

Advanced Cloud Computing

Cloud Pricing and Economics

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Cloud Pricing

Fundamental Drivers of Cost

- ▶ Compute (EC2)

Let's focus on compute

- ▶ charged per hour/second
- ▶ varies by instance type (VM configurations)

- ▶ Storage (S3, EBS)

- ▶ charged typically per GB w/ tiered pricing

- ▶ Data transfer

- ▶ outbound is aggregated and charged, typically per GB
- ▶ inbound has no charge (w/ some exceptions)

How to set the unit instance price?

	vCPU	ECU	Memory (GiB)	Instance Storage (GB)	Linux/UNIX Usage
General Purpose - Current Generation					
t2.nano	1	Variable	0.5	EBS Only	\$0.0059 per Hour
t2.micro	1	Variable	1	EBS Only	\$0.012 per Hour
t2.small	1	Variable	2	EBS Only	\$0.023 per Hour
t2.medium	2	Variable	4	EBS Only	\$0.047 per Hour
t2.large	2	Variable	8	EBS Only	\$0.094 per Hour
t2.xlarge	4	Variable	16	EBS Only	\$0.188 per Hour
t2.2xlarge	8	Variable	32	EBS Only	\$0.376 per Hour
m4.large	2	6.5	8	EBS Only	\$0.108 per Hour
m4.xlarge	4	13	16	EBS Only	\$0.215 per Hour
m4.2xlarge	8	26	32	EBS Only	\$0.431 per Hour
m4.4xlarge	16	53.5	64	EBS Only	\$0.862 per Hour
m4.10xlarge	40	124.5	160	EBS Only	\$2.155 per Hour
m4.16xlarge	64	188	256	EBS Only	\$3.447 per Hour

	vCPU	ECU	Memory (GiB)	Instance Storage (GB)	Linux/UNIX Usage
General Purpose - Current Generation					
t2.nano	1	Variable	0.5	EBS Only	\$0.008 per Hour
t2.micro	1	Variable	1	EBS Only	\$0.016 per Hour
t2.small	1	Variable	2	EBS Only	\$0.032 per Hour
t2.medium	2	Variable	4	EBS Only	\$0.064 per Hour
t2.large	2	Variable	8	EBS Only	\$0.128 per Hour
t2.xlarge	4	Variable	16	EBS Only	\$0.256 per Hour
t2.2xlarge	8	Variable	32	EBS Only	\$0.512 per Hour
m4.large	2	6.5	8	EBS Only	\$0.139 per Hour
m4.xlarge	4	13	16	EBS Only	\$0.278 per Hour
m4.2xlarge	8	26	32	EBS Only	\$0.556 per Hour
m4.4xlarge	16	53.5	64	EBS Only	\$1.113 per Hour
m4.10xlarge	40	124.5	160	EBS Only	\$2.782 per Hour
m4.16xlarge	64	188	256	EBS Only	\$4.45 per Hour

NOVA

Tokyo

t2.nano	\$0.0059 per Hour	\$0.008 per Hour
t2.micro	\$0.012 per Hour	\$0.016 per Hour
t2.small	\$0.023 per Hour	\$0.032 per Hour
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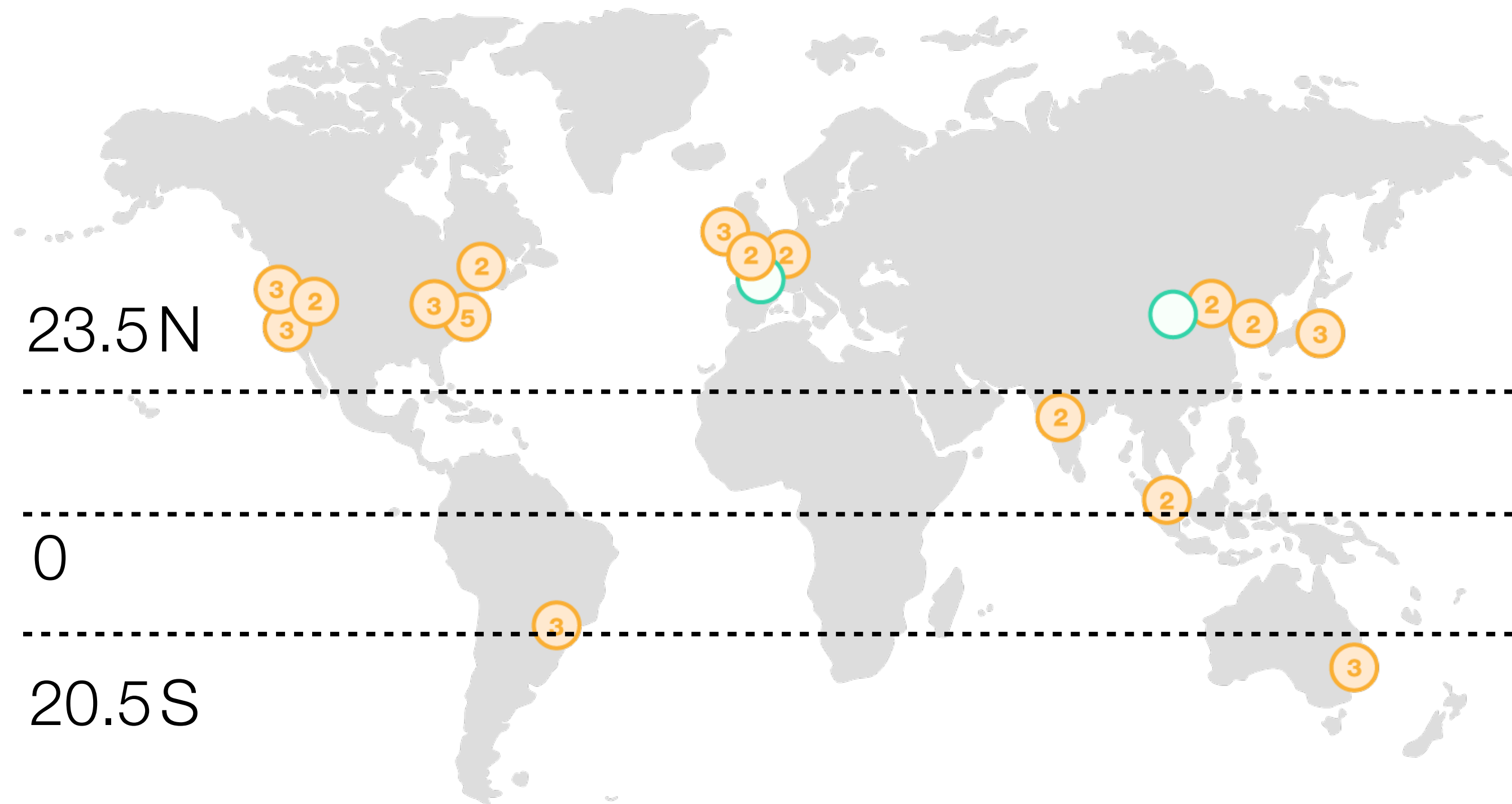
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Why location matters?

Why location matters?

- ▶ Cooling cost
- ▶ Manpower cost
- ▶ Land price
- ▶ Policy issues
- ▶ ...

**Is HK a suitable place for
datacenter?**



Region #



New Regions

Is on-demand pay-as-you-go
pricing enough?

Diverse pricing options

- ▶ On-demand
- ▶ Reservation-based
- ▶ Spot pricing
- ▶ ...

Pay for what you use



Pay less when you reserve



Pay less when you use more and as AWS grows



Reserved pricing

- ▶ Pay an up-front reservation fee to reserve an instance for a long period, e.g., 1 to 3 years
- ▶ Enjoy a significant discount during the reservation period
 - ▶ save up to 75% over on-demand

$$\text{Cost}(t) = U + \textit{discount} \times R \times t$$

Upfront



On-demand rate



Reserved pricing

- ▶ **Guaranteed availability**

- ▶ users signed up for the reserved pricing are always serviced, regardless of the DC load
- ▶ not possible for on-demand pricing

Reserved pricing for t2.xlarge

STANDARD 1-YEAR TERM					
Payment Option	Upfront	Monthly*	Effective Hourly**	Savings over On-Demand	On-Demand Hourly
No Upfront	\$0	\$109.62	\$0.150	20%	\$0.188 per Hour
Partial Upfront	\$562	\$46.85	\$0.128	32%	
All Upfront	\$1102	\$0	\$0.126	33%	
STANDARD 3-YEAR TERM					
Payment Option	Upfront	Monthly*	Effective Hourly**	Savings over On-Demand	On-Demand Hourly
Partial Upfront	\$1164	\$32.33	\$0.089	53%	\$0.188 per Hour
All Upfront	\$2188	\$0	\$0.083	56%	

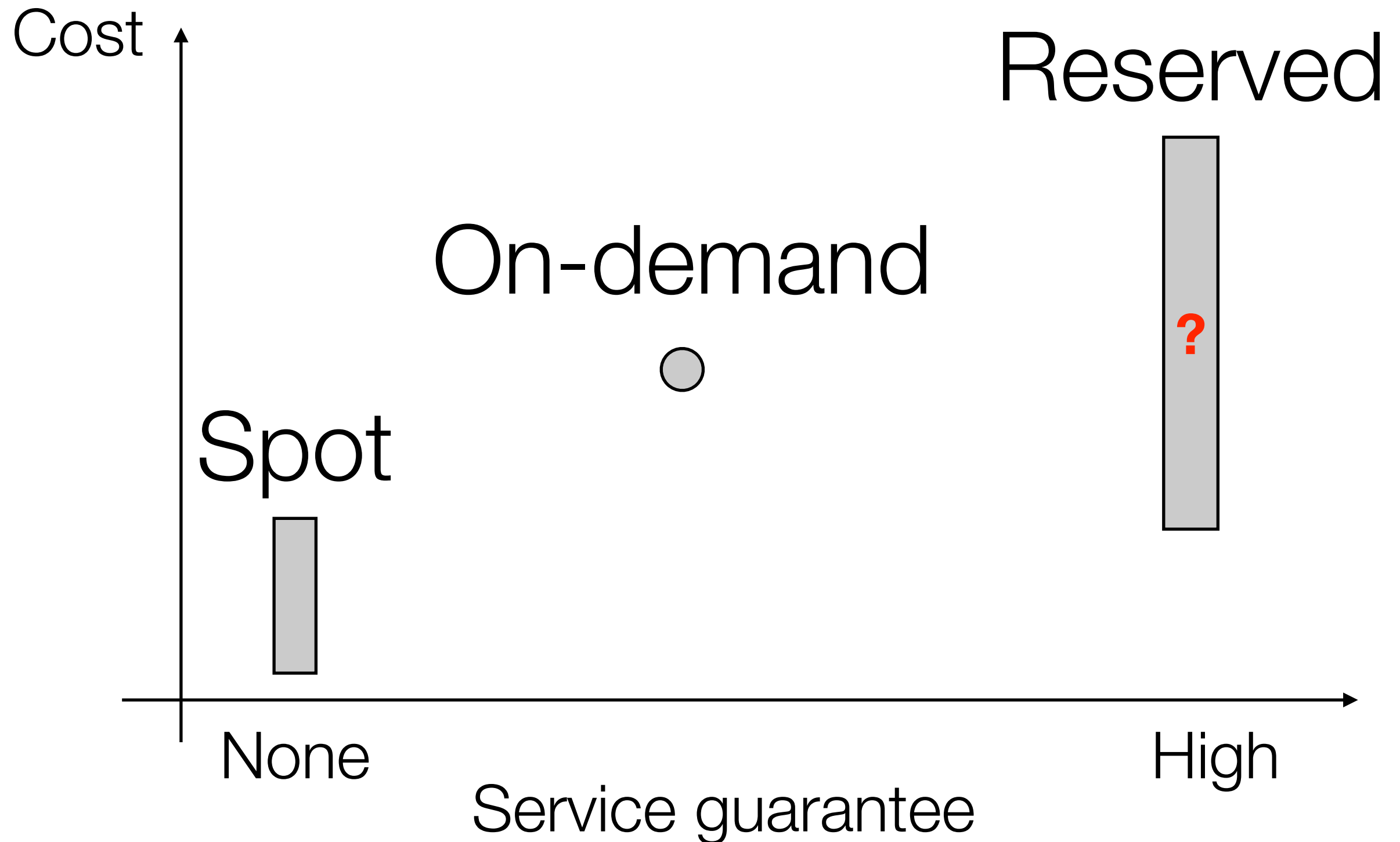
Spot pricing

- ▶ Used to be an **auction-like** pricing option
 - ▶ users submit **bid** for instance acquisition
 - ▶ cloud posts a **spot price** periodically
 - ▶ users with a **higher bid** than the spot price wins
 - ▶ the spot price is applied until a new one is posted
 - ▶ running users with a lower bid get their instances terminated
- ▶ <https://youtu.be/g3saaMFBhJk>

Spot pricing

- ▶ Spot price is usually much cheaper than on-demand
 - ▶ Does it make sense to have a higher spot price than on-demand?
- ▶ No service guarantee
 - ▶ running spot instances get terminated when the spot prices rises above the bid

Summary of pricing



AWS Free Tier

- ▶ Enables you to gain hands-on experience with the AWS platform, products, and services
 - ▶ free for 1-year for new customers only
- ▶ only applies to a restricted set of services (e.g., EC2 t2.micro instances, free usage tier of S3, EBS, etc.)



**Sign up for an
AWS account**



**Learn with 10-
minute tutorials**



**Start building
with AWS**

Services with no charge

- ▶ Many cloud services are free of charge



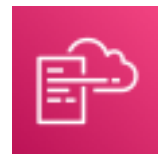
Amazon VPC



Elastic Beanstalk**



Auto Scaling**



AWS CloudFormation**



AWS Identity and Access Management (IAM)

****Note:** There might be charges associated with other AWS services that are used with these services.

Why so many different pricing models?

Market segmentation

- ▶ Reserved pricing
 - ▶ locks in long-term users
 - ▶ helps predict future demand: better for capacity planning
- ▶ On-demand
 - ▶ the fundamental cloud business model
- ▶ Spot pricing
 - ▶ leftover capacity on sale: increase utilization

Provider's problems

- ▶ Datacenter has a limited capacity
- ▶ How to allocate the capacity for each pricing model?
 - ▶ if not planned well, one model can cannibalize the other
- ▶ How to set the price of each model?

User's problems

- ▶ How to cut down the cloud bill by combining different pricing models?
 - ▶ demand/workload prediction
 - ▶ predict spot price: many works try to reverse-engineer how the spot price is set
 - ▶ creative use of spot instances
 - ▶ periodic checkpointing and recovery upon instance revocation
 - ▶ save over 50% compared with on-demand

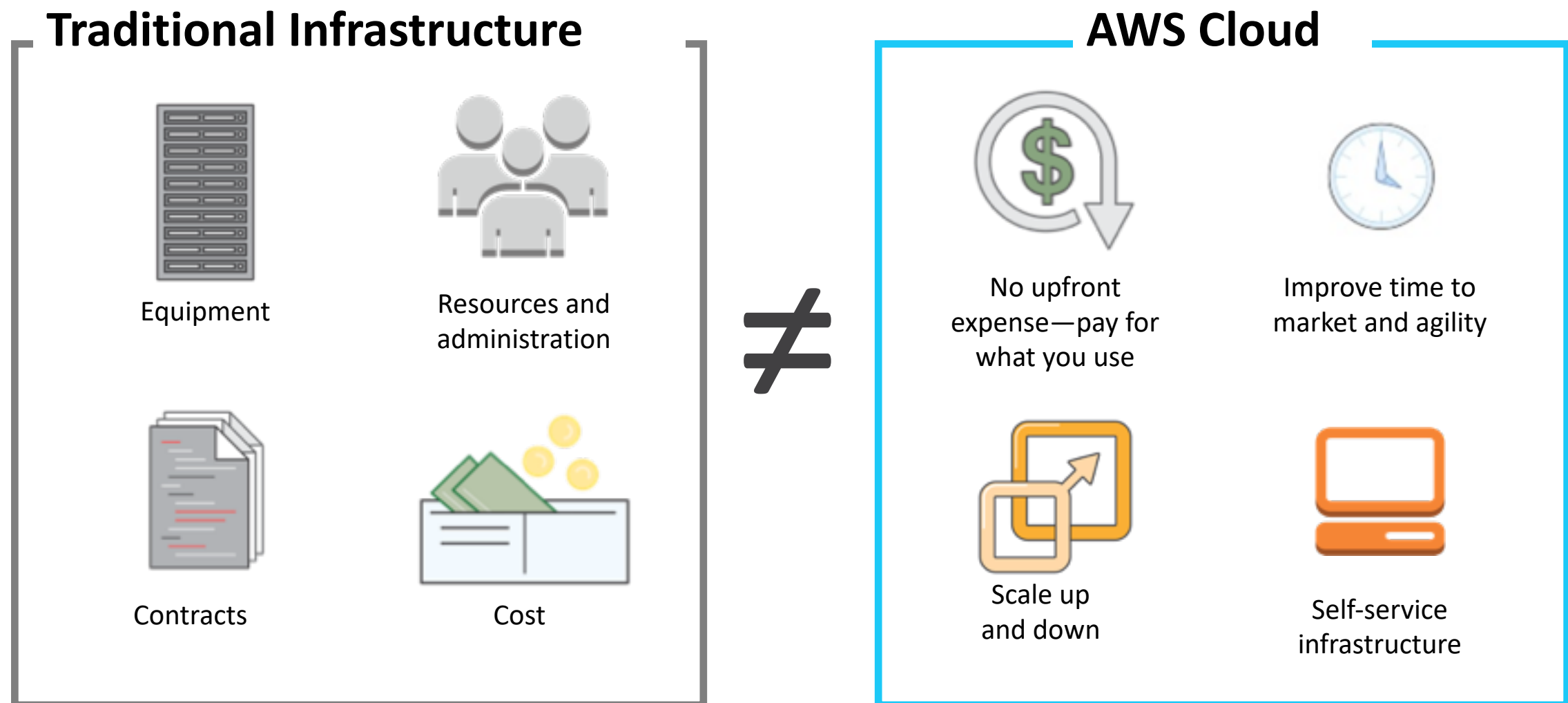
The rise of brokerage service

- ▶ Cloud brokerage service
 - ▶ helps users to make instance acquisition strategies
 - ▶ trade-in unused instances in a secondary cloud marketplace
 - ▶ hybrid cloud: connects to multiple cloud providers to explore the best deal
 - ▶ many innovative business models coming...

Cloud Economics: Total Cost of Ownership (TCO)

On-premises vs. cloud

- Shall I move to the cloud?



Total Cost of Ownership (TCO)

- ▶ **Total cost of ownership (TCO)** is the financial estimate to help identify direct and indirect cost of a system
- ▶ Why use TCO?
 - ▶ to compare the costs of running an **entire infrastructure environment or specific workload** on-premises versus on cloud (e.g., AWS)
 - ▶ to budget and **build the business case** for moving to the cloud



TCO Considerations

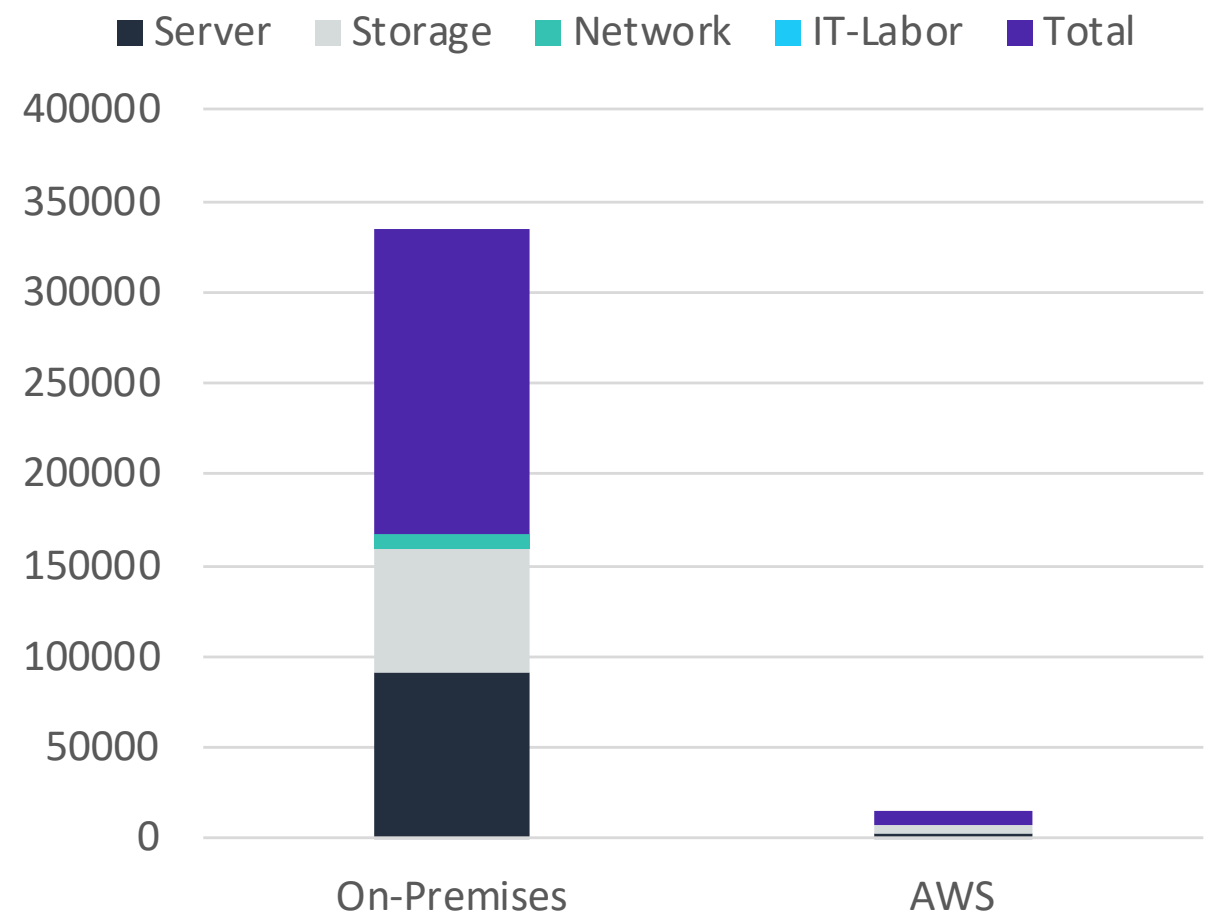
1	Server Costs	Hardware: Server, rack chassis power distribution units (PDUs), top-of-rack (TOR) switches (and maintenance)	Software: Operating system (OS), virtualization licenses (and maintenance)	Facilities cost		
				Space	Power	Cooling
2	Storage Costs	Hardware: Storage disks, storage area network (SAN) or Fibre Channel (FC) switches	Storage administration costs	Facilities cost		
				Space	Power	Cooling
3	Network Costs	Network hardware: Local area network (LAN) switches, load balancer bandwidth costs	Network administration costs	Facilities cost		
				Space	Power	Cooling
4	IT Labor Costs	Server administration costs				

On-premises vs. all-in-cloud

- ▶ Taking AWS cloud as an example, moving infrastructure to it can reduce TCO by up to 96% a year.

3-Year Total Cost of Ownership		
	On-Premises	AWS
Server	\$91,922	\$2,547
Storage	\$67,840	\$4,963
Network	\$7,660	\$-----
IT – Labor	\$ -----	\$-----
	--	
Total	\$167,422	\$7,509

AWS cost includes business-level support and a 3-year PURI EC2 instance



Additional benefit considerations

▶ Hard benefits

- ▶ reduced spending on compute, storage, networking, security
- ▶ reductions in hardware and software purchases (capex)
- ▶ reductions in operational costs, backup, and disaster recovery
- ▶ reduction in operations personnel

▶ Soft benefits

- ▶ reuse of service and apps that enable you to define (and redefine) solutions by using the same cloud service
- ▶ increased developer productivity and customer satisfaction
- ▶ agile business processes that can quickly respond to new and emerging opportunities
- ▶ increase in global reach

TCO case study



Background:

- Is a growing global company with over 200 locations
- Have 500 million customers, \$3 billion (USD) annual revenue

Challenge:

- Meet demand to rapidly deploy new solutions
- Constantly upgrade aging equipment

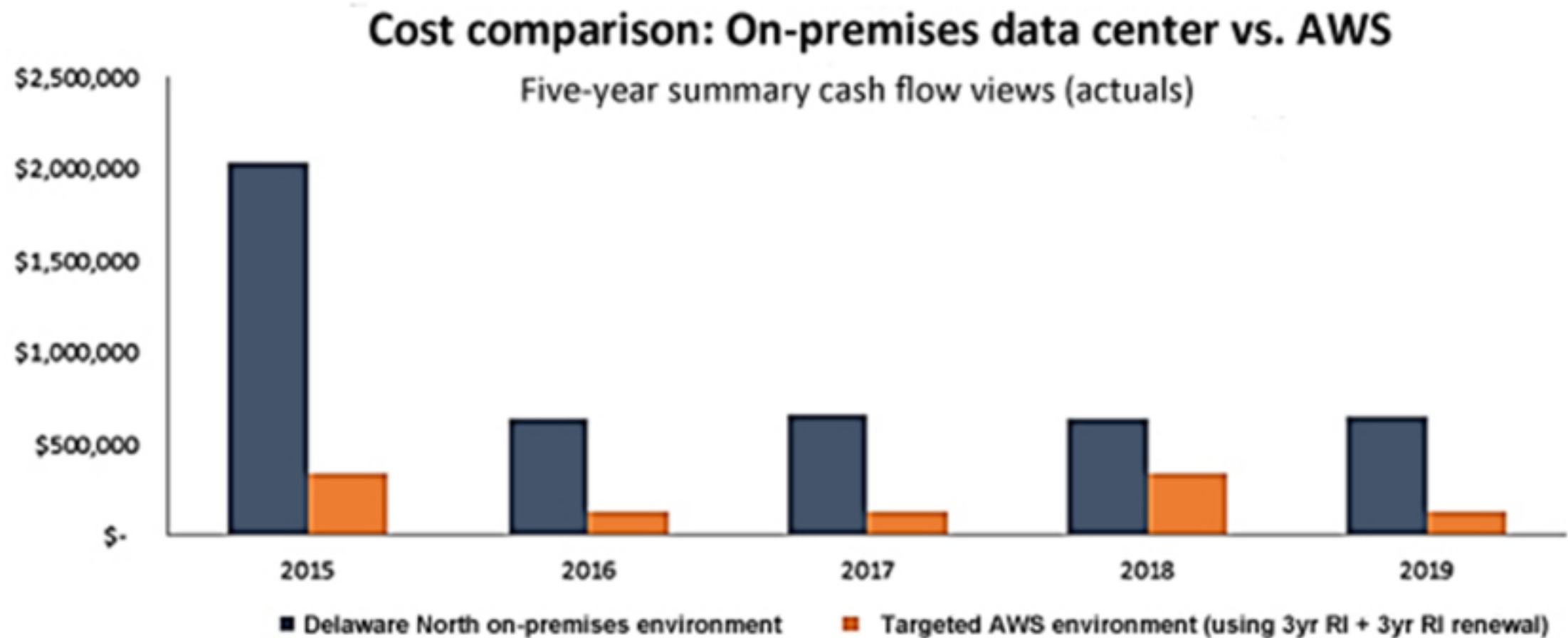
Criteria:

- Have a broad solution to handle all workloads
- Be able to modify processes to improve efficiency and lower costs
- Eliminate busy work (such as patching software)
- Achieve a positive return on investment (ROI)

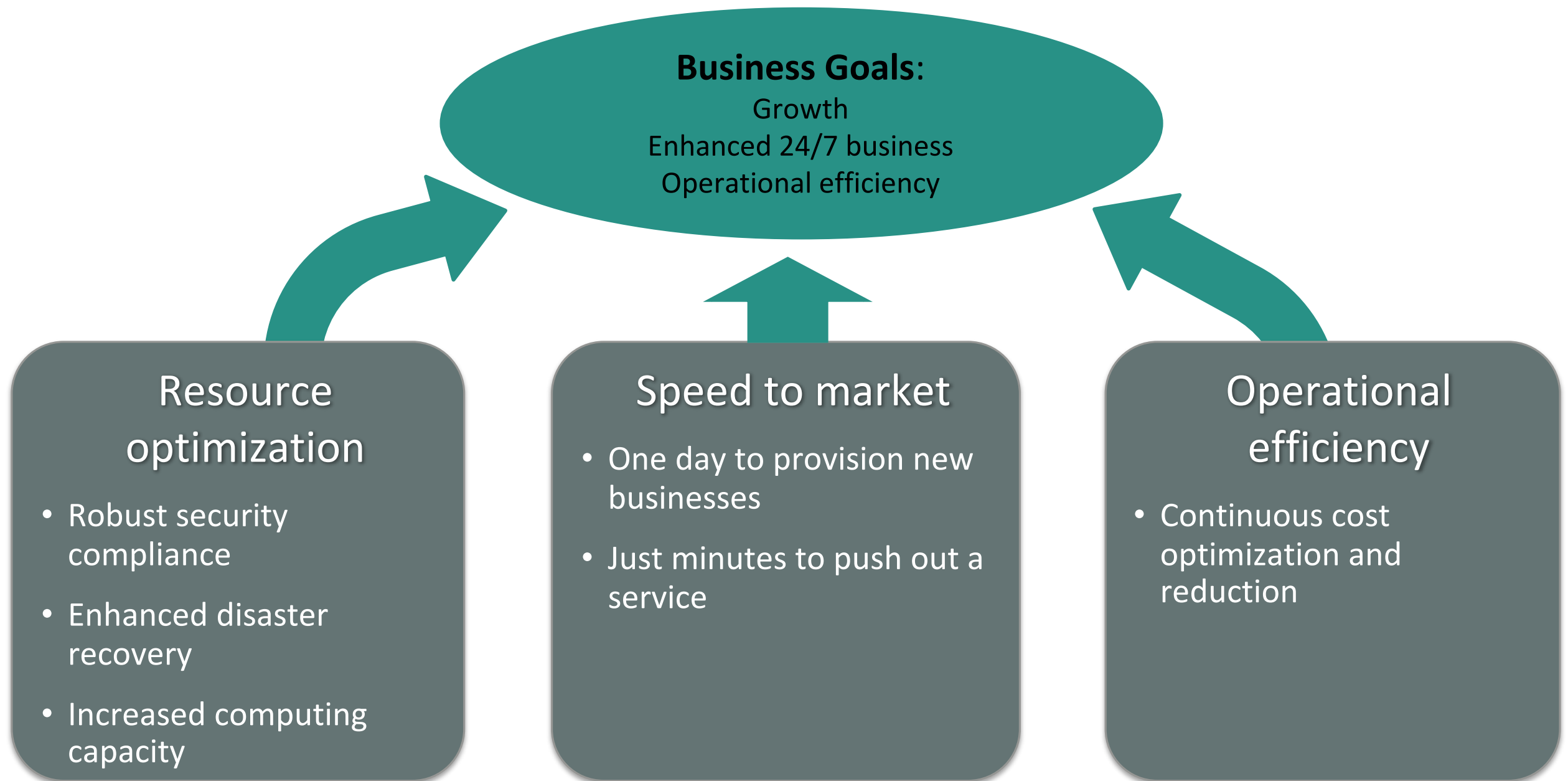
Solution:

- Moved their on-premises data center to AWS
 - Eliminated 205 servers (90 percent)
 - Moved nearly all applications to AWS
- Used 3-year Amazon EC2 Reserved Instances

TCO case study



TCO case study



How can the cloud business
benefit the provider?

Resource pooling

- From the provider's perspective



Resource pooling

- ▶ The provider's resources are **pooled** to serve consumers using a **multi-tenant** model
 - ▶ different *physical* and *virtual* resources dynamically allocated according to consumer demand
 - ▶ creates an illusion of an infinite amount of resources

Resource pooling

- ▶ **Location independence:**

- ▶ the customer generally has NO control or knowledge over the exact location of the provided resources
- ▶ but may be able to specify location at a higher level of abstraction (e.g., country, state, or datacenter)

Resource pooling enables
high utilization

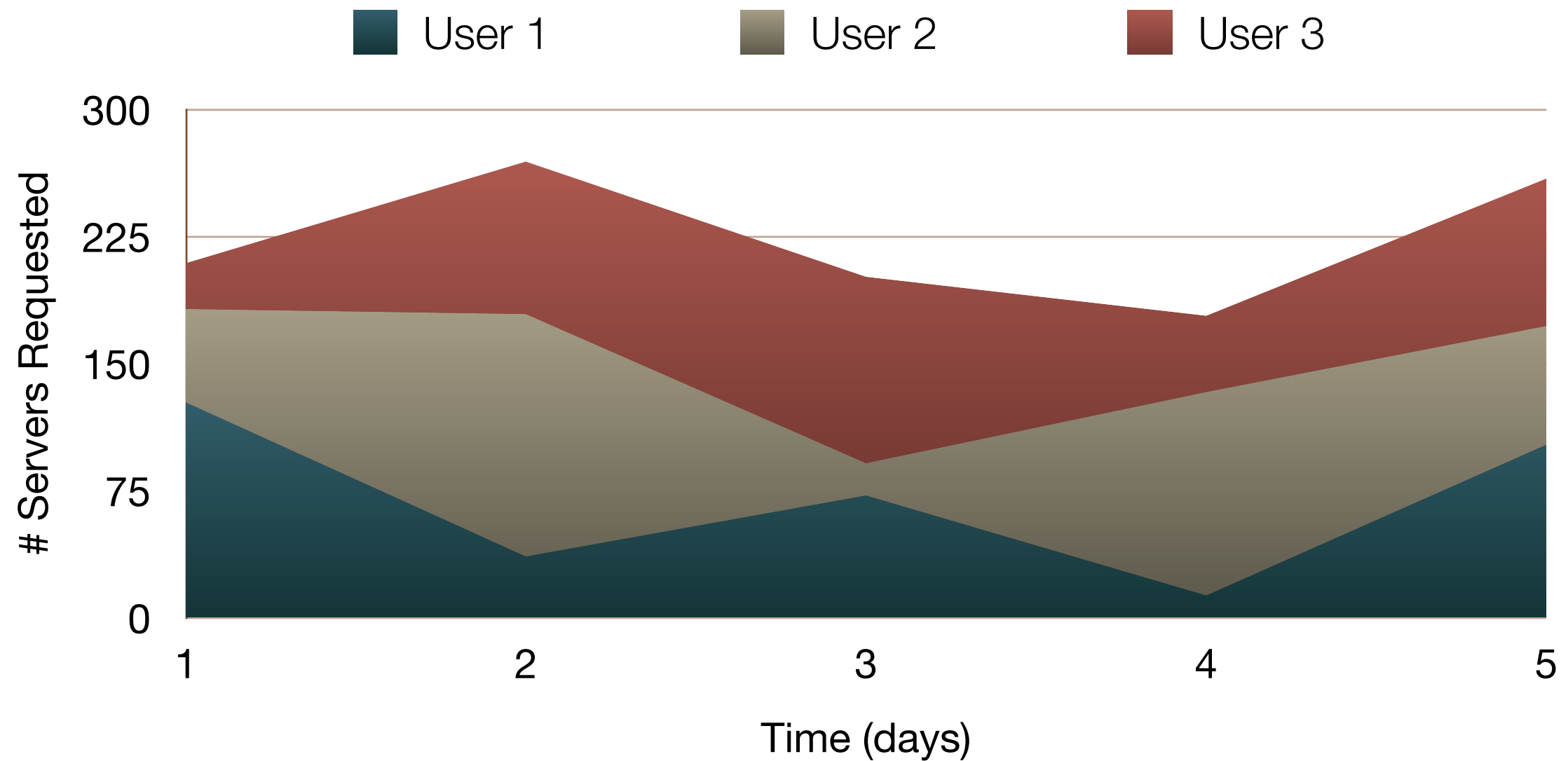
Economy of scale

- ▶ A medium-sized datacenter (~1k servers) vs. a large datacenter (~50k servers) in 2006

Technology	Cost in Medium-sized DC	Cost in Very Large DC	Ratio
Network	\$95 per Mbit/sec/month	\$13 per Mbit/sec/month	7.1
Storage	\$2.20 per GByte / month	\$0.40 per GByte / month	5.7
Administration	≈140 Servers / Administrator	>1000 Servers / Administrator	7.1

5 - 7x decrease of cost!

Statistical multiplexing



Highly profitable business for
Cloud providers

Plus...

- ▶ **Leverage existing investment**, e.g., Amazon
- ▶ **Defend a franchise**, e.g., Microsoft Azure
- ▶ **Attack an incumbent**, e.g., Google Cloud Platform
- ▶ **Leverage customer relationships**, e.g., IBM
- ▶ **Become a platform**, e.g., Facebook, Apple, etc.

Credit

- ▶ Some slides are adapted from Prof. Hong Xu's slides for CS 4296/5296 in CityU
- ▶ Some slides are adapted from AWS Academy Class (Cloud foundations)