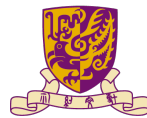


Cloud Computing Service Models and Challenges

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SDS@CUHK-SZ

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The Chinese University of Hong Kong, Shenzhen



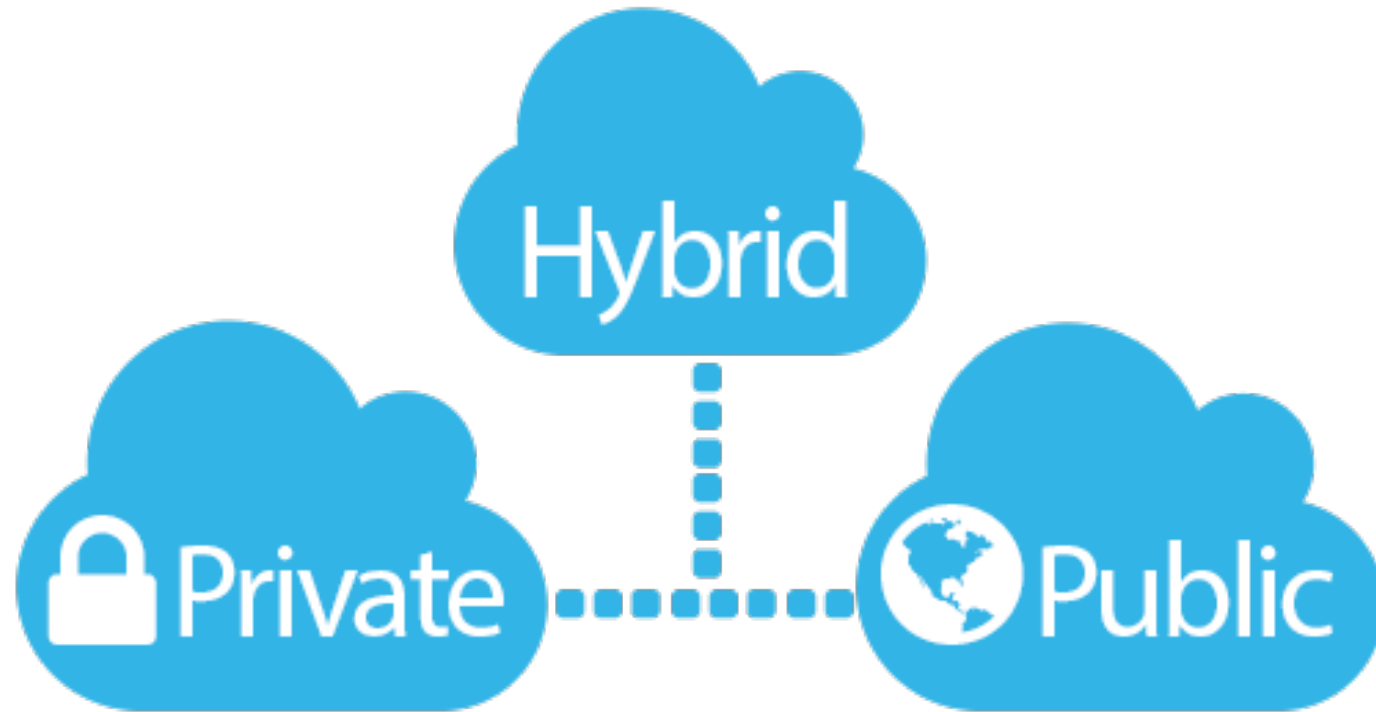
SCHOOL OF
DATA SCIENCE
數據科學學院

Outline

部署

- Cloud deployment models
- Service models
- Issues of Cloud
- Challenges

Cloud deployment models



Public Cloud

- Providers let clients access the cloud via Internet
- Made available to the general public



Public Cloud

多租户 虚拟化

基础设施建设

- Multi-tenant virtualization, global-scale infrastructure
- Functions and pricing vary



Copyright: Google

Private Cloud

唯一的

- The cloud is used solely by an organization (e.g., Facebook)
- May reside in-house or off-premise



vmware®



Private Cloud

- Secure, dedicated infrastructure with the benefits of on-demand provisioning
安全、专用的基础设施，具有按需配置的优势
- Not burdened by network bandwidth and availability issues and security threats associated with public clouds.
不受与公共云相关的网络带宽和可用性问题和安全威胁的困扰。
- Greater control, security, and resilience.
更好的控制、安全性和弹性。

Hybrid Cloud 混合云

由多个云（私有云、公有云等）组成，这些云仍然是独立实体，但使用标准或专有协议进行互操作

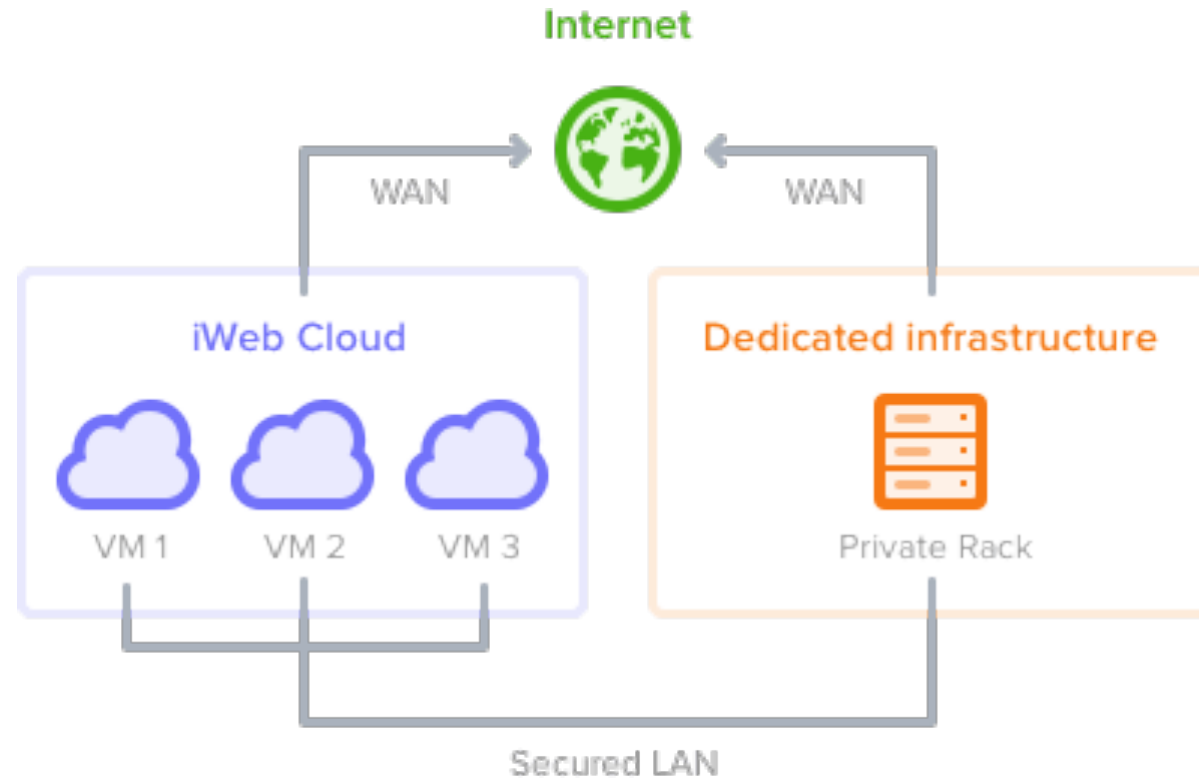
- Composed of multiple clouds (private, public, etc.) that remain independent entities, but interoperate using standard or proprietary protocols
- Banks, hospitals, government

The VMware logo, featuring the word "vmware" in a lowercase, sans-serif font with a registered trademark symbol.

Hybrid Cloud

跨云流动

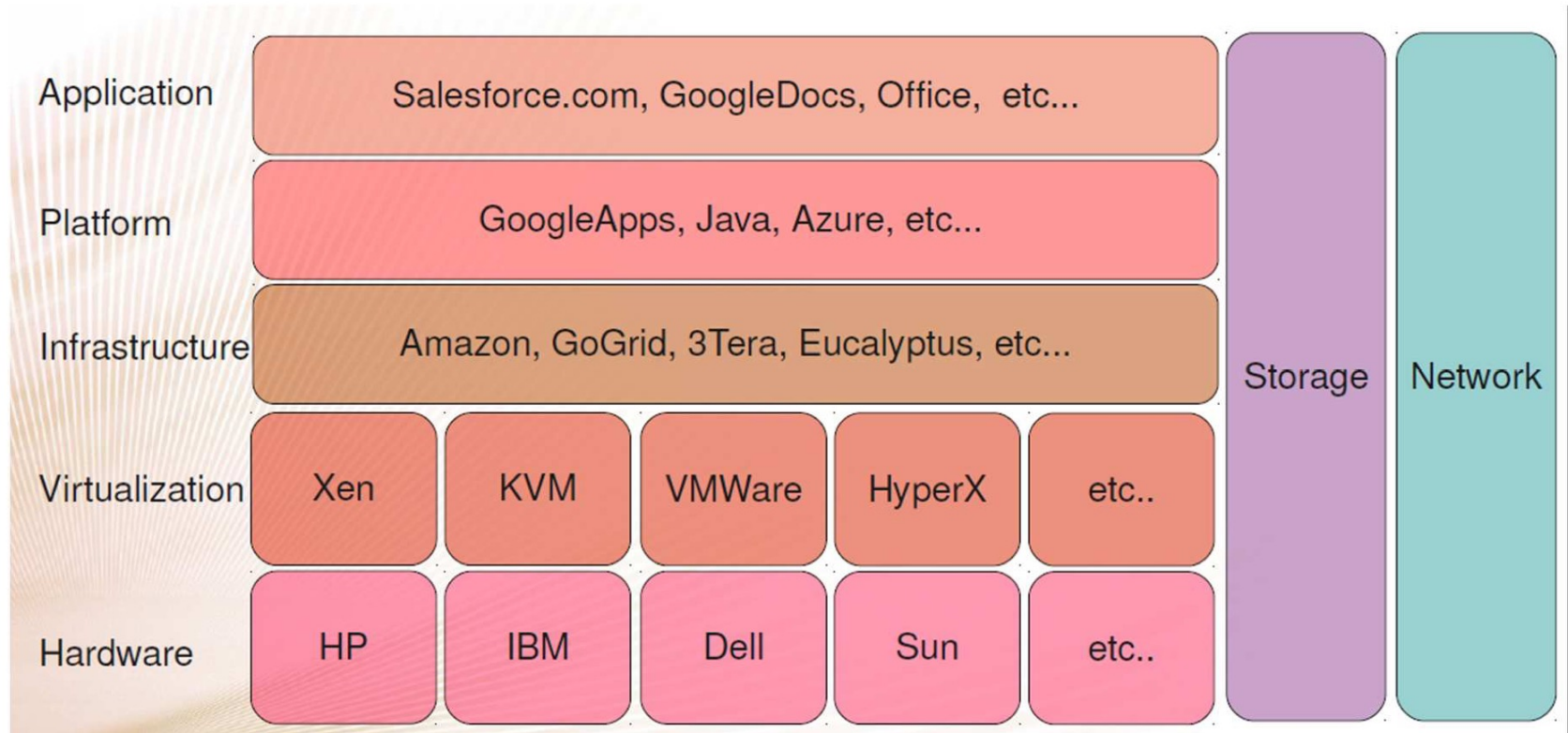
- Allows applications and data to flow across clouds



Copyright: iWeb

Cloud Service Models

Cloud computing stack



By Nick Barcet, "What is Ubuntu Cloud", Nov 2009

Cloud service models

- Infrastructure-as-a-Service (IaaS)
- Platform-as-a-Service (PaaS)
- Software-as-a-Service (SaaS)
- Other X-as-a-Service
 - Function-as-a-Service (FaaS)
 - Machine-Learning-as-a-Service (MLaaS)

基础设施即服务 (IaaS)

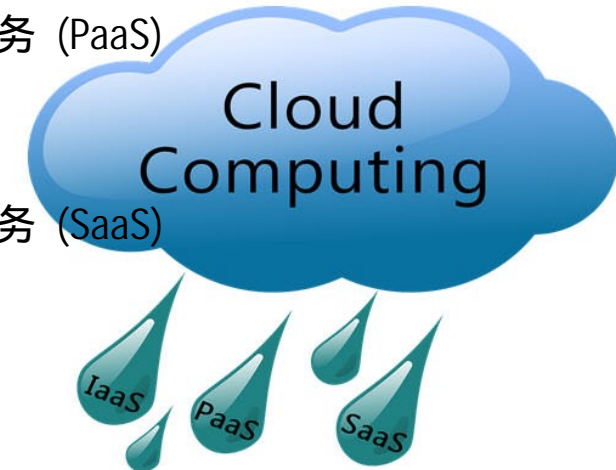
平台即服务 (PaaS)

软件即服务 (SaaS)

其他

功能即服务 (FaaS)

机器学习即服务 (MLaaS)



Infrastructure-as-a-Service 基础设施即服务

- Providers give you the **computing infrastructure** made available as a service. You get “bare-metal” machines. 提供商以服务形式为您提供计算基础设施。您将获得“裸机”机器
- Providers manage a large pool of resources, and use **virtualization** to dynamically allocate 提供商管理大量资源，并使用虚拟化来动态分配
- Customers “rent” these physical resources to customize their own infrastructure 客户“租用”这些物理资源来定制自己的基础设施
- Full control of OS, storage, applications, and some networking components (e.g., firewalls) 完全控制操作系统、存储、应用程序和一些网络组件（例如防火墙）

Infrastructure-as-a-Service

Computation



Storage



Network



Amazon EC2



linode

IaaS use case

- Netflix rents thousands of servers, terabytes of storage from Amazon Web Services (AWS)
- Develop and deploy specialized software for transcoding, storage, streaming, analytics, etc. on top of it
- Is able to support tens of millions of connected devices, used by 40+ million users from 40+ countries



Platform-as-a-Service (PaaS) 平台即服务 (PaaS)

- Providers give you a **software platform**, or **middleware**, where applications run
提供商为您提供软件平台或中间件，应用程序可在此运行
- You develop and maintain and deploy your own software on top of the platform
您可以在平台上开发、维护和部署自己的软件
- The hardware needed for running the software is automatically managed by the platform. You can't explicitly ask for resources.
运行软件所需的硬件由平台自动管理。您无法明确请求资源。

PaaS

- You have automatic scalability, without having to respond to request load increase/decrease 具有自动可扩展性，无需响应请求负载的增加/减少
- No control of OS, storage, or network, but can control the deployed applications and host environment
无法控制操作系统、存储或网络，但可以控制部署的应用程序和主机环境

PaaS use case

- Best for web apps
- Language and API support: Python, Java, PHP, and Go



Software-as-a-Service (SaaS)

软件即服务 (SaaS)

- Providers give you a piece of software/application. They take care of updating, and maintaining it. 提供商为您提供软件/应用程序。他们负责更新和维护。
- You simply use the software through the Internet. 您只需通过互联网使用该软件即可。

Office Web Apps



Word
Web App



Excel
Web App



PowerPoint
Web App



OneNote
Web App

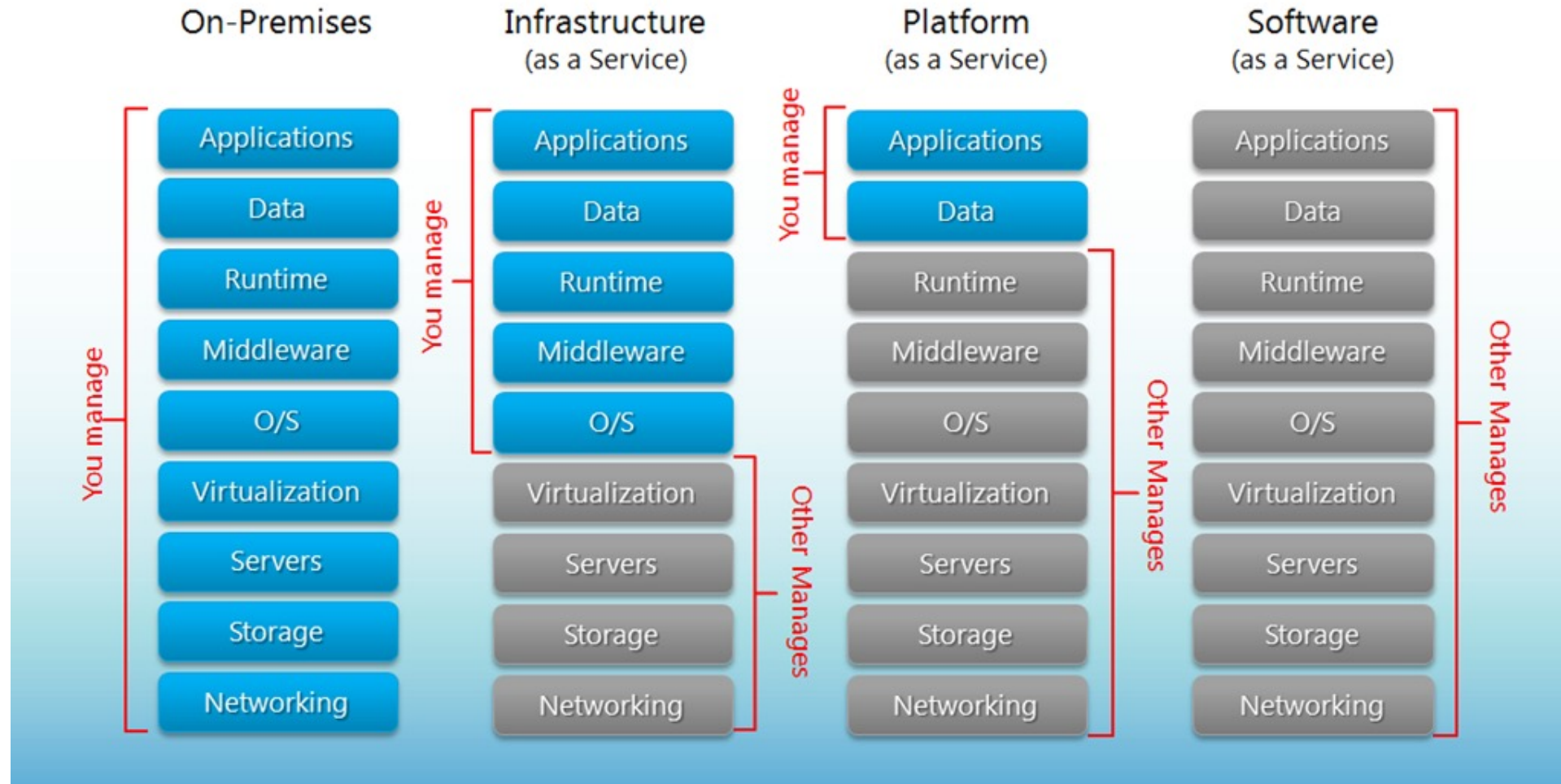


SaaS use case

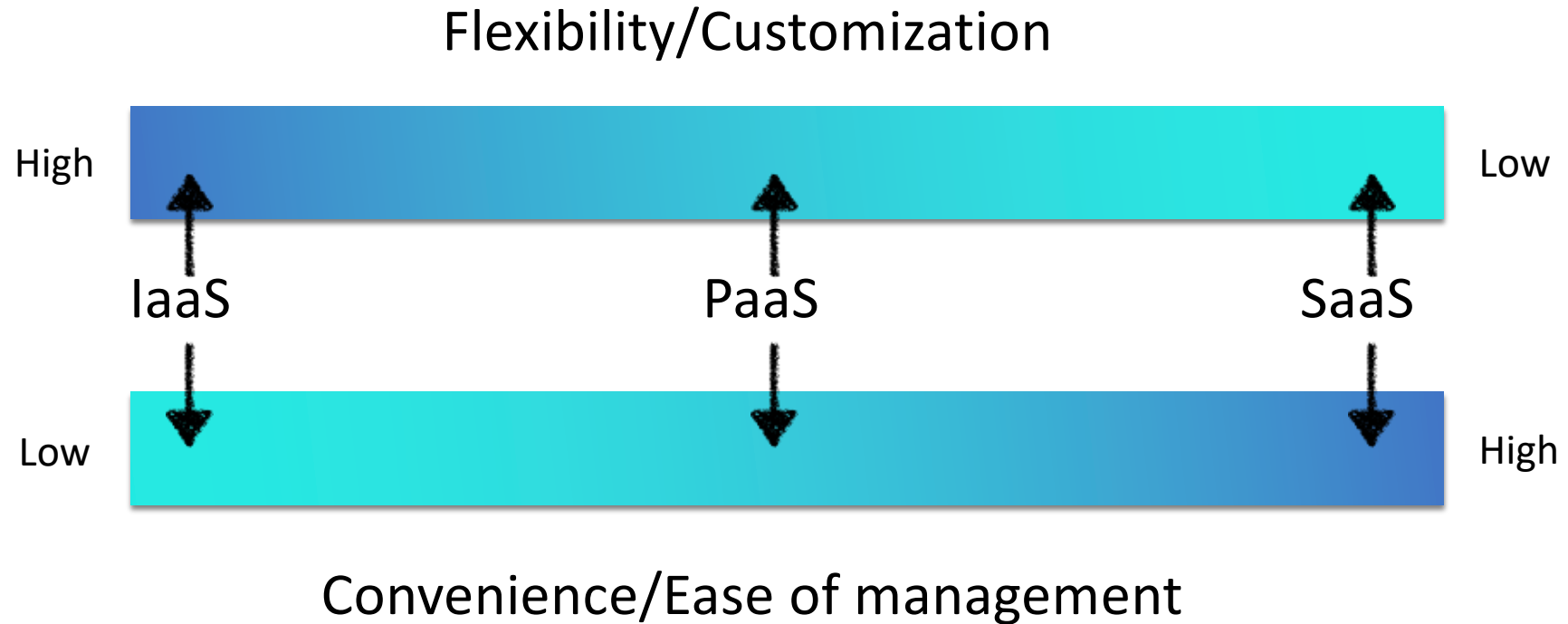
- The university uses Office 365 for student and staff email, calendar, etc.
- Services provided by Google, e.g., Gmail



Separation of Responsibilities



A comparison



Tradeoff between flexibility and “built-in” functionality

Other X-as-a-Service (XaaS)

Function-as-a-Service (FaaS)

函数即服务 (FaaS)

- Users write applications in the form of “cloud functions” 用户以“云函数”的形式编写应用程序
- Users define the events that trigger the execution of those functions (e.g., HTTP requests, webhooks) 用户定义触发这些函数执行的事件（例如 HTTP 请求、webhook）
- Let the cloud platform to handle everything else, including resource provisioning, autoscaling, fault tolerance, etc. 让云平台处理其他所有事务，包括资源配置、自动扩展、容错等。
- Users only pay for the CPU time used to run functions 用户只需为运行函数所用的 CPU 时间付费

Users manage no servers, hence termed “serverless computing”

用户无需管理任何服务器，因此称为“无服务器计算”

Benefits of FaaS

- No server management 无需服务器管理，所有工作均由云提供商处理，而非用户
 - all handled by the cloud provider, not users
- Cost-effective 经济高效，用户只需在执行函数时支付 CPU 时间费用（代码未运行时无需付费）
 - users only pay for the CPU time when functions are executed (no charge when code is not running)
- Flexible scaling 灵活扩展，无需设置自动扩展：这是云提供商的问题
 - no need to set up autoscaling: it's cloud provider's problem
- Automated high availability and fault tolerance

自动化高可用性和容错能力

IaaS vs. FaaS

- ▶ Configure an instance
- ▶ Update OS
- ▶ Install App platform
- ▶ Build and deploy App
- ▶ Configure autoscaling/load balancing
- ▶ Continuously secure and monitor instances
- ▶ Monitor and maintain apps

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Popular FaaS Platforms



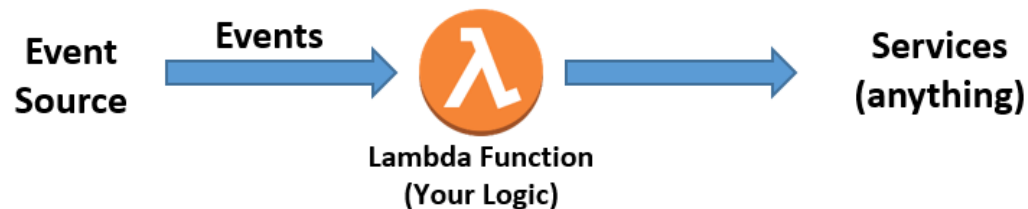
AWS Lambda



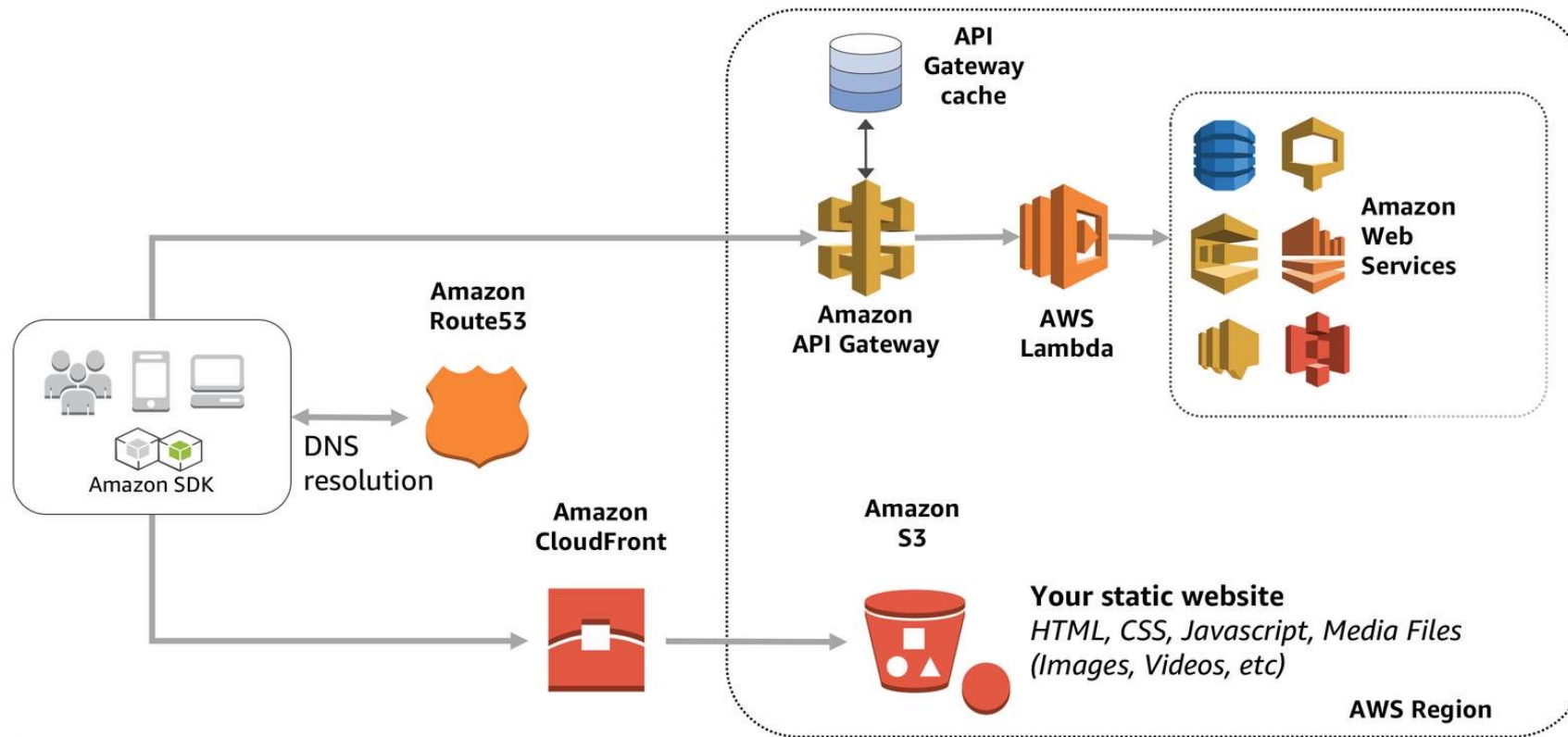
Google Cloud Functions



- Lets you run code without provisioning or managing servers
- Triggers on your behalf in response to events
- Scales automatically
- Provides built-in code monitoring and logging via WebUI or CLI



Example FaaS application



ML-as-a-Service

机器学习即服务

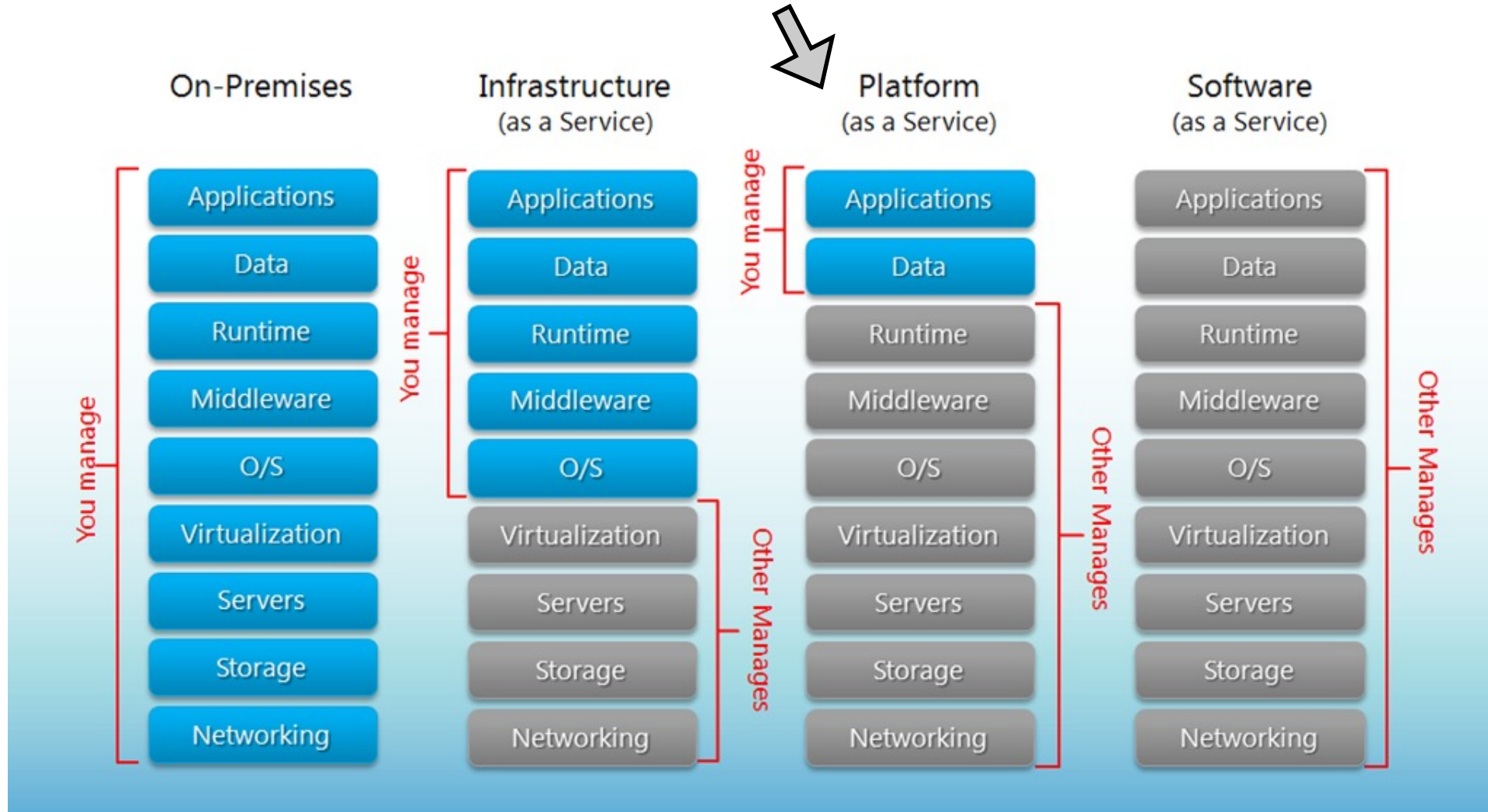
一组基于云的机器学习 (ML) 工具的总称，涵盖大多数 ML 管道，例如数据预处理、模型训练、模型评估和预测服务

- An umbrella term for a set of cloud-based machine learning (ML) tools that cover most ML pipelines
 - e.g., data pre-processing, model training, model evaluation, and prediction serving
- Four key players in the MLaaS market
 - Amazon, Microsoft Azure, Google Cloud, IBM

CLOUD MACHINE LEARNING SERVICES COMPARISON

	Amazon ML and SageMaker	Microsoft Azure AI Platform	Google AI Platform (Unified)	IBM Watson Machine Learning
Classification	✓	✓	✓	✓
Regression	✓	✓	✓	✓
Clustering	✓	✓	✓	✗
Anomaly detection	✓	✓	✗	✗
Recommendation	✓	✓	✓	✗
Ranking	✓	✓	✗	✗
Data Labeling	✓	✓	✓	✓
MLOps pipeline support	✓	✓	✓	✓
Built-in algorithms	✓	✓	✓	✗
Supported frameworks	TensorFlow, MXNet, Keras, Gluon, Pytorch, Caffe2, Chainer, Torch	TensorFlow, scikit- learn, PyTorch, Microsoft Cognitive Toolkit, Spark ML	TensorFlow, scikit- learn, XGBoost, Keras	TensorFlow, Keras, Spark MLlib, scikit- learn, XGBoost, PyTorch, IBM SPSS, PMML

FaaS & MLaaS are closer to PaaS than IaaS



We mainly focus on IaaS in this course, with some coverage of FaaS

Issues of Cloud

Issues of Cloud

云的问题

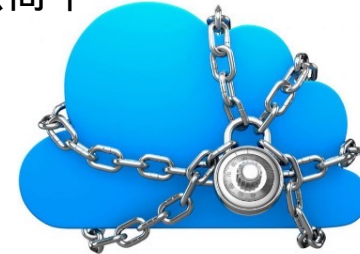
可用性：始终在线的服务有时可能会被取消

- Availability: always-on services can sometimes be taken off...
 - *On Dec 18, 2022, Alibaba Cloud's HK datacenter lost its cool*
 - affecting the Monetary Authority of Macao, takeaway platform mFood, and cryptocurrency exchange OKX
 - *AWS outage in August 2013, about an hour, takes down Vine, Instagram, Flipboard, etc.*
 - Loss of sales: \$1,100 USD per second
- Data loss 数据丢失

Issues of Cloud

- Vendor lock-in 供应商限制
 - Each cloud provides different services to differentiate itself
每个云提供不同的服务，使自己与众不同
 - proprietary services & APIs
 - proprietary hardware: Google TPUs, AWS Inferentia
- Data gravity pricing: Free to move data into the cloud but expensive to move data out
数据重力定价:将数据转移到云端是免费的，但将数据转移出云端是昂贵的
云用户经常发现自己被锁定在当前的提供商中

Cloud users often found themselves
locked into the current provider!



Issues of Cloud

- Security: 安全问题
 - Can an intruder/attacker get my data in the cloud?
 - *Twitter had a data breach due to an attack that exposed the usernames, email addresses, and encrypted passwords of 250,000 users in Feb. 2013.*

Issues of Cloud

- Privacy: 隐私问题
 - Will the provider look at my data in the cloud?
 - Will the provider give my data to the government or other parties?

Table 2. Top 10 obstacles to and opportunities for growth of cloud computing.

Obstacle	Opportunity
1 Availability/Business Continuity	Use Multiple Cloud Providers
2 Data Lock-In	Standardize APIs; Compatible SW to enable Surge or Hybrid Cloud Computing
3 Data Confidentiality and Auditability	Deploy Encryption, VLANs, Firewalls
4 Data Transfer Bottlenecks	FedExing Disks; Higher BW Switches
5 Performance Unpredictability	Improved VM Support; Flash Memory; Gang Schedule VMs
6 Scalable Storage	Invent Scalable Store
7 Bugs in Large Distributed Systems	Invent Debugger that relies on Distributed VMs
8 Scaling Quickly	Invent Auto-Scaler that relies on ML; Snapshots for Conservation
9 Reputation Fate Sharing	Offer reputation-guarding services like those for email
10 Software Licensing	Pay-for-use licenses

Sky Computing

Challenges facing cloud providers

Storage

- Large dataset cannot fit into a local storage 大型数据集无法放入本地存储
- Persistent storage must be **distributed** 持久存储必须是分布式的
 - GFS, BigTable, HDFS, Cassandra, S3, etc.
- Local storage goes **volatile** 本地存储不稳定
缓存正在提供的数据
本地日志记录和异步复制到持久存储
 - Cache for data being served
 - local logging and async copy to persistent storage

Scale

规模

大型集群：能够承载 PB 级数据

- Large cluster: able to host petabytes of data
- Extremely large cluster: at Google, the storage system pages a user **if there is only a few petabytes of spaces left available!**
- A 10k-node cluster is considered small- to medium-sized

超大型集群：在 Google，如果只剩下几 PB 级可用空间，存储系统就会向用户发送消息

10k 节点集群被视为小型到中型集群

Faults and failures

故障

>1%	DRAM errors per year
2-10%	Annual failure rate of disk drive
2	# crashes per machine-year
2-6	# OS upgrades per machine-year
>1	Power utility events per year

Failure is a norm, not an exception!

故障是一种常态，而不是例外

- “A 2000-node cluster will have >10 machines crashing per day”

— Luiz Barroso

Networking

网络

云如何为来自全球的数亿客户提供快速连接来访问他们的服务？

在一个有成千上万的租户、他们的应用程序和服务器的云中，如何确保网络足够快速和健壮，可以将比特从任何地方移动到任何地方？

那么带宽资源的公平性呢？

- How can a cloud provide fast connections for hundreds of millions of clients coming from the entire globe to access their services?
- Inside a cloud, with hundreds of thousands of tenants, their apps, and servers, how to make sure the network is fast and robust enough to move bits from anywhere to anywhere?
- What about fairness of the bandwidth resources?

Machine heterogeneity

机器异构性

- Machines span multiple generations representing different points in the configuration space

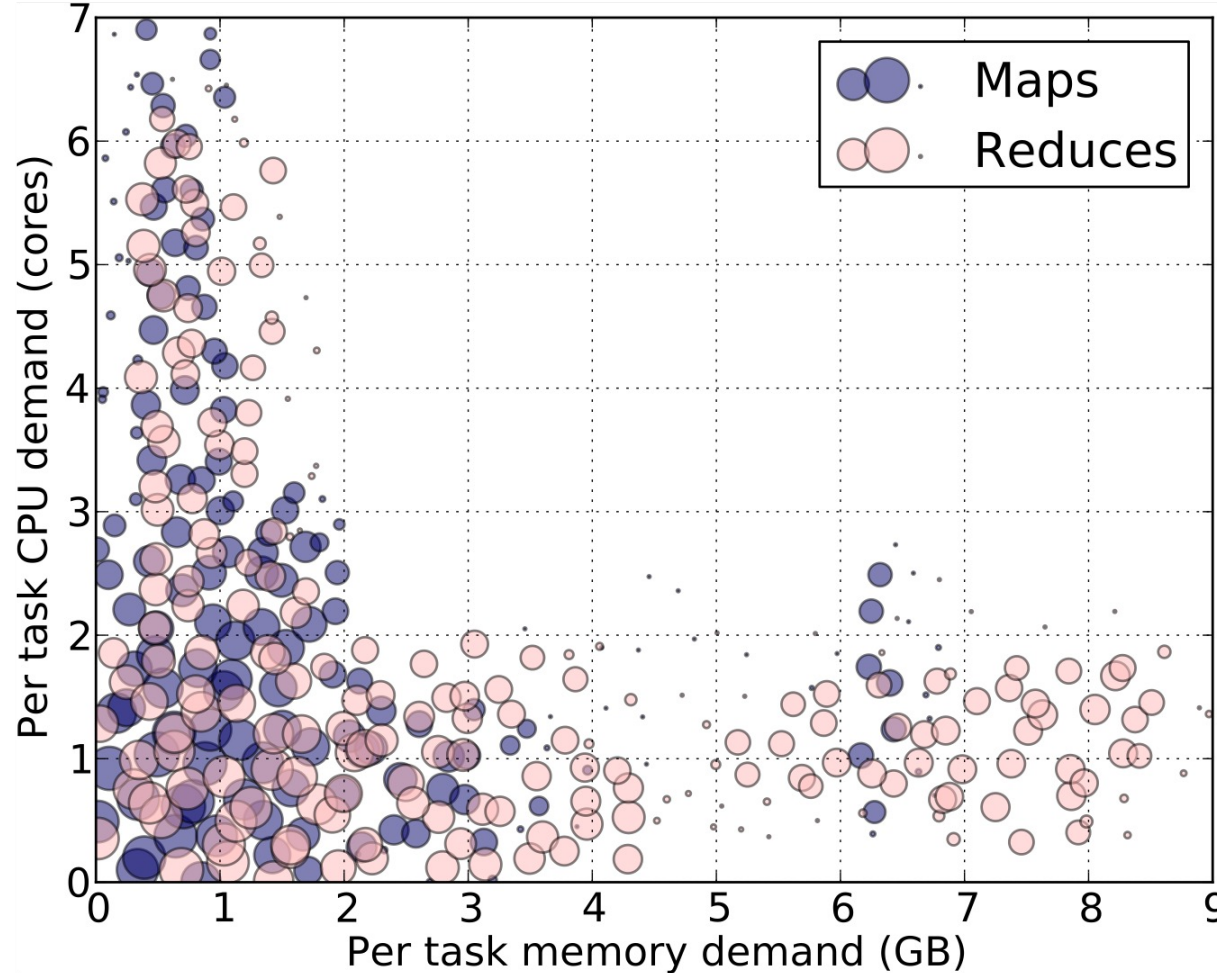
机器跨越多个代，代表配置空间中的不同点

System	#CPUs	Mem (GiB)	#GPUs	GPU type	#Nodes
PAI	64	512	2	P100	798
	96	512	2	T4	497
	96	512	8	Misc.	280
	96	384	8	V100M32 [†]	135
	96	512/384	8	V100 [†]	104
	96	512	0	N/A	83

Machine specs. of a GPU cluster in Alibaba Platform for AI (PAI)

Workload heterogeneity

工作负载异构性



Challenges due to heterogeneity

由于异构性而造成的挑战：

- Hard to provide predictable and consistent services
难以提供可预测的和一致的服务
- Hard to monitor the system, identify the performance bottleneck, or reason about the stragglers
难以监控系统，难以识别性能瓶颈，或导致偏离的原因
- Hard to achieve fair sharing among users
难以实现用户之间的公平共享

Nevertheless, we still want to achieve...

Objectives

目标

- Able to run everything at scale 能够大规模运行一切
- Fault tolerance 容错
- Predictable services 可预测的服务
- High utilization 高利用率
- Network with high bisection bandwidth 具有高二分带宽的网络

With the minimum human intervention!

最少的人为干预

Credits

- Some slides are adapted from course slides of COMP 4651 in HKUST