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Towards green edge computing through renewable energy resources and distributed control

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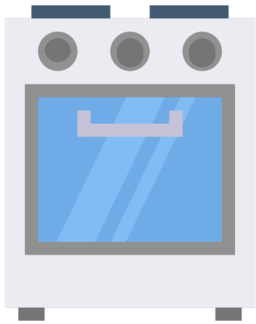
The energy problem



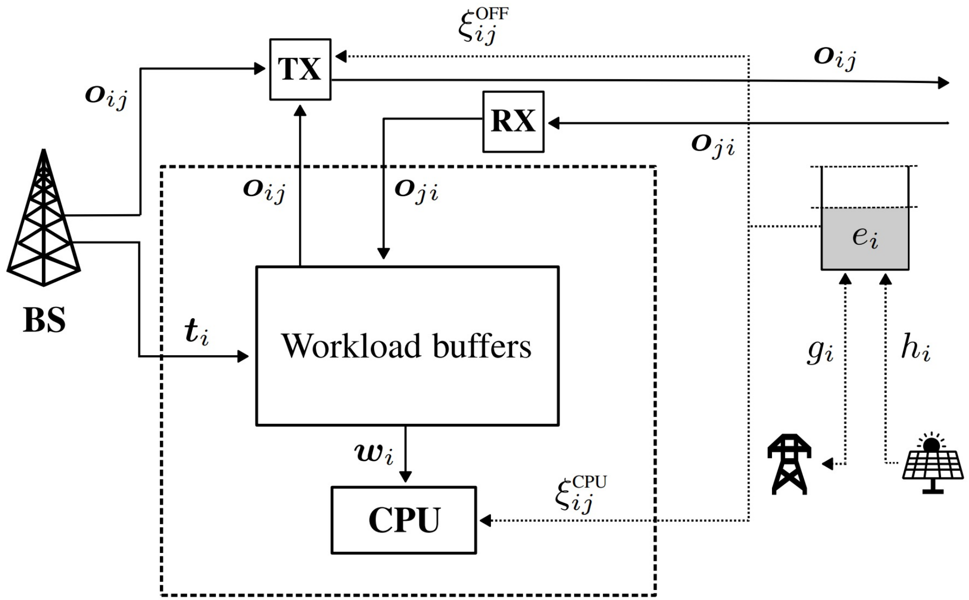
10 mins HD streaming

5 mins oven at 2 kW

- Watching a 10 minutes HD video on your smartphone ~ 600 kJ
- < 0.1% consumed by your smartphone
- ~ 8% consumed by the cloud (without considering cooling)
- ~ 92% consumed by the network
- ICT responsible of 20% of energy consumption by 2030

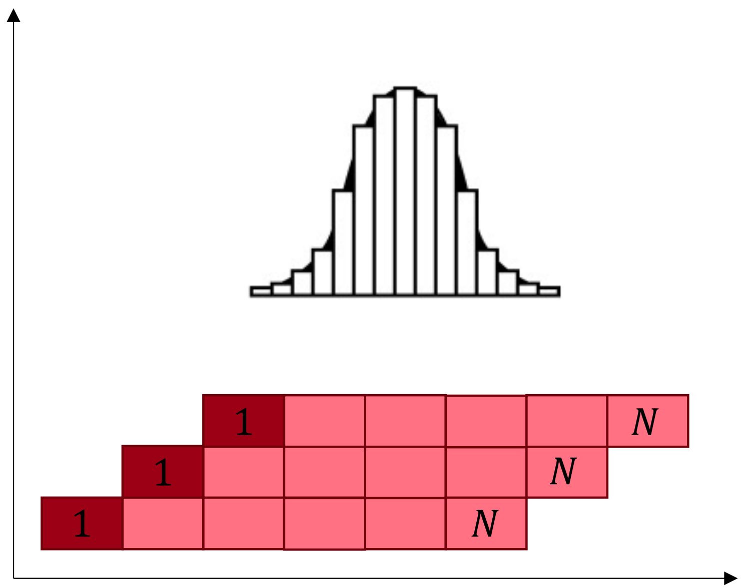
System model and objectives

- Edge servers in Urban environment
- Possibly co-located with BSs
- IoT nodes and mobile devices ask for computing resources
- The edge is co-powered by renewables and the goal is to manage in the best way the green energy
- IoT – load balancing vs consolidation
- IoV – follow users' mobility



Model predictive control

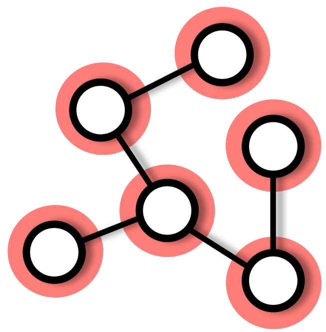
- Adaptive predictive controller inspired by optimal control
- Optimal control computed on the whole predictive window N
- First control is applied and procedure is repeated, sliding the window
- The controller self-adapts to exogenous processes (e.g. job and energy arrivals) estimation
- Scheme known as ***receding horizon***



Distributed solution

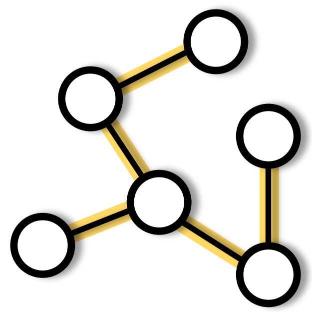
- The global cost function is a sum of separable local functions
- Minimizing the global cost can be done in a distributed way via ***message passing*** (with neighbors only), as a ***consensus problem***
- Nodes must agree on the value of the exchanged workload, i.e., variable ***o***, by doubling it

QP problem (node)



LOCAL STEP
Every node solves
a local sub-problem

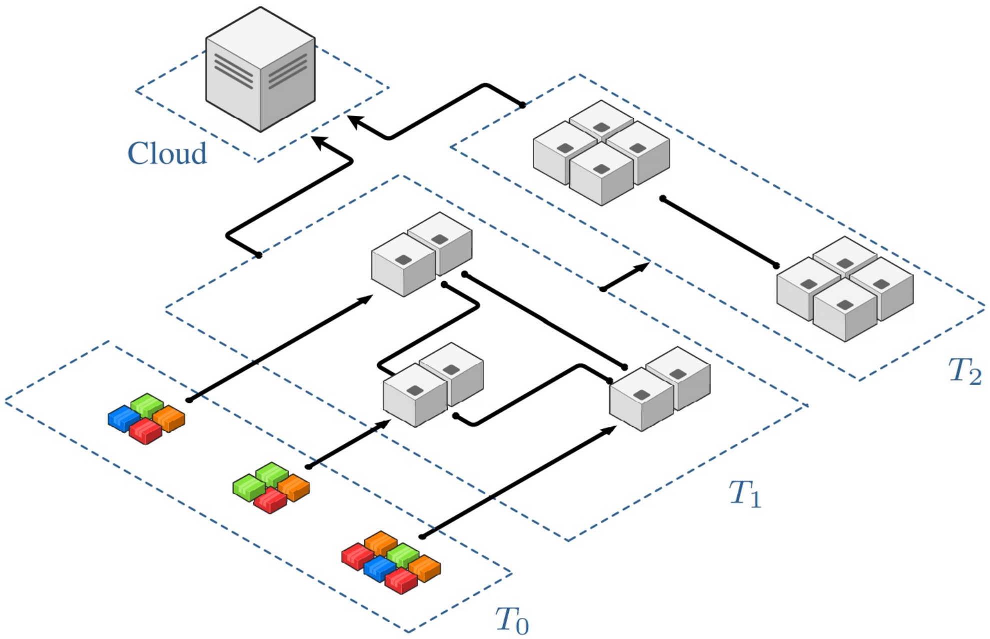
Per-edge averages



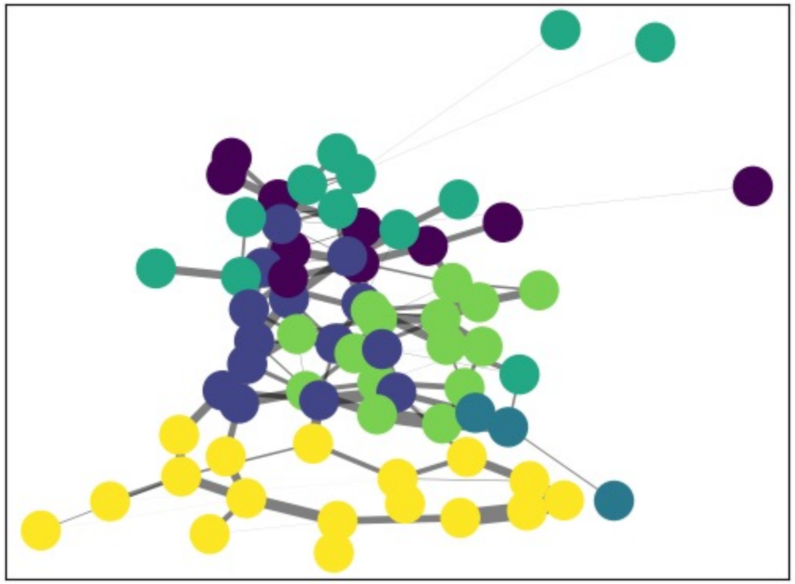
COMMUNICATION STEP
Neighbors exchange a
portion of the local solutions
Consensus constraints
projection (**Averaging**)

Application scenarios

IoT devices

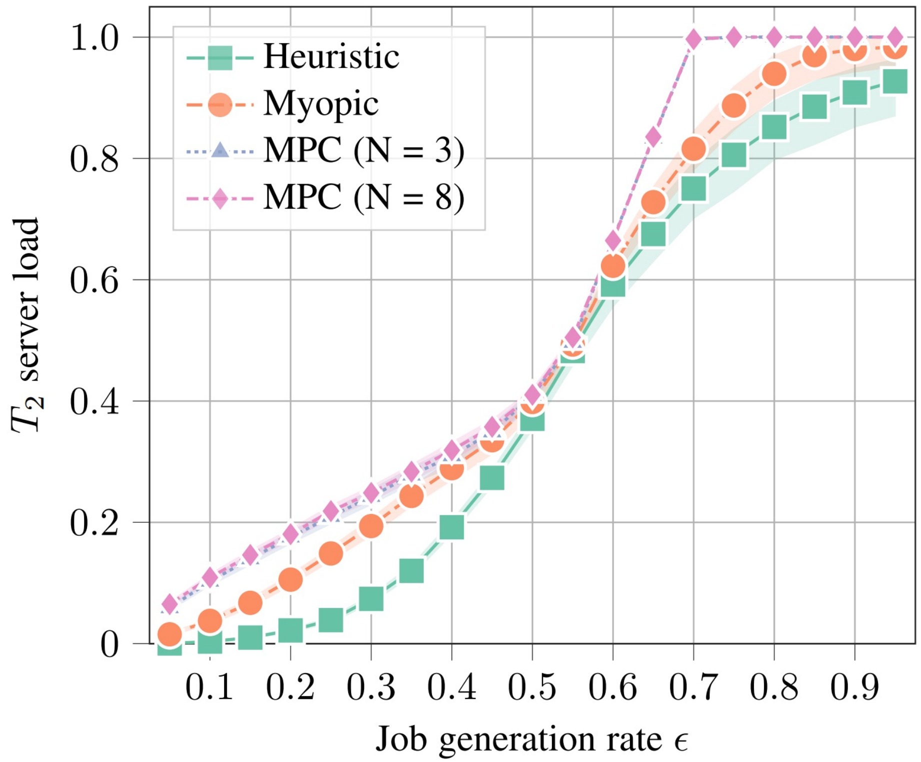


Vehicular (IoV)

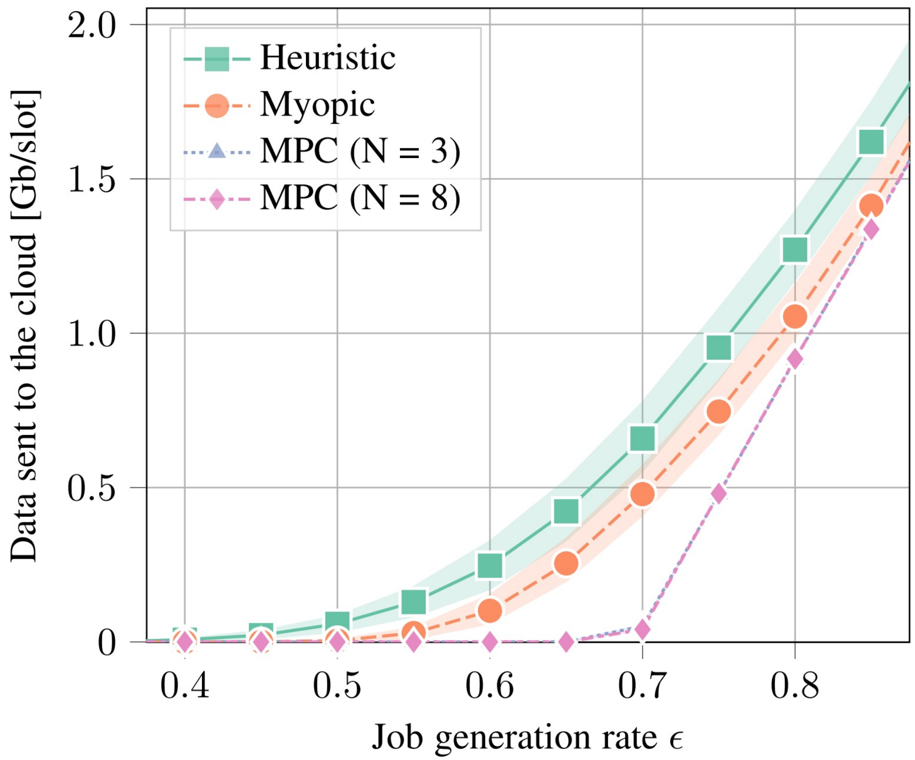


Executing jobs inside the edge

T2 servers load factor

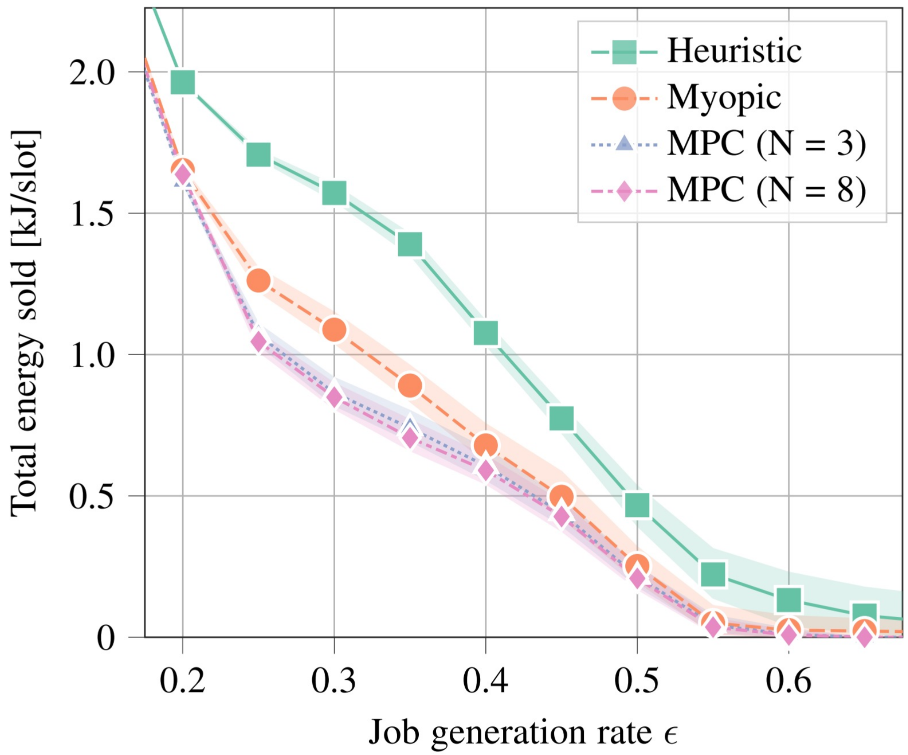


Data sent to the cloud

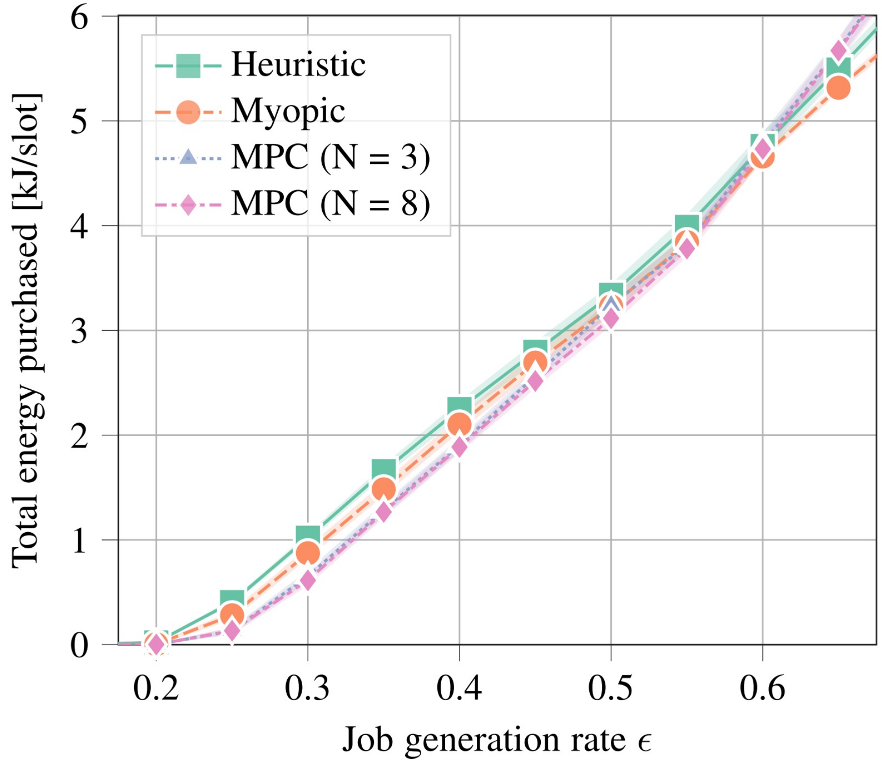


Energy traded with the power grid

Sold



Purchased



Conclusion

- Predictive job scheduling subject to deadline
- Decentralized solution
- MPC is able to fully exploit the edge facilities
- Improvement in harvested energy management
- Convergence in a reasonable amount of communication rounds

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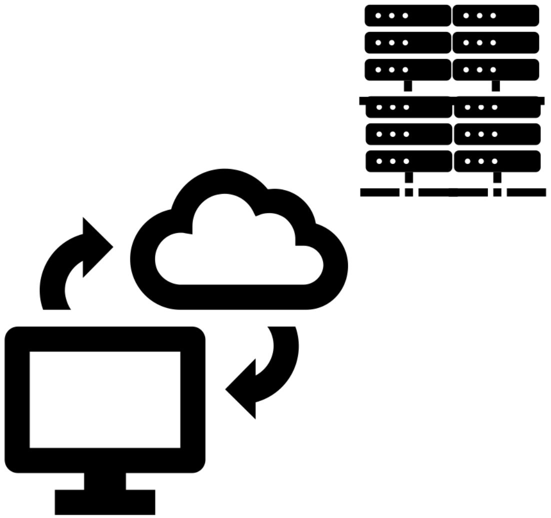
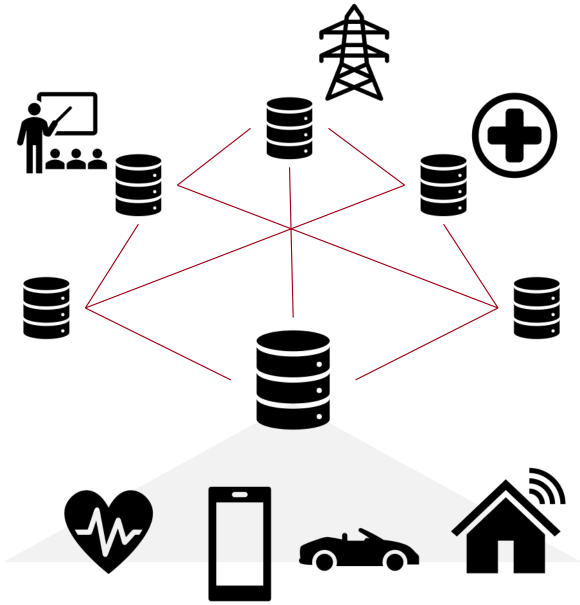
Multi-access Edge Computing

Cloud computing

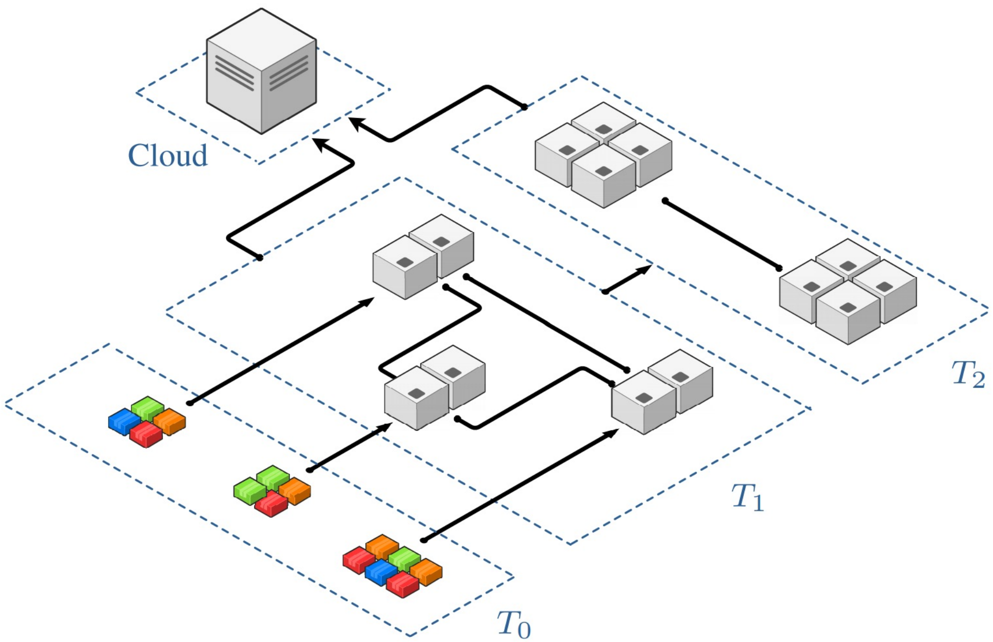
Edge computing



Around the city
Lower latency



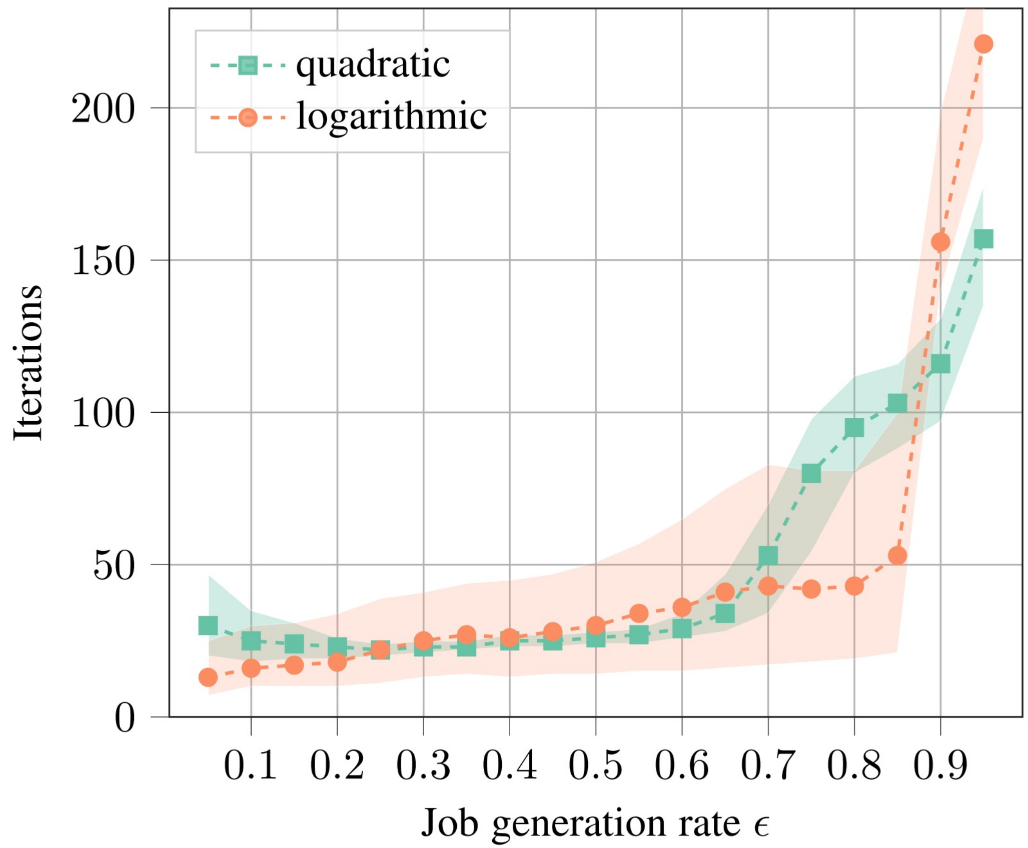
Simulation scenario



- Hierarchical network
- End devices send jobs to T1 servers
- T1 servers can process locally, exchange among each other or send to T2
- T2 servers cannot send back to T1, and are doubly powerful
- All servers can send workload to the cloud if the scheduling is unfeasible
- Considered networks with 12 T1 and 4 T2, with sparse links

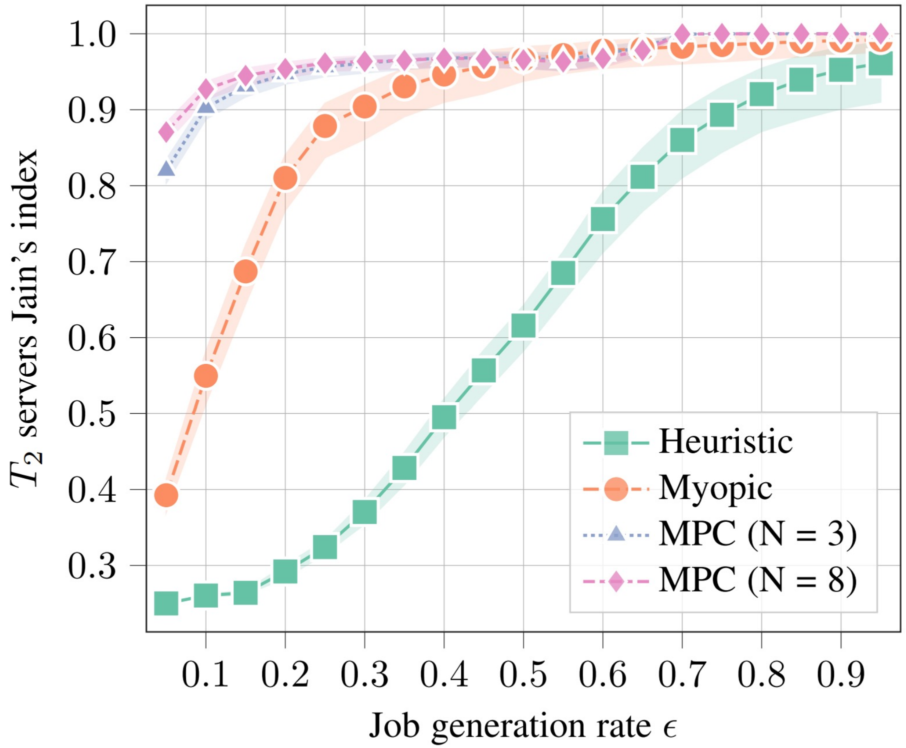
Communication burden

- Main working region ($\epsilon < 0.7$) - both cost functions require < 50 iterations
- Convex cost ~ 25 iterations with small variance
- Variance is larger with log
- For high ϵ iterations required by log explodes: the problem is ill-posed

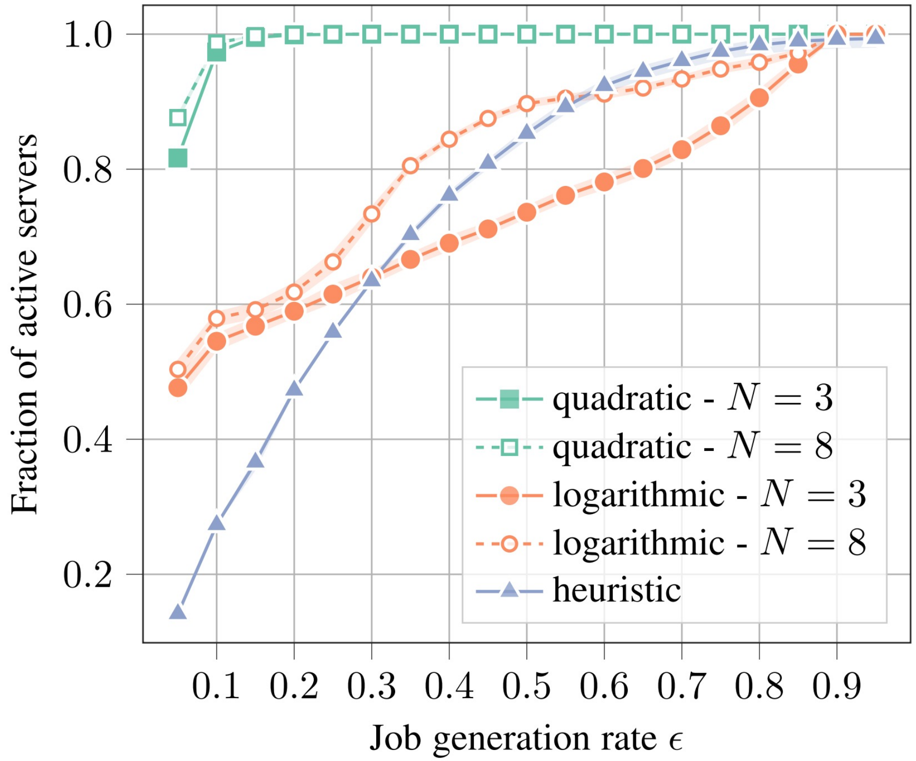


Load balancing vs consolidation

Jain's fairness index (load)



Fraction of active servers



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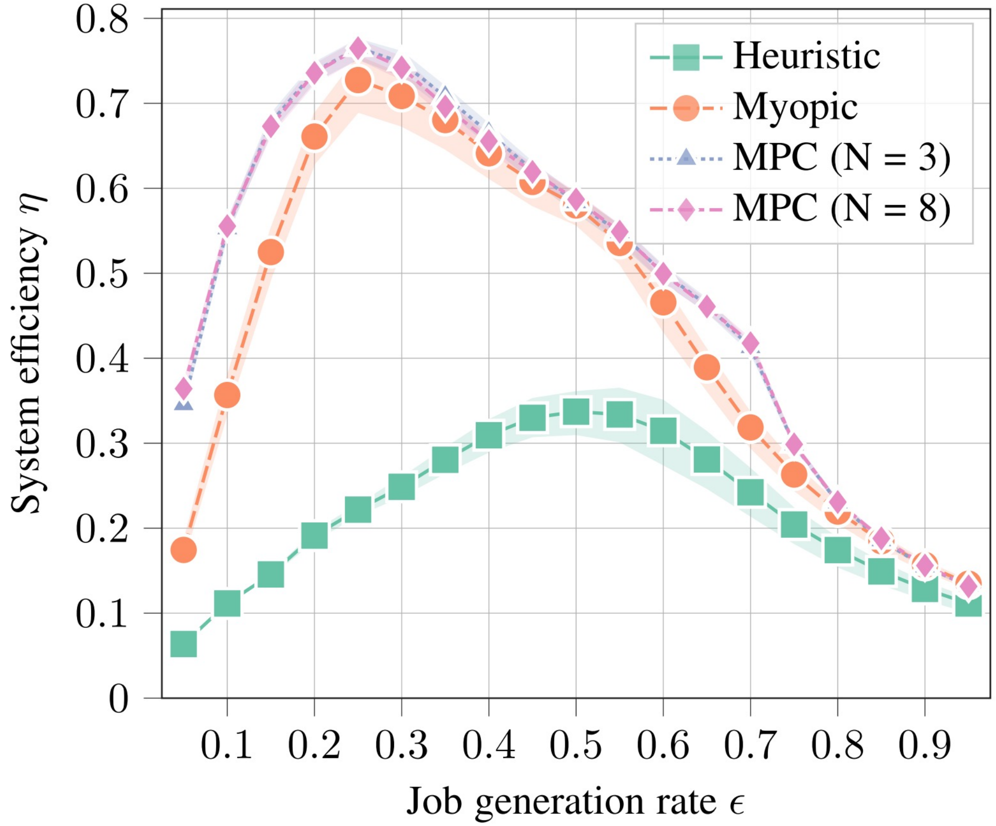
$$\eta = \frac{E_h}{E_h + E_p} \times \frac{\mu_1 W_e}{\mu_1 W_e + \mu_2 W_c} \times F(\phi)$$

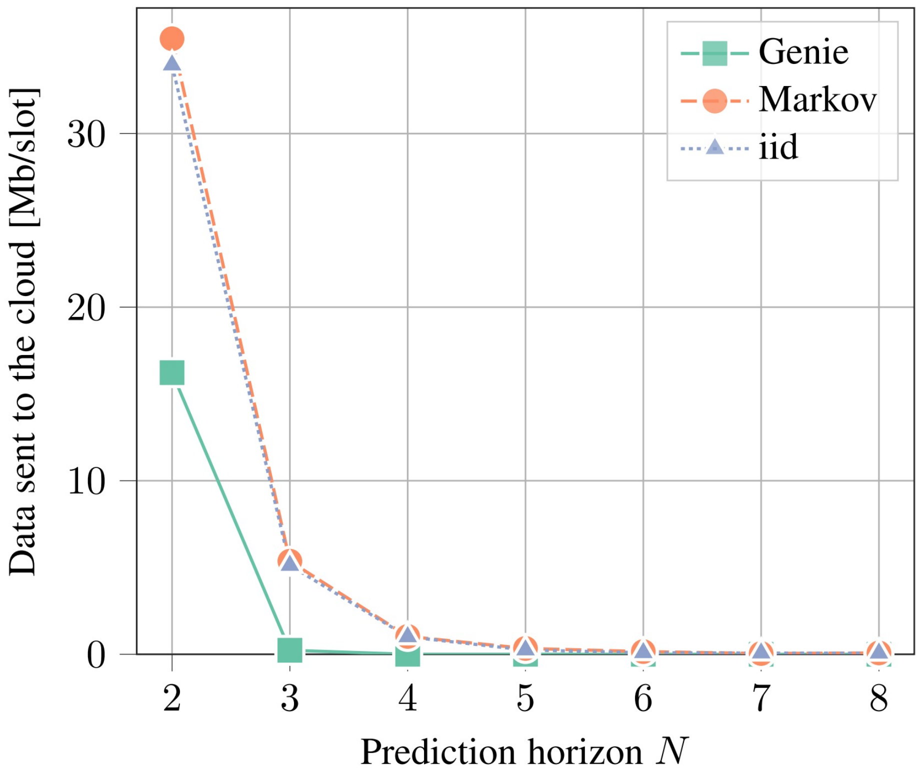
Efficiency

- Advantage for low ε, because load balancing is better induced
- For ε in $[0.6, 0.8]$, although the system is full (workers are all active), the advantage comes from a better exploitation of both harvested energy and edge resources



Effect of using different predictors

Data sent to cloud



Efficiency – N = 8