Using Batteries to Reduce the Power Costs of Internet-scale Distributed Networks

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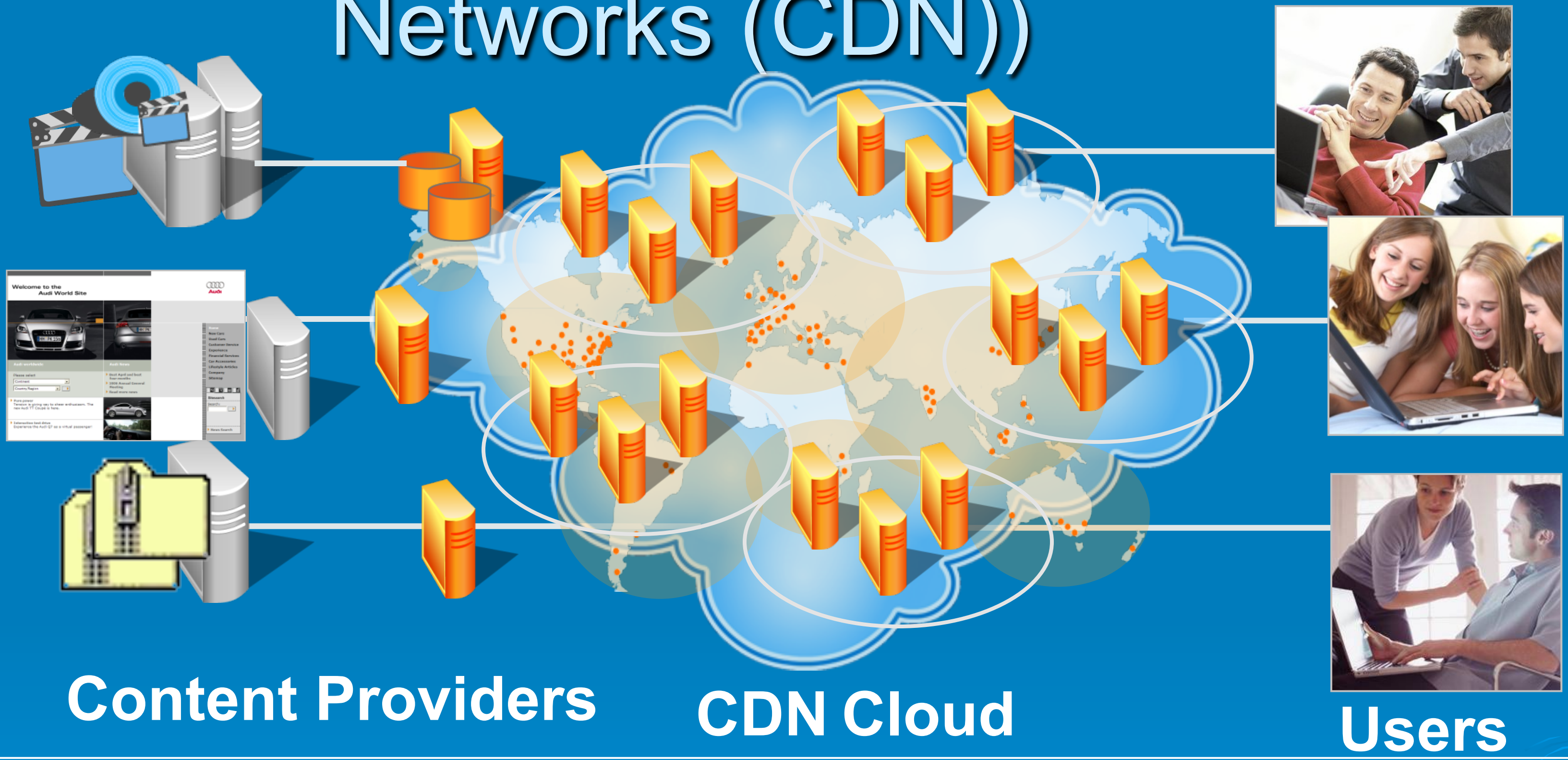
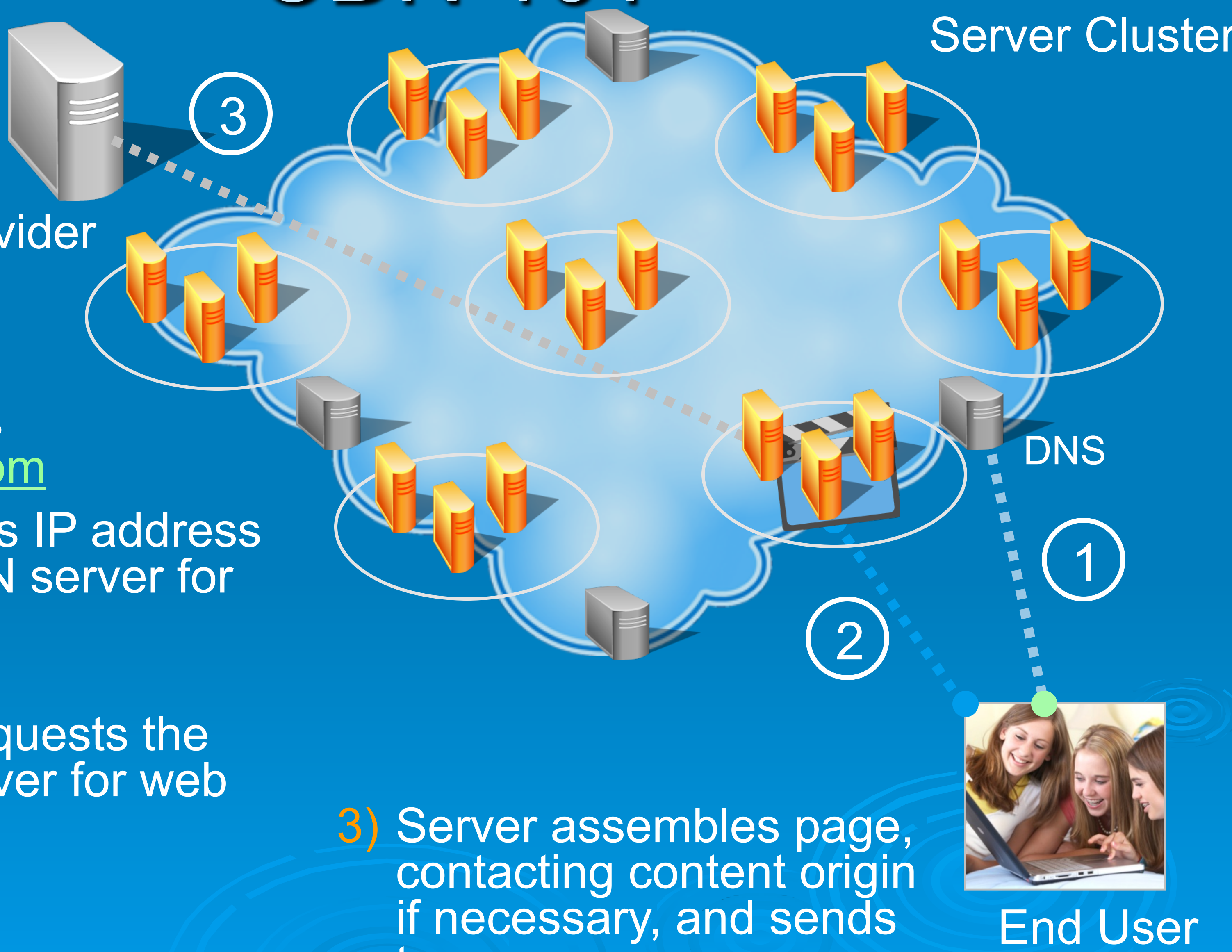
Internet-Scale Distributed Networks (Example, Content Delivery Networks (CDN))



Example: Akamai Network

- 100, 000+ servers in 1000+ clusters in 1000+ networks in 70+ countries serving trillions of requests a day.
- Web, Live & VoD Media, Downloads, Social Networks, e-commerce, Apps.

CDN 101



1) User enters www.xyz.com

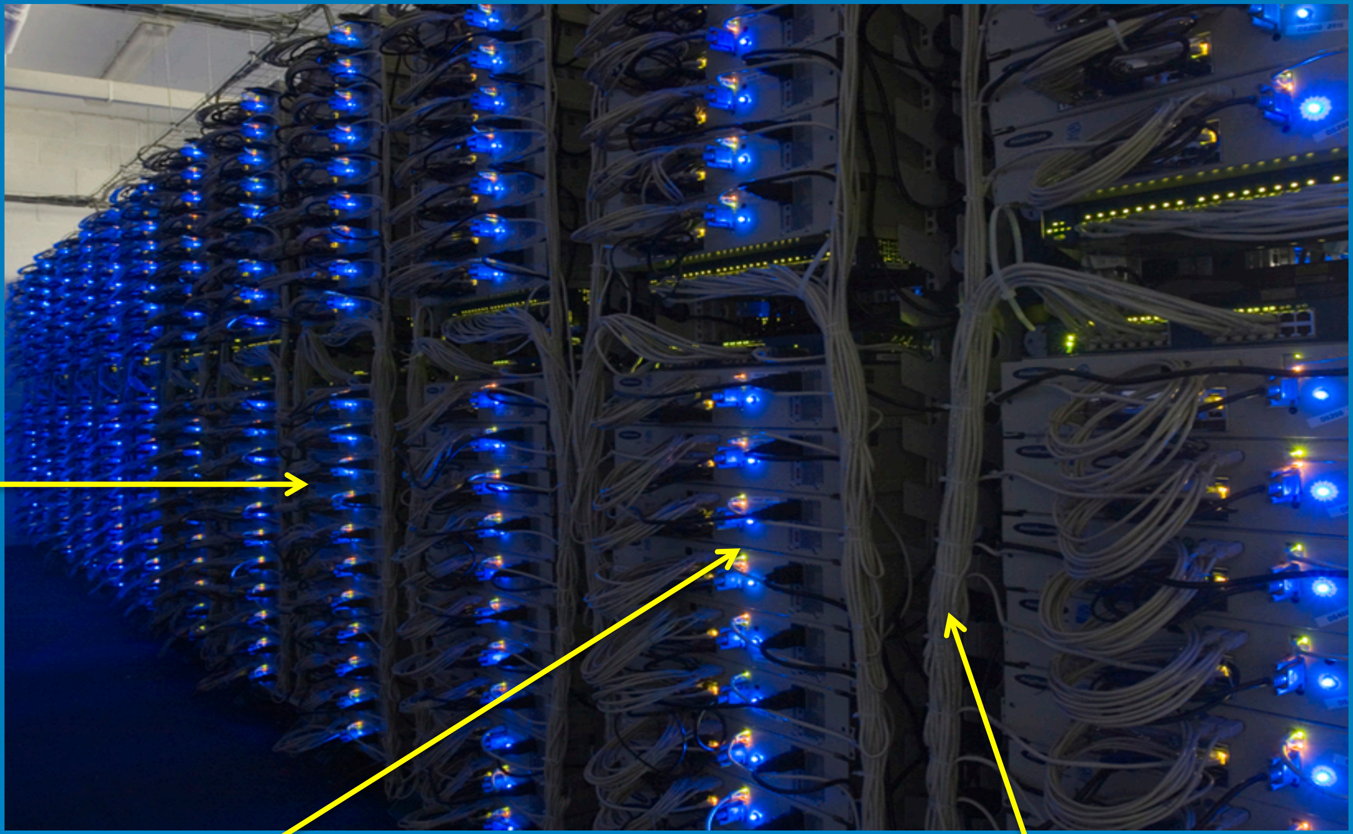
   DNS returns IP address of best CDN server for the user

2) Browser requests the chosen server for web page.

3) Server assembles page, contacting content origin if necessary, and sends to user.

The Cost of Running an Internet-Scale Network

Server
Cost
(CapEx)

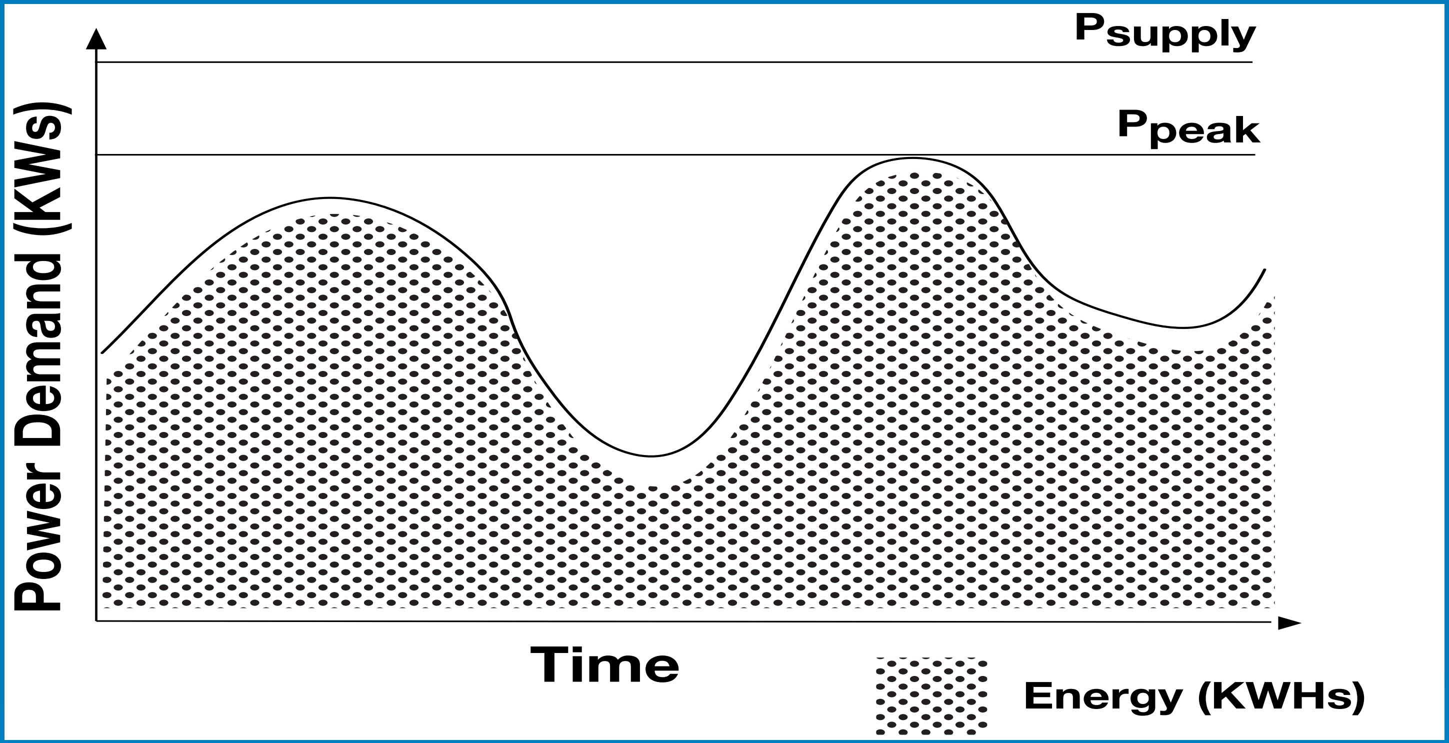


Not
Own!

Power
(and rack space)
Rent from colo provider
Example, Switch&Data

Bandwidth
From network provider
Example, Comcast

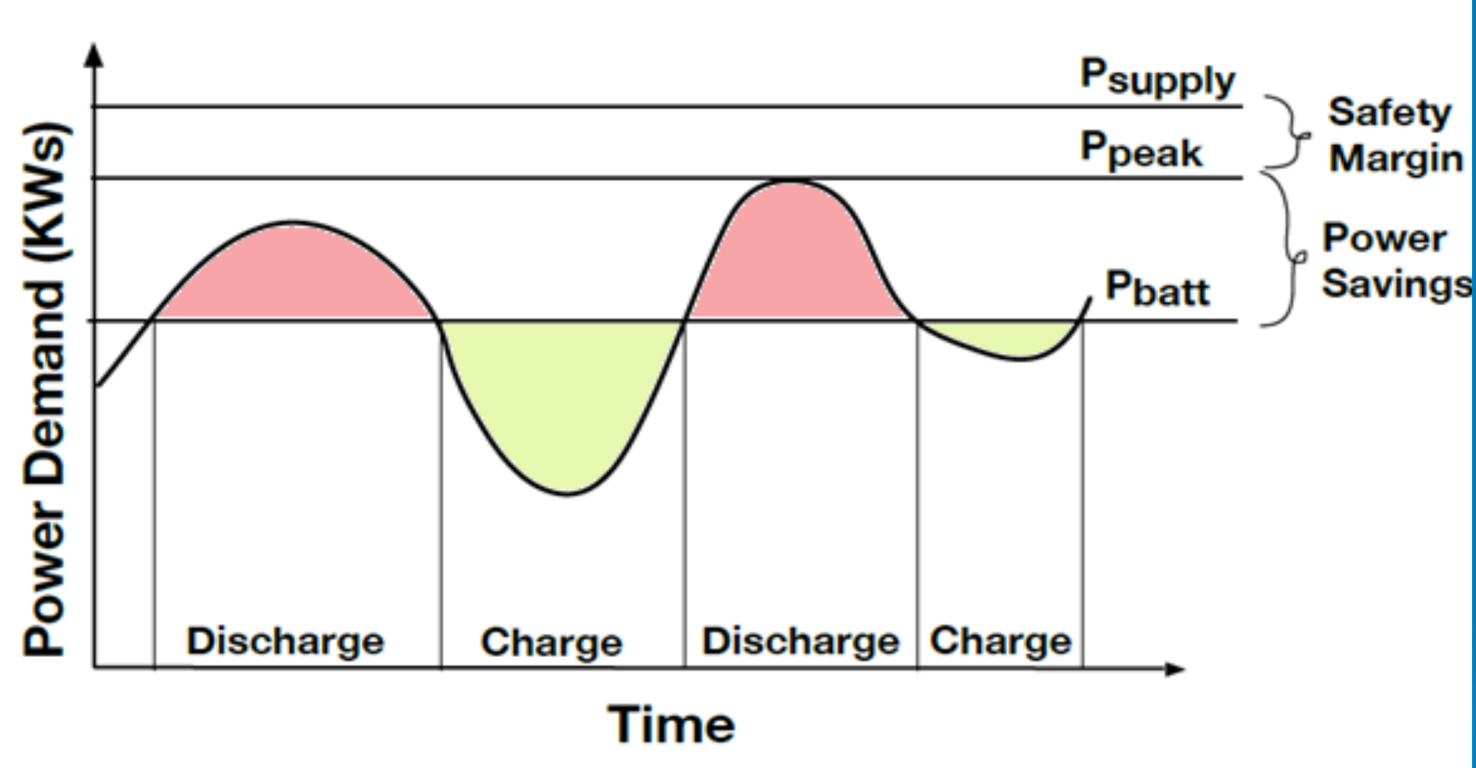
How CDNs buy power?



Supplied Power Model (Mostly): Pay for KW's supplied, not based on usage. Like cell phone minutes, use it or loose it!

Metered Power Model (Rarely): Pay based on usage.

Key Idea: Use batteries to reduce the power supply from P_{supply} to P_{batt} (+ safety margin)

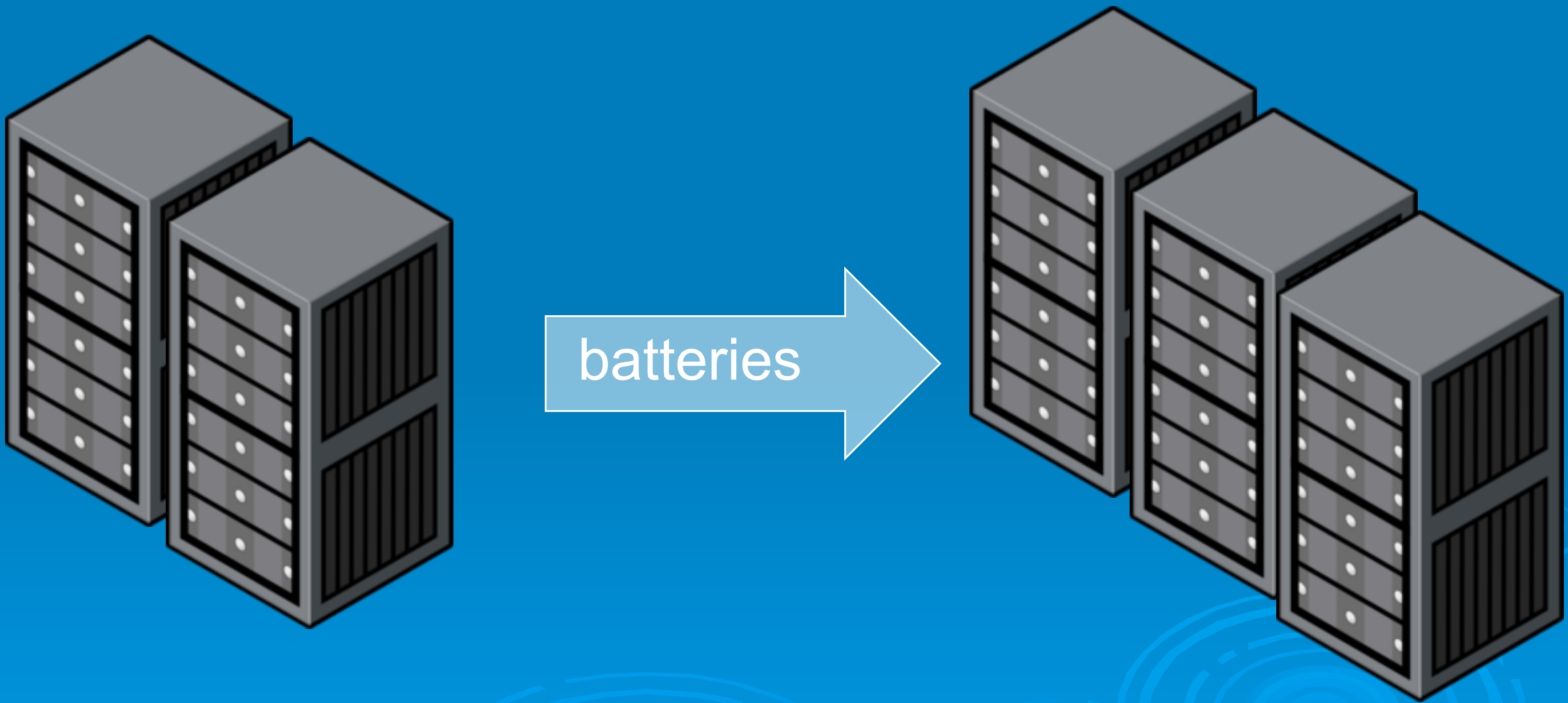


Power Savings: $(P_{peak} - P_{batt})$

Cost Savings: $c_p(P_{peak} - P_{batt}) - c_b B/L$

c_p= cost of power (\$/KW), c_b = cost of battery (\$/KWH), B= battery size, L = battery lifetime.

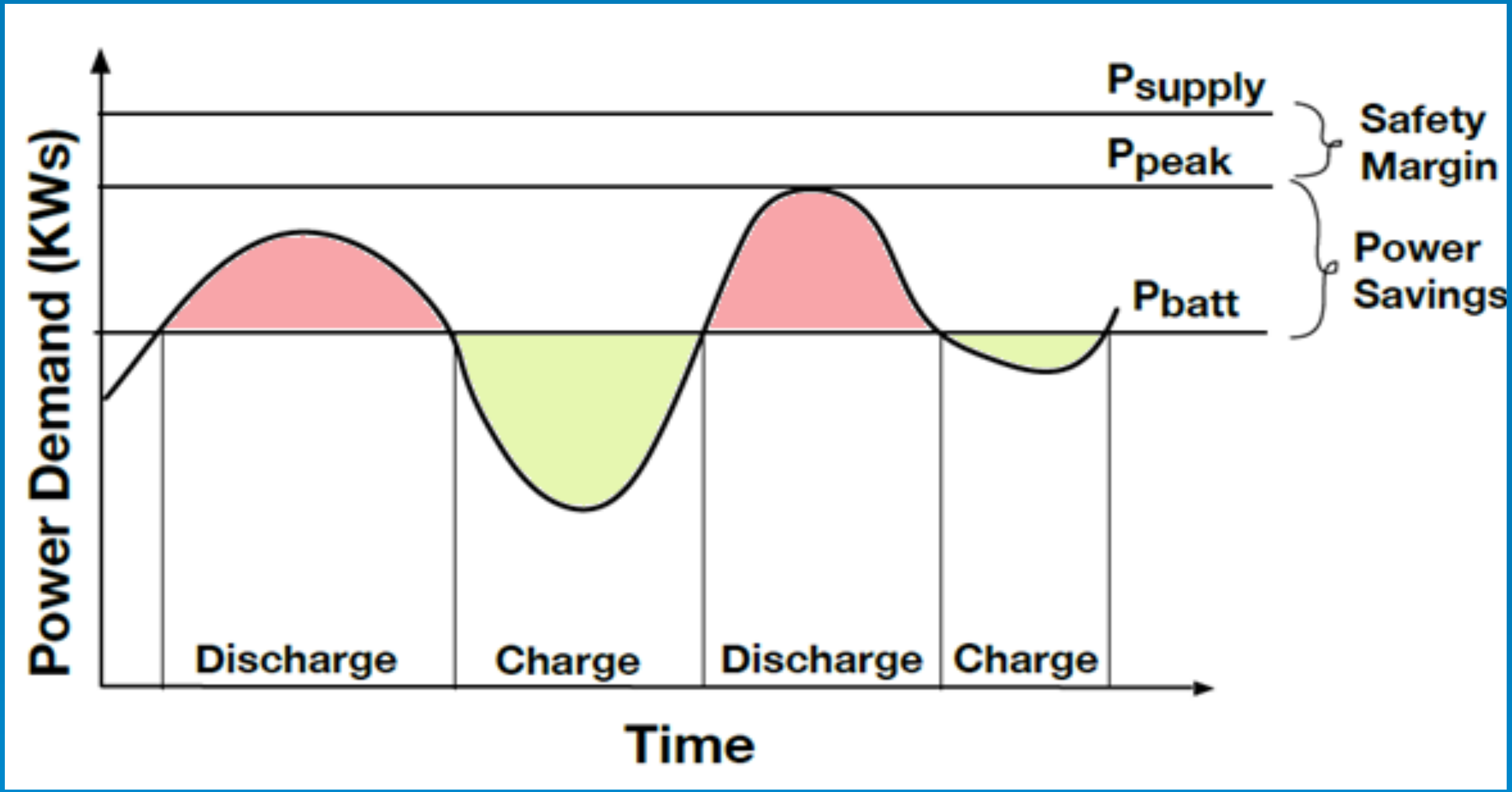
Alternate view: Use batteries to deploy more servers for the *same purchased power supply*



Outline

- Provisioning Algorithms
- Empirical Evaluation: Power Savings
- Empirical Evaluation: Cost Savings
- Concluding Remarks

Power Supply Minimization



Optimum P_{batt} = min value such that for *every time interval* (charge area) x (1 – α) + B ≥ (discharge area), given α = loss factor, B = battery size.

Fast algorithm: $O(T^2 \log(P_{peak}))$ per cluster

Cost Minimization (LP formulation)

Minimize Total Power Cost + Total Battery Cost

- Input: Power demand over time for each cluster.
- Output: Amount of power supply (KWs) and battery (KWHs or minutes) to be provisioned for each cluster.

Constraints:

- [*Demand Satisfaction*.] For each cluster, power demand is met by the available power supply or battery charge.
- Additional Constraints: Battery Lifetime, Global Load Balancing, etc.

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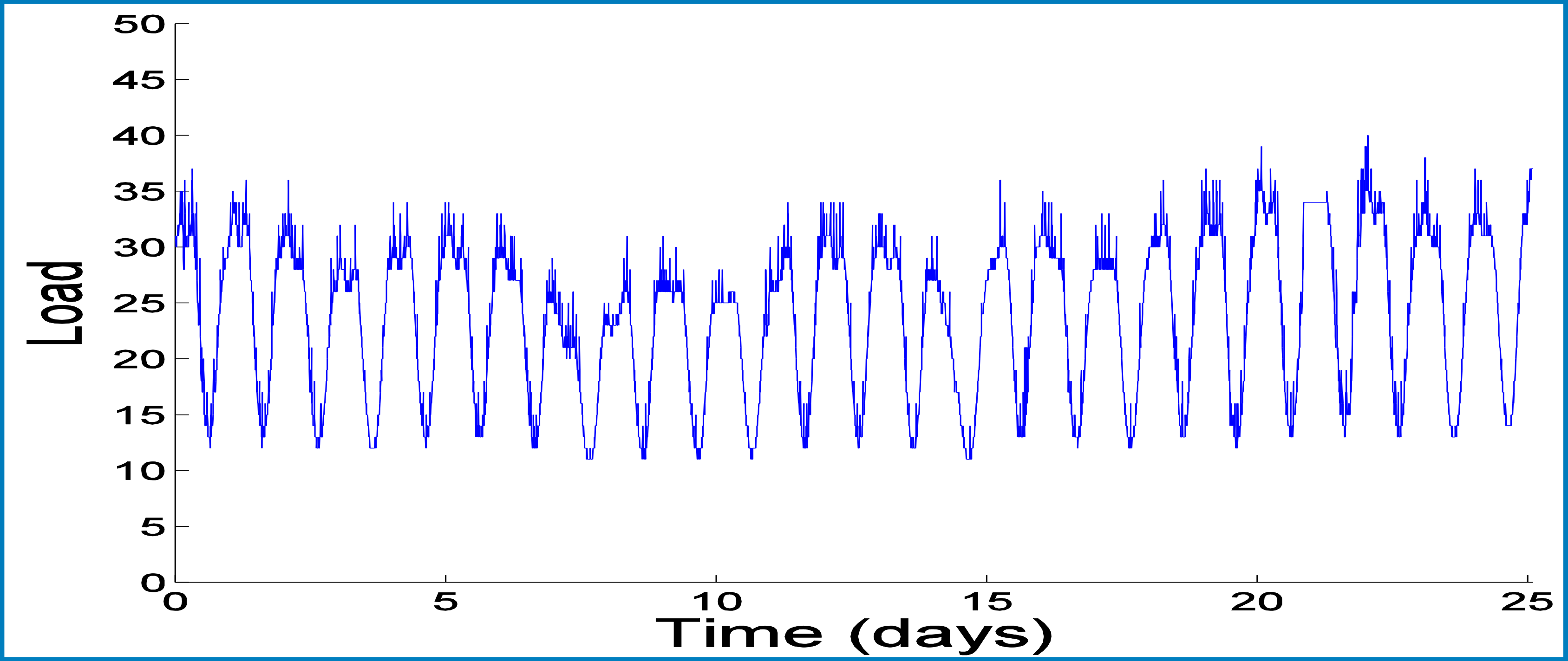
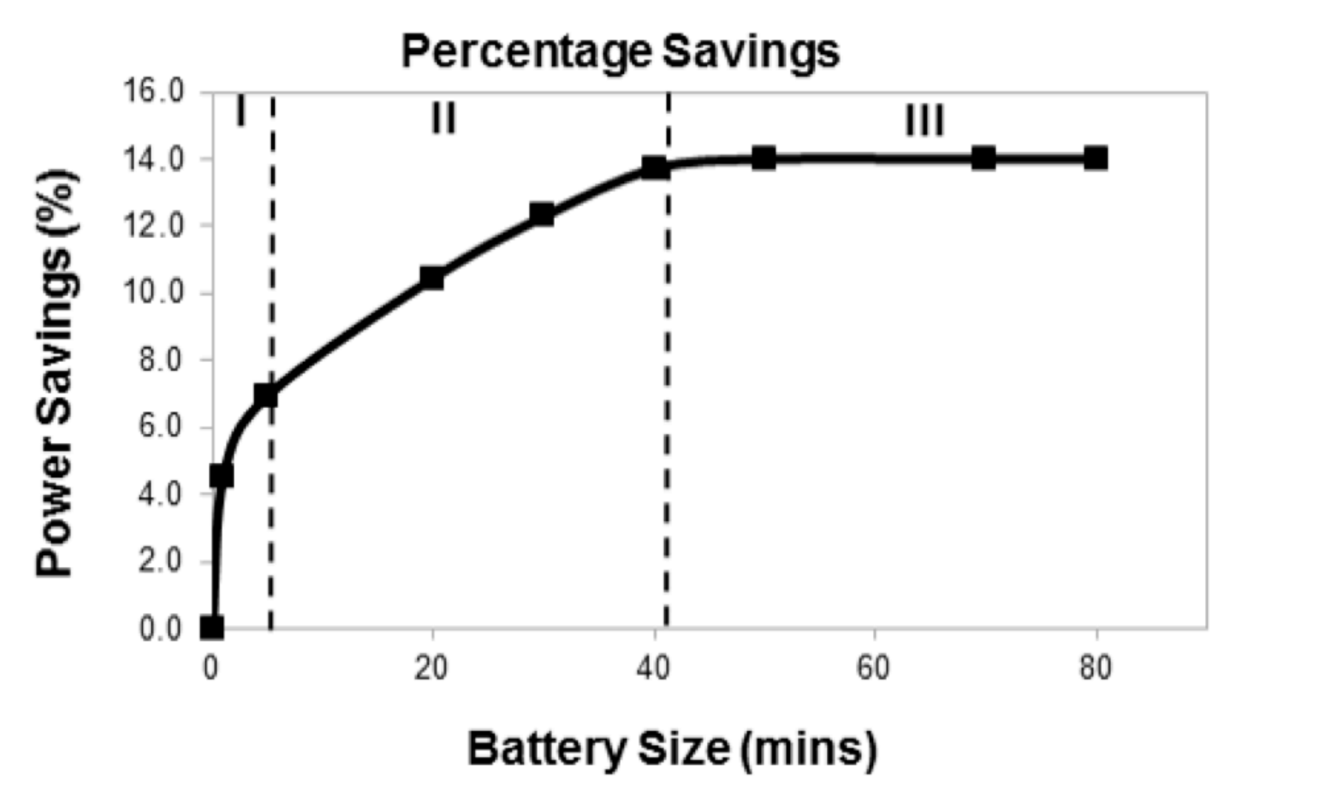
Akamai Load Traces



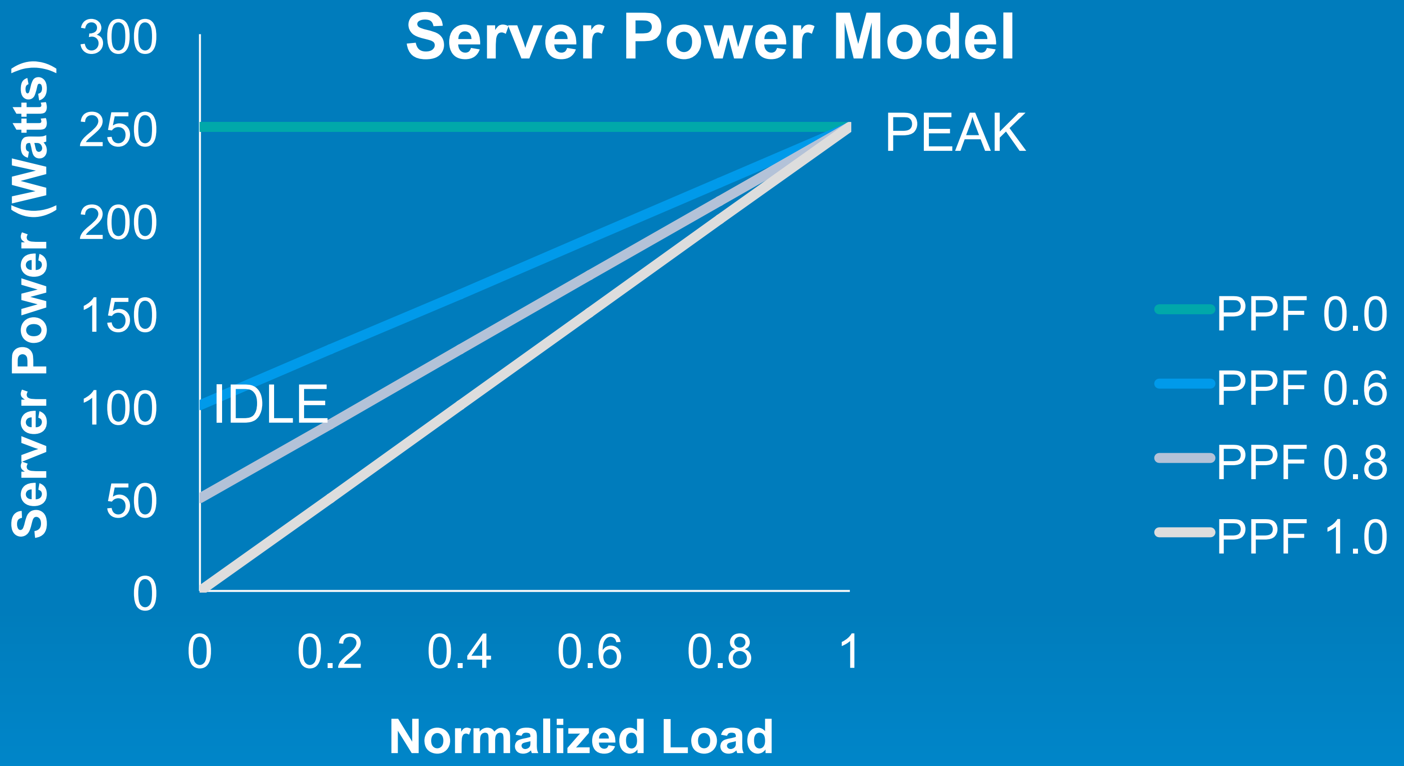
- Average load per server measured every 5 minutes across 22 major clusters in the US of Akamai's CDN over 24 days.
- 15, 439 servers measured, 950 Million user requests, 800K peak concurrent requests
- Busy holiday shopping season.

Power Savings versus Battery Size



- Rapid increase to 7% (battery size = 5 mins, comparable to an UPS battery).
- Grows more slowly to about 14% (battery size = 40 mins).
- Reaches a point of diminishing return beyond.

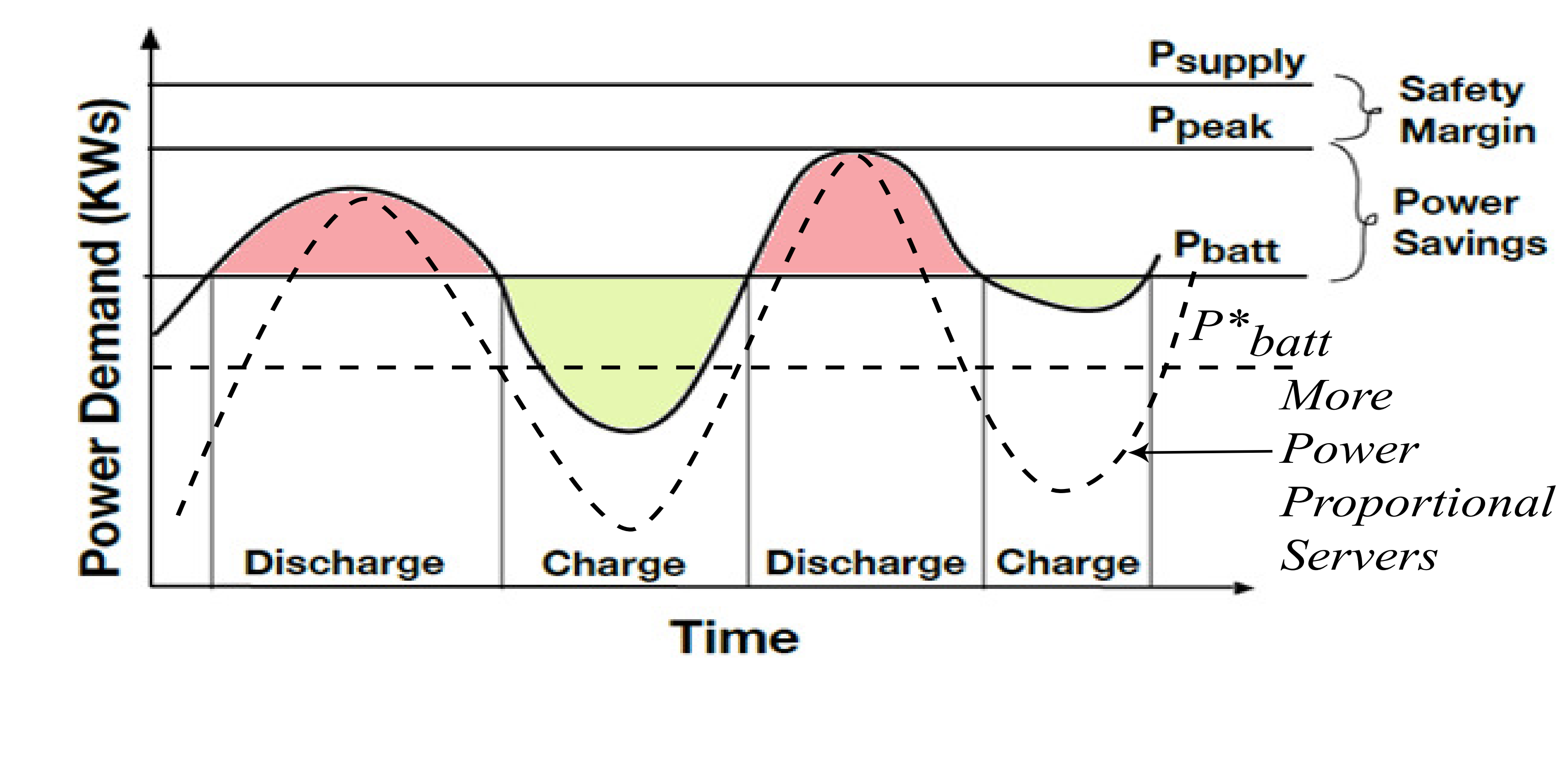
The Quest for Power Proportional Servers



Power Proportionality Factor (PPF) = (PEAK– IDLE)/PEAK.

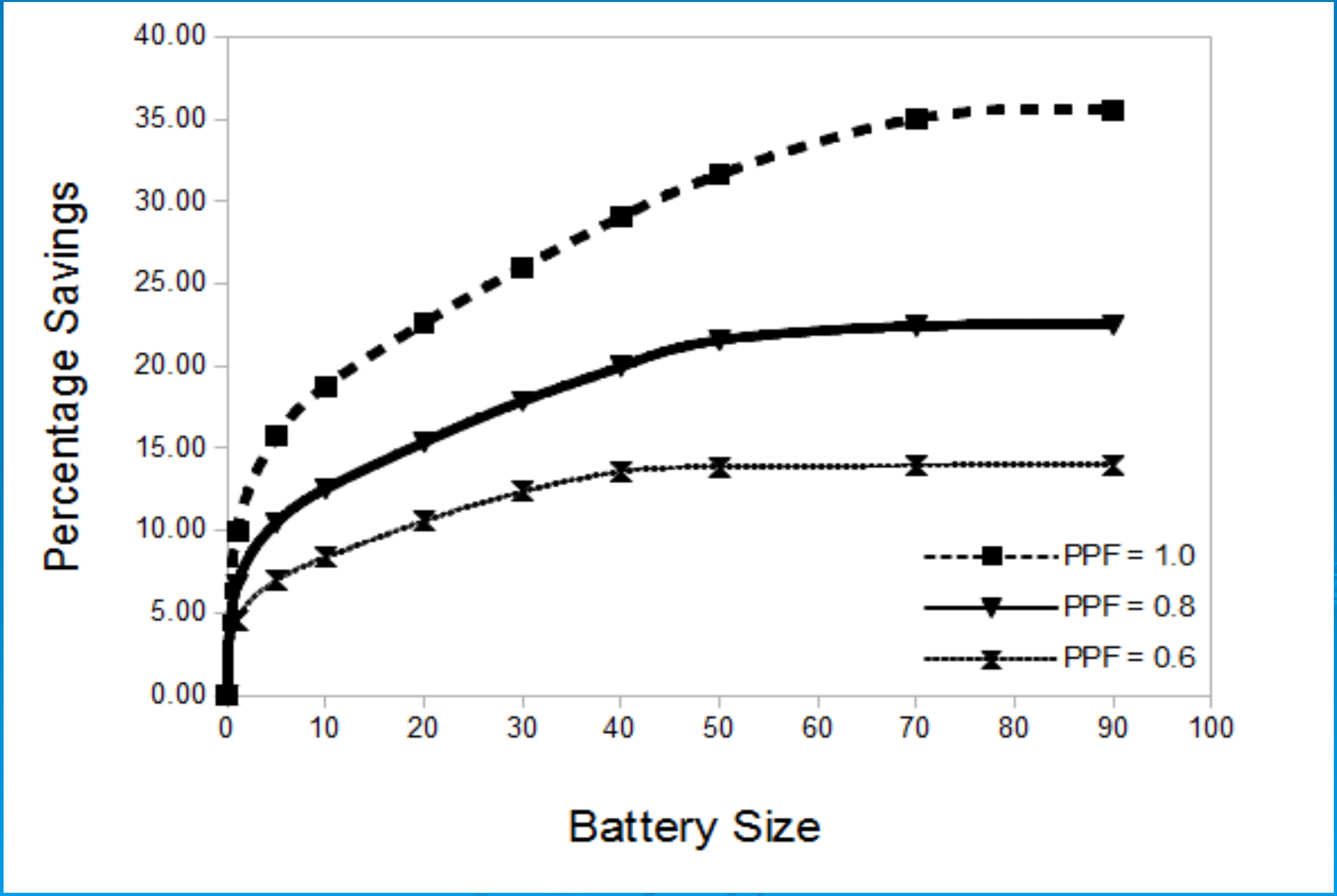
(worst) 0.0 <= PPF <= 1.0 (best)

Power savings increase as servers become more power proportional (intuition)

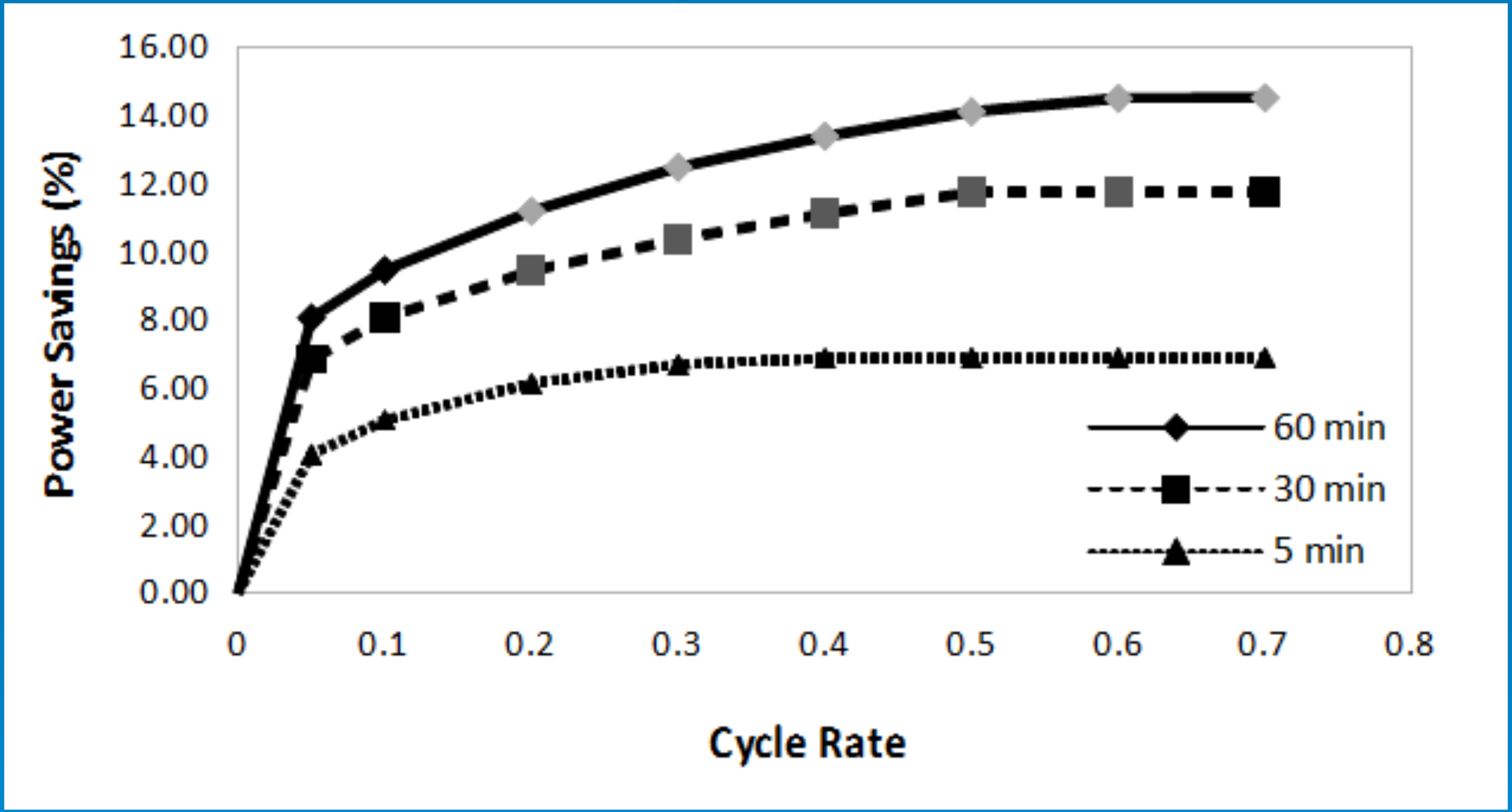


As servers become more power-proportional, the power demand curve gets sharper peaks resulting in more power savings of ($P^{*}_{batt} - P_{supply}$), instead of ($P_{batt} - P_{supply}$).

Power savings increase as servers become more power proportional



Battery Lifetimes



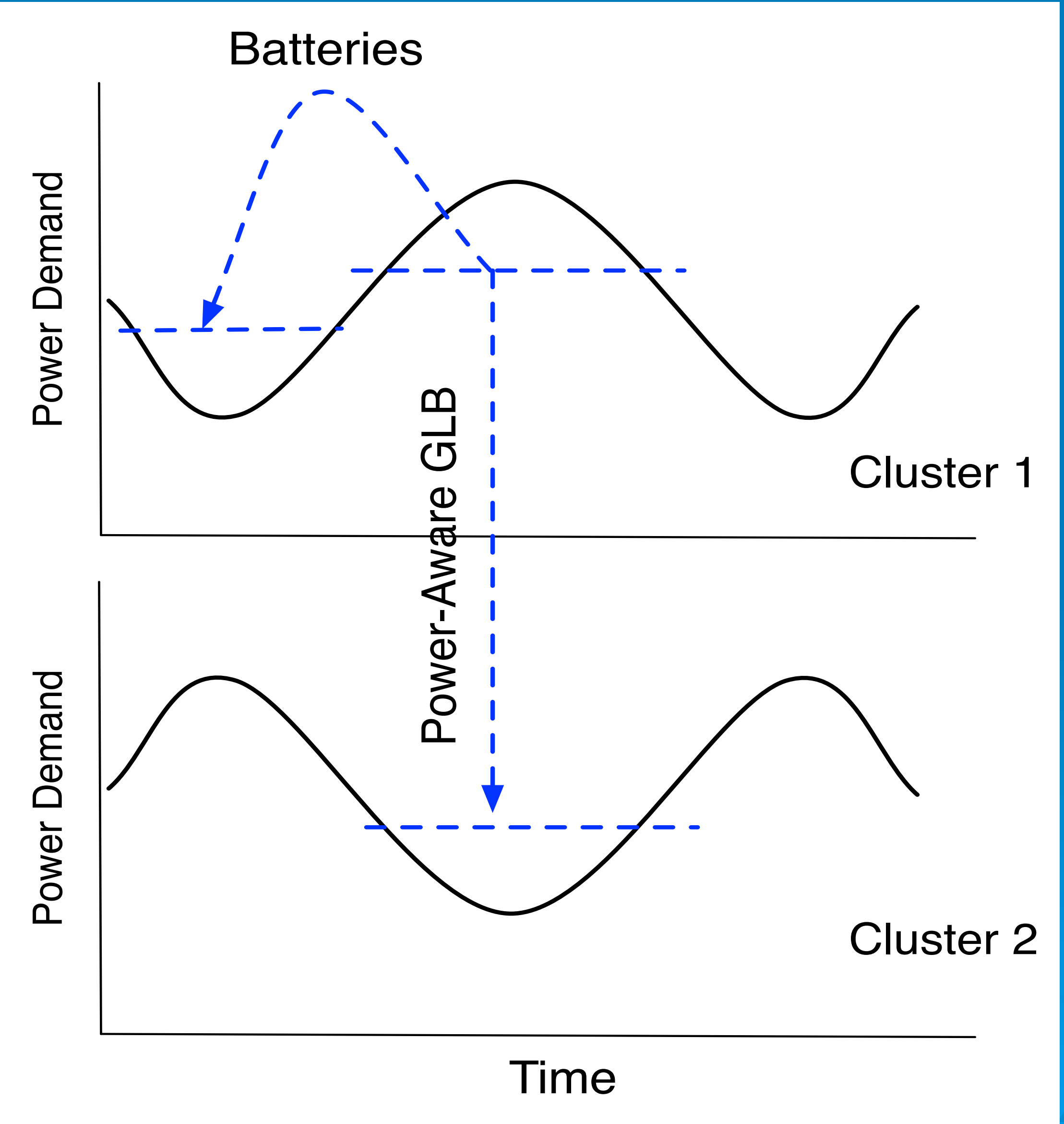
Most power savings can be realized with a small cycle rate (say, 1 in 3 days).
Consistent with a 5-year battery lifetime. (Typical lead-acid battery lasts about 600 to 700 full charge-discharge cycles.)

Global Load Balancing (GLB): Moving load (and power demand) across clusters

Mapping subsystem maps each user to a server.

- Map to cluster (Global Load Balancing)
- Map to server in chosen cluster (Local Load Balancing)

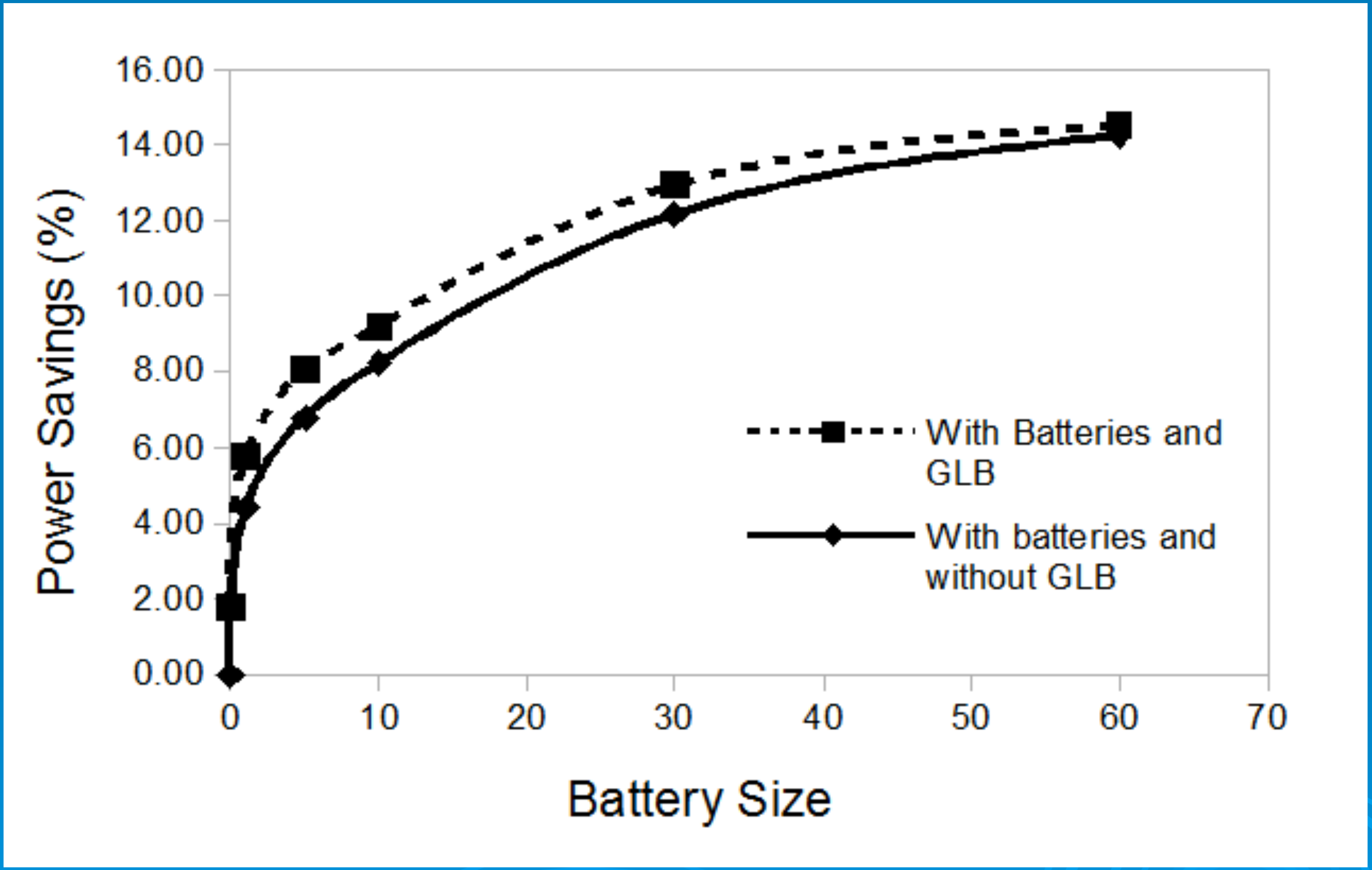
Power-aware GLB versus Batteries



Power-aware GLB: Knows how much power supply is available at each cluster and ``fits'' demand to the supply.

Power-aware GLB does in space what batteries do in time.

Batteries versus Power-Aware Global Load Balancing



Batteries provide more benefit than global load balancing.
Maximum additional benefit of GLB over batteries was 1.78%.

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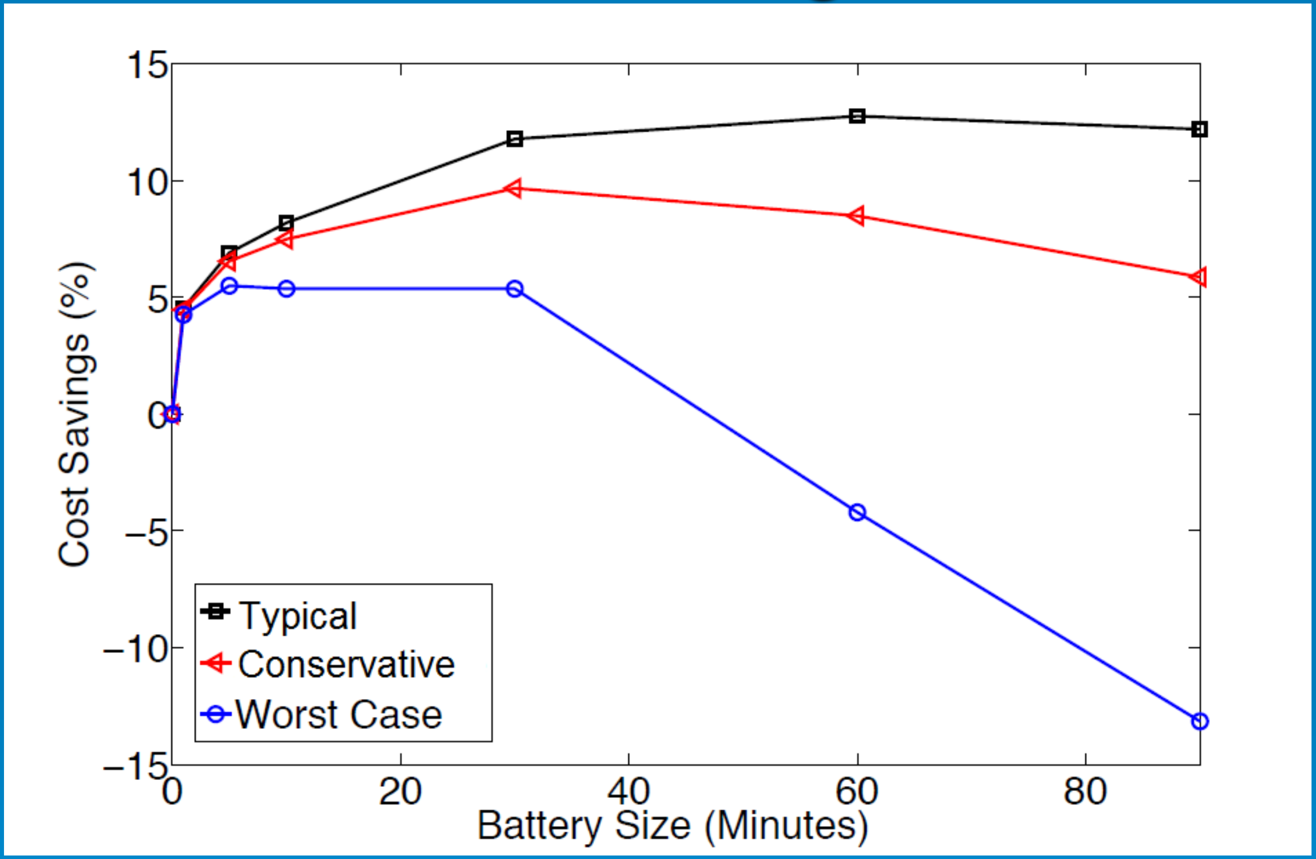
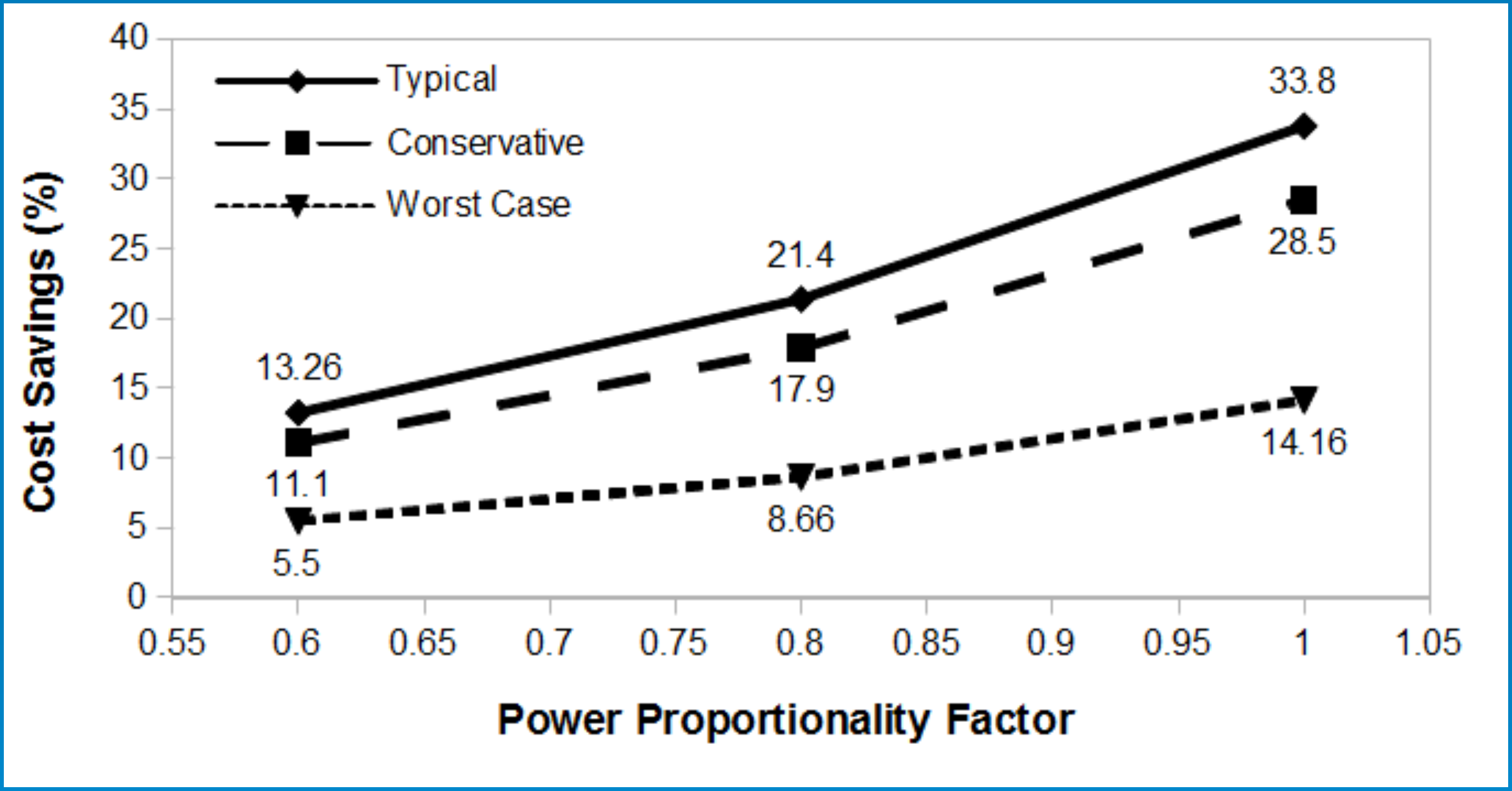
Cost Savings



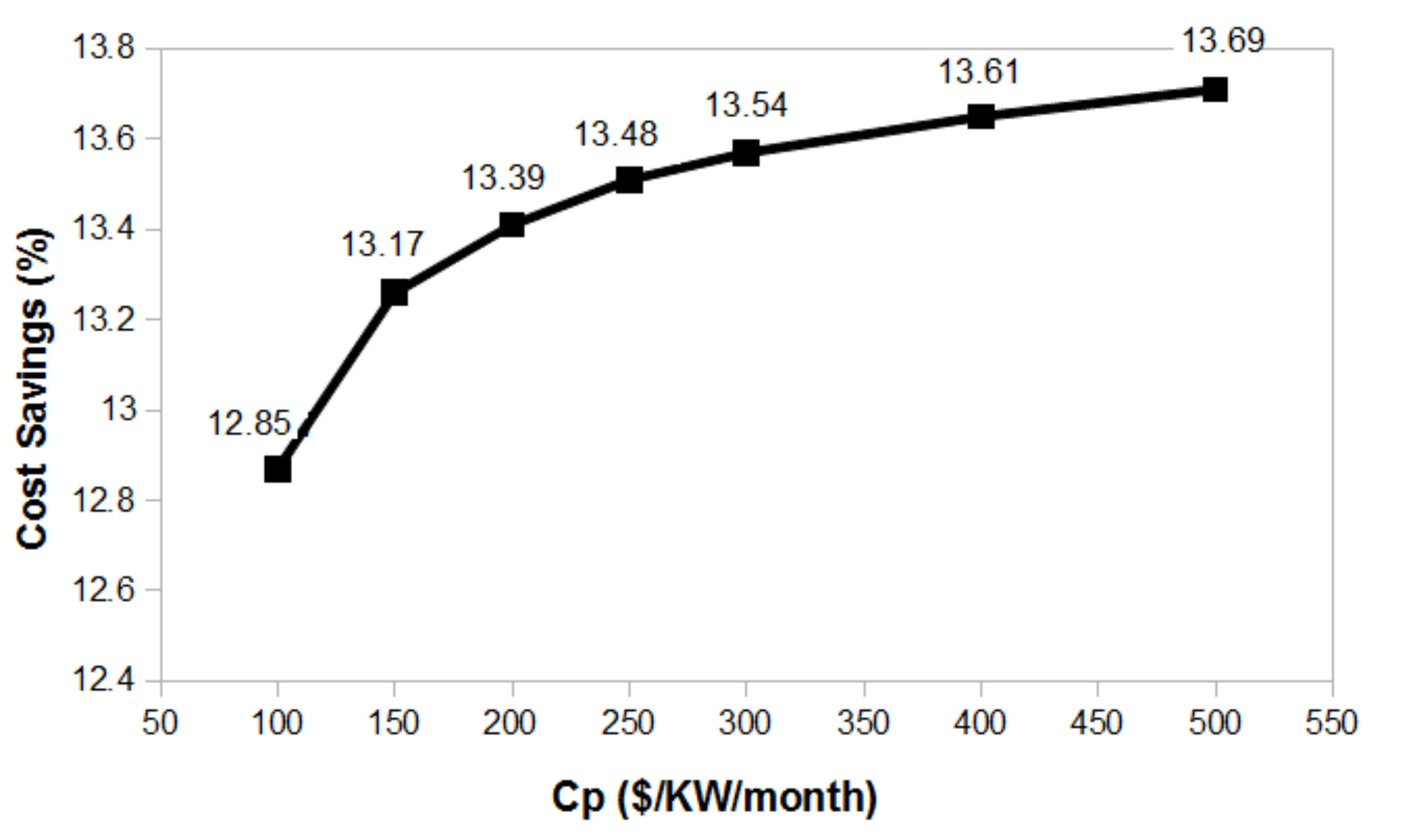
Typical Battery: $100/kWh, Lifetime=5 years
Conservative Battery: $300/kWh, Lifetime = 3 years
Worst Case Battery: $500/kWh, Lifetime = 1 year
Power cost = $150/kW per month

Cost Savings and Power Proportionality



Cost savings increase as servers become more power proportional.

Cost Savings and Power Prices



Cost savings increase with power supply prices, as cost of battery is recovered sooner. Impact greater in absolute terms.

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Contributions

Establishes batteries as a key architectural element of Internet-Scale Distributed Networks such as CDNs.

First to propose and quantitatively evaluate batteries for power supply minimization and the resulting operating expense (OpEx) reduction.
(Related battery work in other contexts: reliability (UPS), demand response in a data center or home…)

The case for batteries gets even better with future technology trends of (a) more power-proportional servers, (b) better and cheaper batteries, and (c) rising power costs.

Why the time for batteries may have finally come?

- One of only a few ways to save power costs in the supplied power model. Power costs will be a significant factor of the OpEx of Internet-Scale Distributed Networks in the next decade.
- Server-level or rack-level batteries are now technologically feasible, e.g., used for distributed UPS by Google, Facebook…
- Virtuous cycle: Batteries convert improvements in energy efficiency into cost savings.

Questions?