption** first
- Prioritizes **deadline** if tasks require the same energy consumption



Offline heuristics is **easier to implement** than the optimal model.

Online Greedy Model

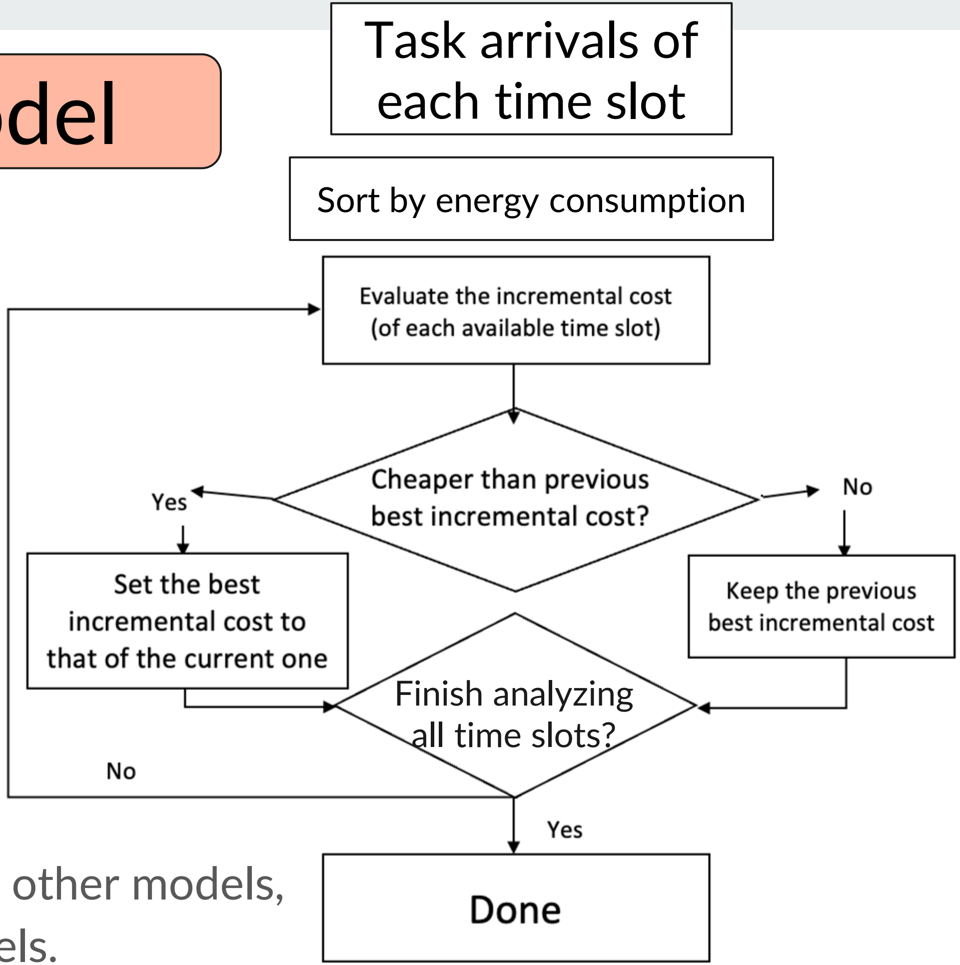
Key difference from offline greedy:

- Does **NOT know future** task arrivals, renewable generation, ...

However, they both:

- Greedily assigns tasks with the largest **energy consumption** first
- Prioritizes **deadline** if tasks require the same energy consumption

Online greedy algorithm is more **flexible** than other models, but it makes worse decisions than other models.



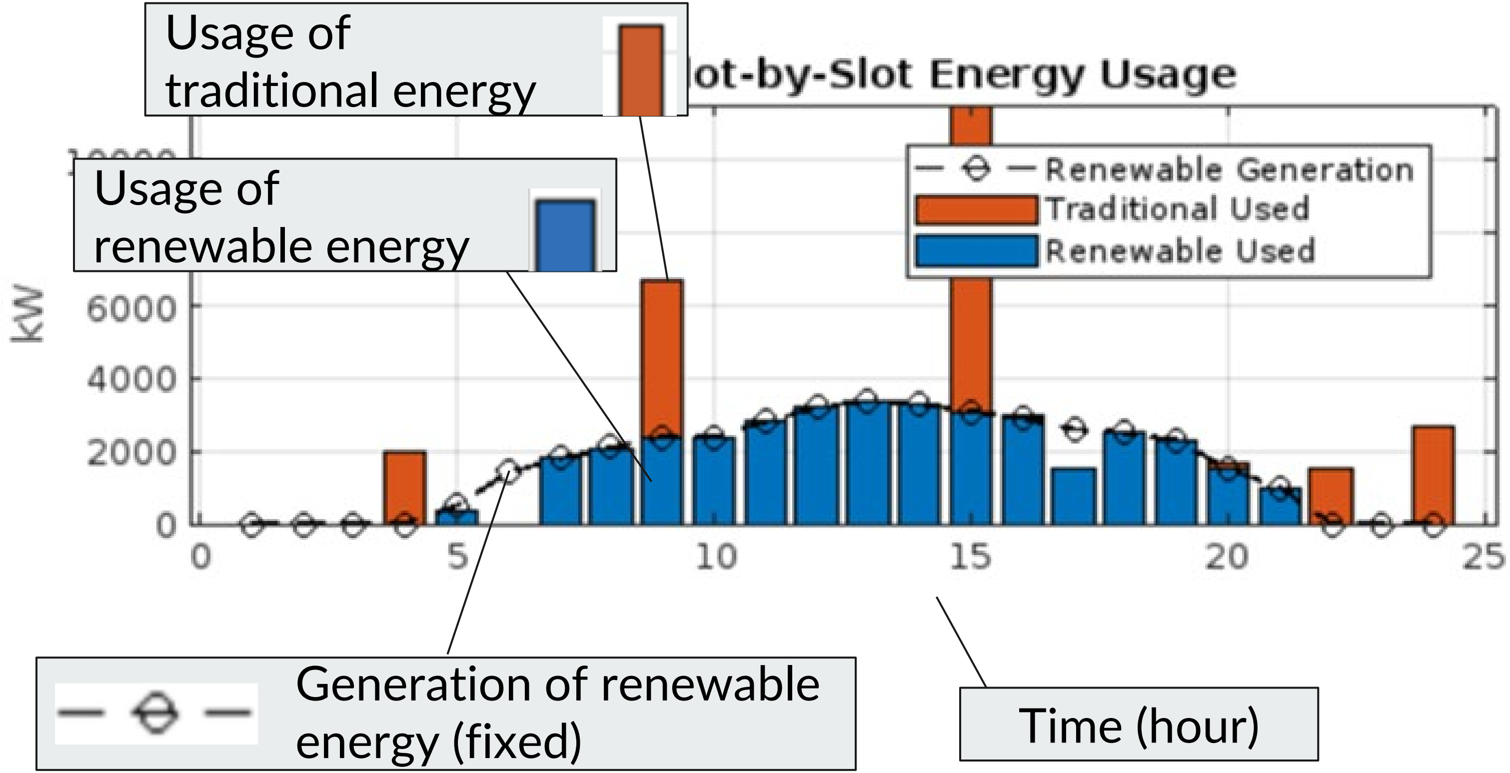
Numerical Experiments

Optimal Scheduler and *Conventional Scheduler*

Optimal, Offline Greedy, and Online Greedy Schedulers

Optimal, Offline Greedy, and Online Greedy Schedulers (With Computational Limits)

How to interpret our graphs?



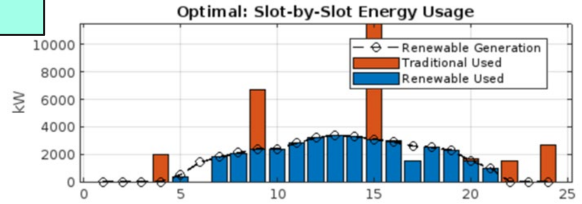
Optimal Scheduler and Conventional Scheduler

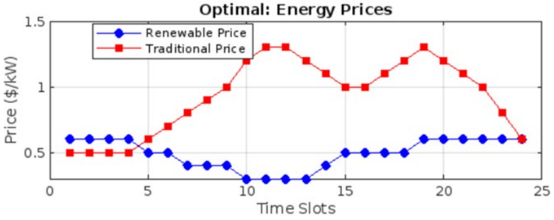
Completes tasks
as soon as possible

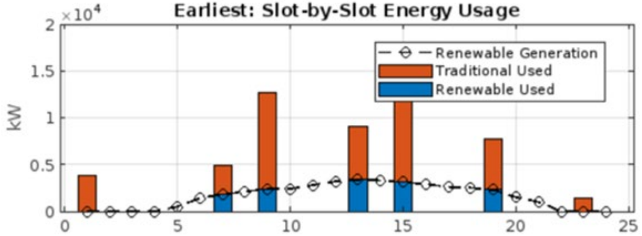
Setup:

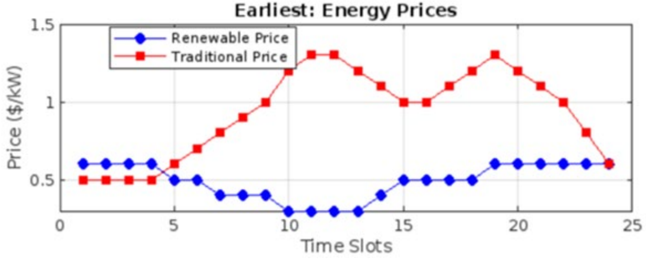
- Batch Arrival
- Delay requirement for (h, m, l) = (2, 4, 24)
- Weighting factor = 0.1
- Computational limit = 1000 (abundant)

	Ren usage(kW)	Total cost($)
Optimal	36550	32620
Conventional	13000	48334







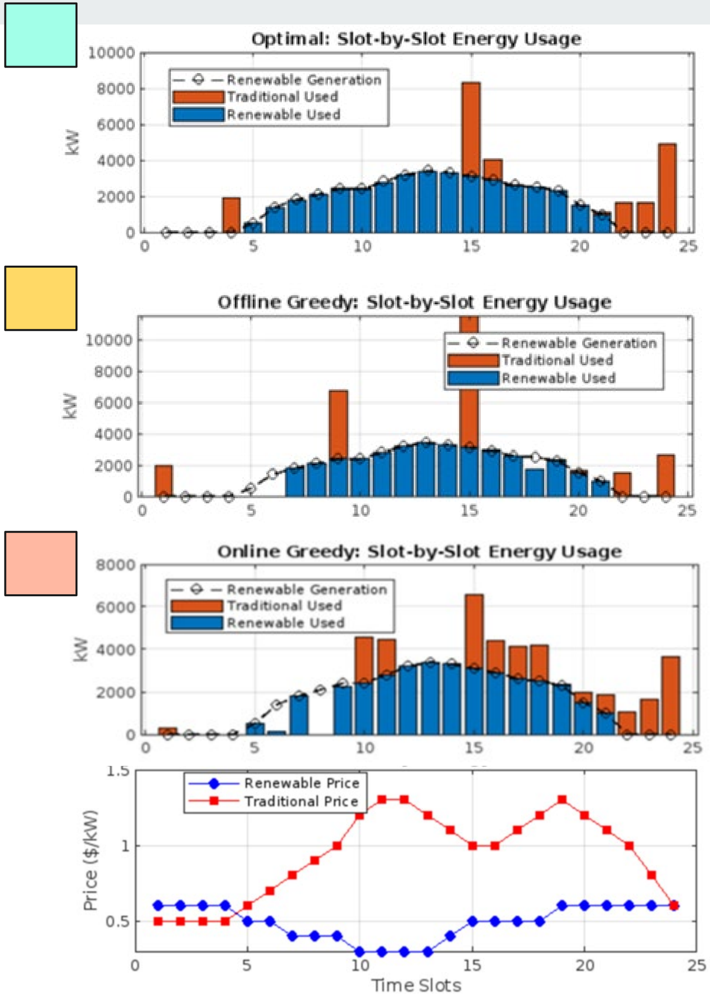


Optimal, Offline Greedy, and Online Greedy Scheduler

Setup:

- Dispersed Arrival
- Delay requirement for (h, m, l) = (2, 4, 24)
- Weighting factor = 0.1
- Computational limit = 1000 (abundant)

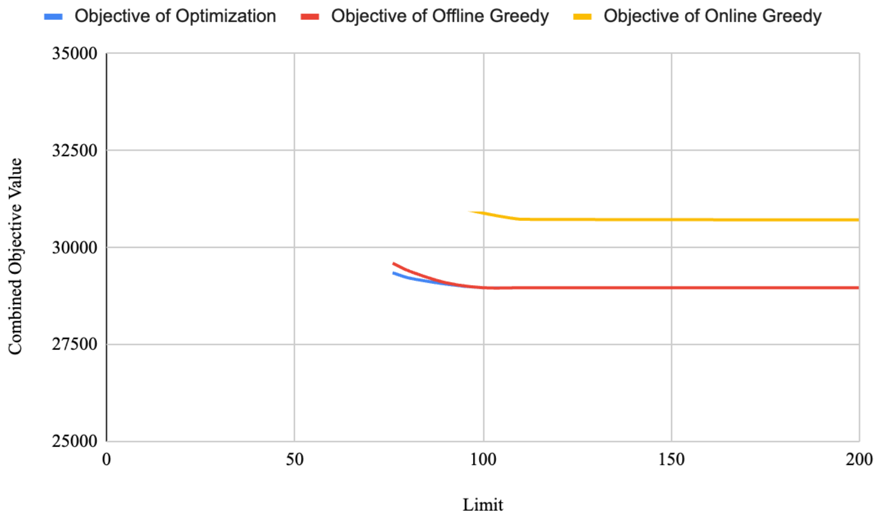
	Ren usage(kW)	Total cost($)
Optimal	39190	30086
Offline Heuristic	38150	31176
Online Heuristic	35660	35008

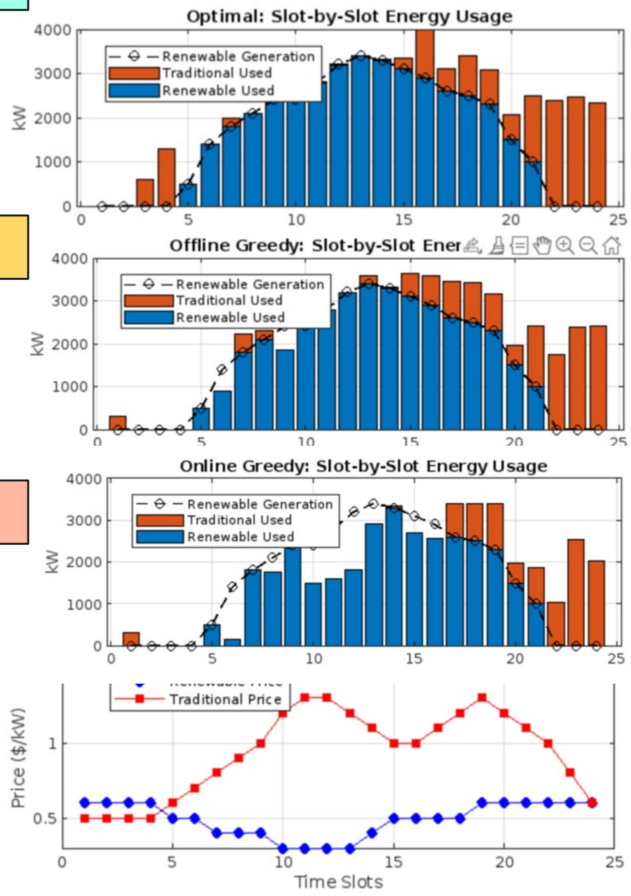


Optimal, Offline Greedy, and Online Greedy Scheduler (With computational limitations)

Setup:

- Batch arrival
- Delay requirement for (h, m, l) = (2, 4, 24)
- Weighting factor = 0.1
- Computational limit = changing





e.g. Computational limit = 100

Conclusion

We successfully designed three models in order to achieve an effective scheduling that is both practical and accurate. From our analysis, we can conclude that:

Offline Optimal Model: has the best performance, high adaptability but harder to implement

Offline Greedy Model: slightly worse performance than optimal model, but easy to implement

Online Greedy Model: performs worse than the optimal model, high practicality and easy to deploy

Thank You!

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Questions?

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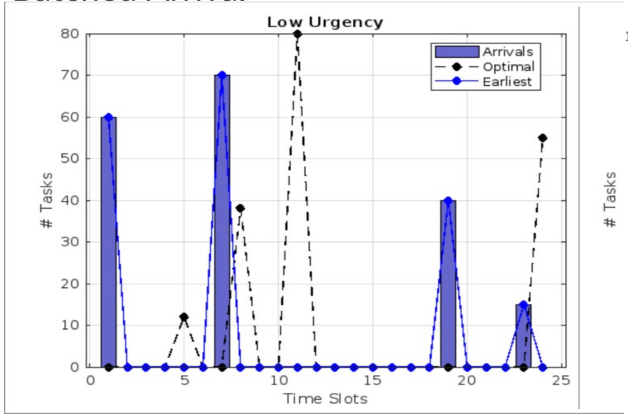
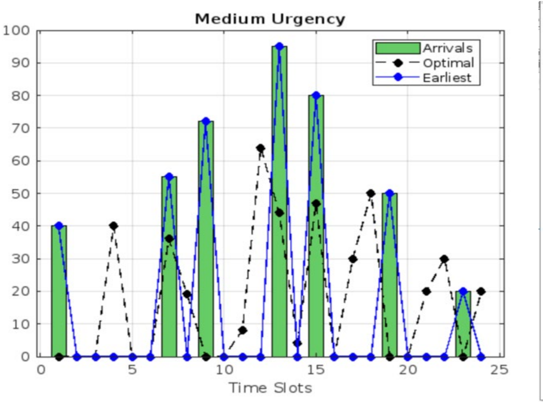
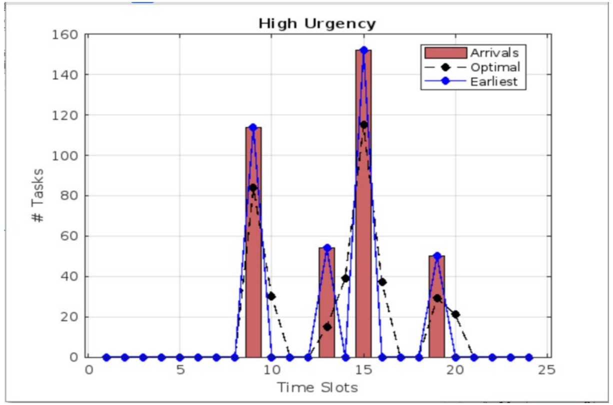
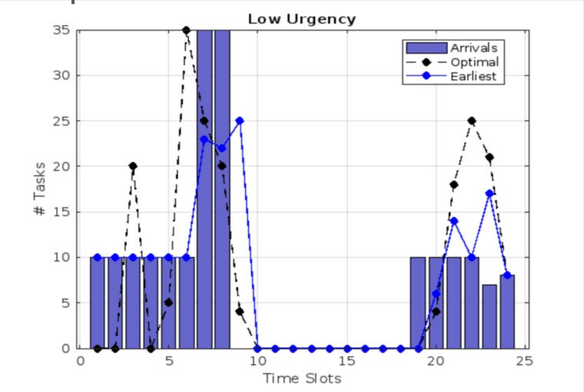
Batched Arrival

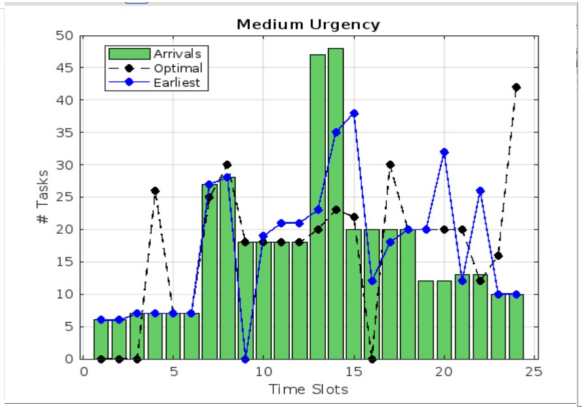


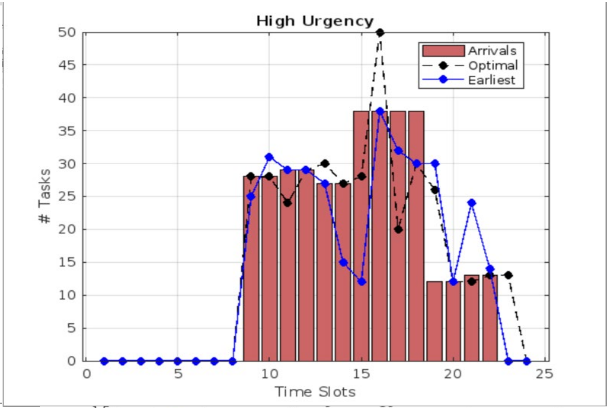


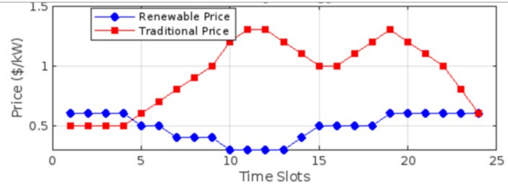


Dispersed Arrival









Causality constraint

$$\sum_{t=1}^{\tau} d_h(t) \le \sum_{t=1}^{\tau} a_h(t) \quad \forall \tau \in \{1, \ldots, T\}$$

$$\sum_{t=1}^{\tau} d_m(t) \le \sum_{t=1}^{\tau} a_m(t) \quad \forall \tau \in \{1, \ldots, T\}$$

$$\sum_{t=1}^{\tau} d_l(t) \le \sum_{t=1}^{\tau} a_l(t) \quad \forall \tau \in \{1, \ldots, T\}$$

Deadline constraint

$$\sum_{t=1}^{min\left(\tau+\Delta_h-1,\ T\right)} d_h(t) \ge \sum_{t=1}^{\tau} a_h(t) \quad \forall \tau \in \{1, \ldots, T\}$$

$$\sum_{t=1}^{min\left(\tau+\Delta_m-1,\ T\right)} d_m(t) \ge \sum_{t=1}^{\tau} a_m(t) \quad \forall \tau \in \{1, \ldots, T\}$$

$$\sum_{t=1}^{min\left(\tau+\Delta_l-1,\ T\right)} d_l(t) \ge \sum_{t=1}^{\tau} a_l(t) \quad \forall \tau \in \{1, \ldots, T\}$$

Server capacity constraint

$$d_h(t) + d_m(t) + d_l(t) \le L \quad \forall t$$

Renewable energy supply constraint

$$e_r(t) \le g_r(t) \quad \forall t.$$