Right-sizing Geo-distributed Datacenters for Latency and Availability

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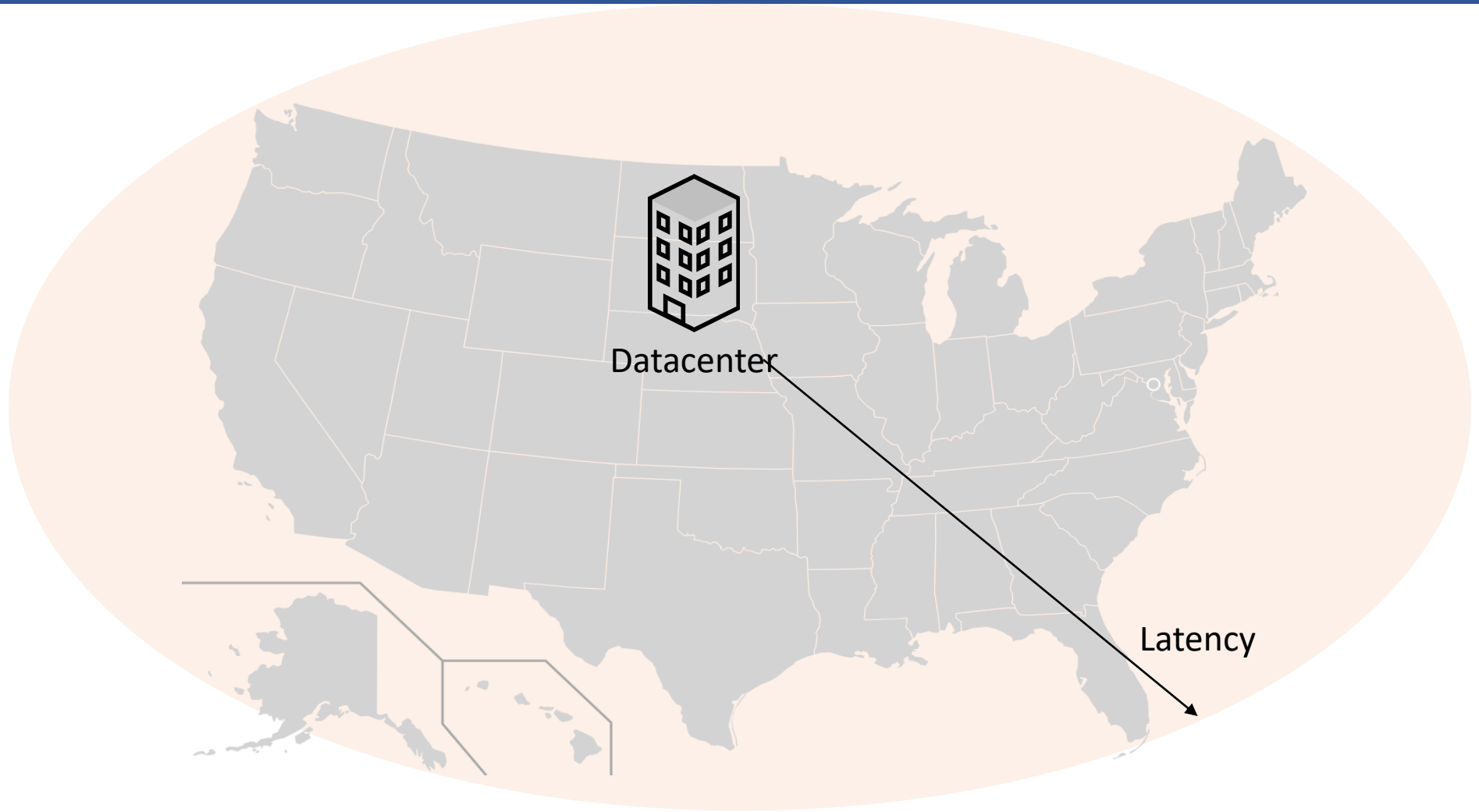
Latency is important for apps



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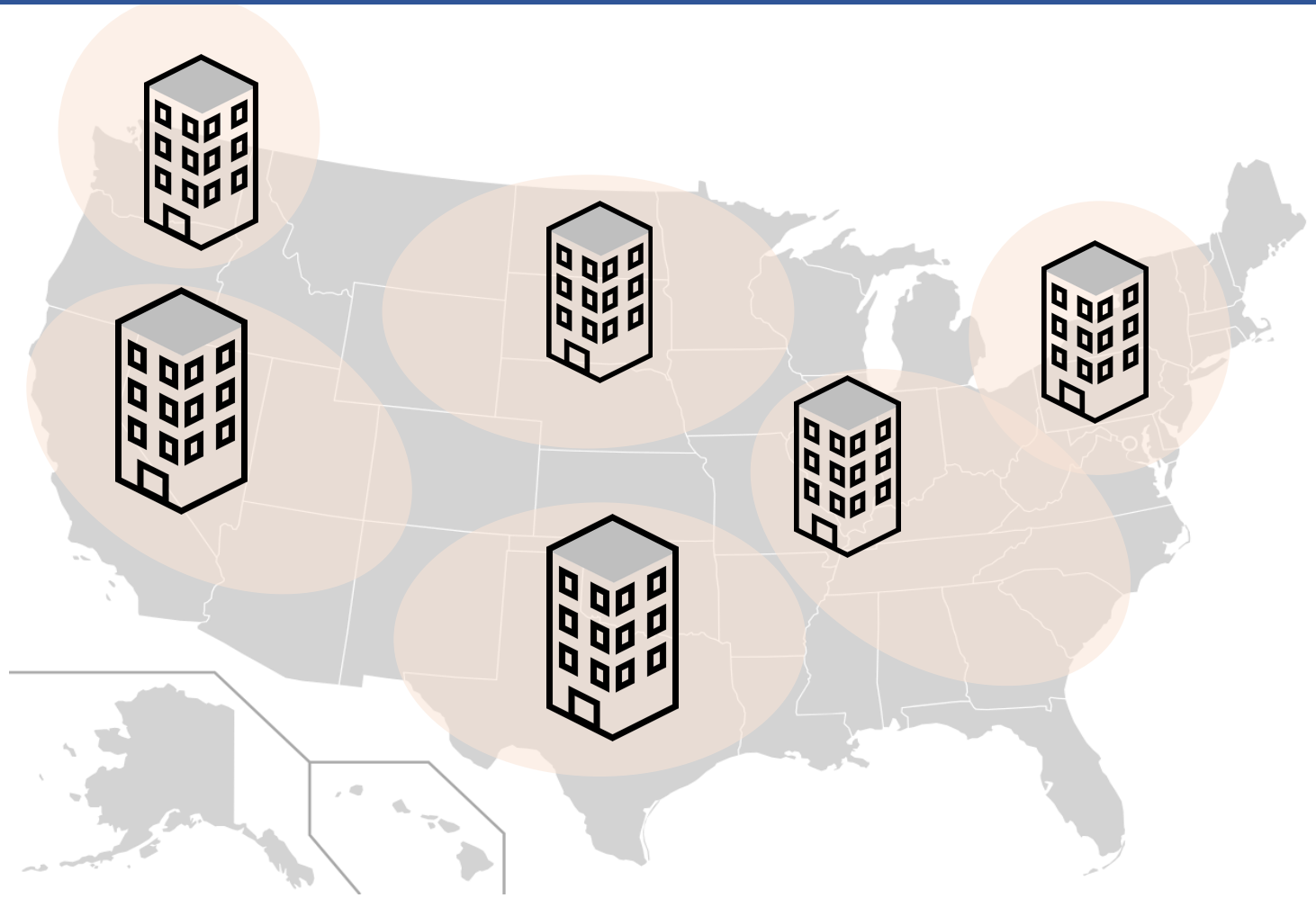
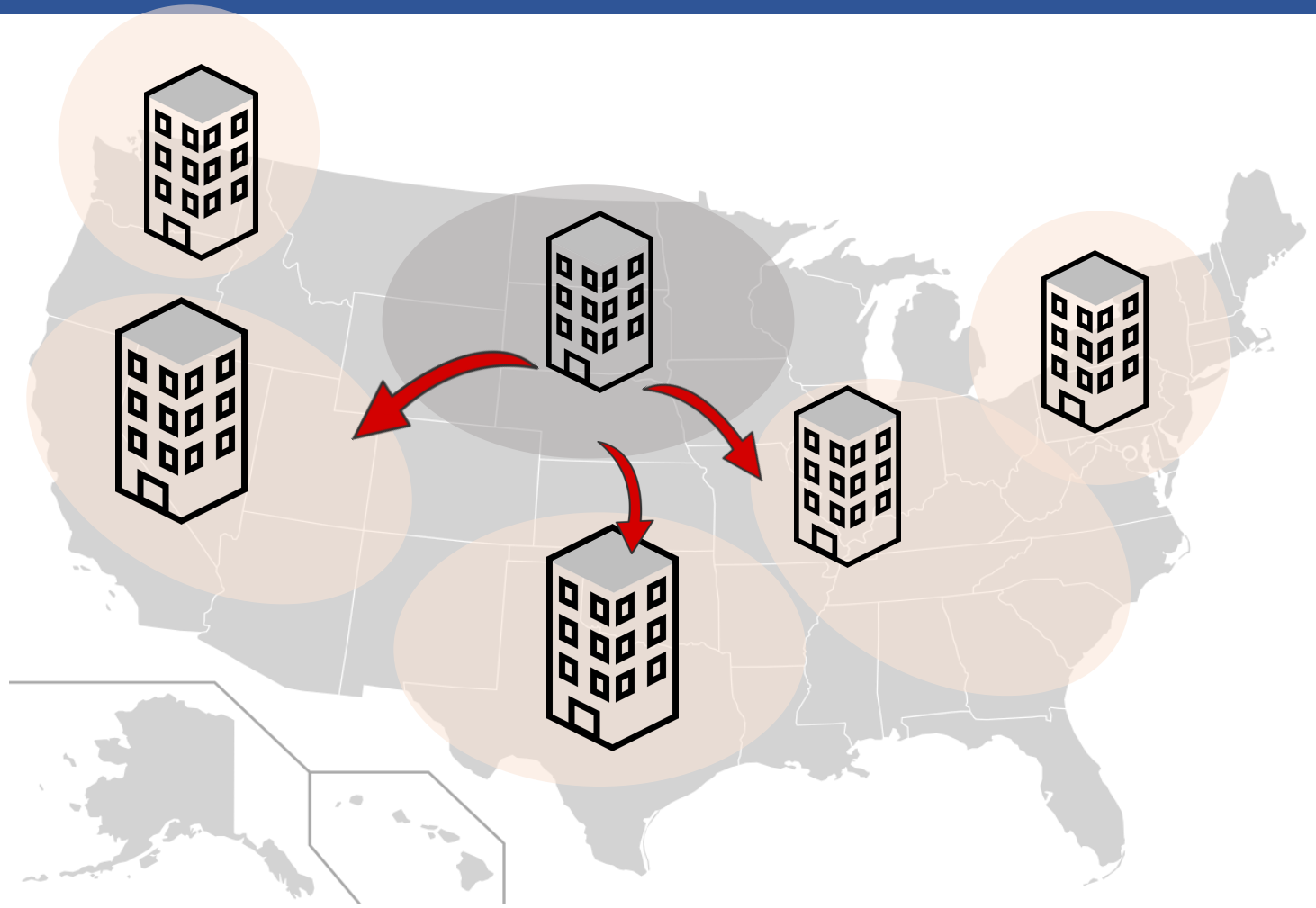


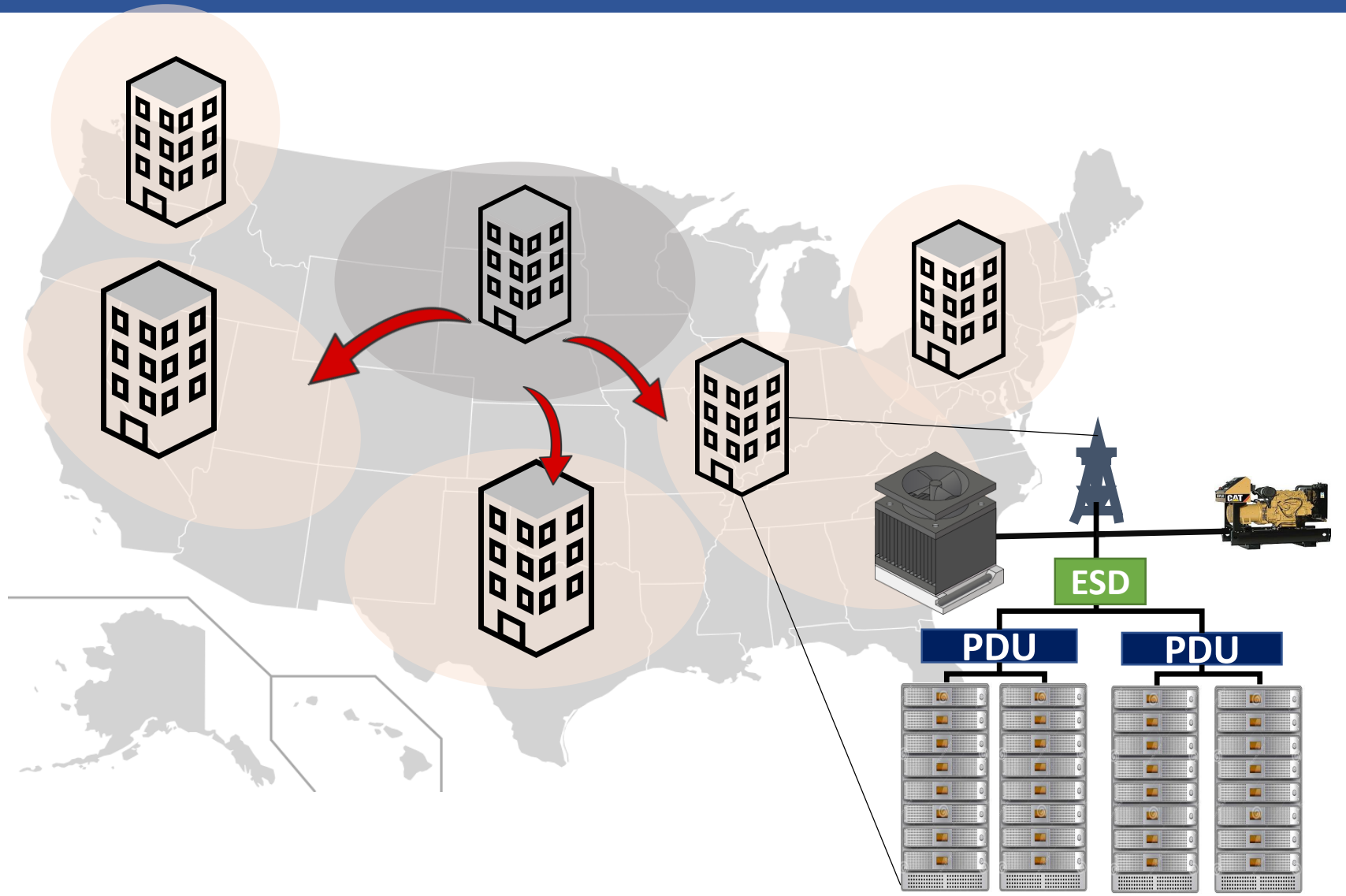
Geo-distribution helps to achieve low latency

Availability is important for apps

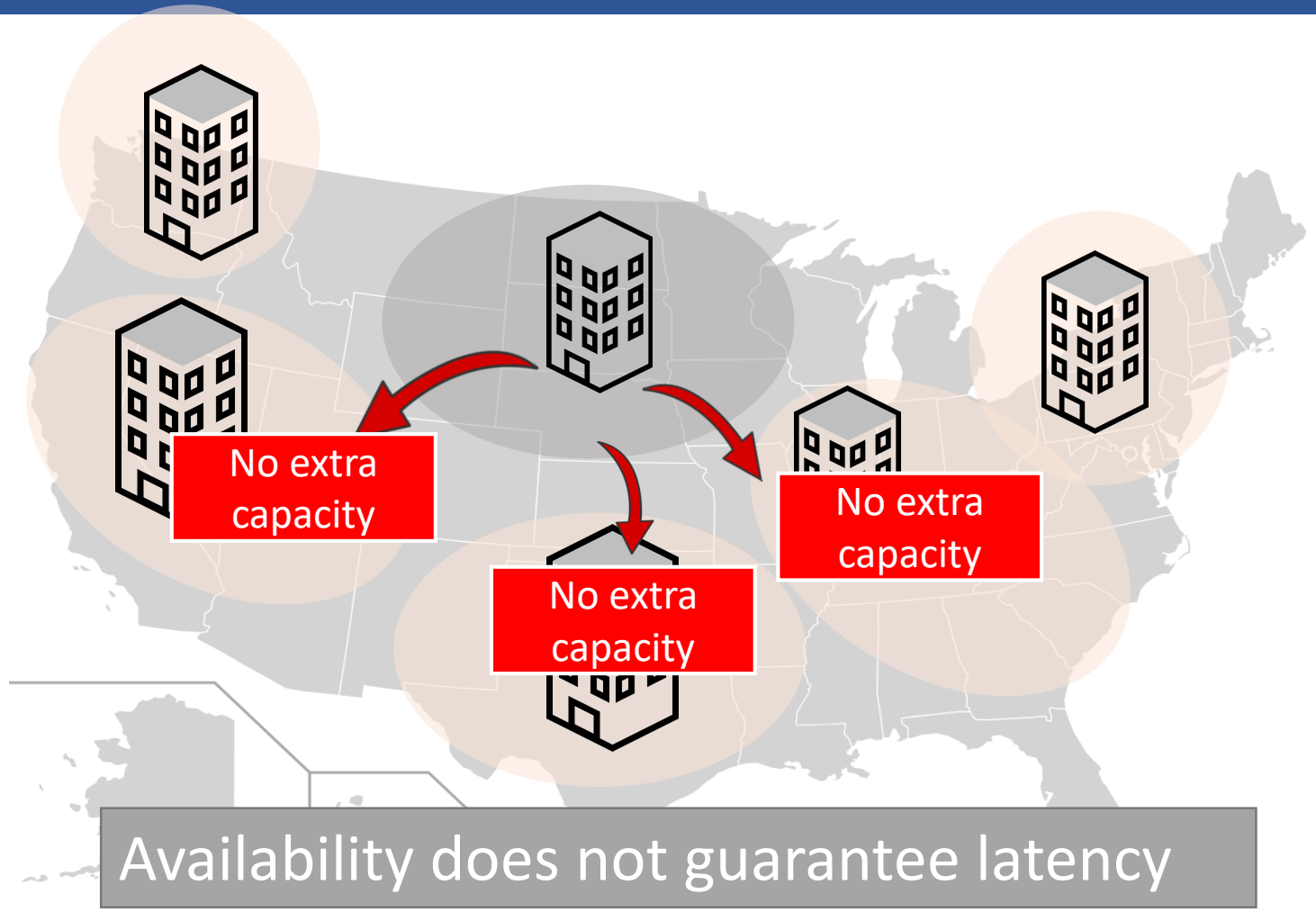


Geo-distribution can be leveraged to achieve high availability

Cloud infrastructure is not elastic



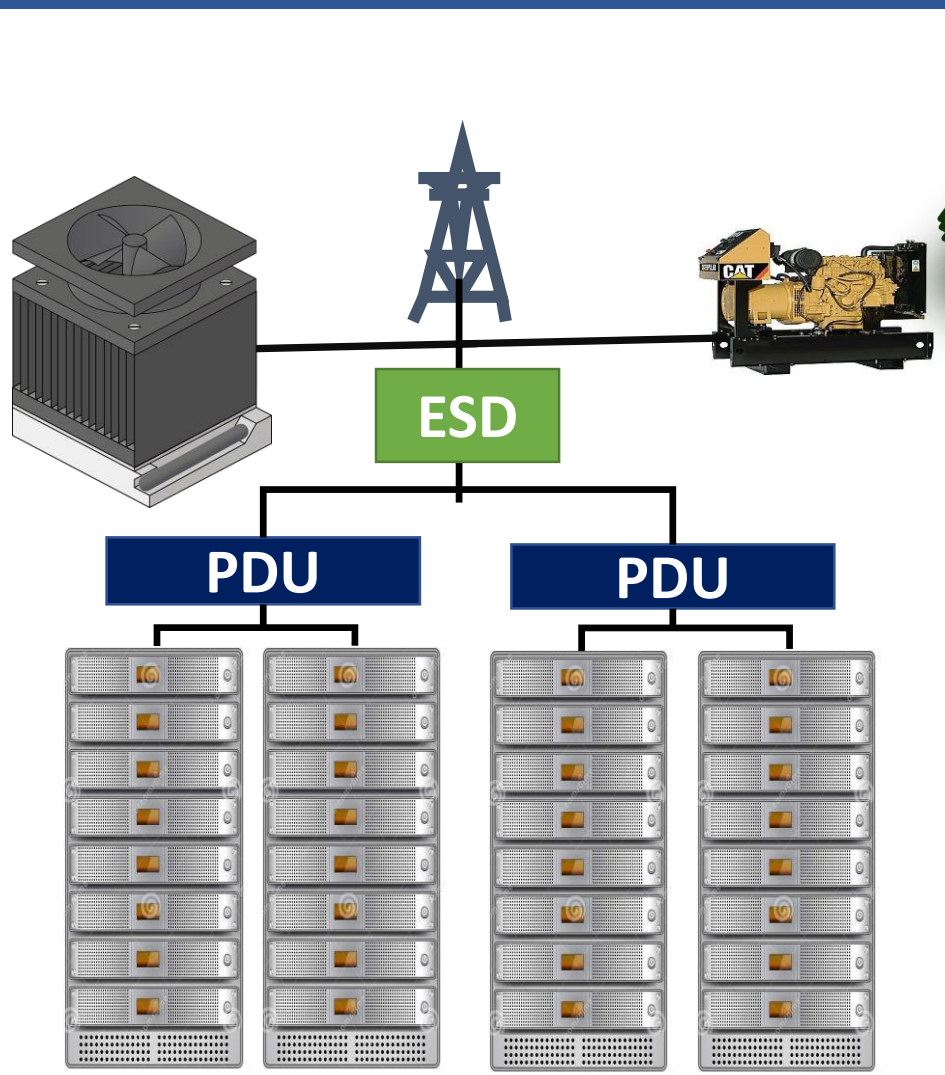
Cloud infrastructure is not elastic

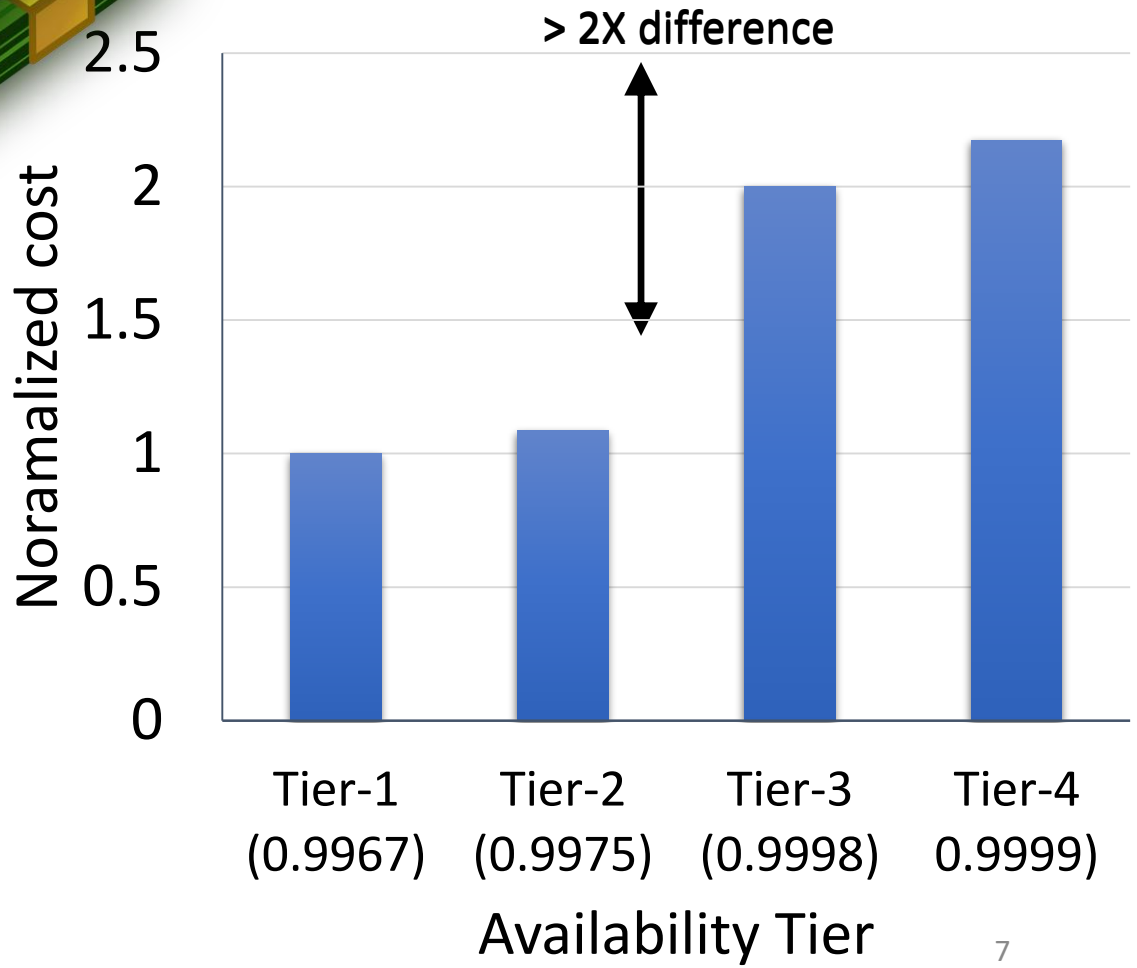


Availability does not guarantee latency

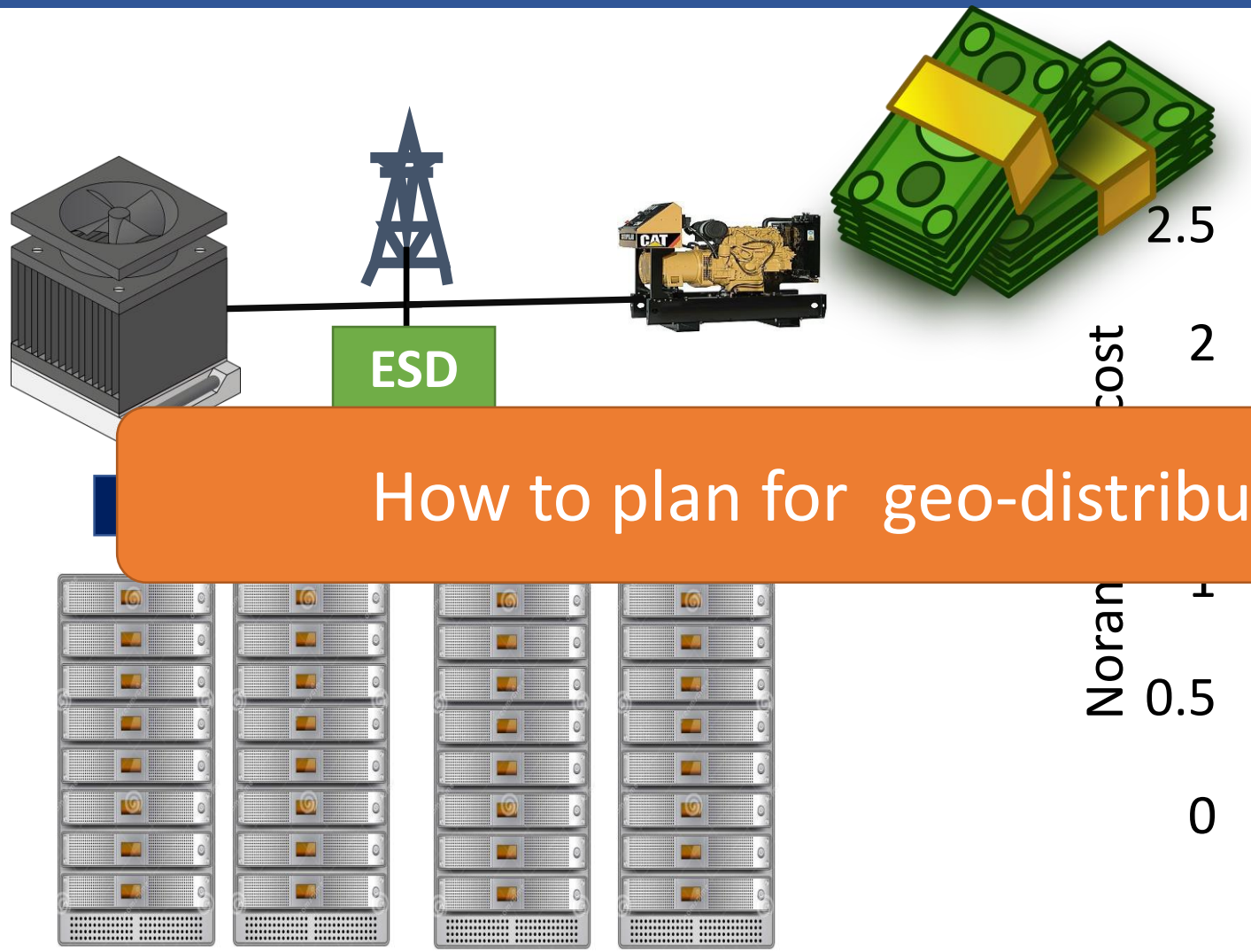
Physical infrastructure capacity has to be planned in advance

Capacity planning is important for operators, too

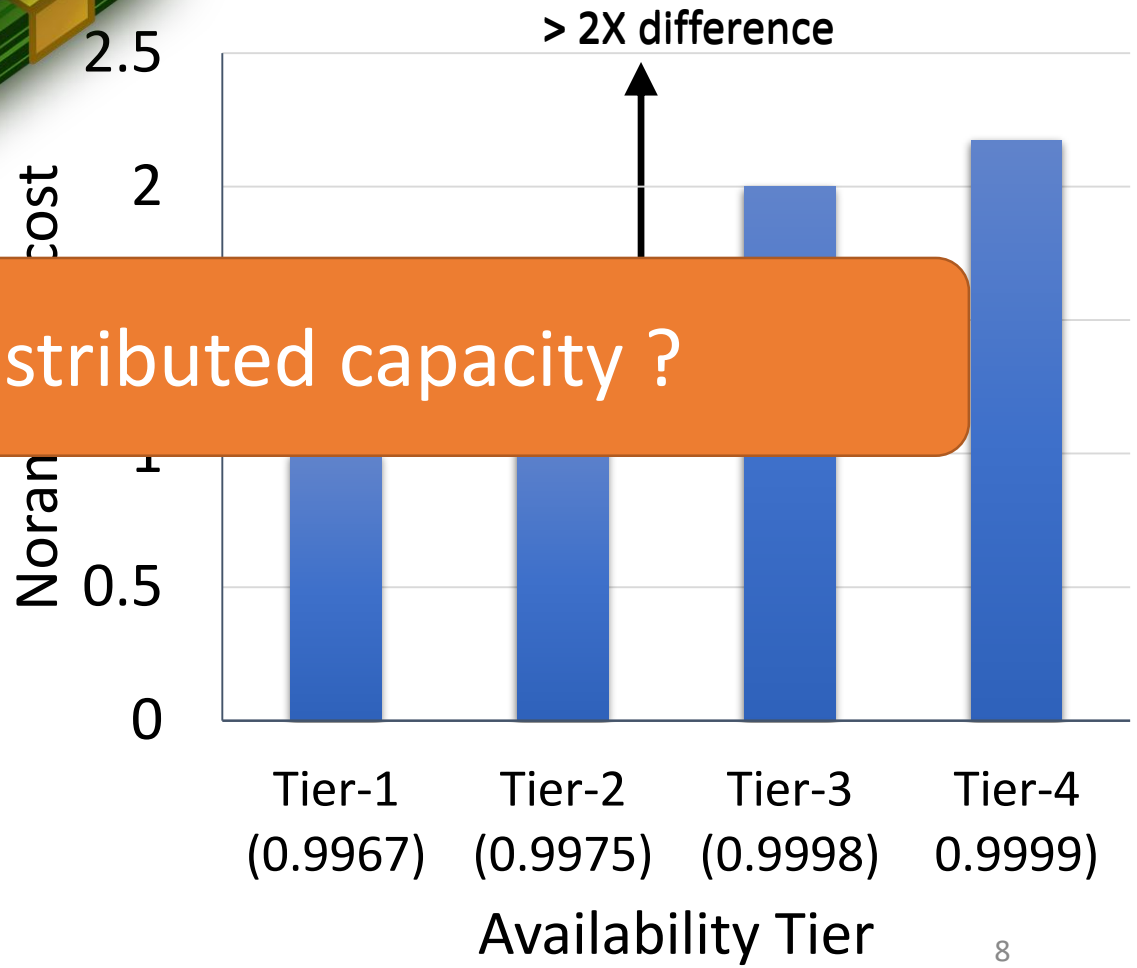




Capacity planning is important for operators, too

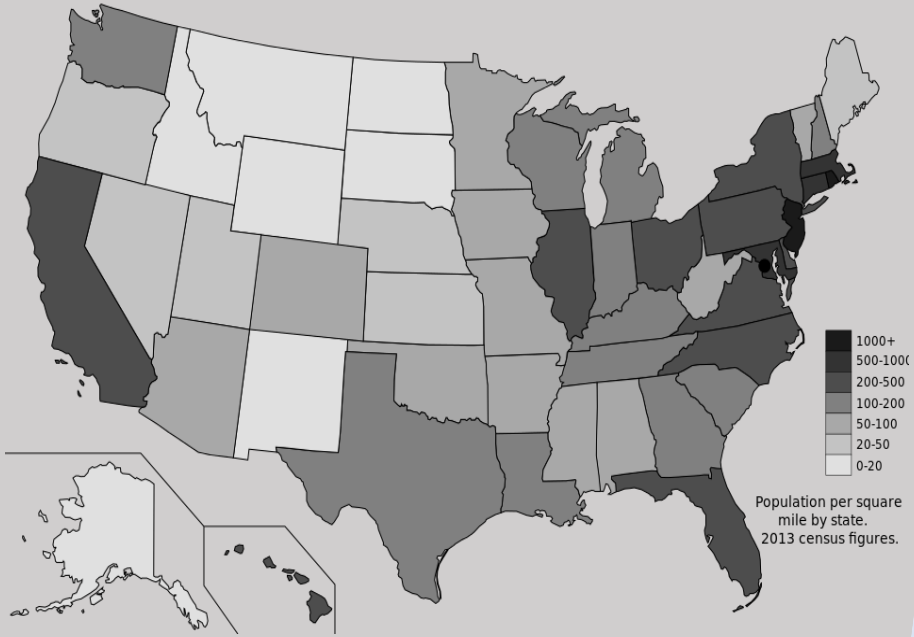


How to plan for geo-distributed capacity ?



Geo-distributed capacity planning

Geography

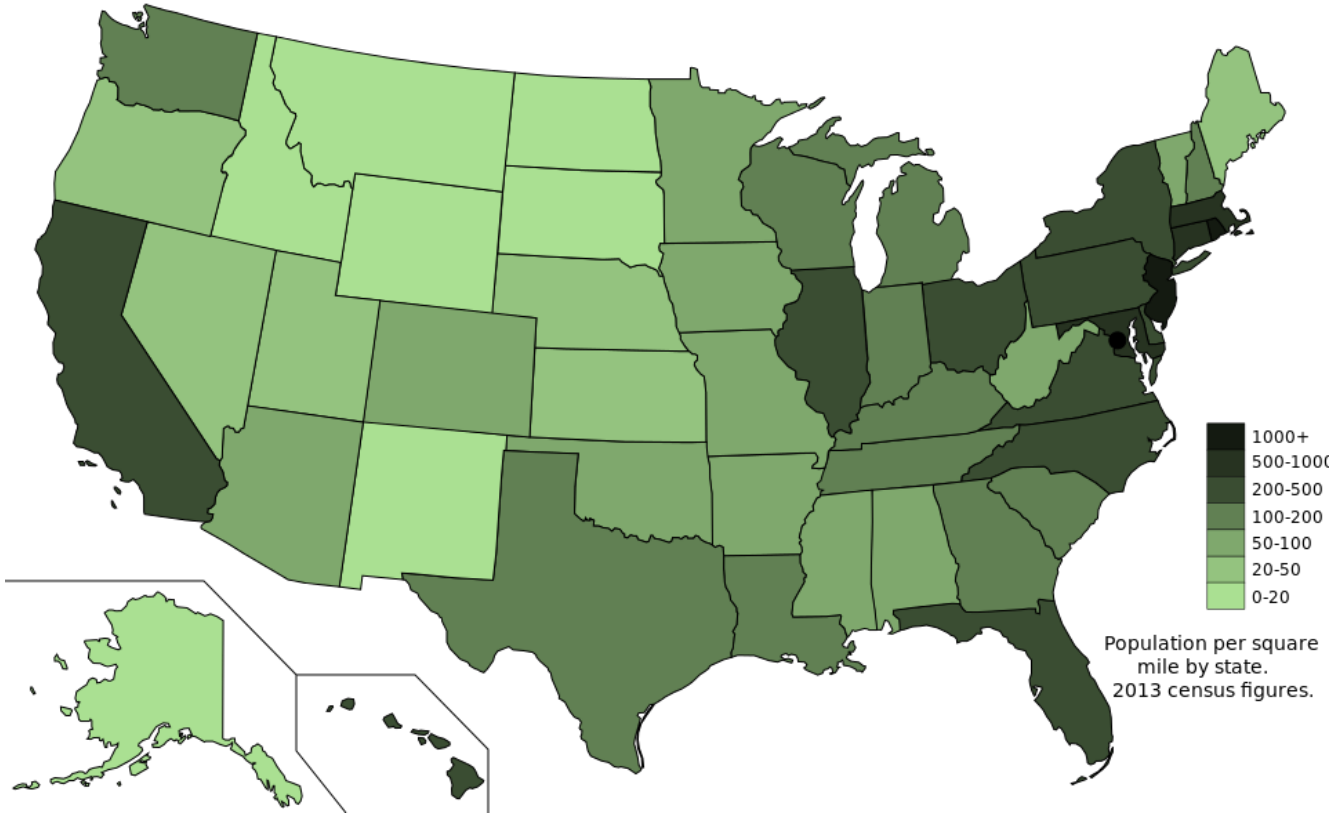


Datacenter

Application

Geographical factors

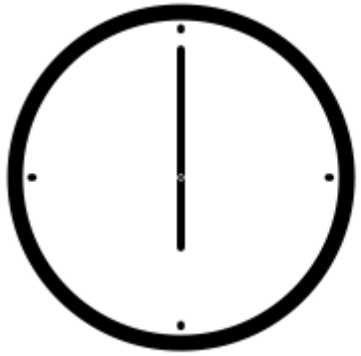
Client distribution may vary with population

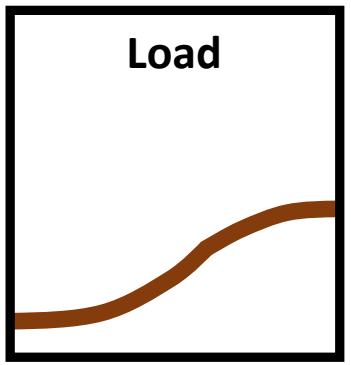


Source: Wikipedia

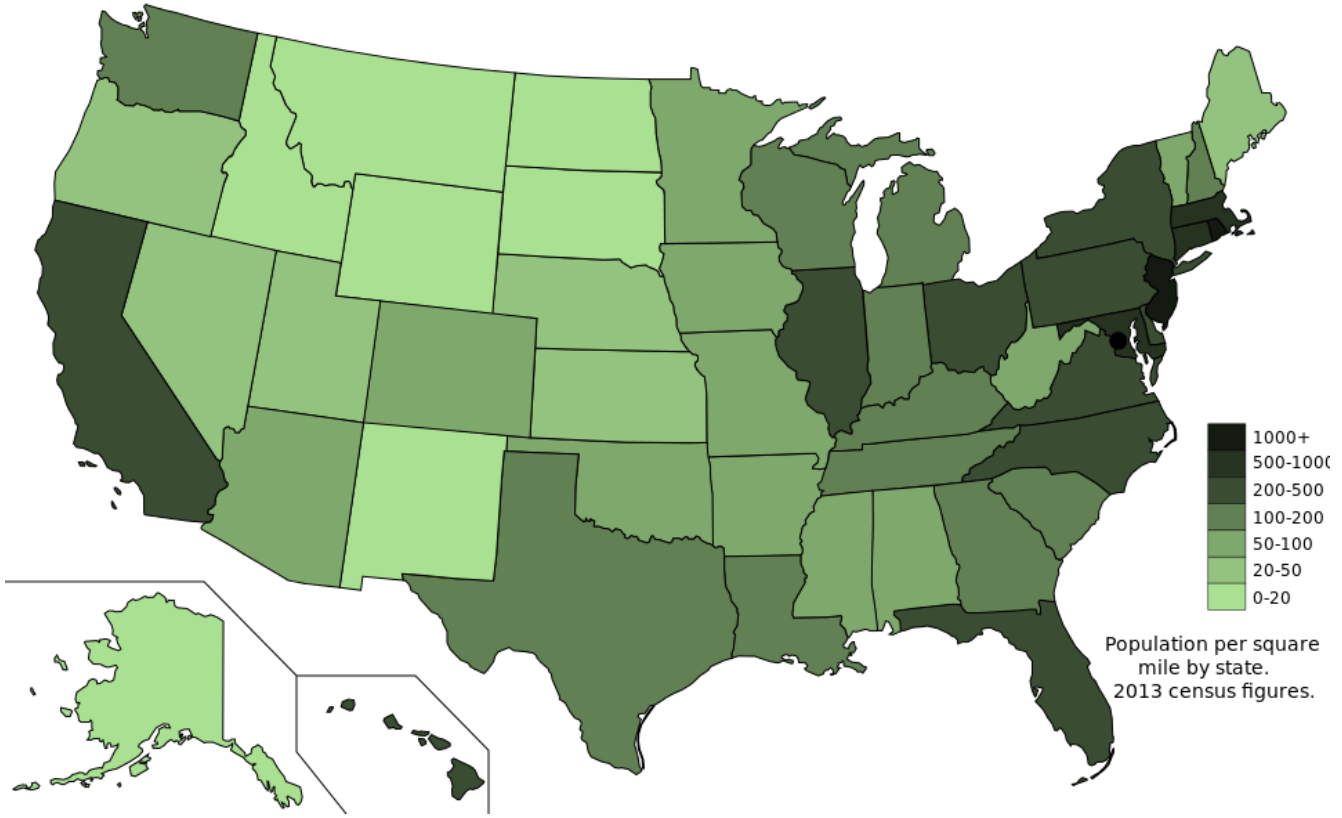
Geographical factors

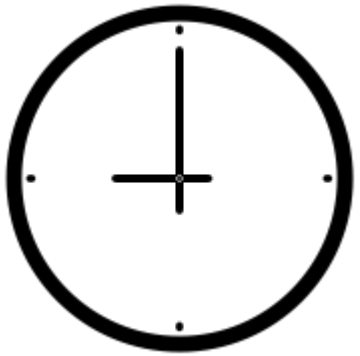
Load can vary with time zones

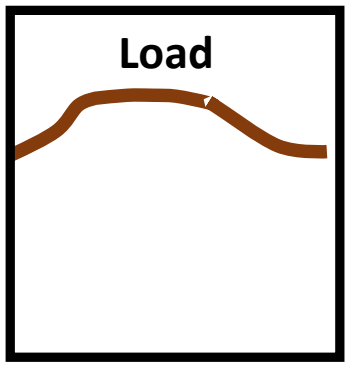




5 am 6 am 7am

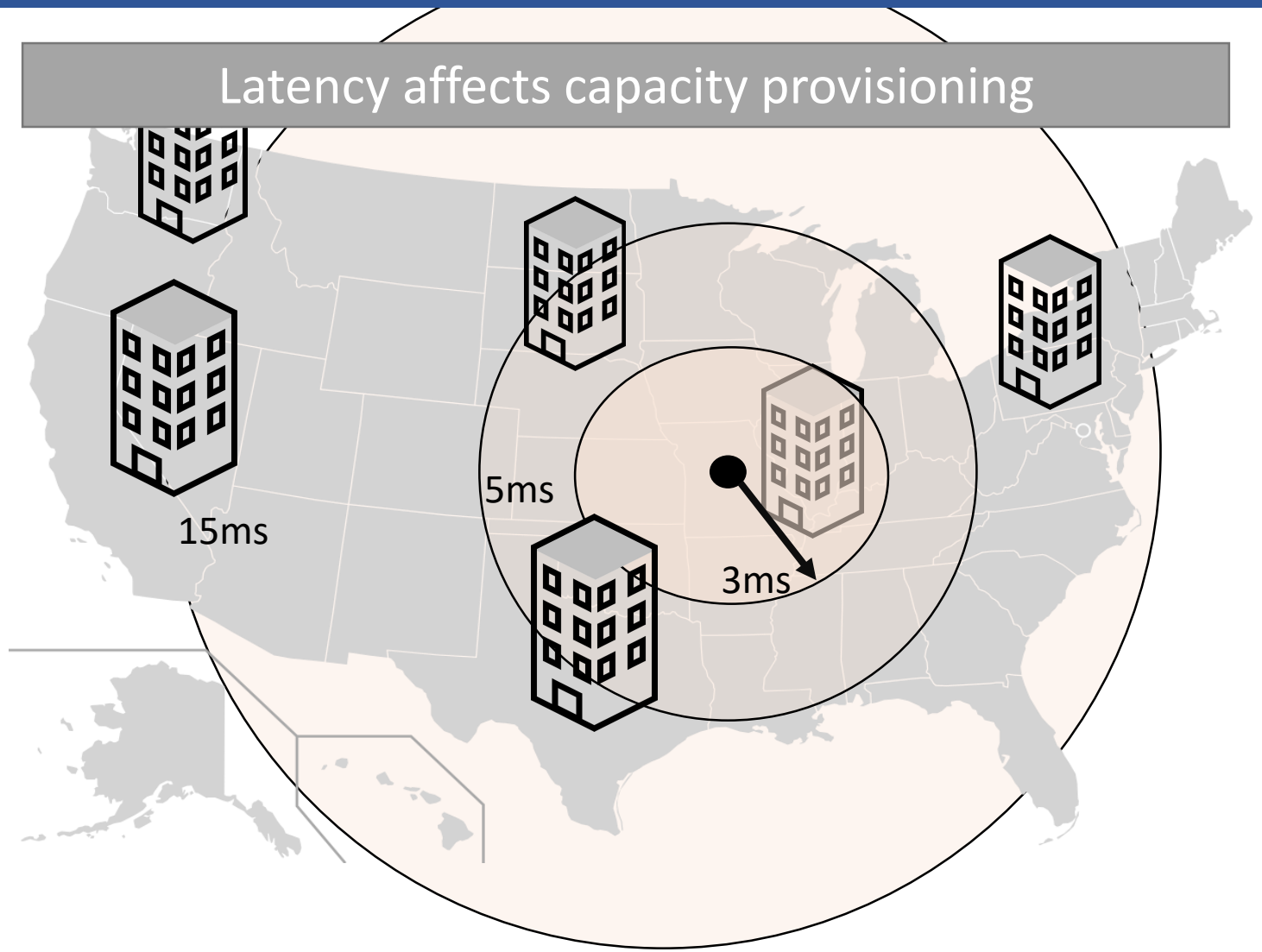




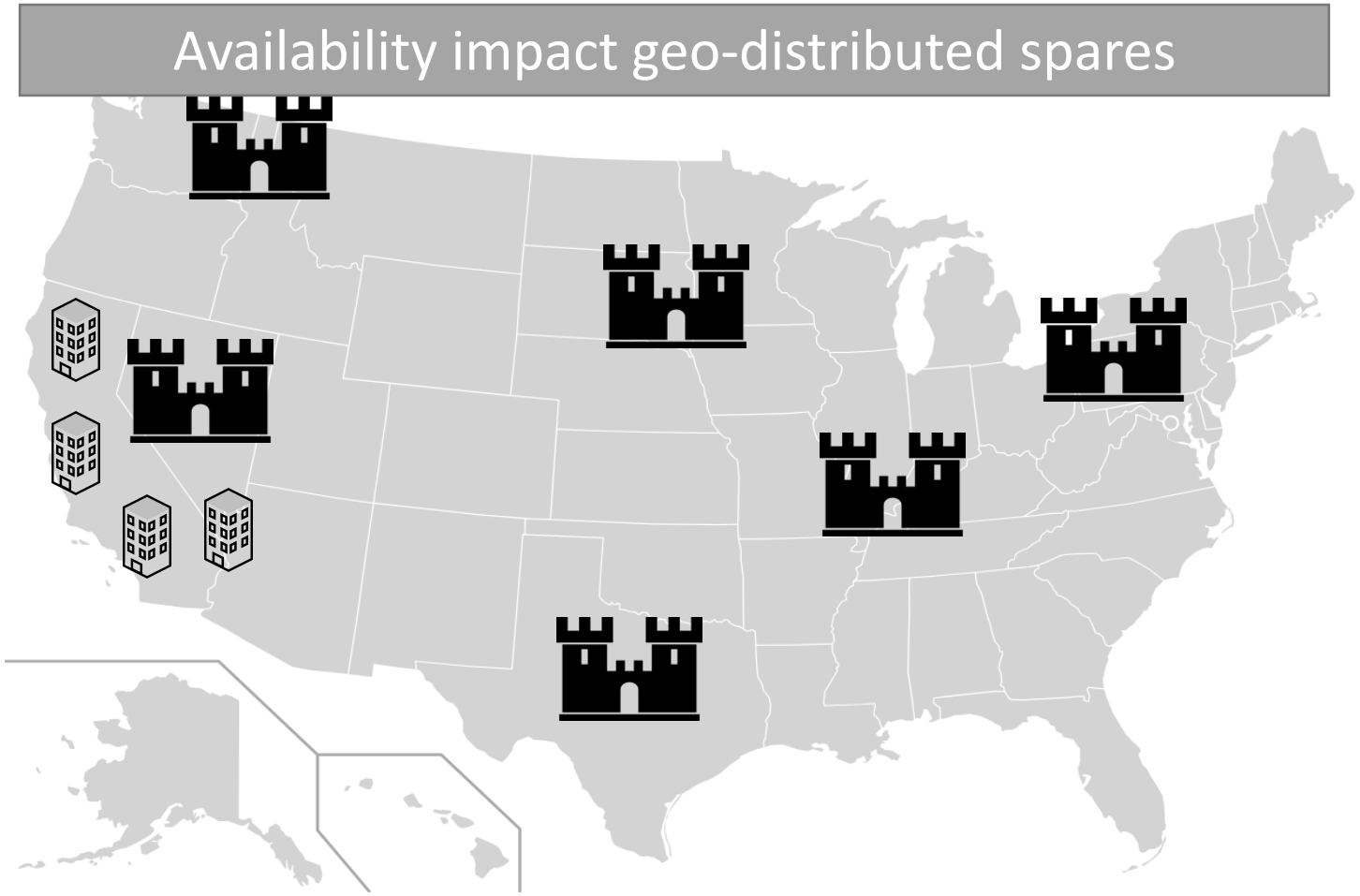


8 am 9 am 10 am

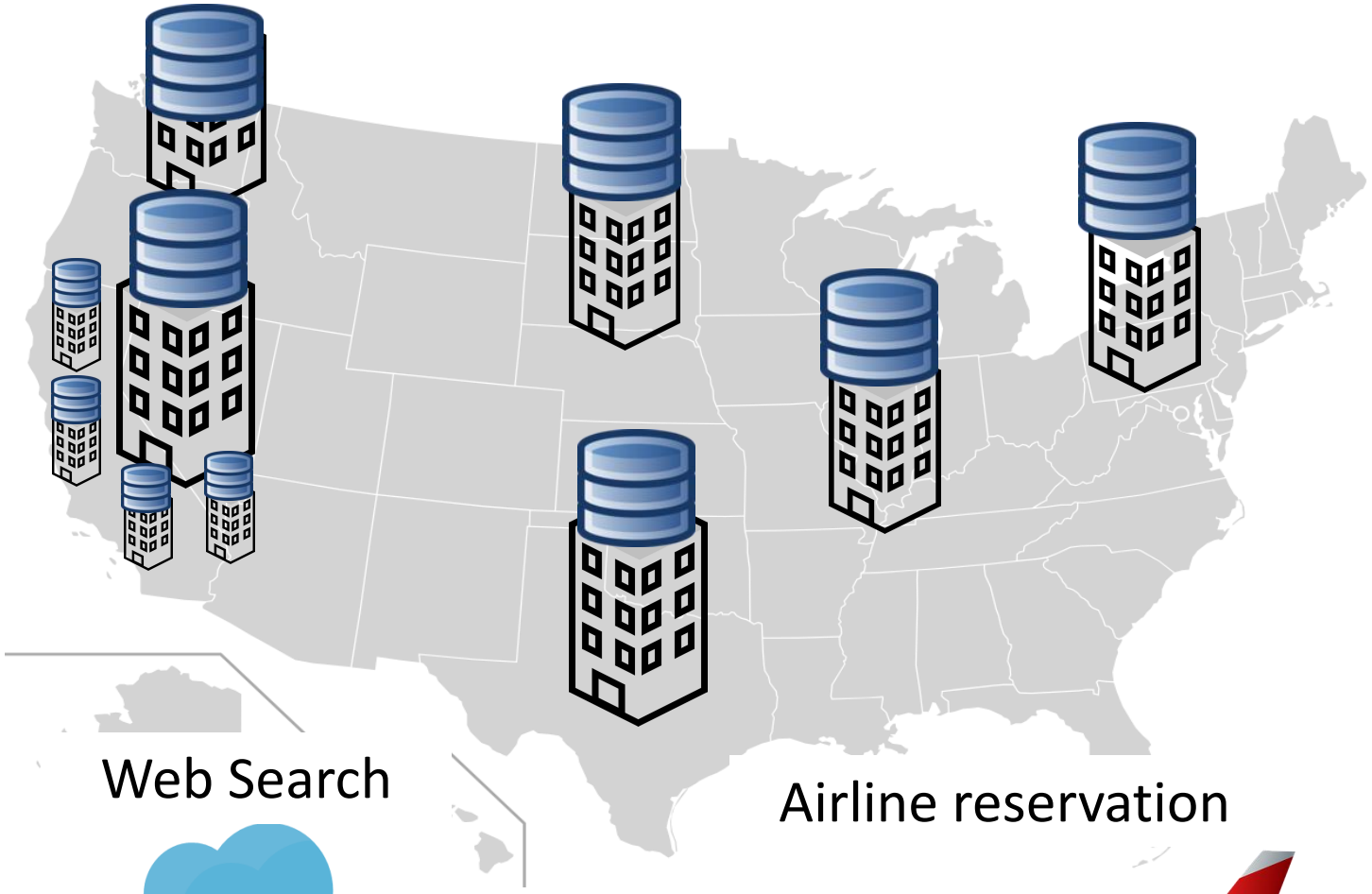
Geographical factors



Datacenter factors: Availability



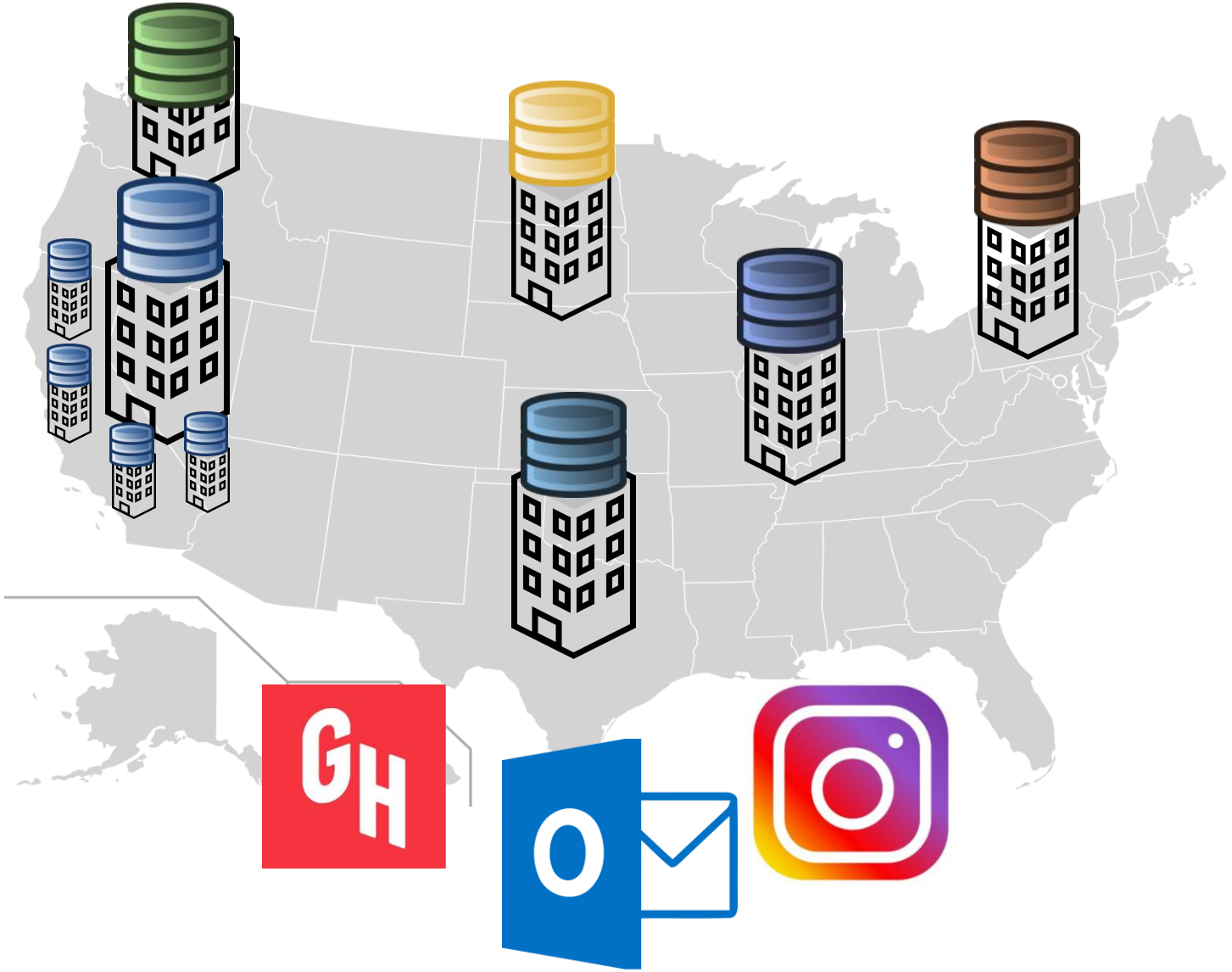
Application factors: Replicated data



Web Search

Airline reservation

Application factors: Partitioned data



Factors affecting capacity planning

Geography

Datacenter

Application

What are the challenges ?

Capacity planning challenges

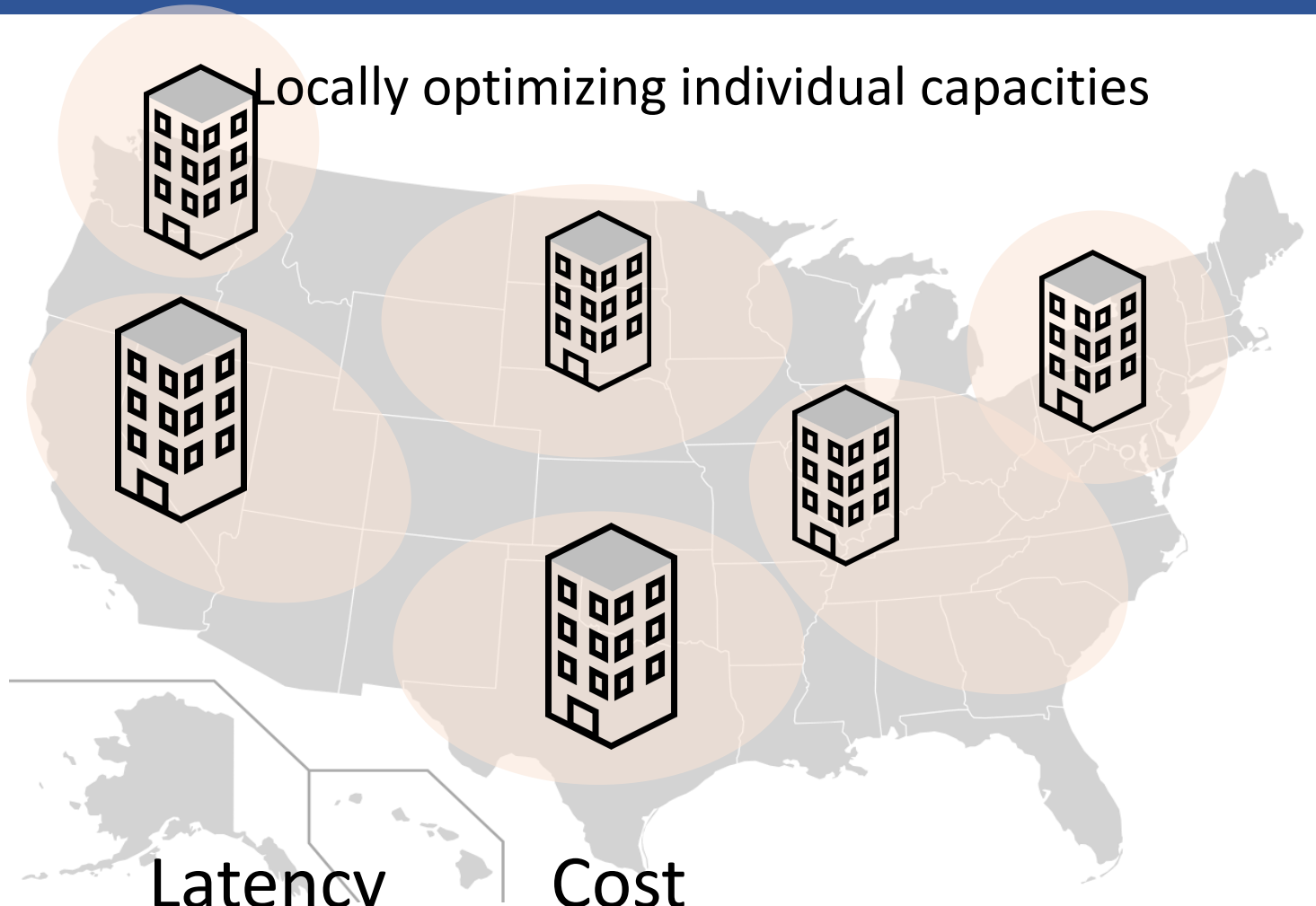
Performance metrics

Latency

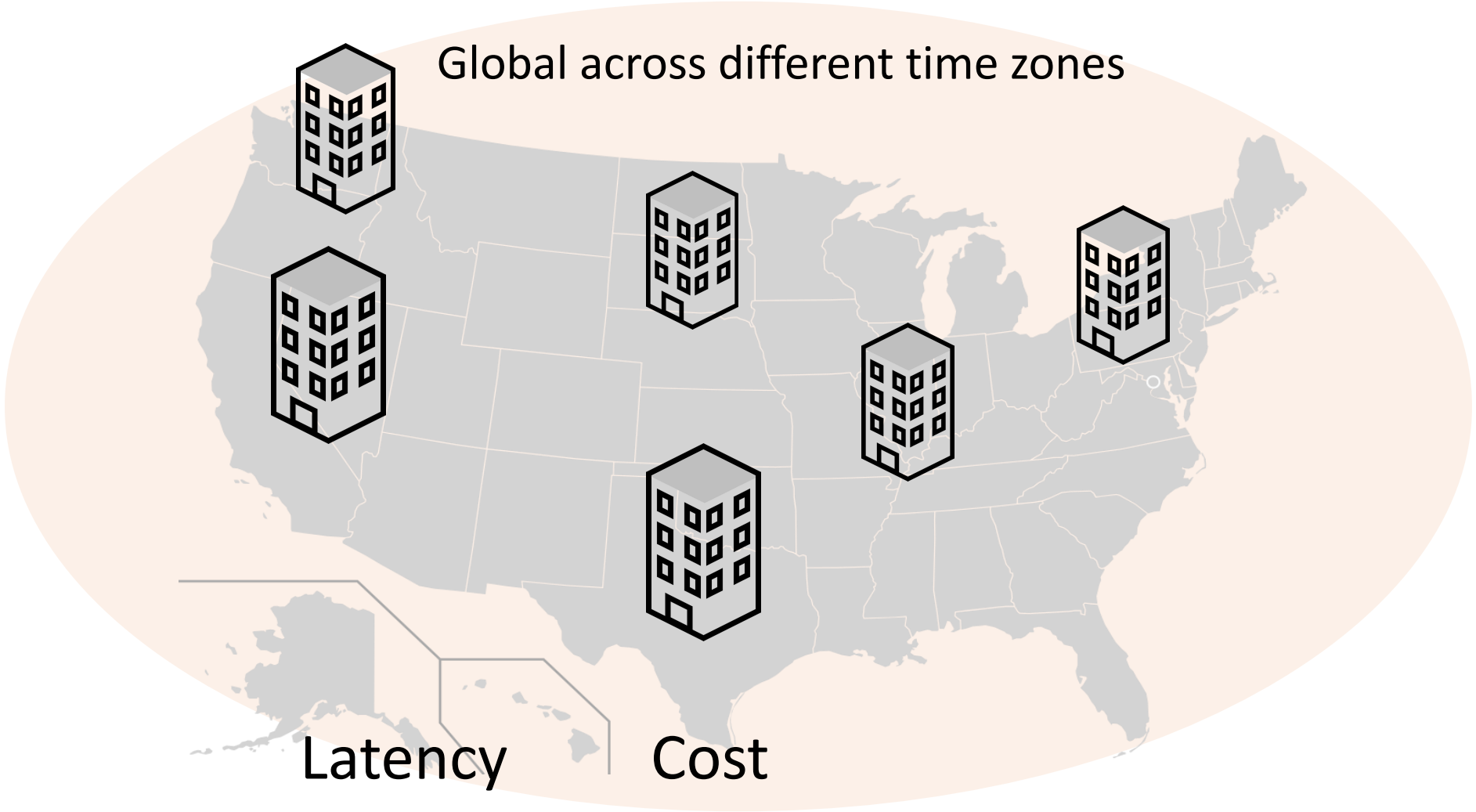
Cost

Availability

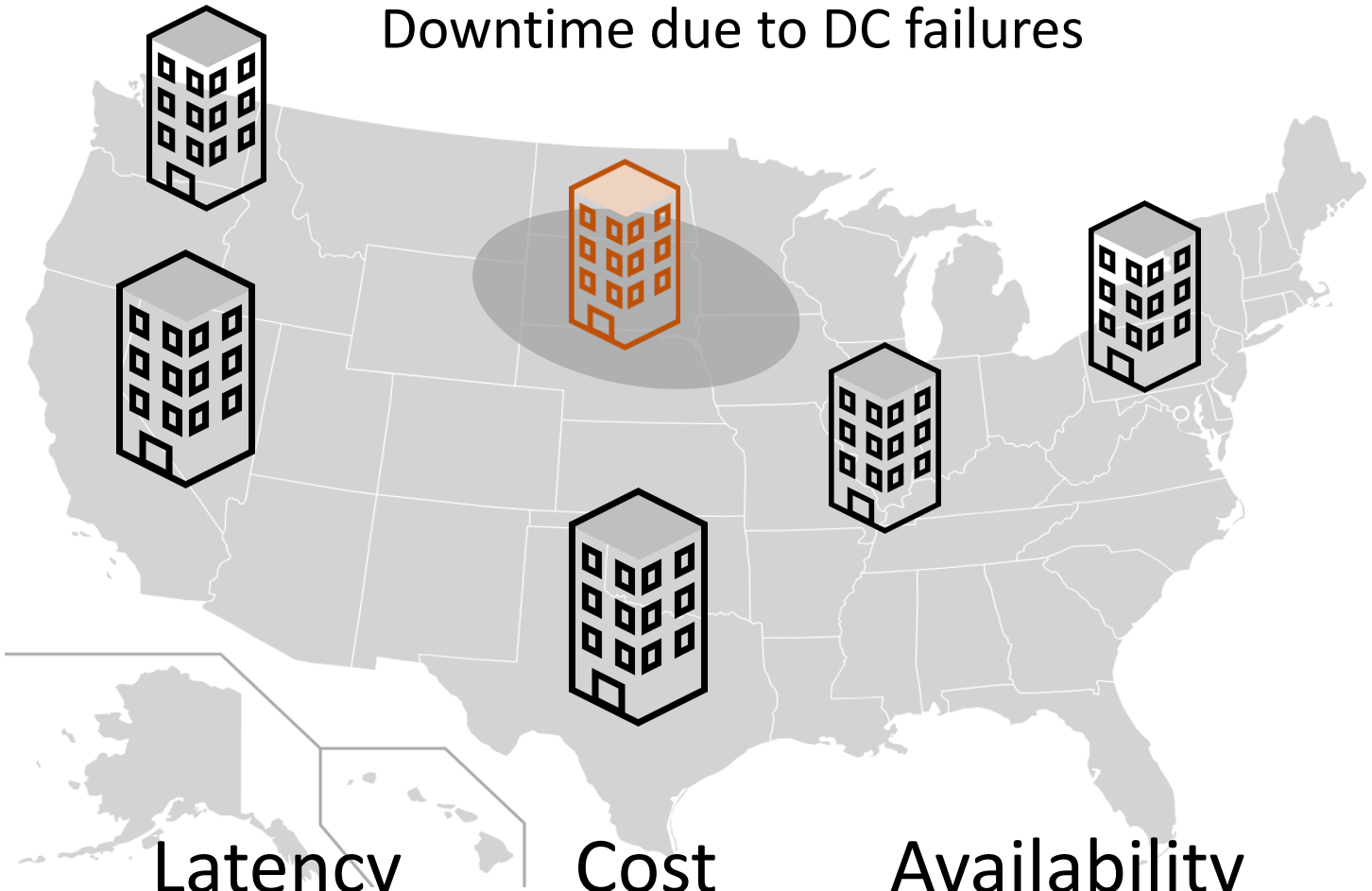
Local planning vs. global planning



Local planning vs. global planning

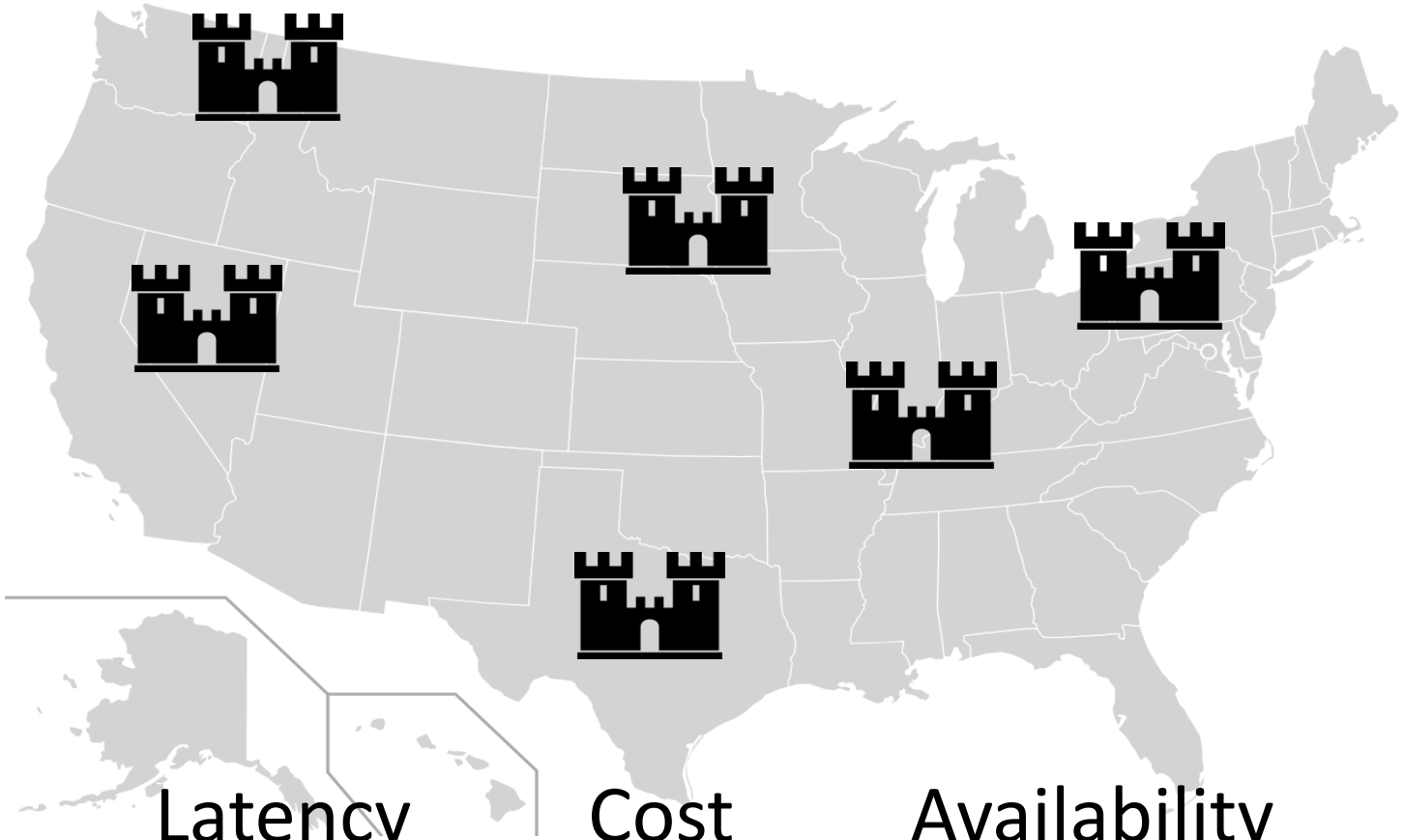


Handling geo-distributed failures



Handling geo-distributed failures

Hardening individual DCs

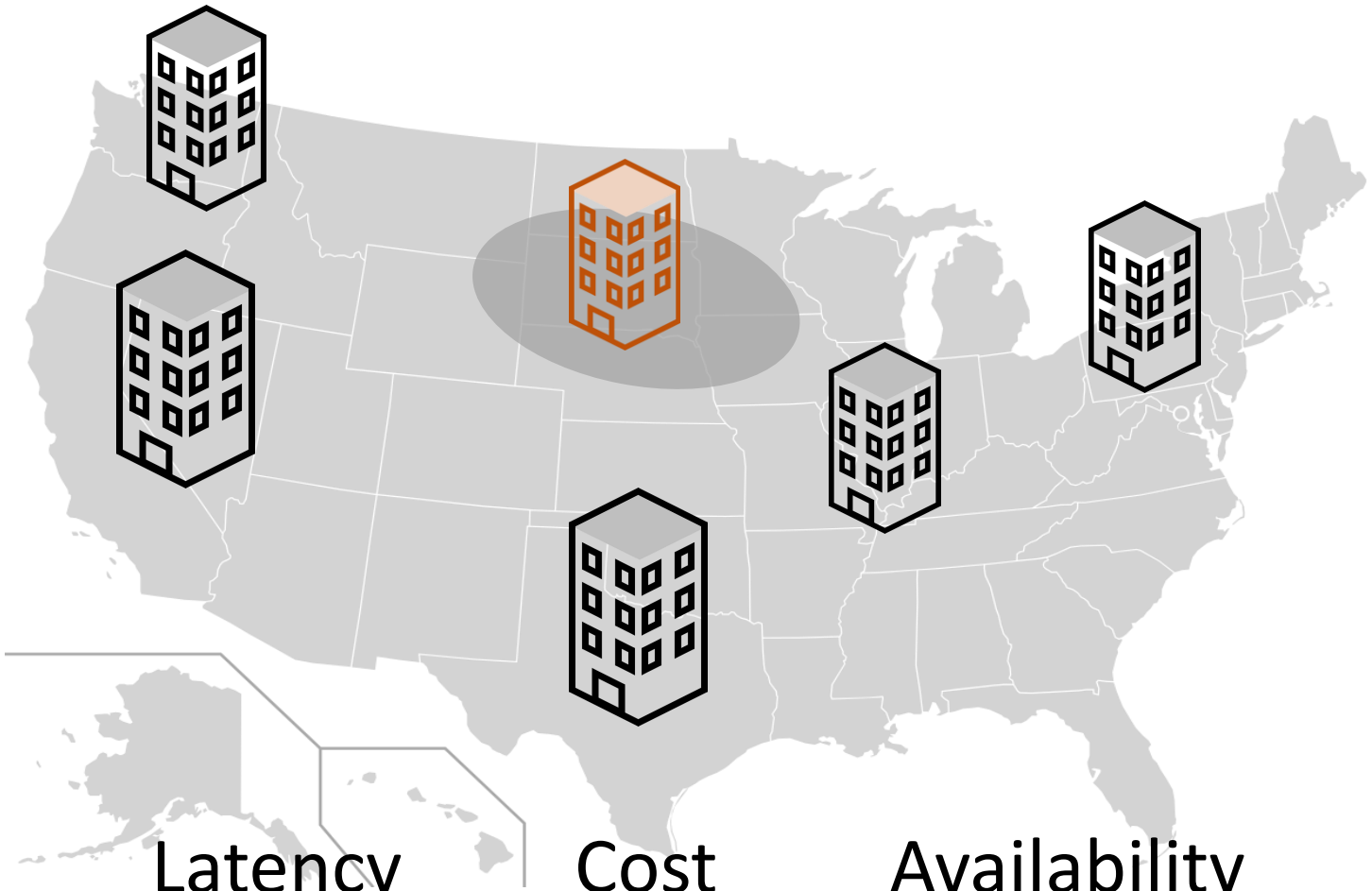


Latency

Cost

Availability

Handling geo-distributed failures



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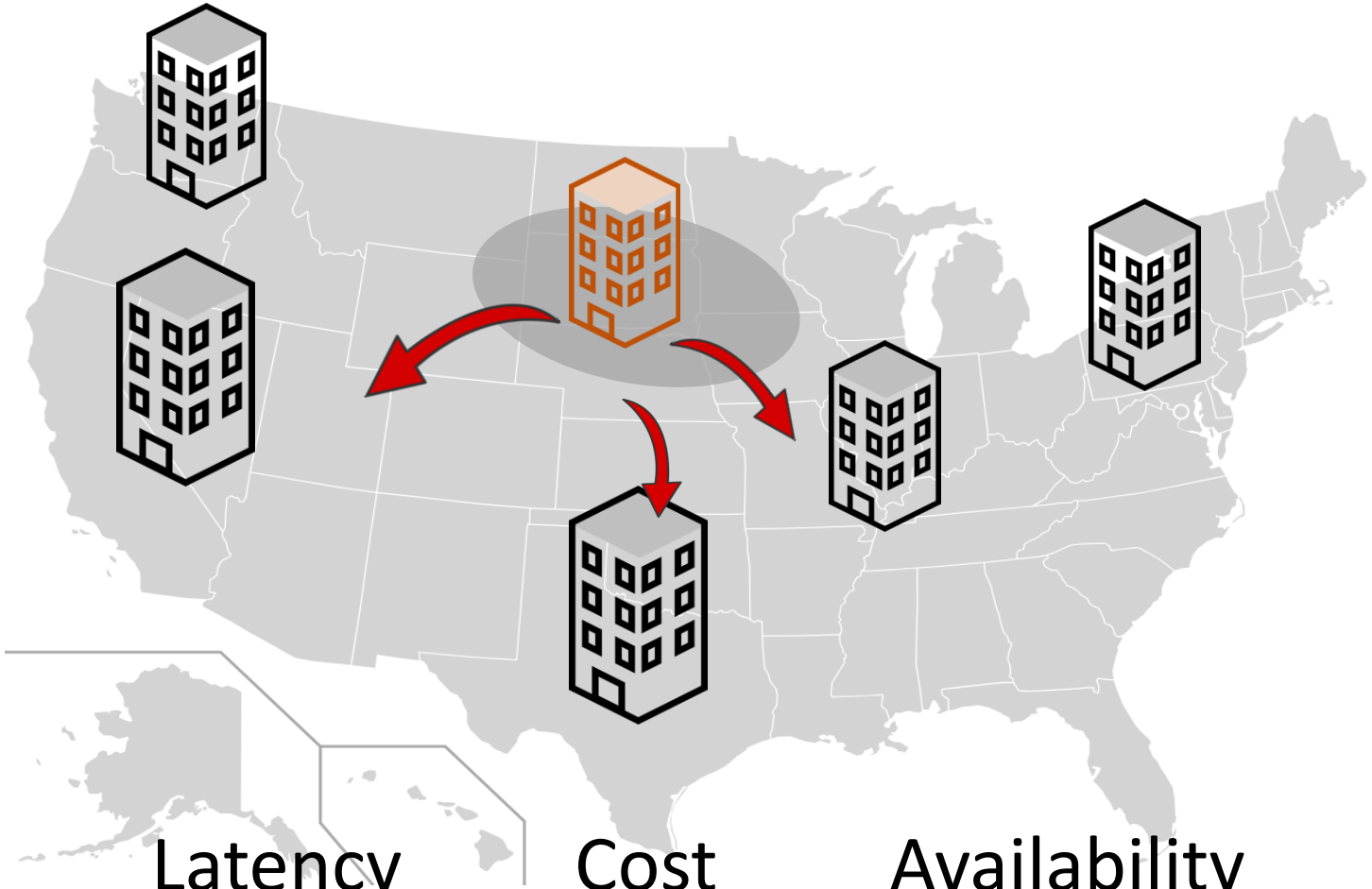
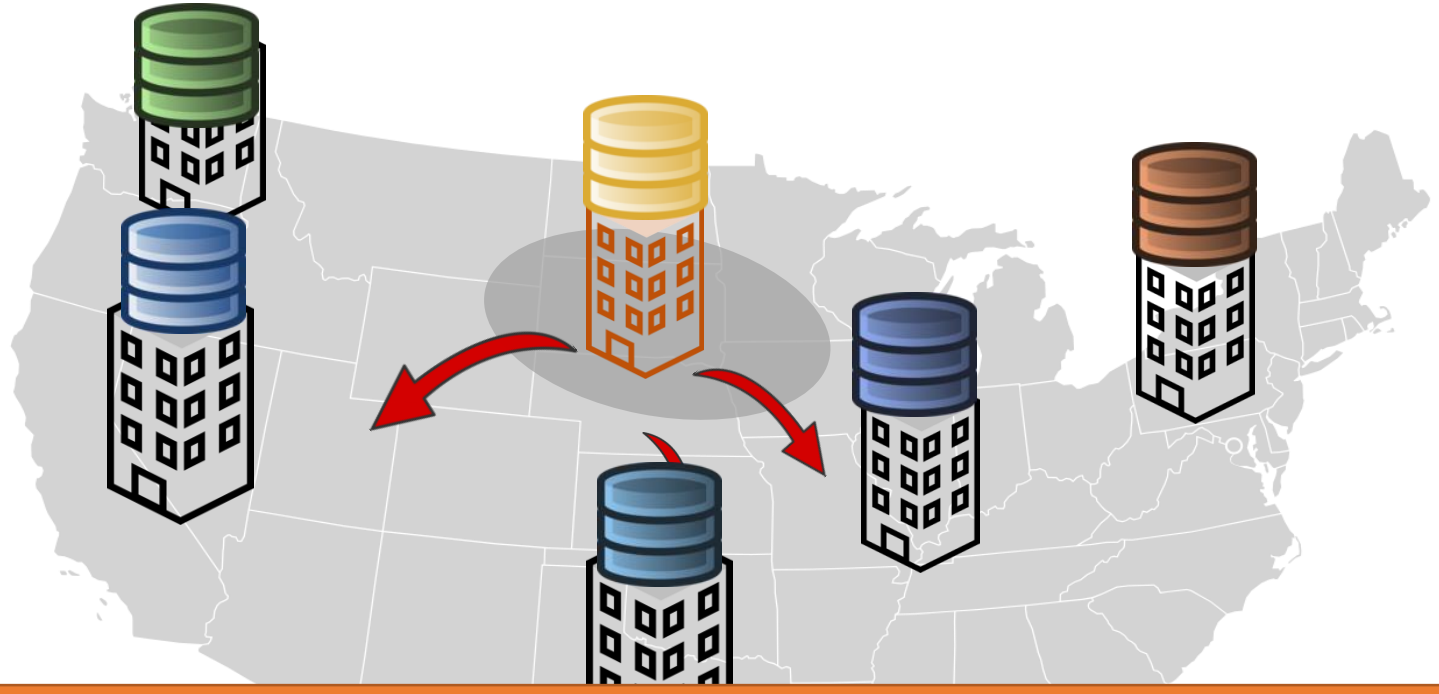


Latency

Cost

Availability

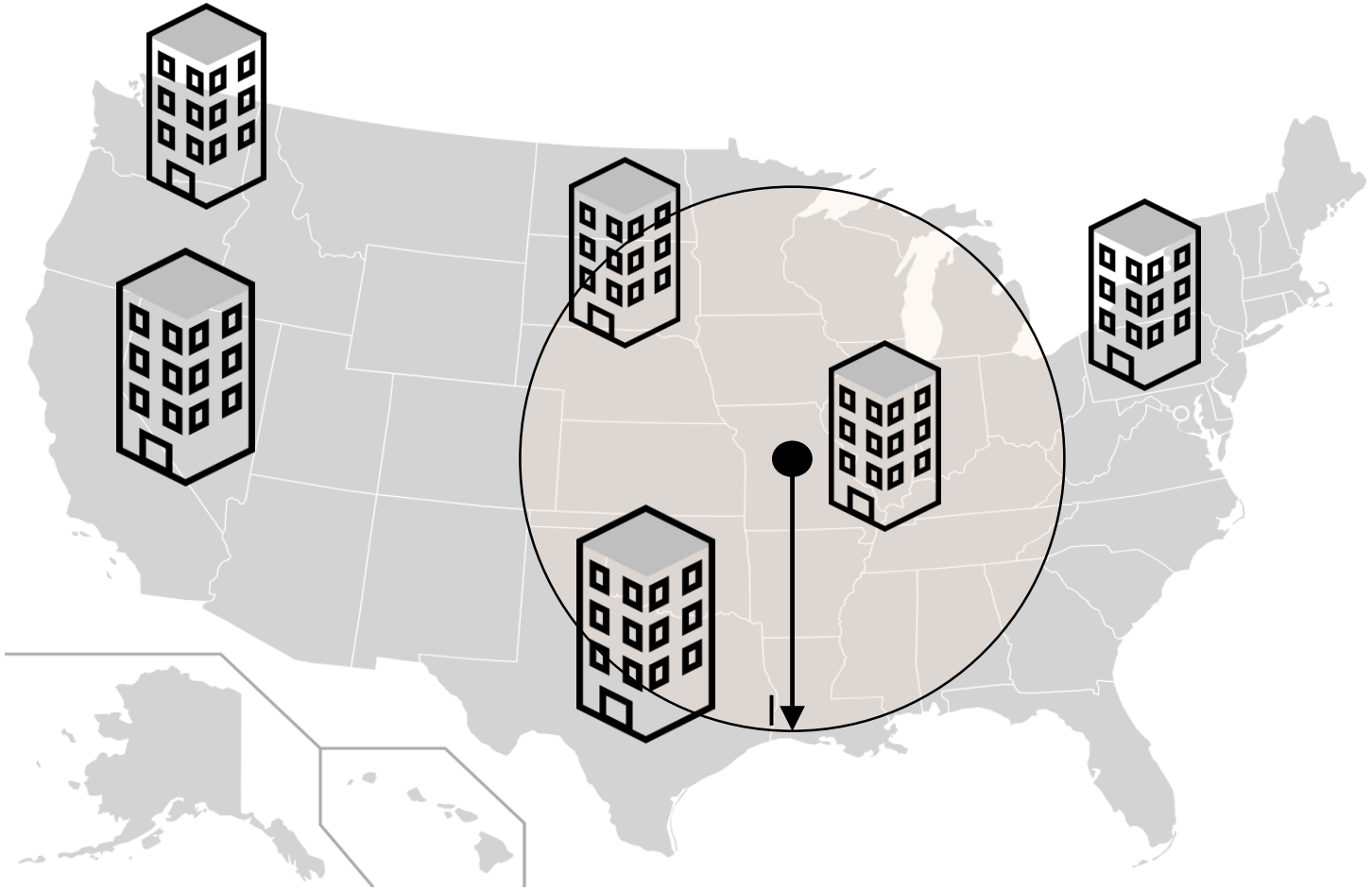
Handling geo-distributed failures



How to guarantee latency and availability for apps cost effectively ?

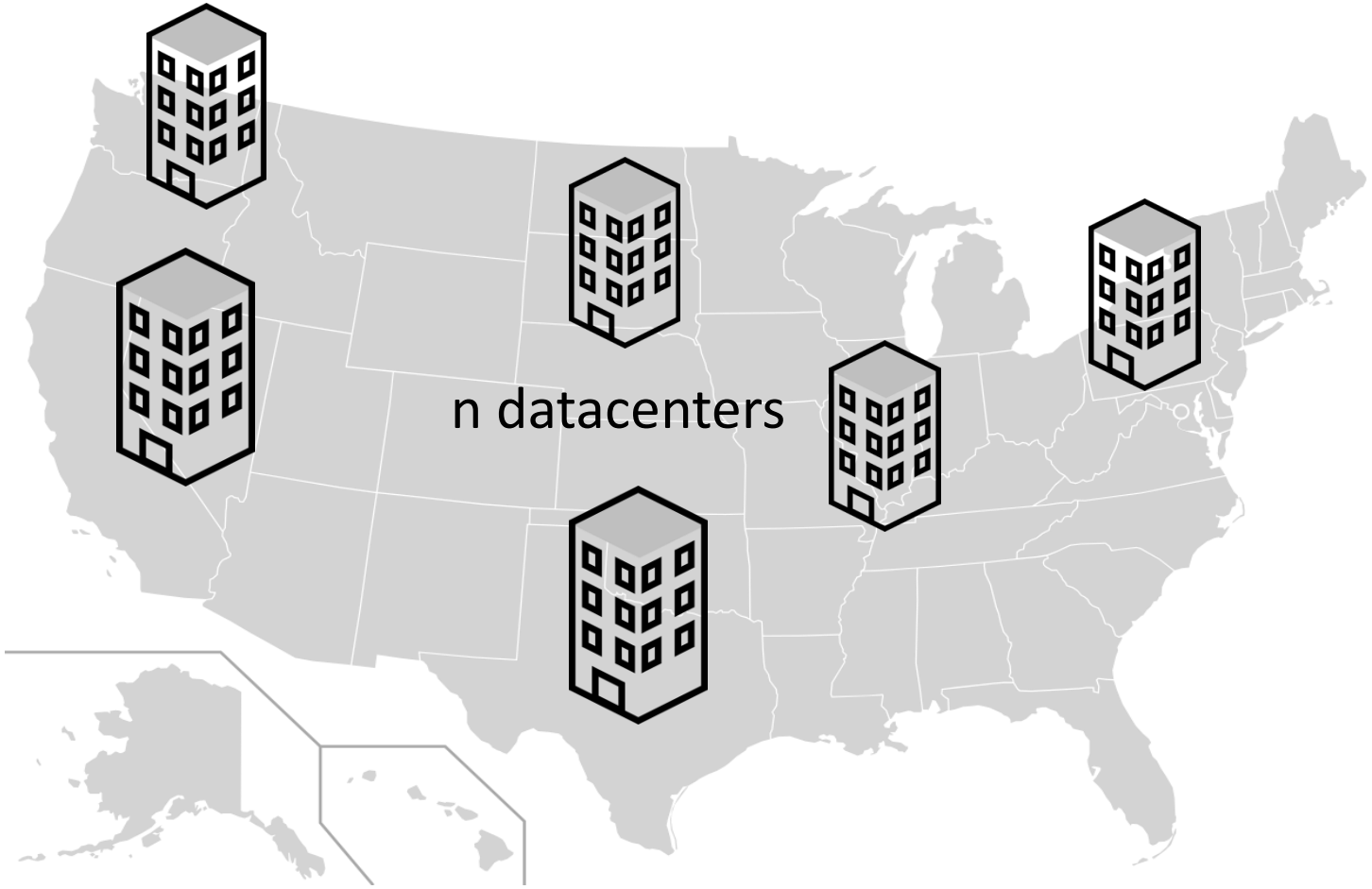
Latency | Cost | Availability

System model



Client desires Tier-4 availability

System model



Optimization objective

$$\min \sum_{j \in \{1,\ldots,n\}} \$ \text{ x } C_j$$

Geo-distribution for cost savings

$$\sum_{j:l_{ij} \leq l} f_{ij0}(t) \geq d_i(t), \forall i, t.$$

within the latency limit

Distribute across DCs

Client demand

Client index

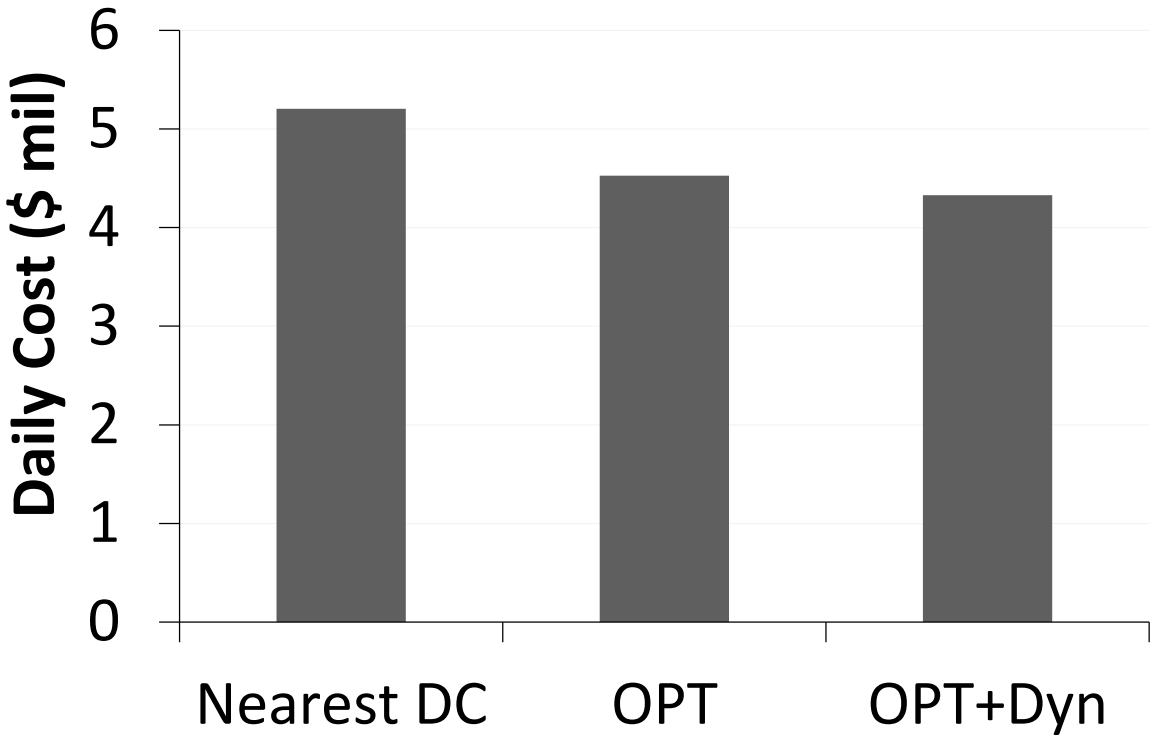
$$C_j - \sum_i f_{ij0}(t) \geq 0, \forall j, t$$

DC capacity

Assigned load from all clients

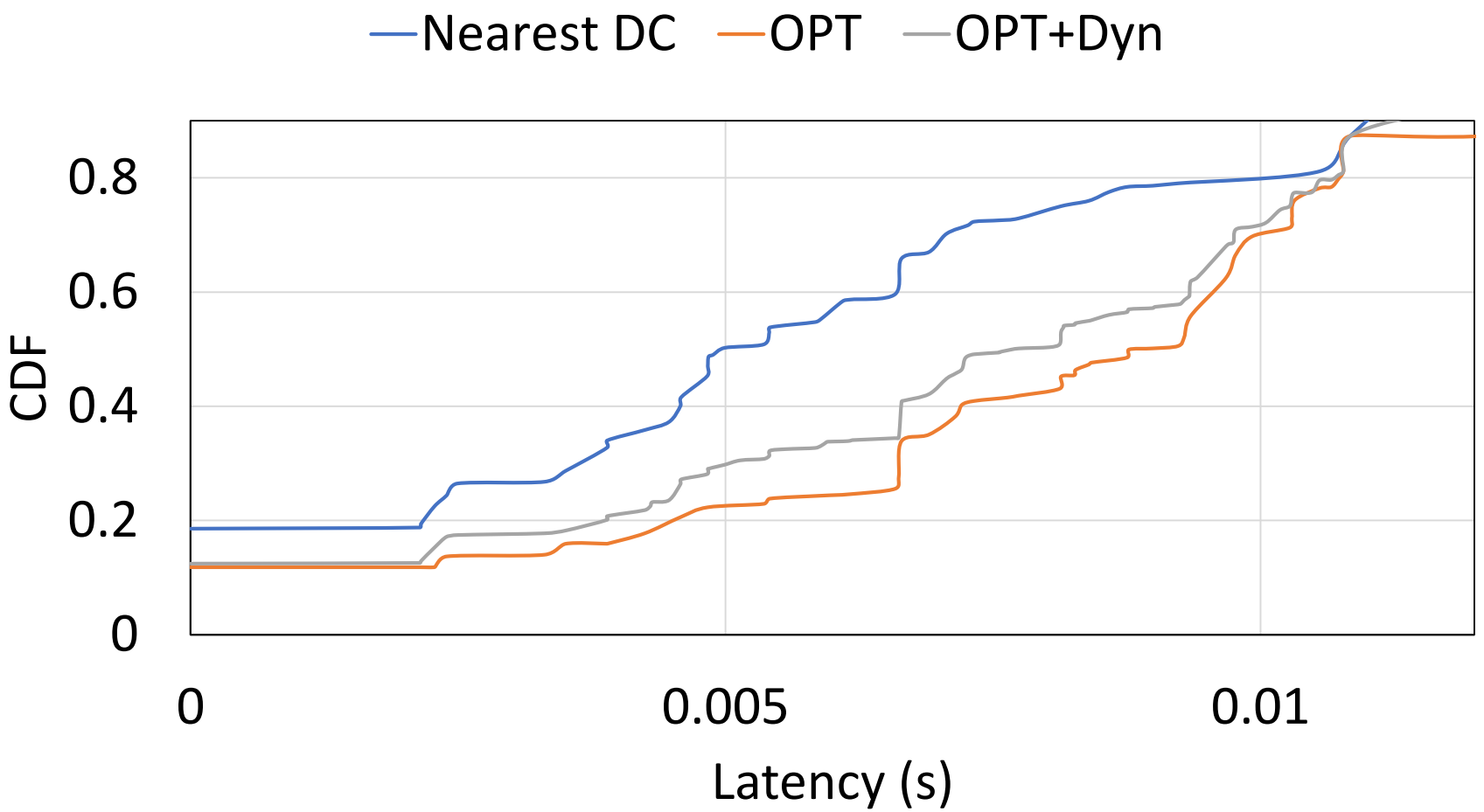
DC index

Geo-distribution for cost savings



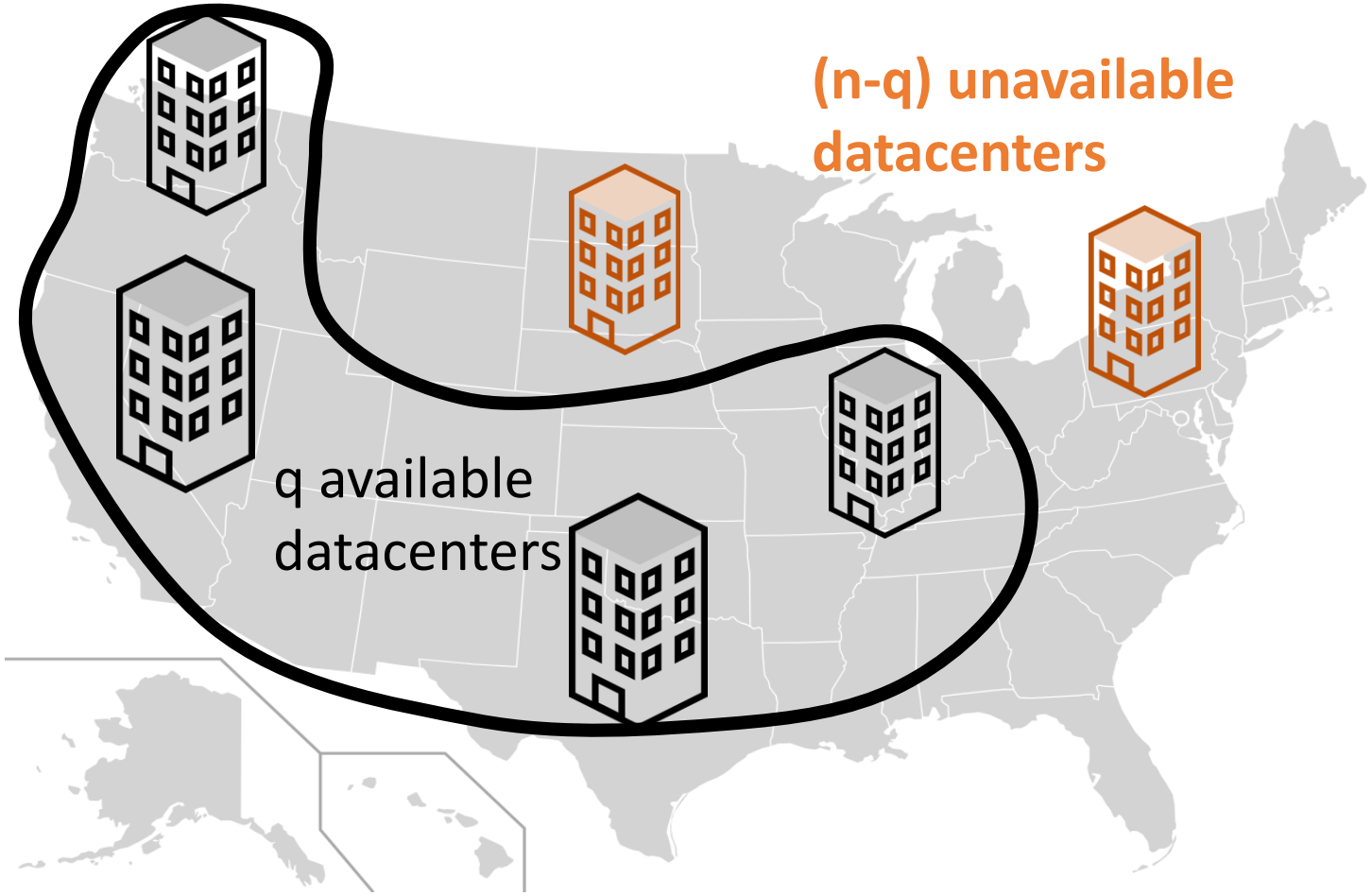
Geographical factors help reduce provisioned capacity by 16%

Geo-distribution for high availability

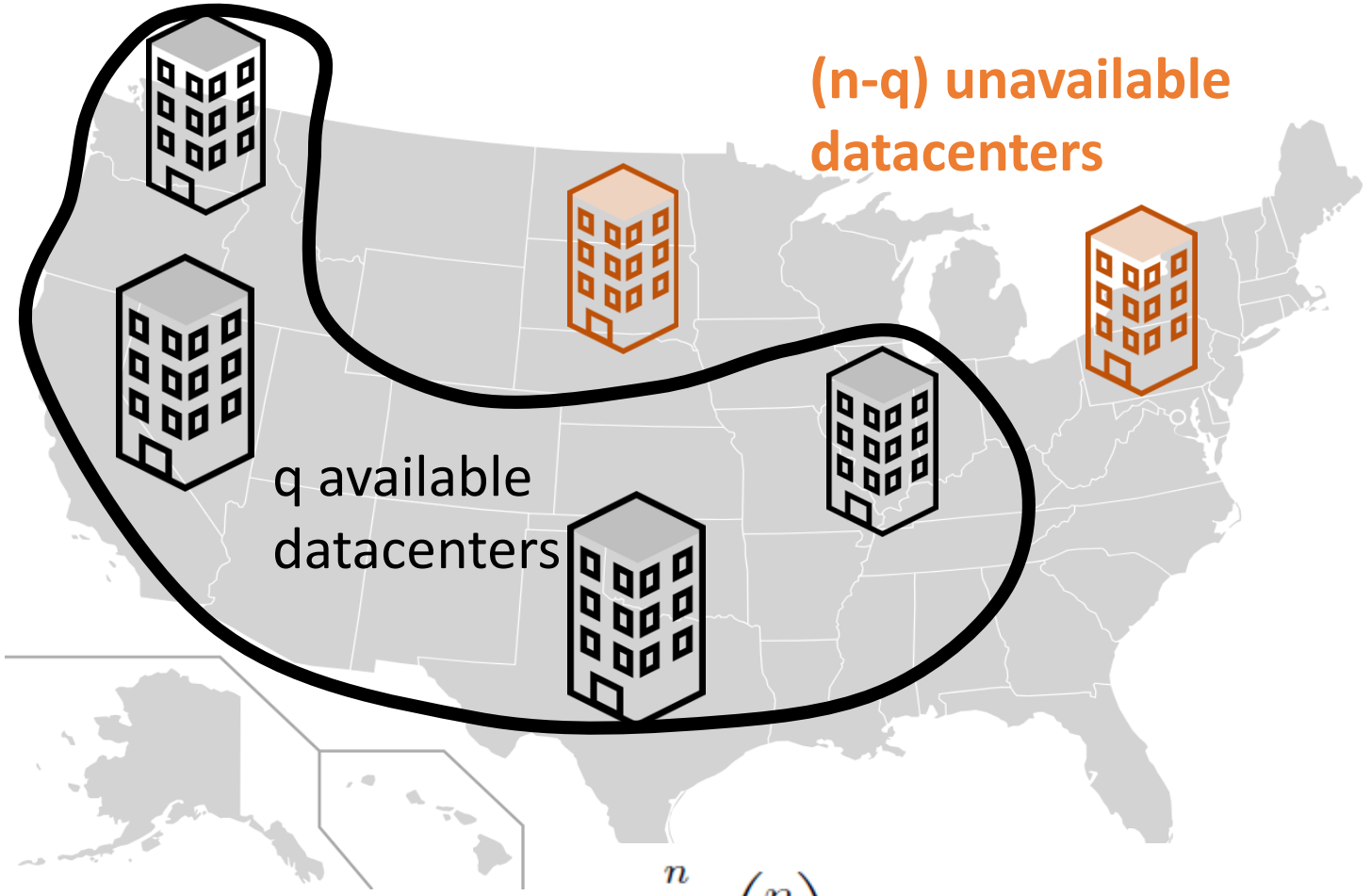


Capacity reduction by optimizing latency for a large fraction of clients

System model



System model



System Availability = $\sum_{i=q}^{n} \binom{n}{i} a_d^i (1 - a_d)^{n-i}$

Geo-distribution for high availability

Latency guarantee even if a single DC has failed

$$\sum_{j:j\neq k, l_{ij}\leq l'} f_{ijk}(t) \geq d_i(t), \forall k > 0, i, t.$$

DCs within the latency limit (l')

Distribute across all DCs except k

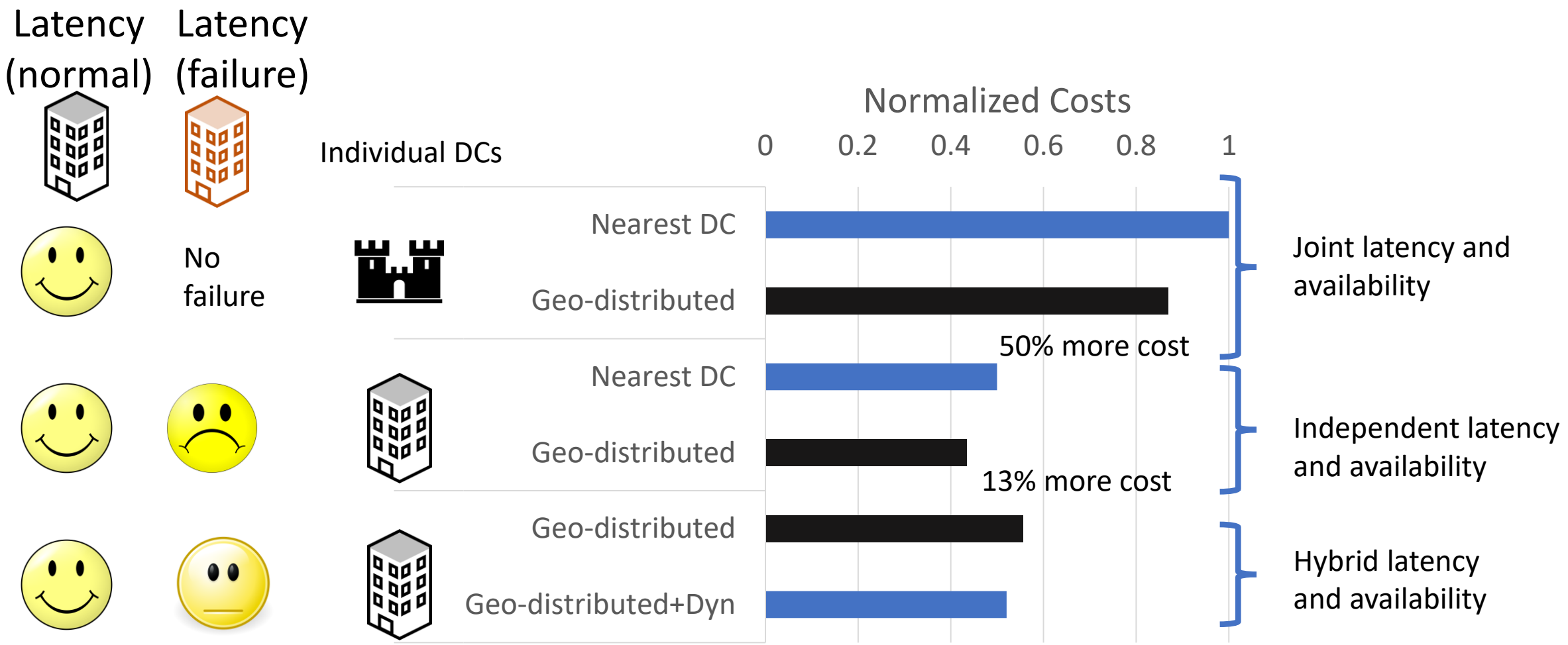
Client demand

Failed DC

Client index

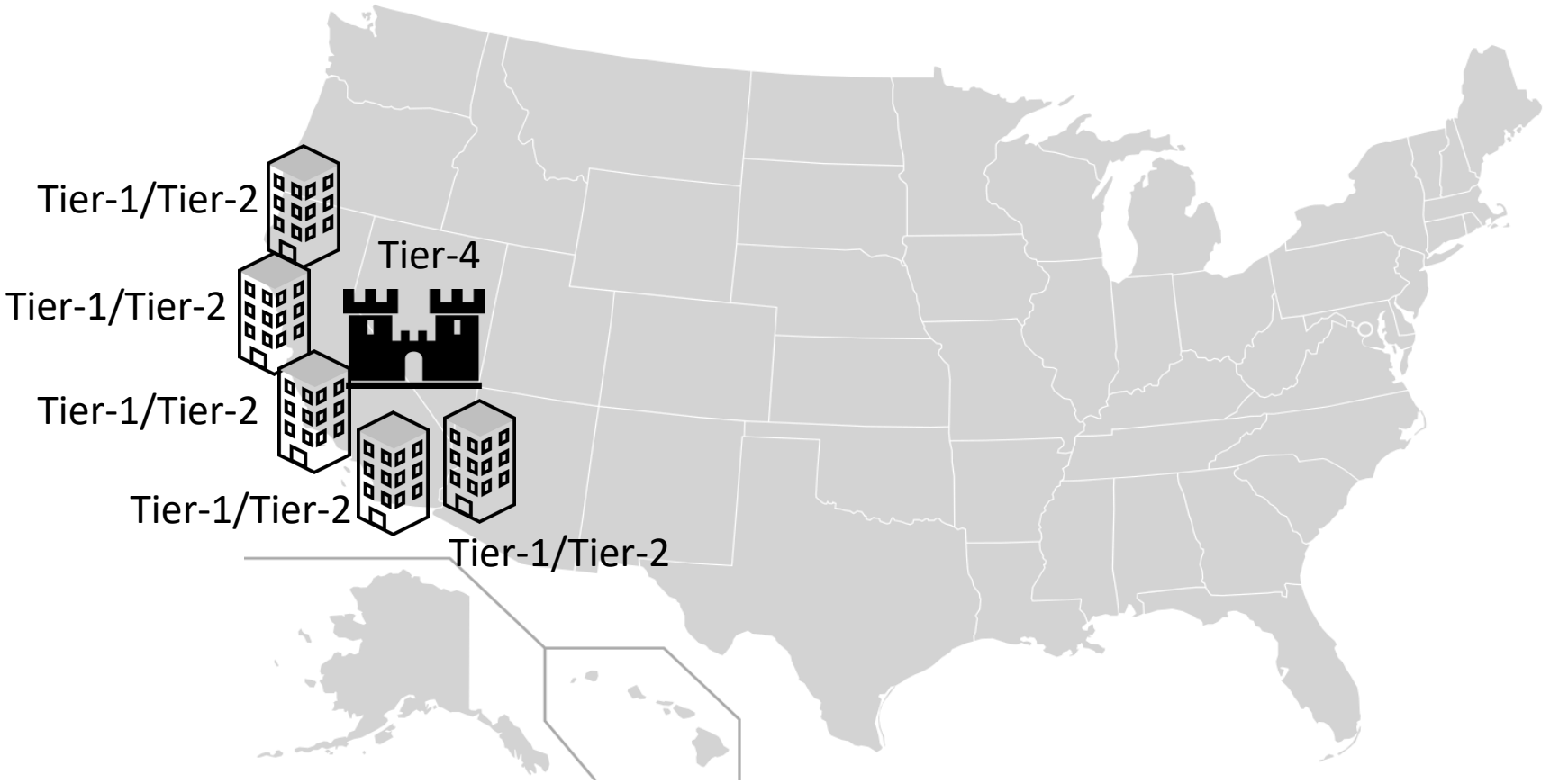
$$C_j - \sum_i f_{ijk}(t) \geq 0, \forall k(k > 0, k \neq j), j, t$$

Geo-distribution for high availability



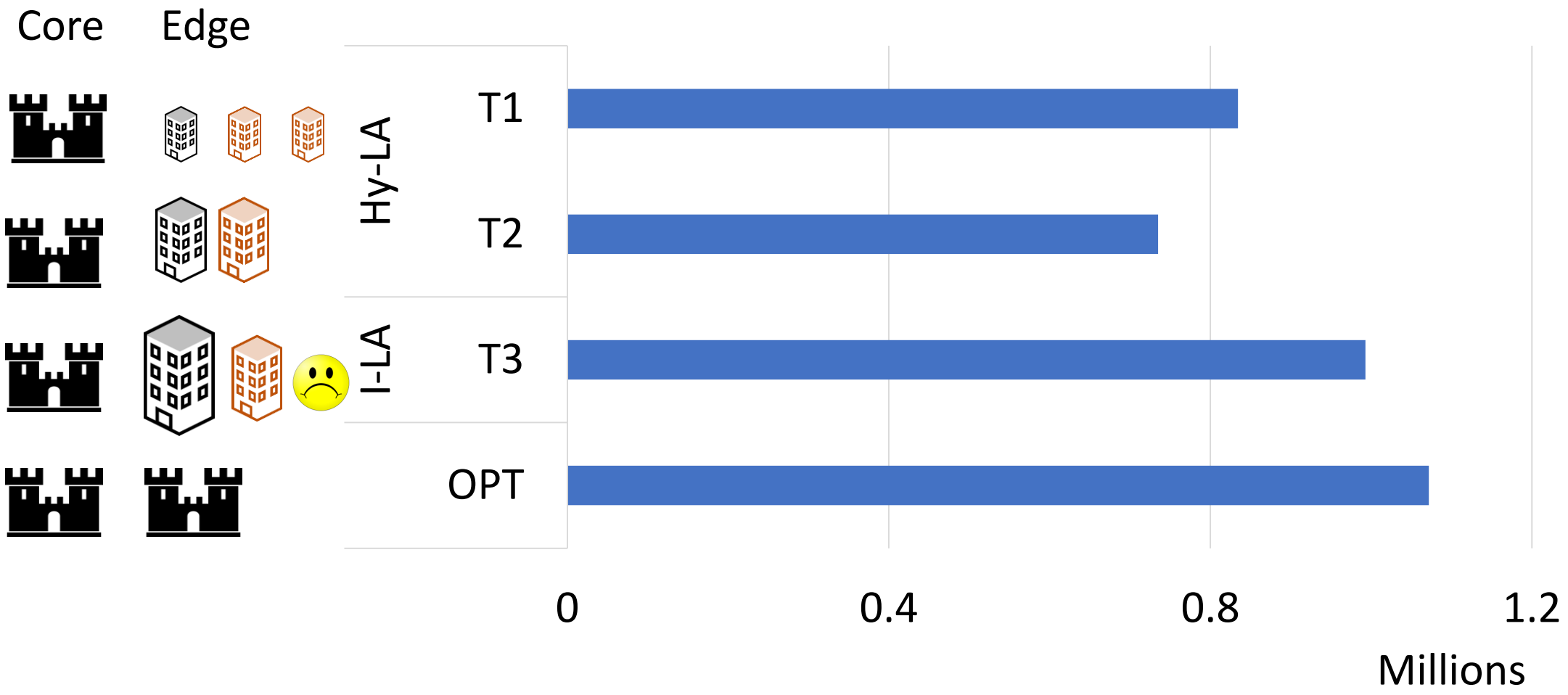
Geo-distribution helps to achieve latency and availability at low costs

Geo-distributed core and edge datacenters



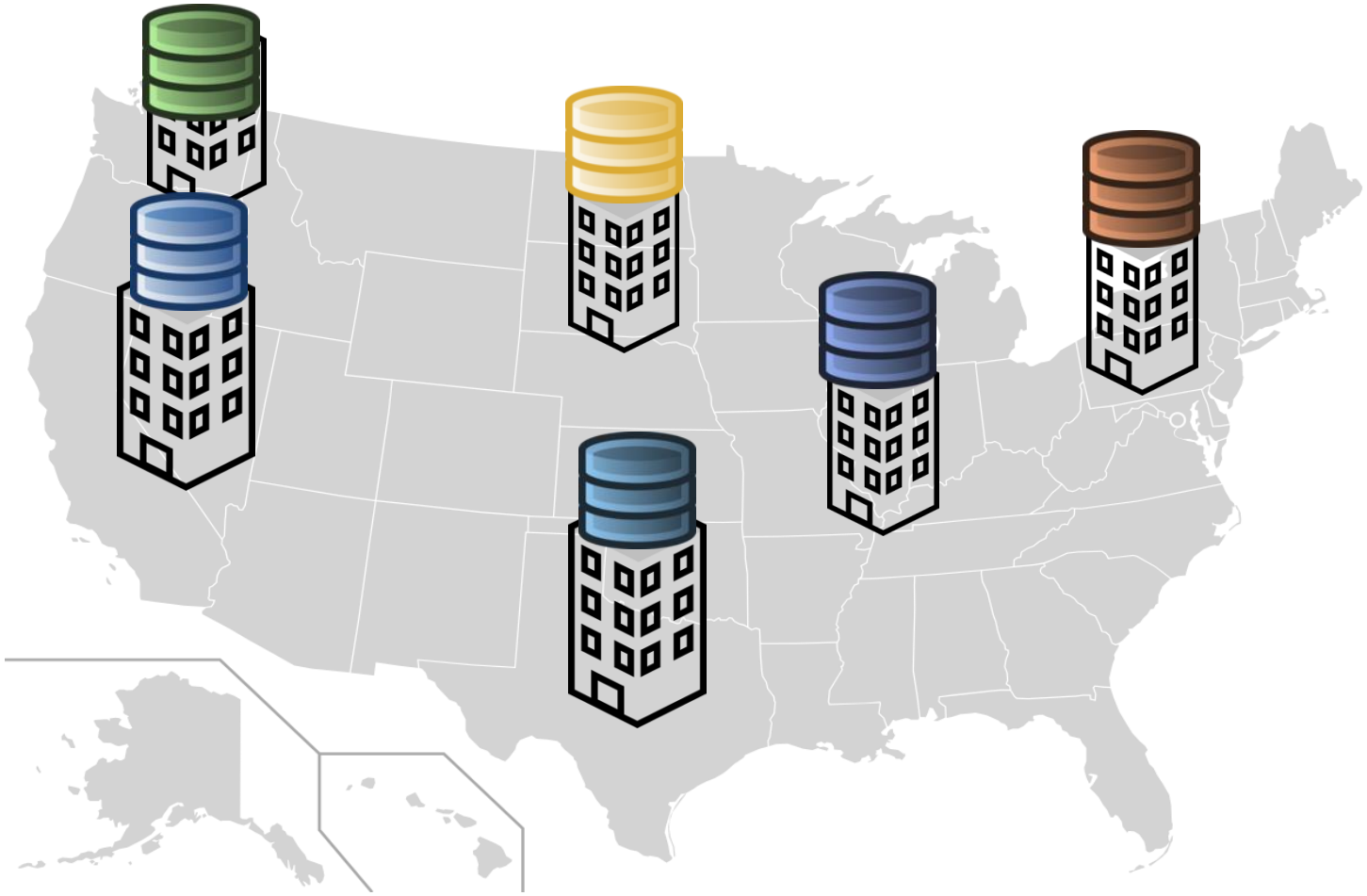
Extend the previous equation to handle multiple failures

Geo-distributed core and edge datacenters



Cost benefit from using low availability DC reversers

Application factors: Replicated data



Geo-distribution for availability

Replicate all data before failure

$$\sum_{d:d\neq j, l_{ij}\leq l} r_{ijd}(t) \geq f_{ij0}(t), \forall i, j, t$$

Synchronous
or
Asynchronous

Make sure that enough replicas are available upon redirection due to failures

$$\sum_{j:j\neq d, l_{id}<l'} r_{ijd}(t) \geq \delta f_{idk}(t), \forall k > 0, k \neq j, i, d, t$$

Geo-distribution for availability

Storage Costs

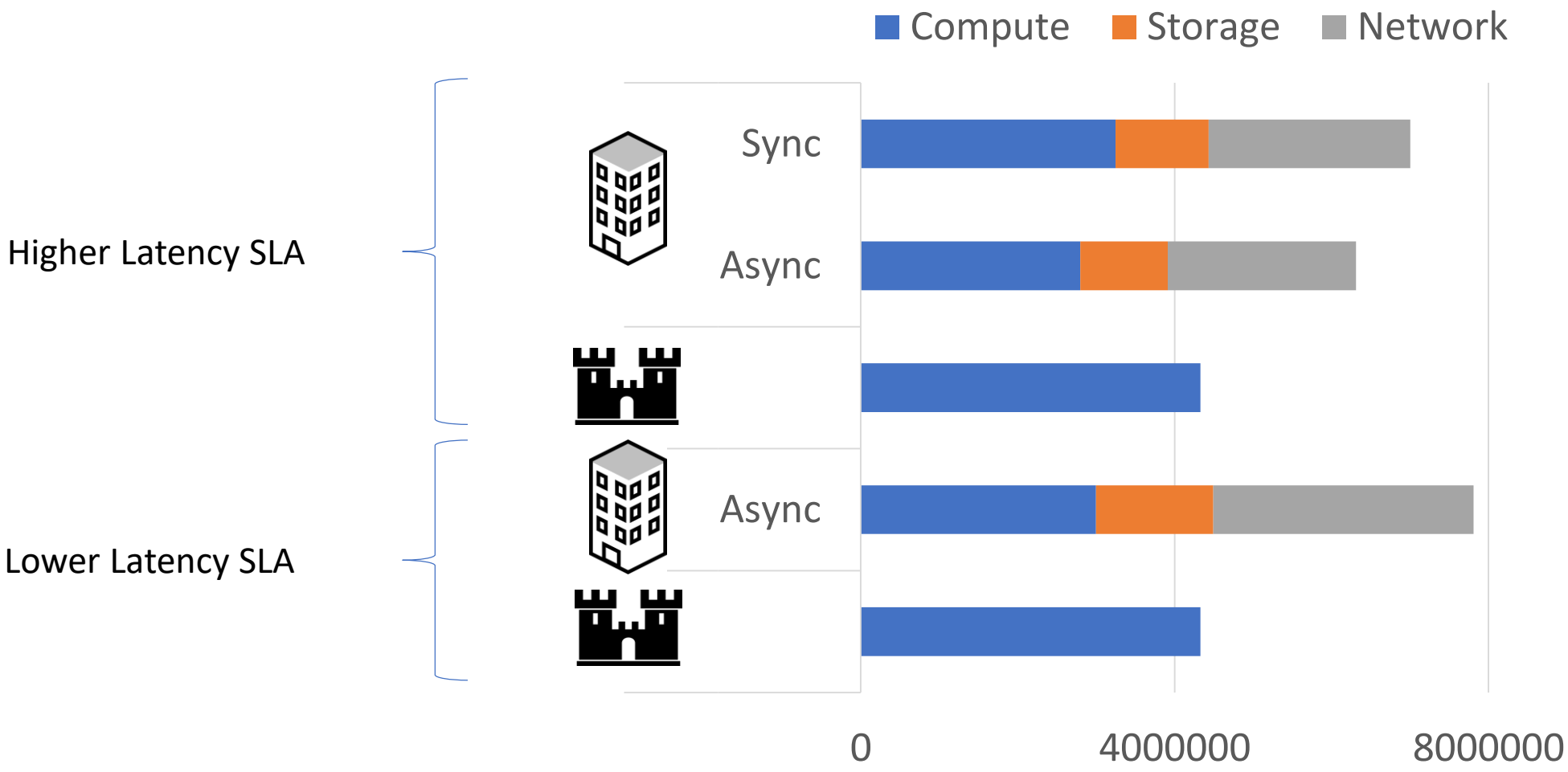
Network Costs

$$\min \left[\mathcal{C} \times C_j + (\mathcal{S} \times \mathcal{SC}_{\mathcal{R}}) \sum_{i,j,k,t} r_{ikj}(t) + \mathcal{N} \sum_{j,k,t} N_{jk}(t) \right]$$

$$N_{jk}(t) = \mathcal{NC}_{\mathcal{R}} \sum_{i} (r_{ijk}(t) + r_{ikj}(t)), \forall t, j, k (j \neq k)$$

Replication between i and j

Geo-distribution for high availability

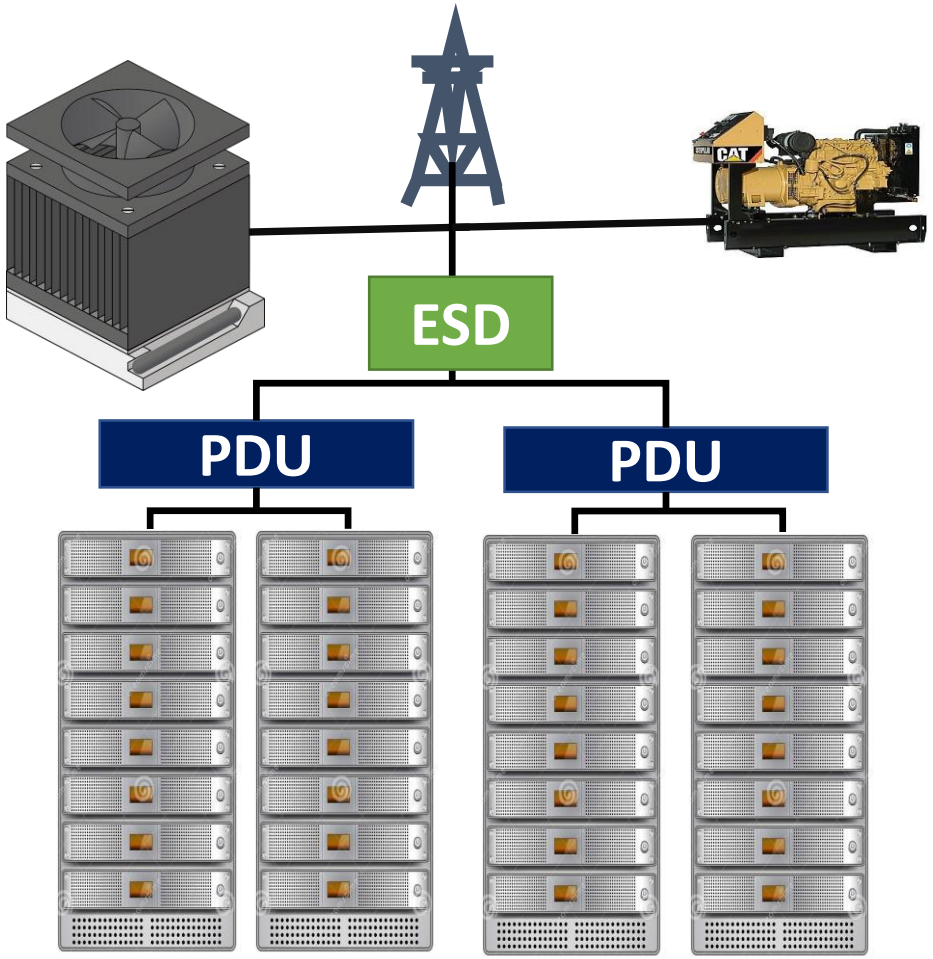


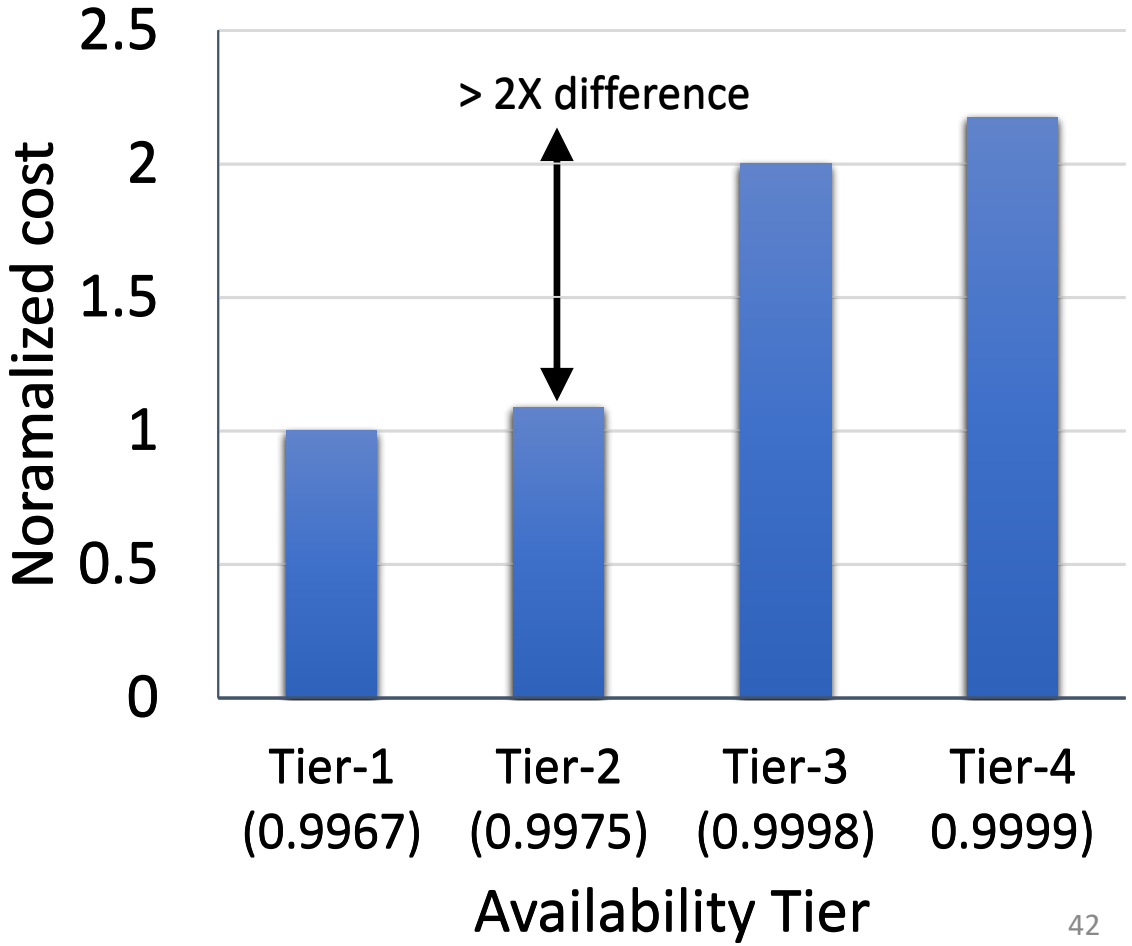
Replication costs overweigh the benefits

Summary

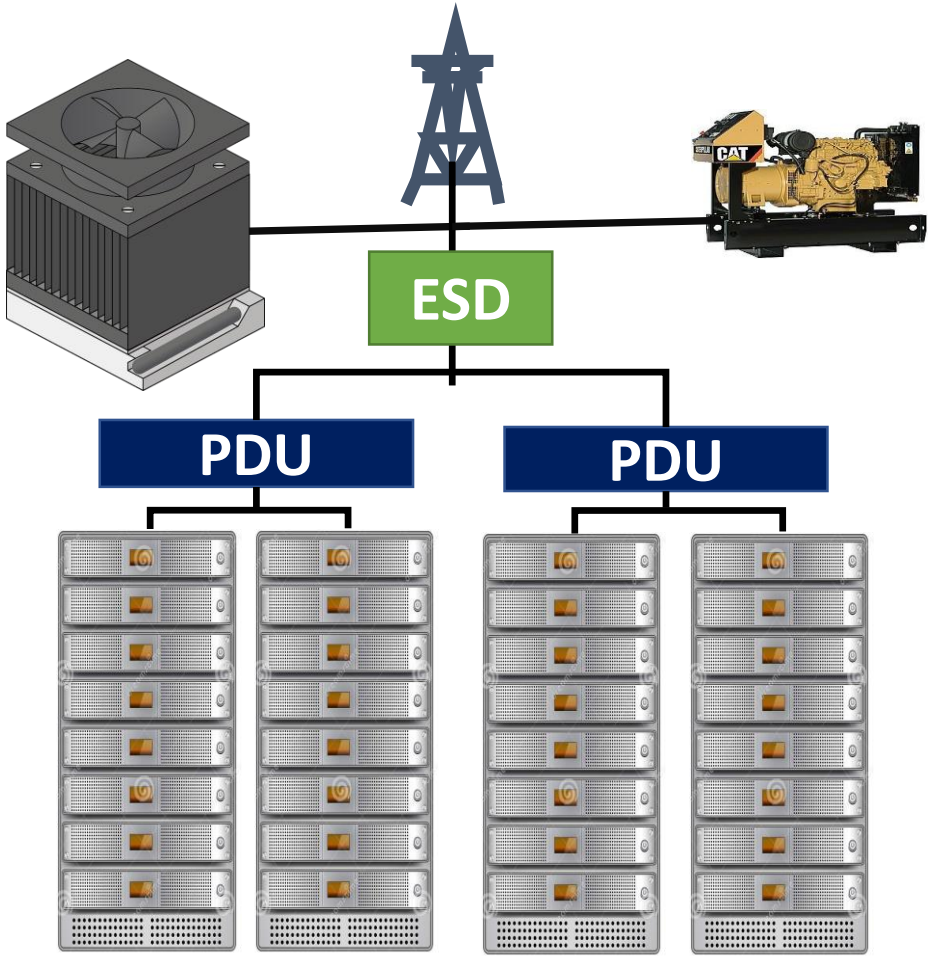
- Latency and availability are important for cloud apps
- Geo-distributed capacity planning
  - Geographical factors, Datacenter factors and Application factors
- Capacity optimization framework
  - Geo-distribution for lower costs
  - Geo-distribution for joint latency and availability
  - Geo-distributed replication aware capacity planning
  - More results in paper

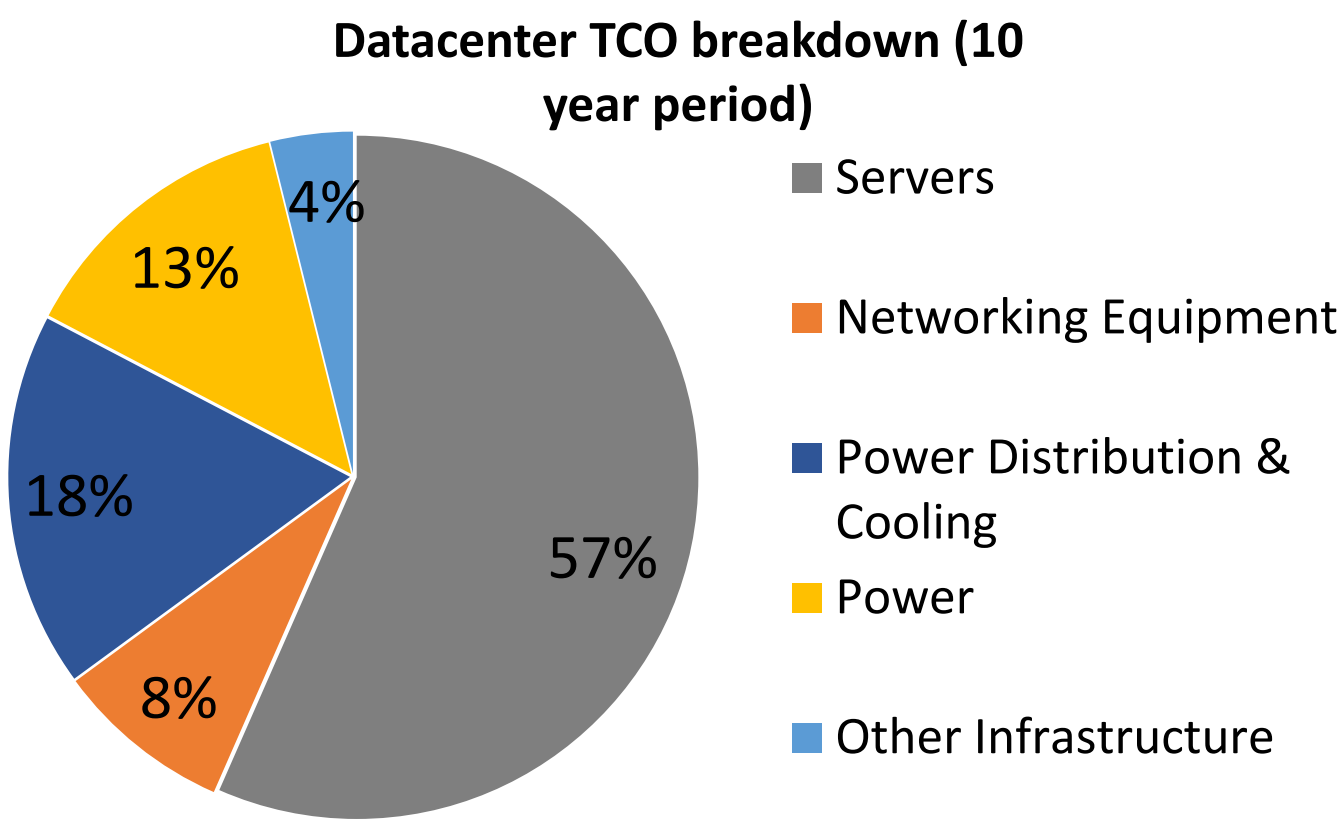
Capacity planning – Important for operators





Capacity planning – Important for operators



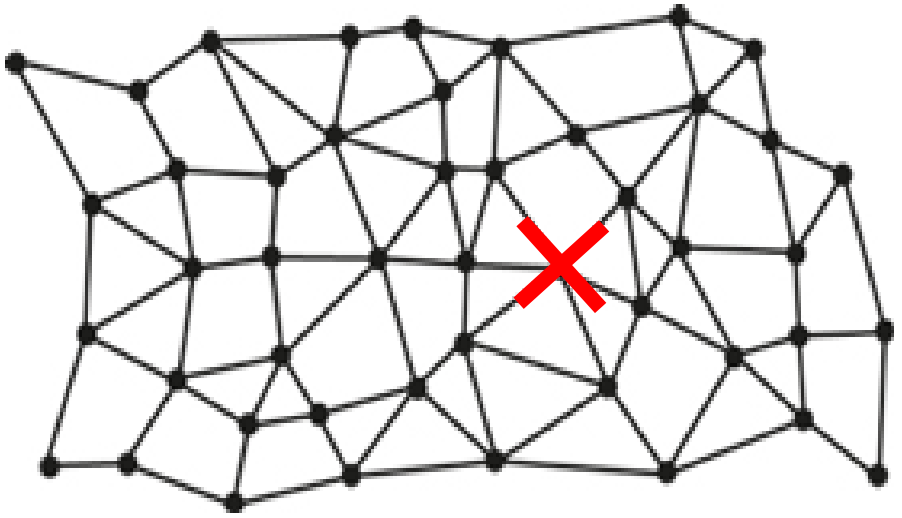


Source: Perspectives Datacenter Cost And Power

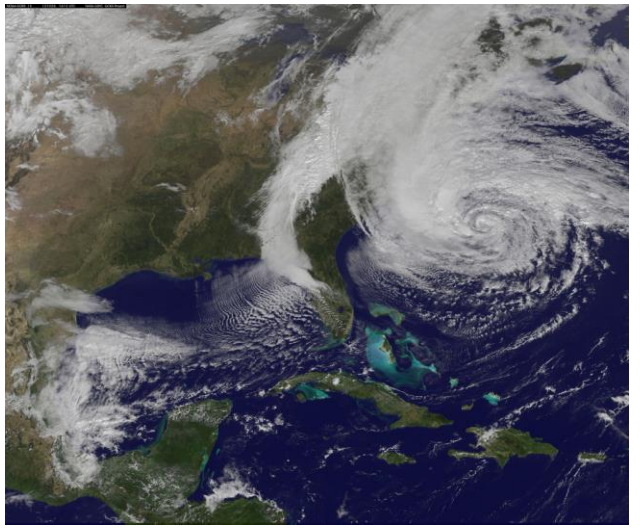
Availability is important for applications

DCs are prone to failures

Power failures

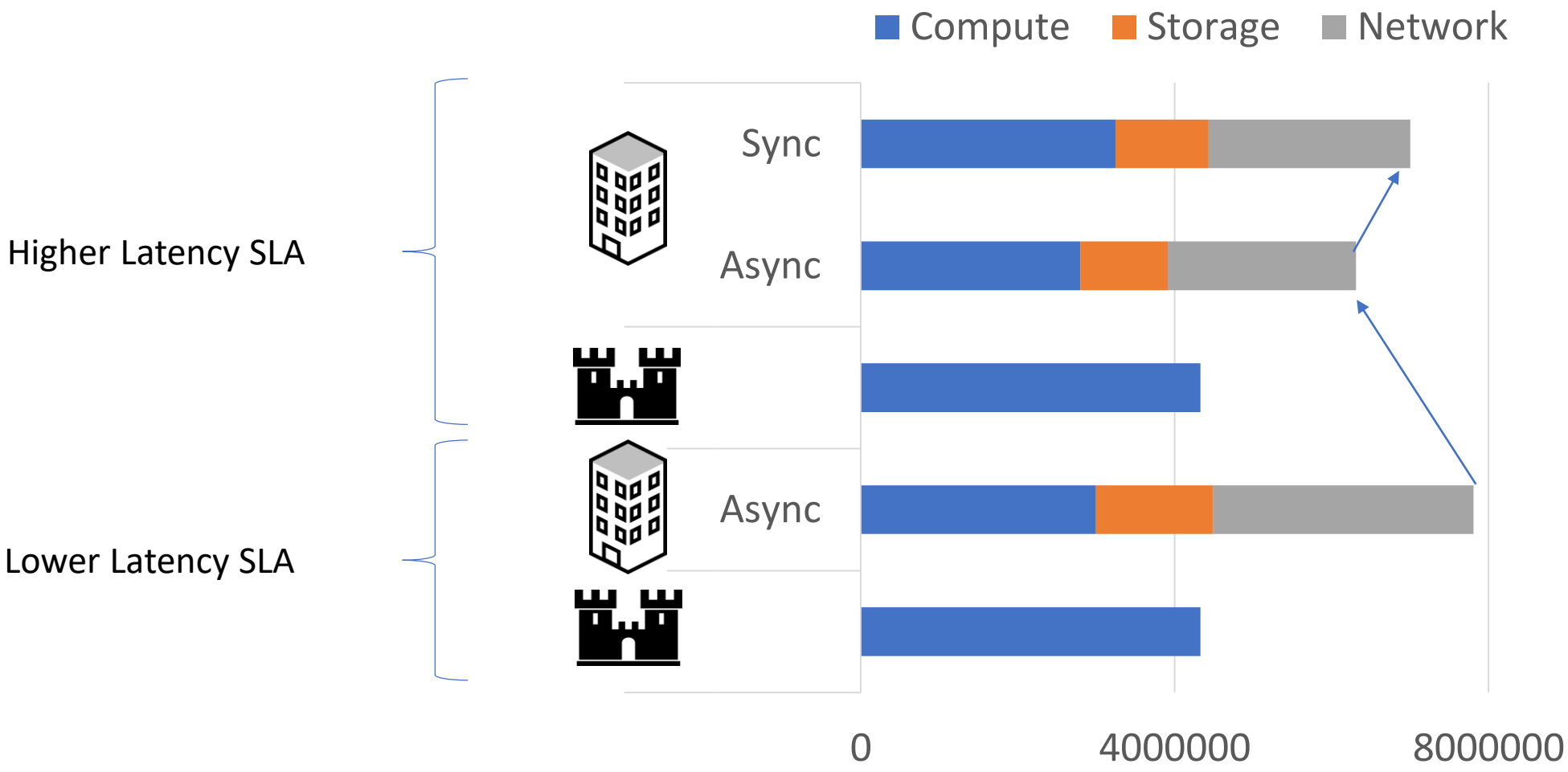


Network failures



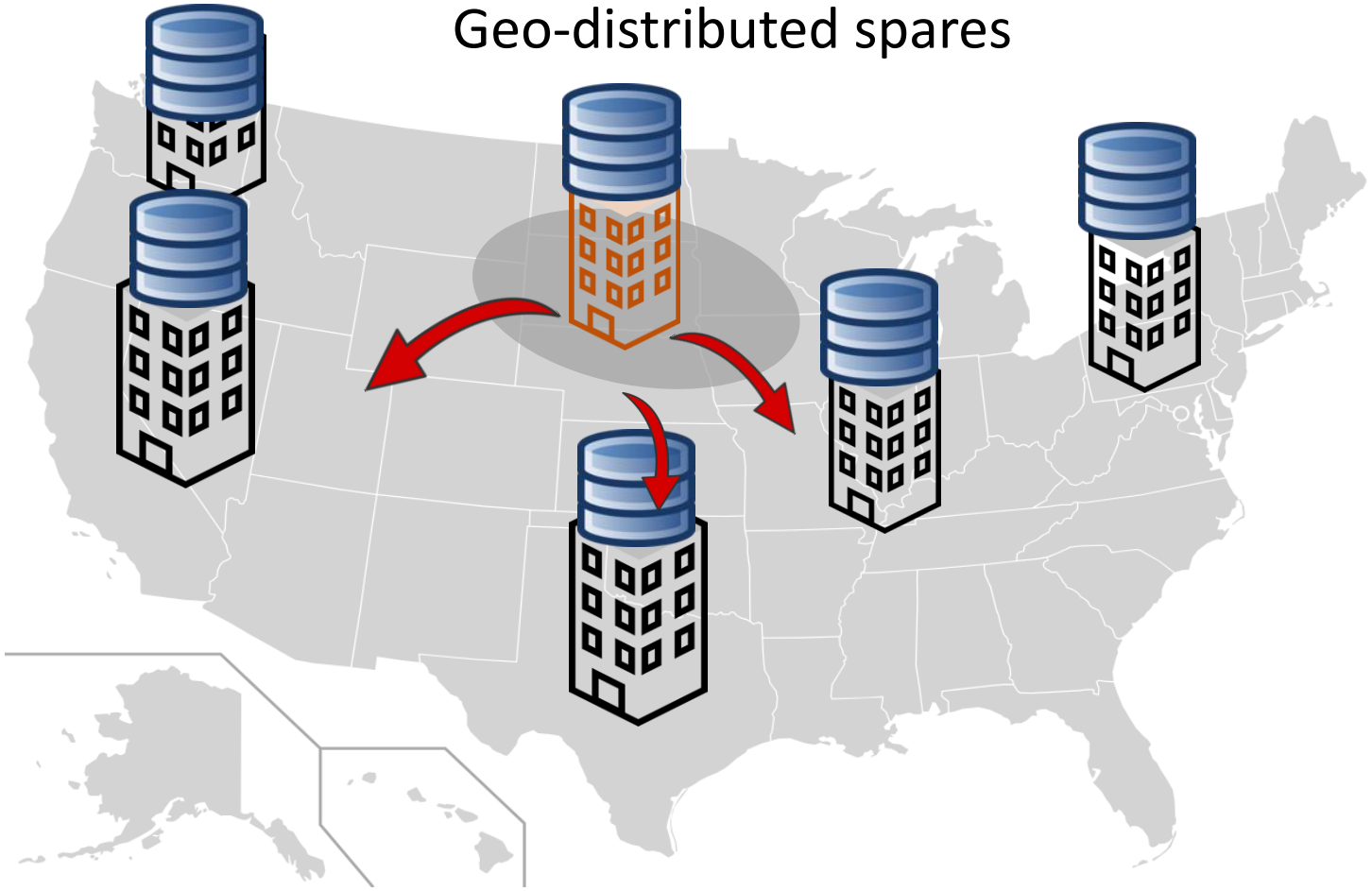
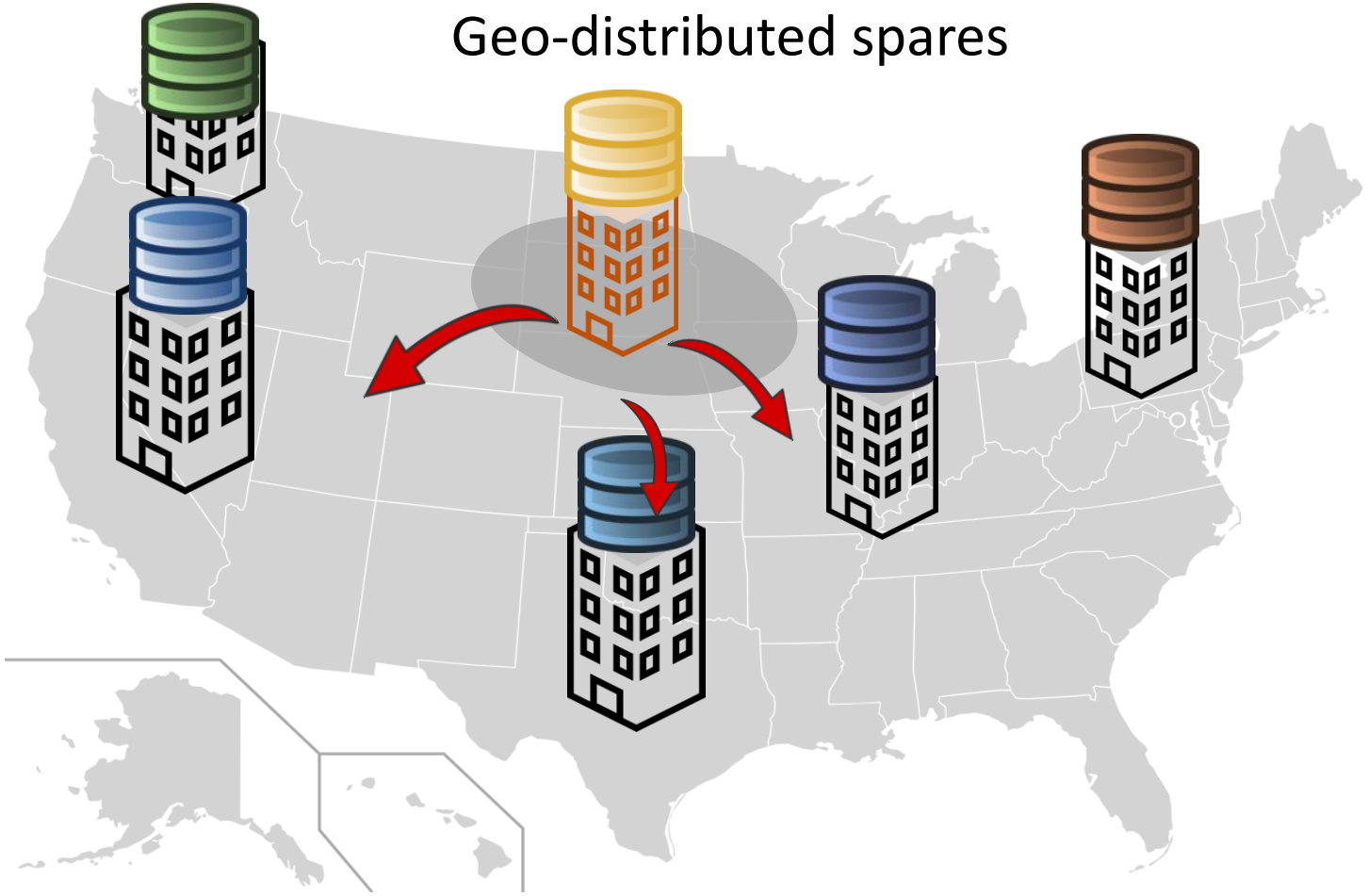
Natural calamities

Geo-distribution for high availability



Replication costs overweigh the benefits

Replication to use geo-distributed spares



Replication to use geo-distributed spares