Dynamic Workload Migration Over Optical Backbone Network To Minimize Data Center Electricity Cost

Sabidur Rahman*, Abhishek Gupta*, **Massimo Tornatore***†, and Biswanath Mukherjee*
*University of California, Davis, USA †Politecnico di Milano, Italy

ONS-2: Optical Data Center Networking

Agenda

- Introduction to problem
  - Motivation
  - Electricity market
  - Formal statement
  - Power consumption model
- Proposed algorithm
  - *Dynamic Workload-Aware VM Placement and Migration*
- Results
- Summary and future work

Geographically distributed data centers

Source: http://royal.pingdom.com/2008/04/11/map-of-all-google-data-center-locations/

Annual electricity cost

Company	Servers	Electricity	Cost
eBay	16K	$\sim 0.6 \times 10^5$ MWh	$\sim$\$3.7M
Akamai	40K	$\sim 1.7 \times 10^5$ MWh	$\sim$\$10M
Rackspace	50K	$\sim 2 \times 10^5$ MWh	$\sim$\$12M
Microsoft	>200K	$> 6 \times 10^5$ MWh	>\$36M
Google	>500K	$> 6.3 \times 10^5$ MWh	>\$38M
USA (2006)	10.9M	610×10^5 MWh	\$4.5B
MIT campus		2.7×10^5 MWh	\$62M

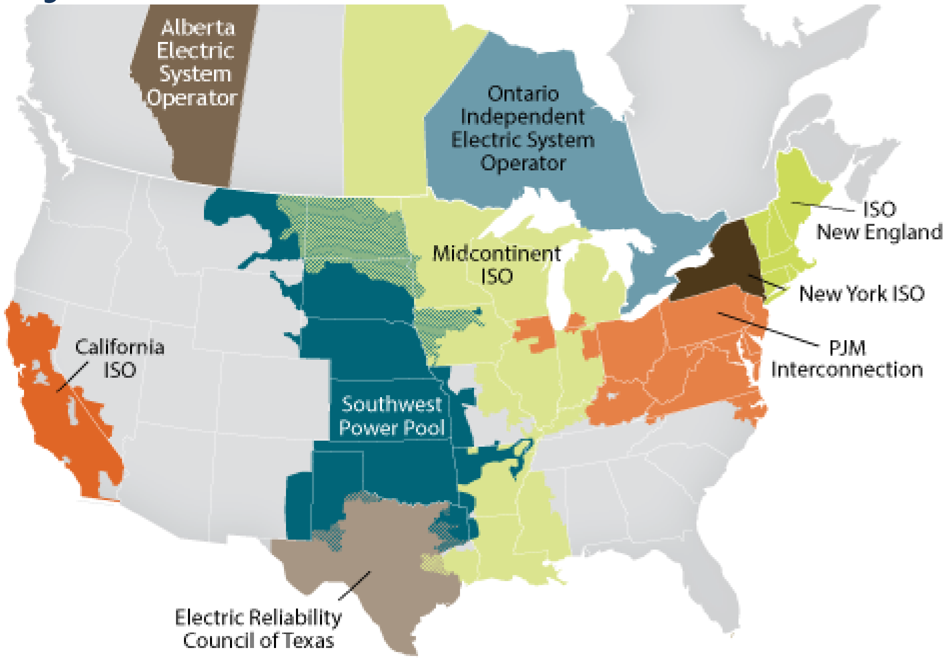
A. Qureshi, R. Weber, H. Balakrishnan, J. Guttag, and B. Maggs, “Cutting the electric bill for internet-scale systems,” SIGCOMM ’09, vol. 39, no. 4, pp. 123–134, Oct. 2009.

Electricity market

- 7 major ISOs/RTOs in USA

- Electricity cost varies over:
  - *time*
  - *location*

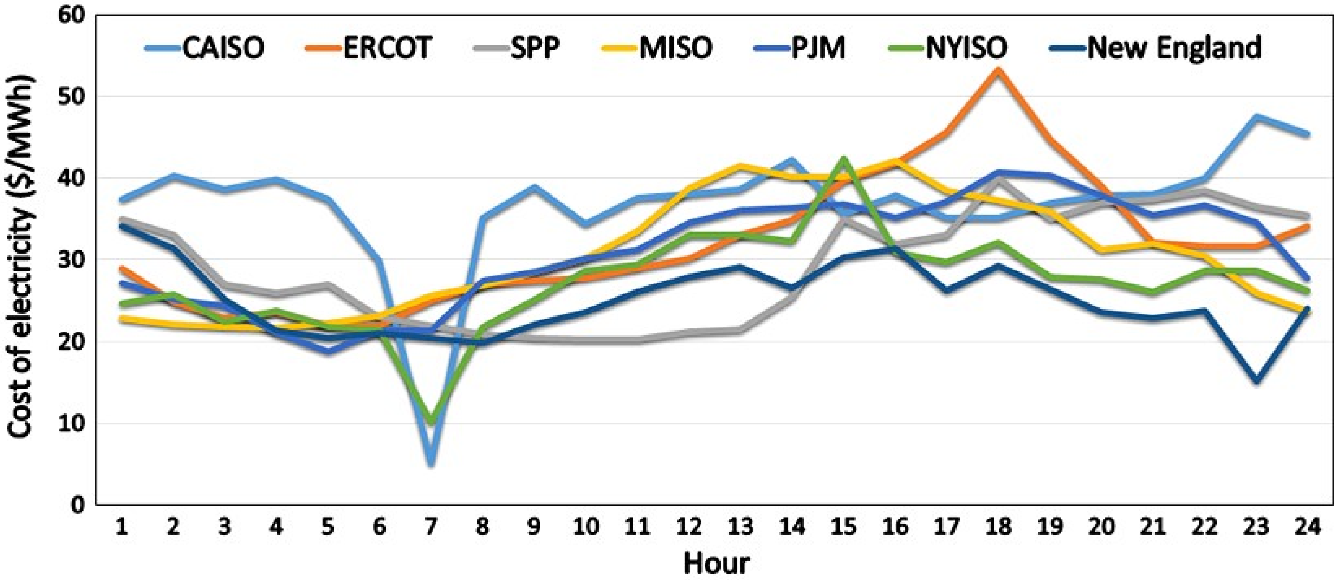
  (mostly due to characteristics of power sources and supply /demand behavior)



Independent System Operator (ISO)
Regional Transmission Organization (RTO)

Source: http://www.isorto.org/about/default

Variable electricity cost



A. Gupta, U. Mandal, P. Chowdhury, M. Tornatore and B. Mukherjee, “Cost-efficient live VM migration based on varying electricity cost in optical cloud networks”, Photonic Network Communications, Sep 2015

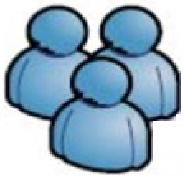
Key concepts

- Exploit spatio-temporal variation of electricity prices for geographically-distributed data centers
  - Live VM migration
  - Service request re-routing (considering SLA!)
- Solution for dynamic scenarios
  - Most existing work on static/quasi-static scenarios
- Power model
  - Backbone network power consumption (due to VM migration)

Problem statement

DCs' current capacities

Network state and link capacities



Service requests

Dynamic Optimization

Where to 'serve' the request, or where to 'migrate' the running service

Electricity price data

Service SLA

DC power model

Server	$P_s = P_{idle} + P_{peak} * u$	(*u*= server utilization)
Rack	$P_R = \sum_{s \in R} P_s$	
Total IT equipment	$P_{IT} = \sum_{R \in DC} P_R$	
Total DC	$P_{DC} = P_{IT} * PUE$	

Heating, cooling, ventilation, lighting, and maintenance.

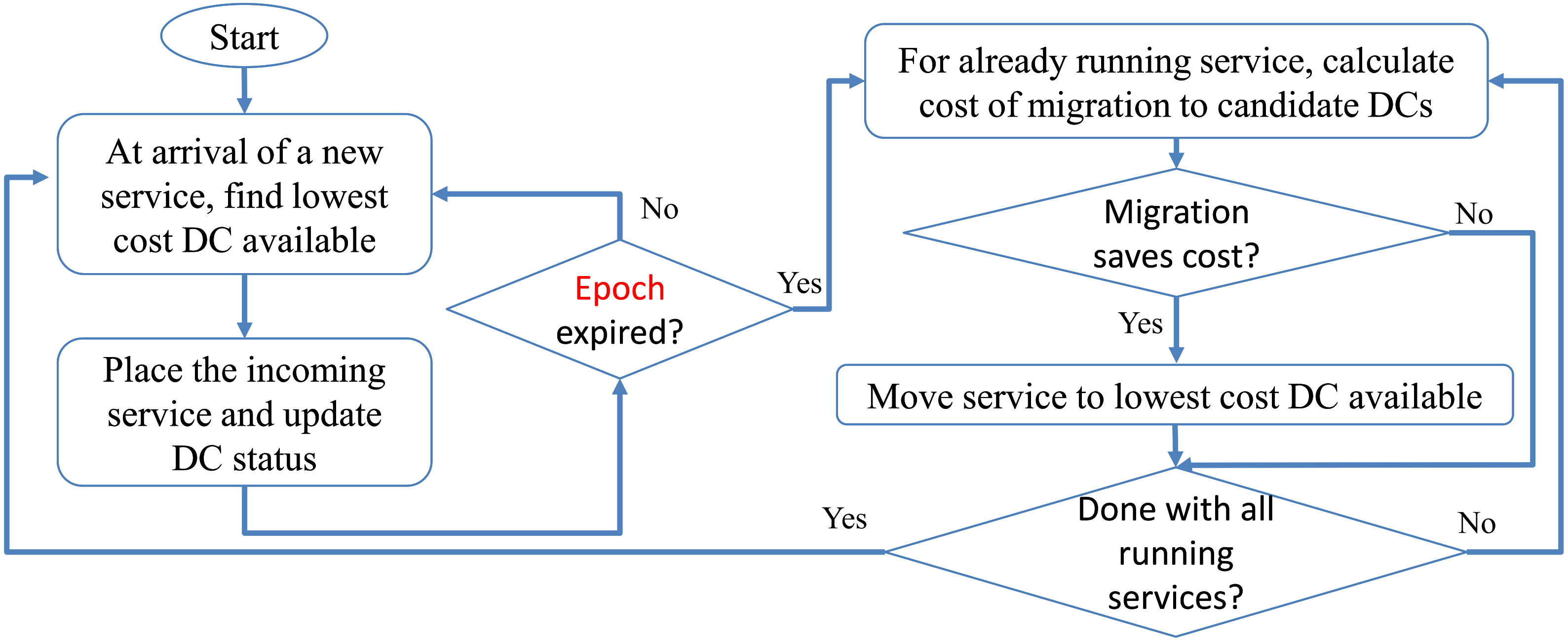
VM migration power model

Network nodes	$P_{bn} = \sum_{1}^{K} n * P_{bit} * C_{i,j}$	(*n*= total # of bits, $C_{i,j}$ cost of electricity)
DC + Network	$P_V = P_{dc} + P_{bn}$	
VM migration	$P_{VM} = P_V * (1 + \mu)$	

Administrative overhead of managing VM migration

Algorithm

Dynamic Workload-Aware VM Placement and Migration (DWVPM)



Step I (initial placement)
where to place new requests?

Step II (migration of services)
where to migrate running services?

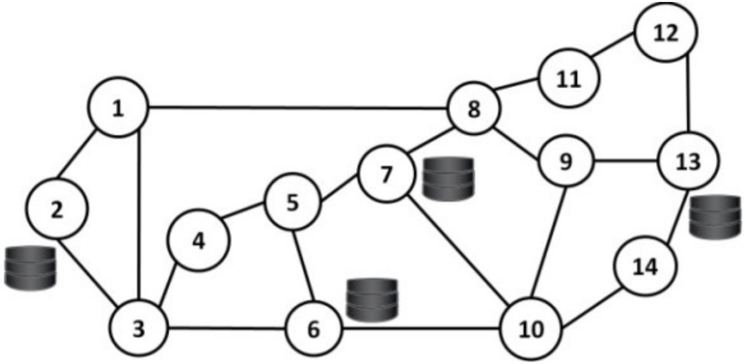
Novelties of approach

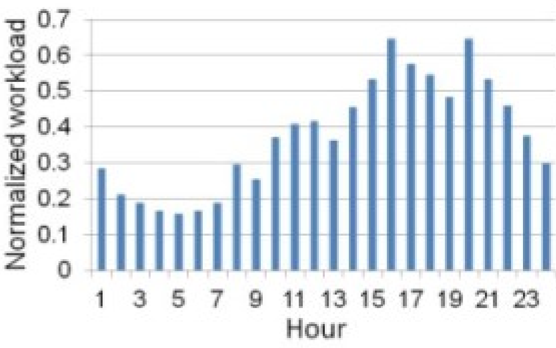
- Epoch makes the migration frequency variable
  - epoch dynamically adjusts migration frequency
- Dynamic service arrival and duration
  - We use practical values from DC workload traces studied in prior works
- Combination of backbone network and server power consumption
- Per-Rack VM consolidation in DCs which further reduces the electricity cost

Simulation setup

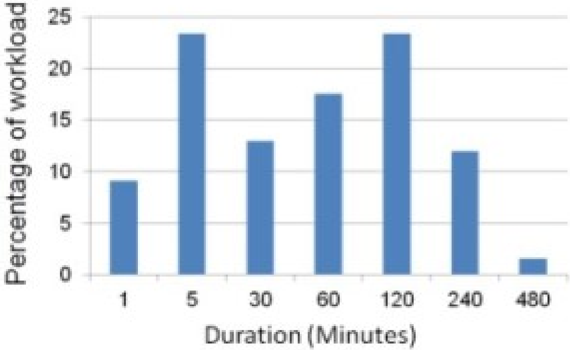
TABLE I. POWER CONSUMPTION VALUES.

Type	Power consumption
Server idle power consumption	90.9 Watt/hour [18]
Server peak power consumption	527.8 Watt/hour [18]
Power consumption in network node	1.108×10^{-5} W/bit [19]
PUE	1.12 [20]





(a)

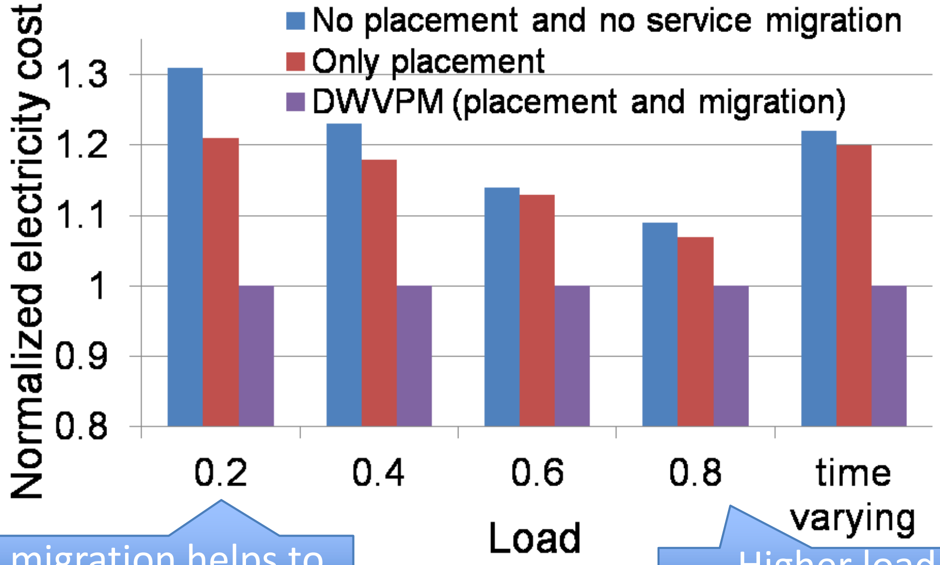


(b)

[15] A. K. Mishra,et al., “Towards Characterizing Cloud Backend Workloads: Insights from Google Compute Clusters,” ACM SIGMETRICS Performance Evaluation Review, 2010.

[16] T. Paul, et al., “The User Behavior in Facebook and its Development from 2009 until 2014,” arXiv, 2015.

Results: normalized cost vs. load

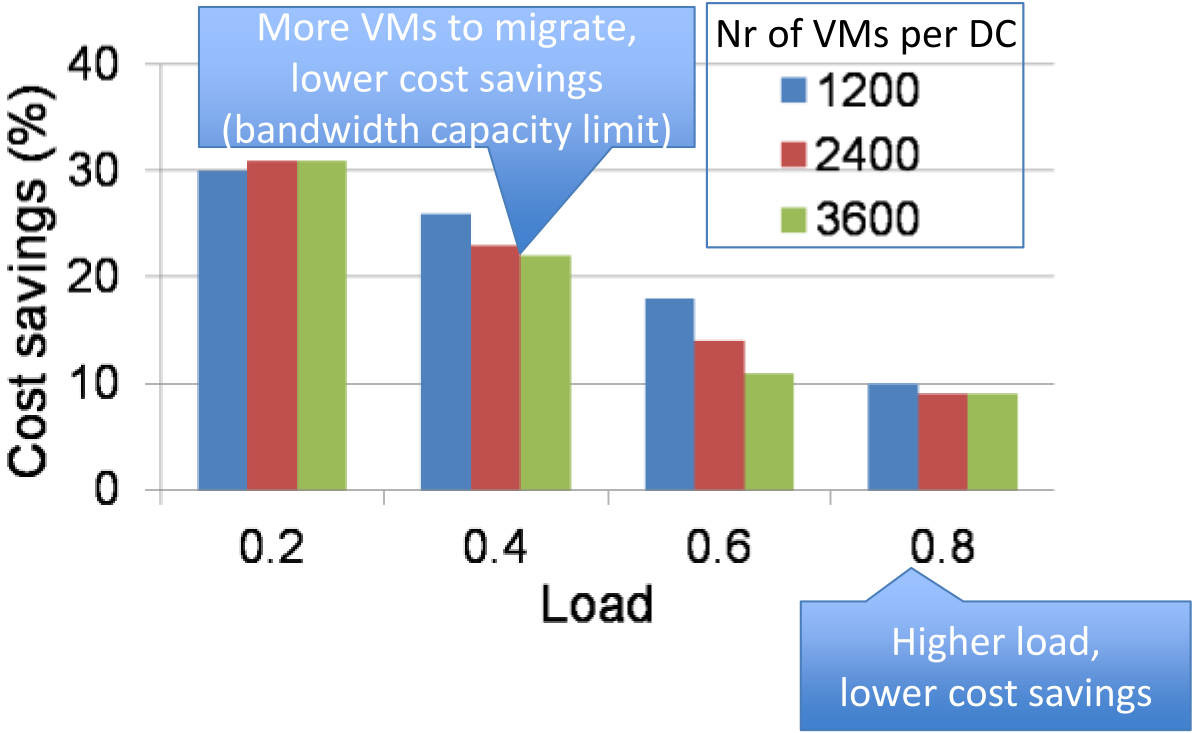


VM migration helps to minimize cost

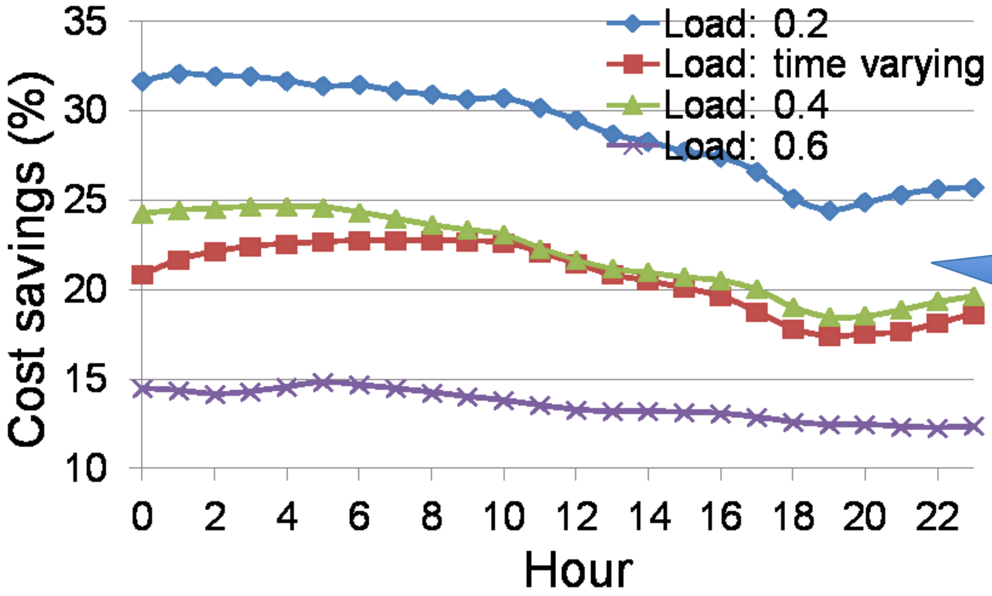
Higher load, lower cost savings

UCDAVIS

Results: impact of DC capacity
(for fixed transport capacity)

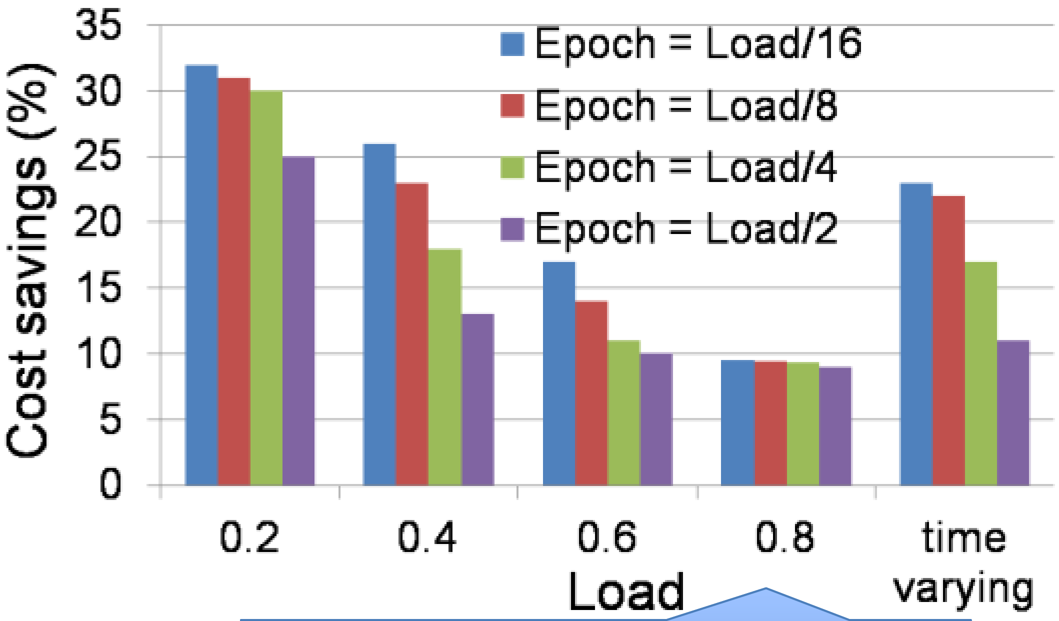


Results: 24-hour variation on cost savings



Cost savings over the day varies with the load and electricity price

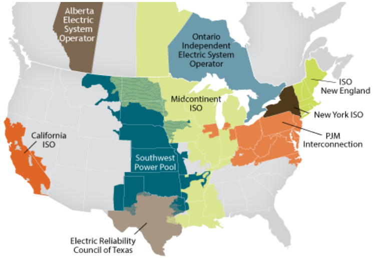
Results: impact of epoch

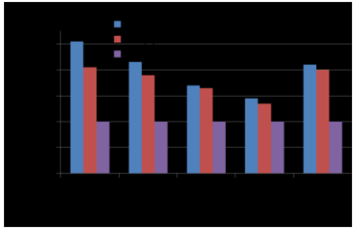


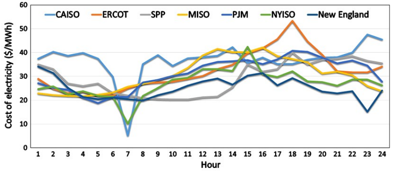
Frequently executing the algorithm has more cost savings in lower loads than higher loads

Summary and future work

- Spatio-temporal variation of electricity prices can help to minimize DC electricity cost significantly
- DWVPM optimizes DC electricity cost in dynamic scenarios
    - Savings in the orfer of 20-30%
- Future work:
    - Use of new virtualization platforms such as ‘docker containers’
    - A-priori identification of the right “dynamicity”







UCDAVIS


THANK
YOU!