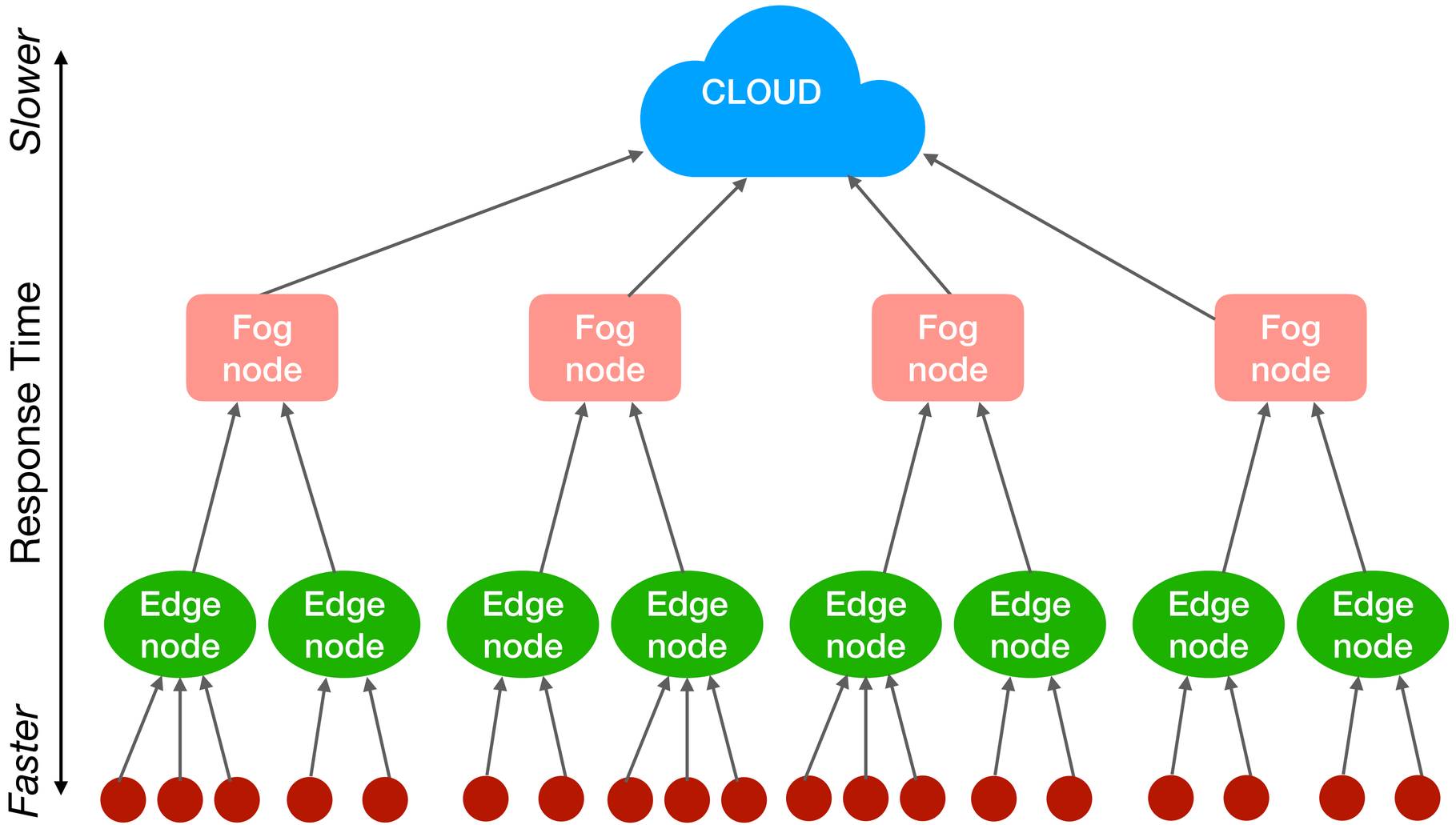
Remote Computing

- Remote Computing (Fog/Cloud) offer more flexibility and scalability than hosting on a local server.
  - Reduced costs.
    - No need to buy expensive equipment, configuring and managing mainframe computers and infrastructures.
  - Increased speed.
    - Availability of enterprise applications, no need to wait weeks for the IT to respond to a request, purchase and configure supporting hardware and install software.
  - Scalability.
    - You pay for what you need instead of purchasing excess capacity that is unused most of the time.
  - Flexibility.
    - Services can be installed on remote servers and deliver better customer response time.

Cloud/Fog/Edge (1)



Cloud Layer

- Big data processing
- Business Logic
- Data storage

Fog Layer

- Local Area Network
- Data Analysis
- Control Response

Edge Layer

- Large volume real time data processing
- At source data visualisation
- Industrial PCs
- Embedded systems
- Gateways
- Micro data storage

Sensors

Edge Computing

- Edge computing is a distributed architecture in which client data is processed at the **periphery of the network**, i.e., as geographically close to the source of data as possible.
- In a IoT system, edge computing is performed by embedded systems, local computers/servers, IoT gateways to provide initial processing and filtering of all the data continuously sent from sensors.
- Data does not travel through the Internet, but is transmitted from the sensors using IoT protocols.

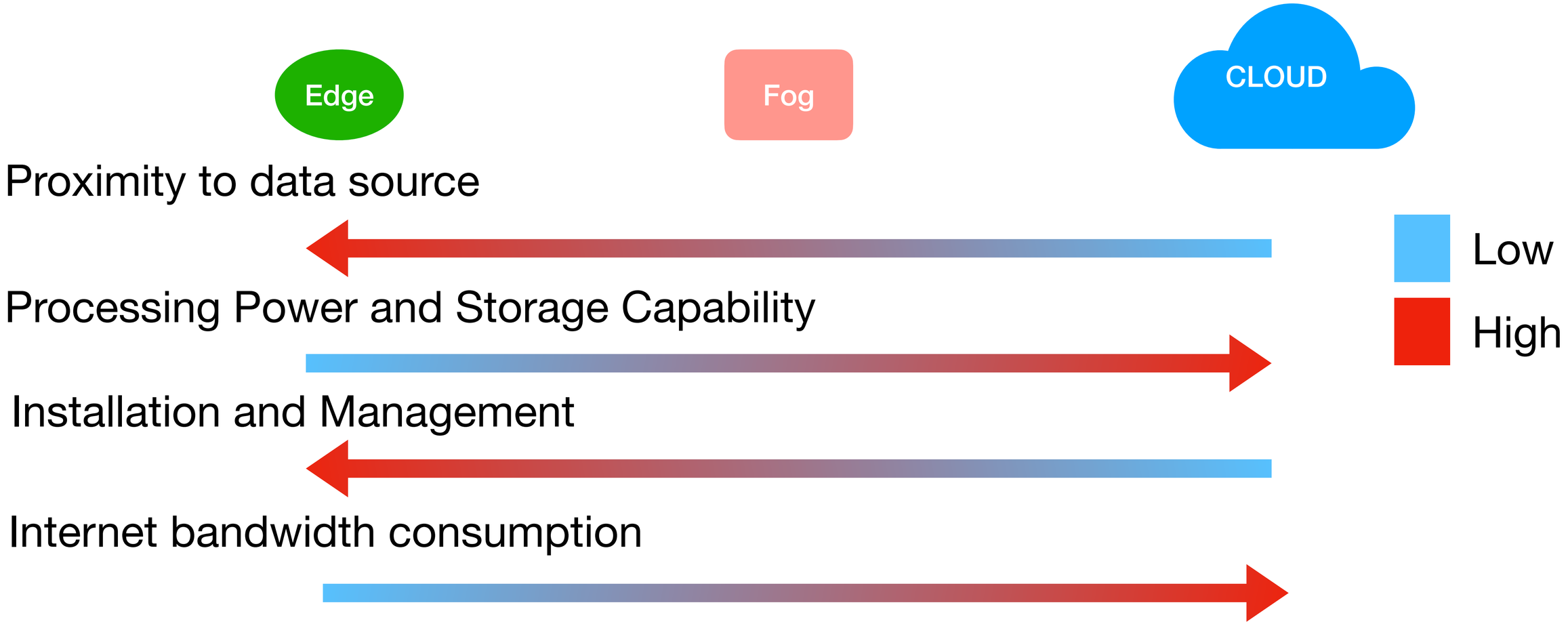
Cloud Computing

- Cloud computing is the delivery of on-demand computing resources—physical or virtual servers, data storage, networking capabilities, application development tools, software, AI-powered analytic platforms and more—over the internet with **pay-per-use pricing**.
- Resources are **dynamically assigned** and reassigned among multiple users and scale up and down in response to user's needs.
- Cloud data centres are connected to the Internet with very high speed, high capacity fibre optical cables.

Fog Computing

- Fog computing lies in between edge and cloud computing.
- The concept was introduced by Cisco and represents a decentralised infrastructure that places storage and processing components (e.g., servers) at the edge of the cloud.
- Depending on the IoT application, fog computing can provide more power resources and storage capacity than edge devices with lower costs than cloud resources.
- Fog servers usually located in LANs.
- Difference with Edge layer is blurry.

Cloud/Fog/Edge (2)



Why do we need the Fog if we have the Cloud?

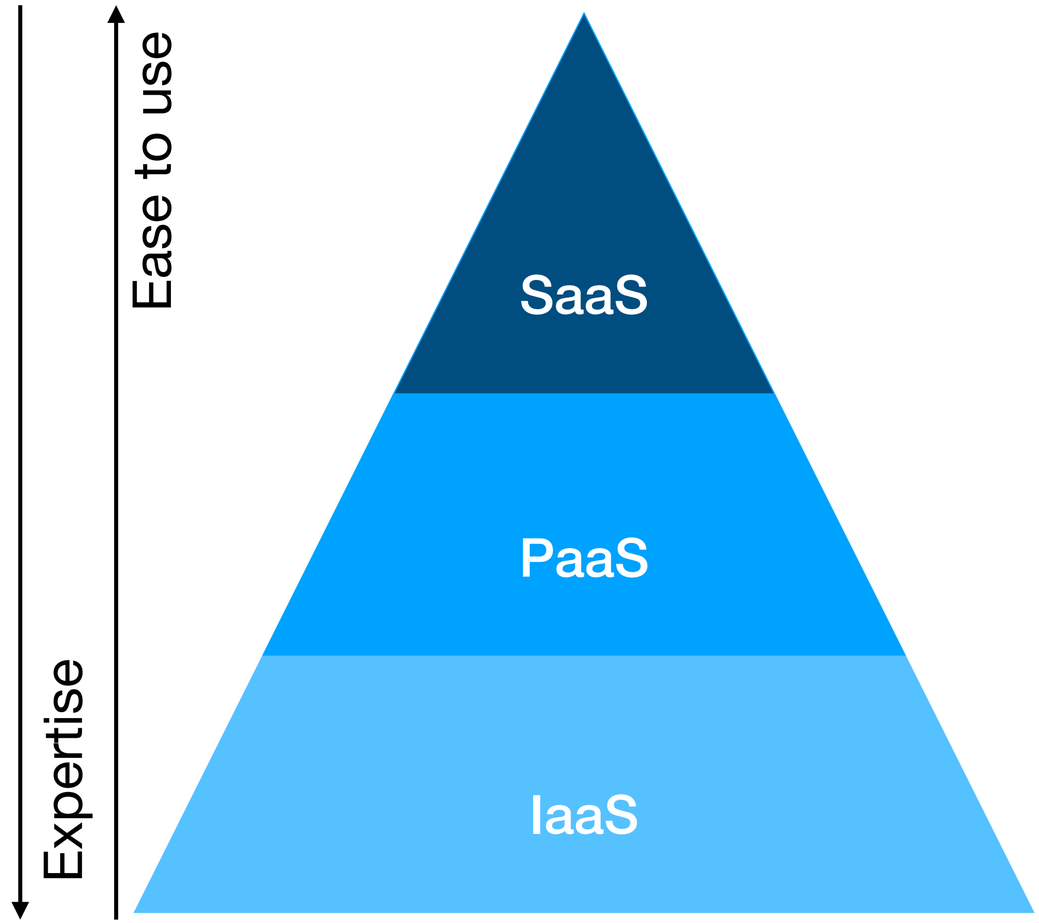
- Offload the cloud, specially after the evolution of IoT.
- Optimised use of network and computing resources.
  - Reducing latency.
  - Reducing transport costs through the Internet.
- Supports cellular connections.

“X as a Service” XaaS

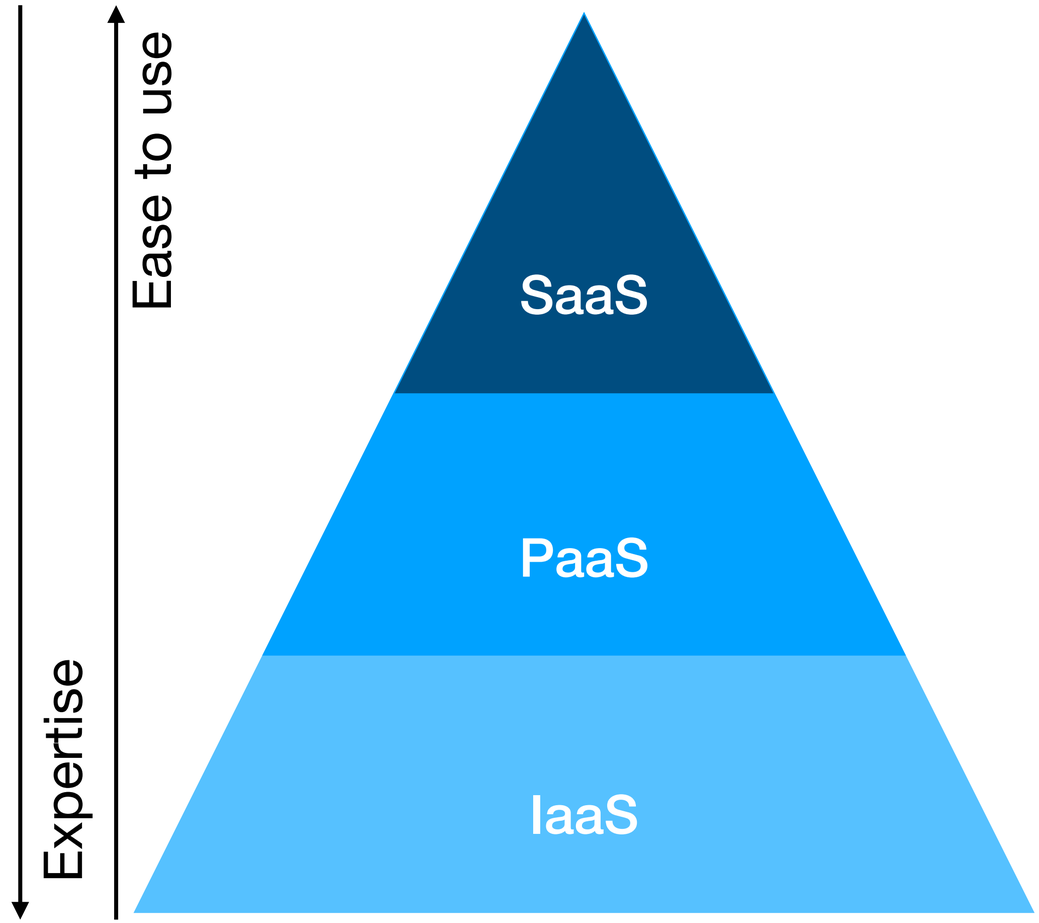
- Cloud computing allows businesses to deploy and run their applications on cloud servers.
- Users can access the services via requests to the Cloud hosting the application.
- XaaS “anything as a service”: delivery of solutions, application, products, tools and technologies as services, which exist on some Cloud platform.

IaaS/PaaS/SaaS

- The National Institute of Standards and Technology recognised three cloud service models in 2011:
  - **Infrastructure as a Service (IaaS):** Set of computing, networking and storage resources that have been virtualised by a vendor.
    Users can access and configure them as they want.
  - **Platform as a Service (PaaS):** cloud providers deliver a computing platform, typically including an operating system, programming-language execution environment, database, and the web server.
  - **Software as a Service (SaaS):** users gain access to application software and databases. Cloud providers manage the infrastructure and platforms that run the applications.

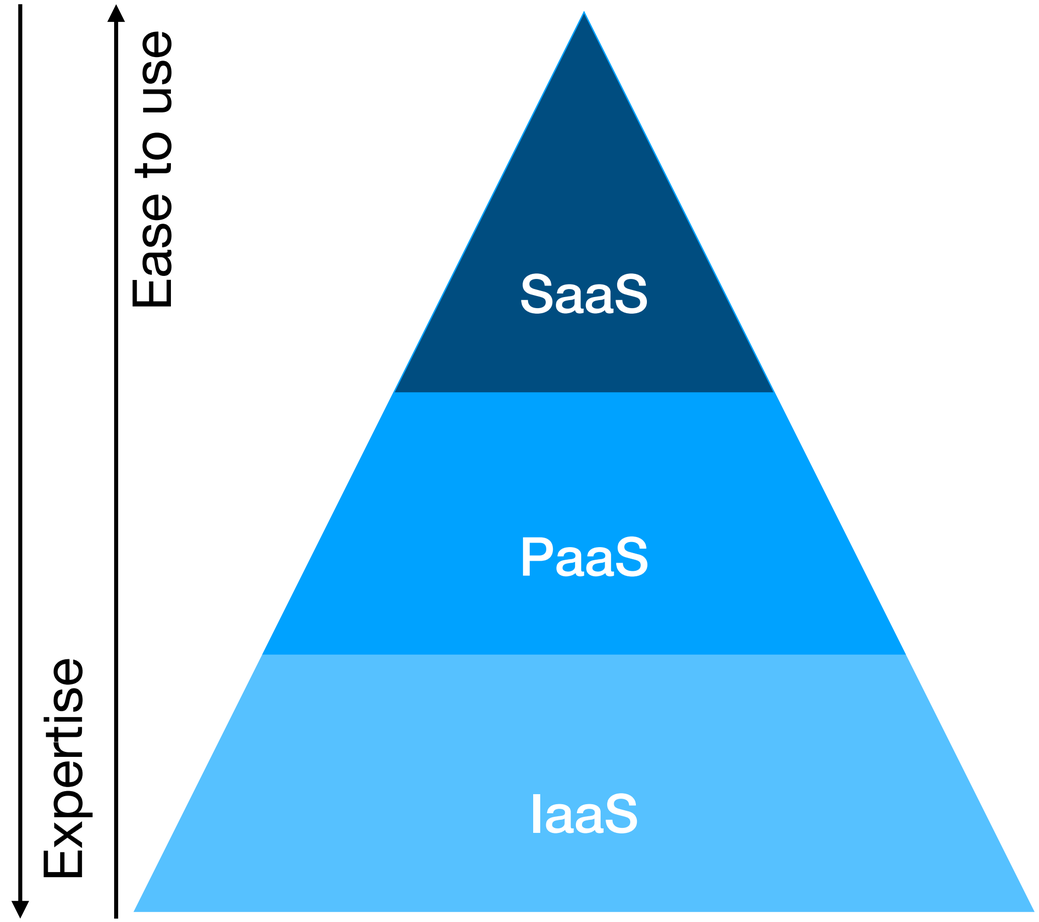


IaaS/PaaS/SaaS



IaaS/PaaS/SaaS

- Metaphor:
  - **Infrastructure as a Service (IaaS)- Leasing a car.** You pay for the car, you care about its performance, you choose the model, the colour, and you can customise it. You drive the car.
  - **Platform as a Service (PaaS) - Renting a car.** You do not care of most of the specs and the colour of the car. You drive it and pay for the gas and any tolls you go through.
  - **Software as a Service (SaaS) - Taxi/Uber.** You do not care about any specs of the car, you do not choose anything. You do not drive or pay for the gas, all tolls are included in the price.



Top Cloud Providers (1)

- **Amazon Web Services (AWS).**
  - Offers services like database storage, computing power, networking. Can virtually host any applications, including networks like firewall, Load balancers.
  - Netflix, Airbnb, Uber and many other companies rely con AWS.

- **Microsoft Azure**
  - Offers services like AI, Machine Learning, Analytics, Blockchain, Compute, Containers, Databases, Developer Tools.
  - Microsoft has invested billions in OpenAI and provides the cloud infrastructure for running large AI models.

Top Cloud Providers (2)

2.4 Example of optimisation for task offloading on the fog

Fall Detection - minimise costs (1)

- Consider an IoT architecture with N wearable sensors $s_1, \ldots, s_N$, one for each patient.
- Every second, each sensor s_i produces some data that requires computational resource r_i (FLOPs). The data is sent every second to a dispatcher.
- The dispatcher collects the data from the sensors and has to decide how to deploy the tasks on fog nodes $f_1, \ldots, f_F$ to perform fall detection.
- Fog nodes have limited resources (FLOPS), $g_1, \ldots, g_F$, and using fog node f_j has a cost c_j. The dispatcher knows the resources and the costs.

Fall Detection - minimise costs (2)

- We want to minimise the costs for computation while performing all the tasks.
- We can introduce the decision variables:
  - $y_j = \begin{cases} 1 & \text{if } f_j \text{ is used} \\ 0 & \text{otherwise} \end{cases}$, $x_{i,j} = \begin{cases} 1 & \text{if task of sensor } s_i \text{ is offloaded on fog node } f_j \\ 0 & \text{otherwise} \end{cases}$
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$$\min \sum_{j=1}^{F} y_j \cdot c_j$$

Subject to: $\sum_{j=1}^{F} x_{i,j} = 1, \forall i = 1,\ldots,N$

$$\sum_{i=1}^{N} x_{i,j} r_j \leq g_j y_j, \forall j = 1,\ldots,F$$

$$y_j, x_{i,j} \in \{0,1\}$$

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The resource necessary to process all tasks arranged to fog f_j cannot exceed its capacity

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Bin packing problem (NP complete)

Fall Detection - minimise costs (3)

- The problem is oversimplified. We are omitting
  - Latency
  - Dynamism
  - Queues of fog nodes
  - Etc
- How to solve this?
  - Approximation algorithms
  - Heuristics
  - Optimisation algorithms (exponential in the worst case)