Optimal Energy Procurement for Geo-distributed Data Centers in Multi-timescale Markets

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Problem & Motivation

2 data centers in TX & NY:

TX: $0.03 kWh (*long-term*) $X kWh (*real-time*)

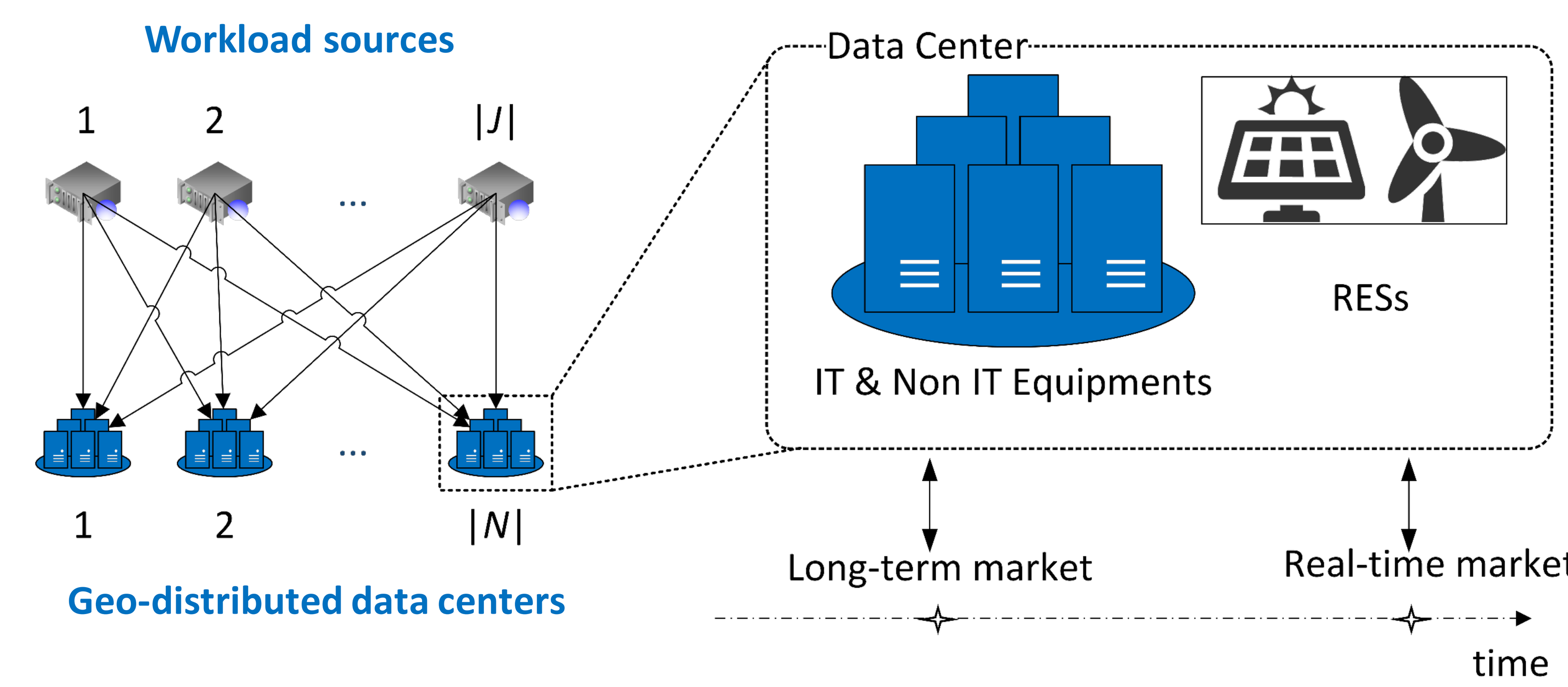
NY: $0.05 kWh (*long-term*) $Y kWh (*real-time*)

(In real-time, renewable energy & electricity prices are uncertain.)

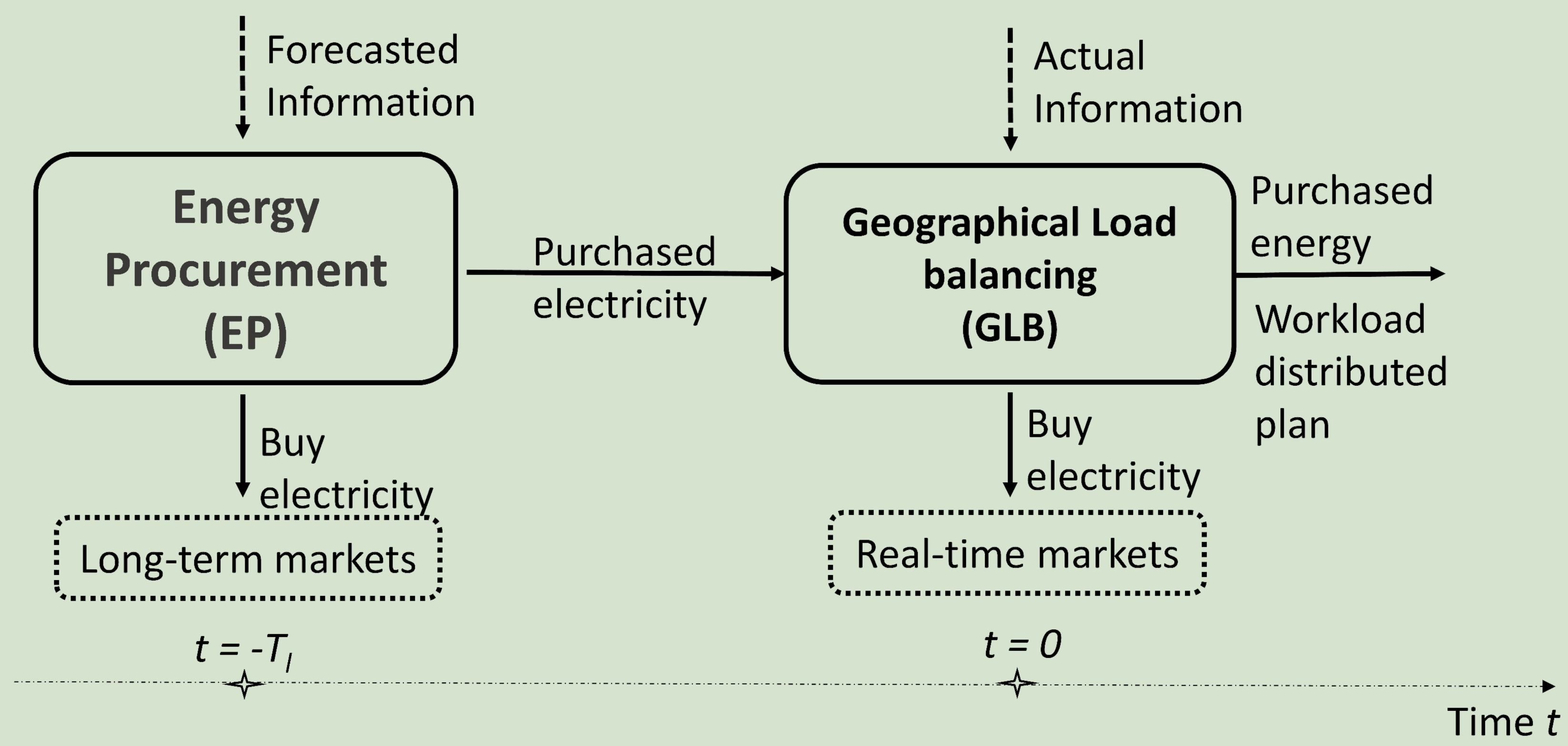
How much electricity should we purchase in long-term for each data center?

Over procurement → **waste** of energy & money

Under procurement → **pay a lot** in real-time

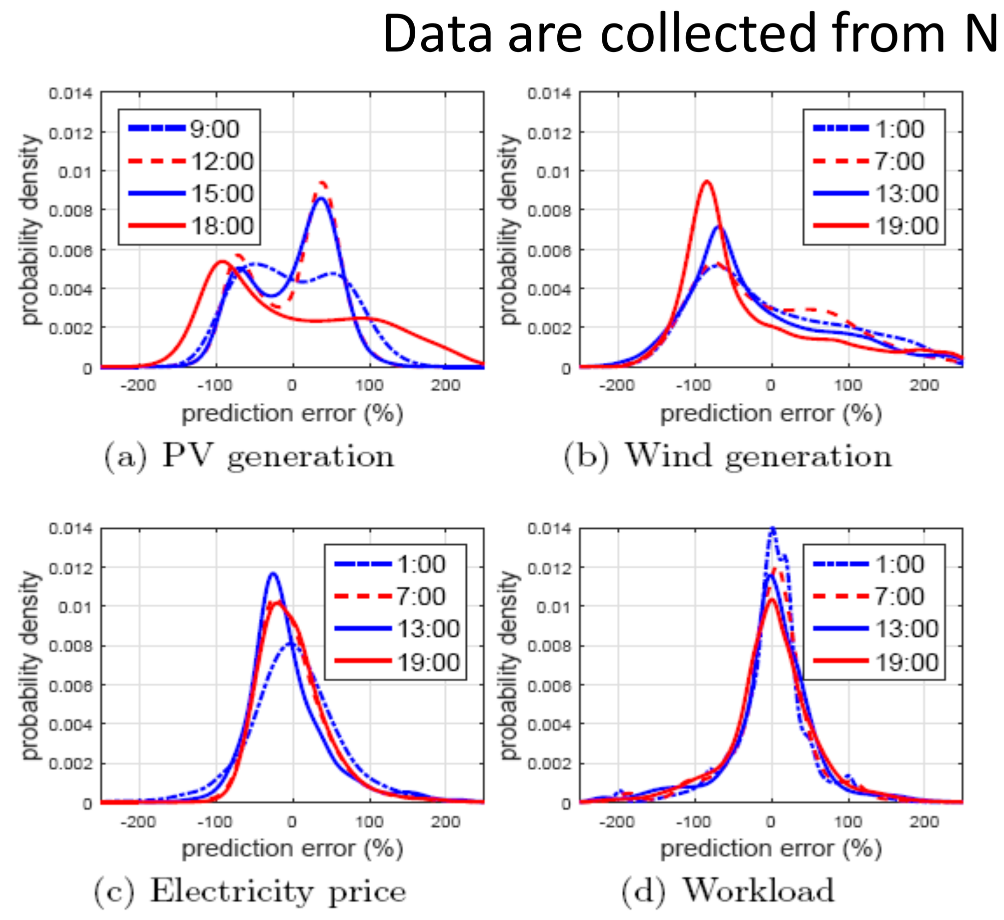


Proposed Energy Procurement System

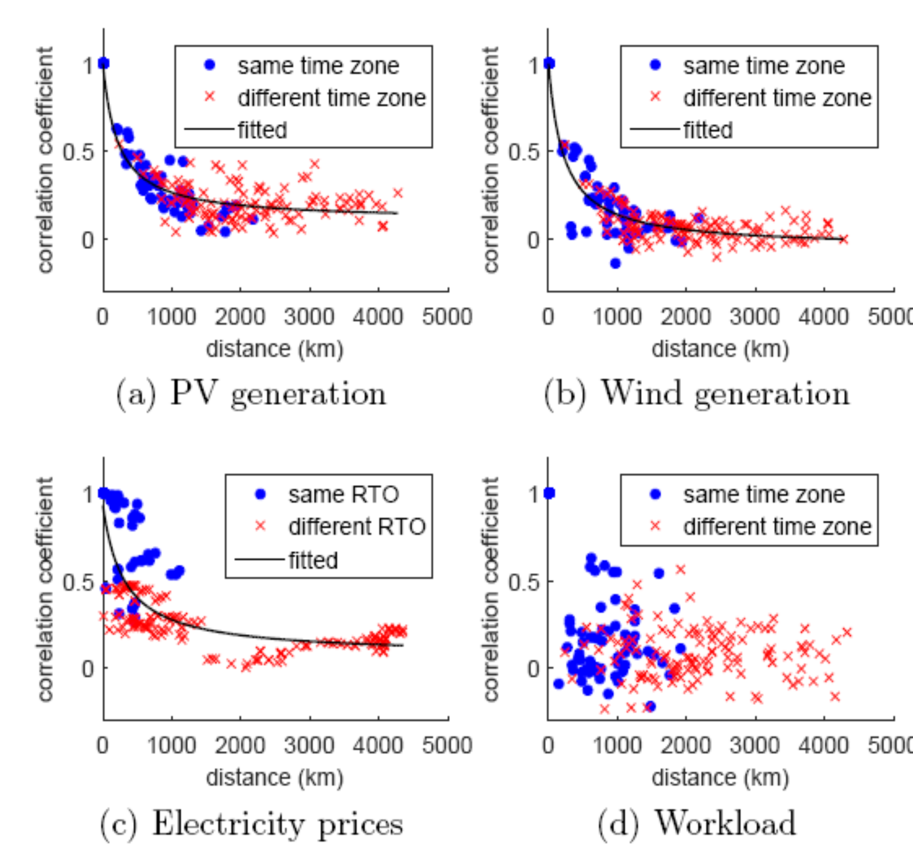


Prediction Error Analysis for the EP input

Data are collected from NREL, Akamai, ISOs in USA

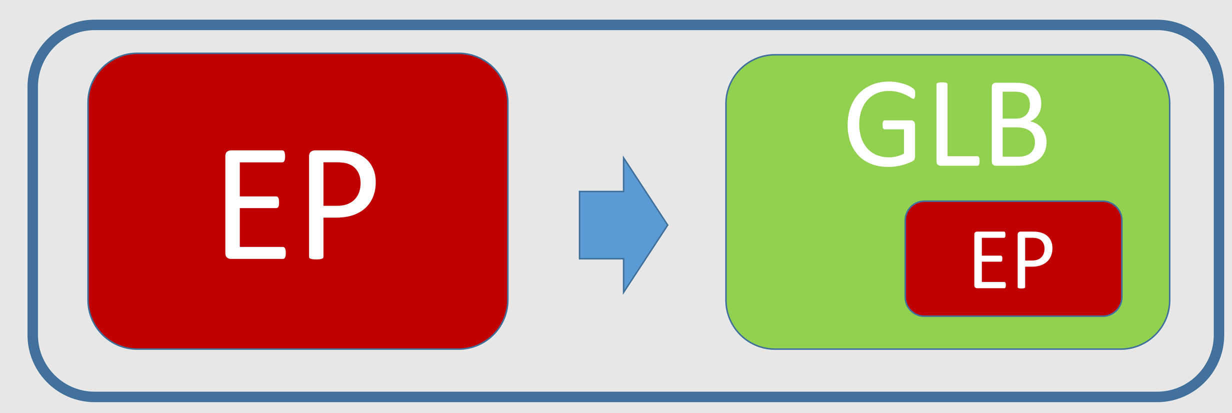


Error distributions are divert



Low-correlated in space domains

Optimal Energy Procurement (EP) in Long-term



min cost(EP + GLB(EP))

Stochastic Gradient based Algorithm (SGA)

Input: Prediction error distribution

Step 1: Generate the all the possible input for GLB based prediction errors.

Step 2: Pick a feasible EP

While loop:

Step 3: Solve GLB on each sample path

Step 4: Solve GLB on each possible output

Step 5: Obtain expected gradient of objective

Step 6: Stop if the gradient is small enough

Experimental Setup

Data centers: 14 Google data centers

Renewable penetration: 30% capacity

Akamai **workload** traces: 40 sources

Electricity **prices**:

Long term = $\frac{1}{2.5}$ avg. real time

Base line methods

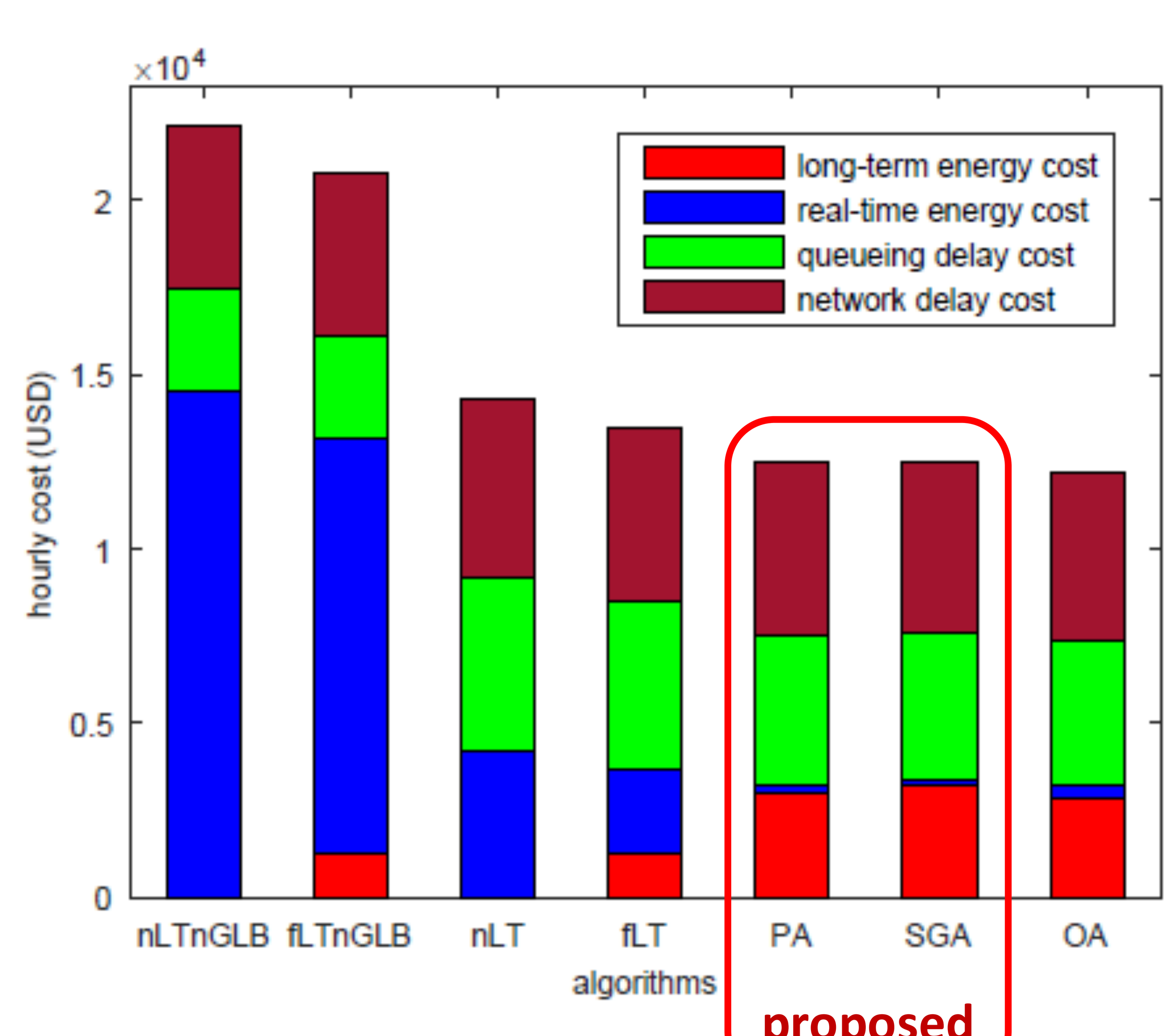
PA: Prediction Algorithm is proposed using predicted values

nLTnGLB: no Long Term EP & no GLB

fLTnGLB: fixed 50% Long Term EP & no GLB

nLT: no Long Term EP & using GLB

fLT: fixed 50% Long Term EP & using GLB



Lessons learnt

Up to **50% savings** with SGA

Be **aggressive in long-term** markets thanks to GLB.

PA & SGA are very **close to optimal** because of 2 reasons:

1. *Long-term energy is used up to reduce the delay cost*
2. *GLB does a good job on distributing workload to compensate the over-procurement.*