Fog Computing

… Cloud Computing at the Edge of the Network

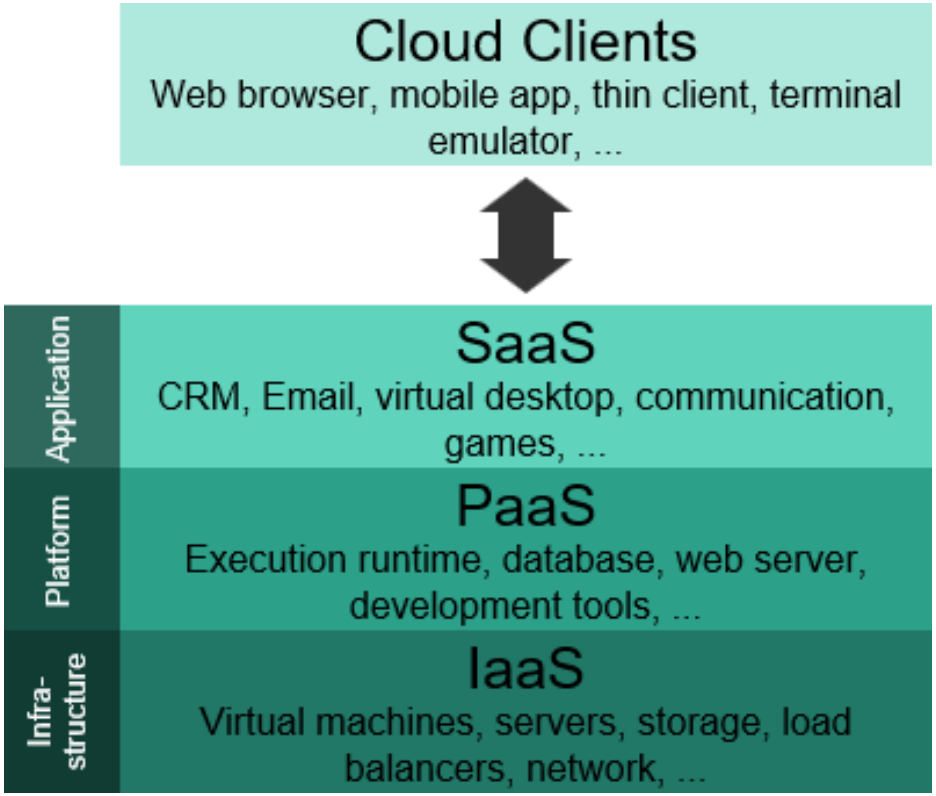
https://commons.wikimedia.org/wiki/File:Golden_Gate_Bridge_fog_2014.jpg

Cloud Computing

AWS definition:

The **on-demand delivery** of **compute power**, **database storage**, **applications**, and other IT resources through a cloud services platform via the internet with **pay-as-you-go** pricing.

OPEX – operational expense model



https://commons.wikimedia.org/wiki/File:Cloud_computing_layers.svg

The Edge of the Cloud

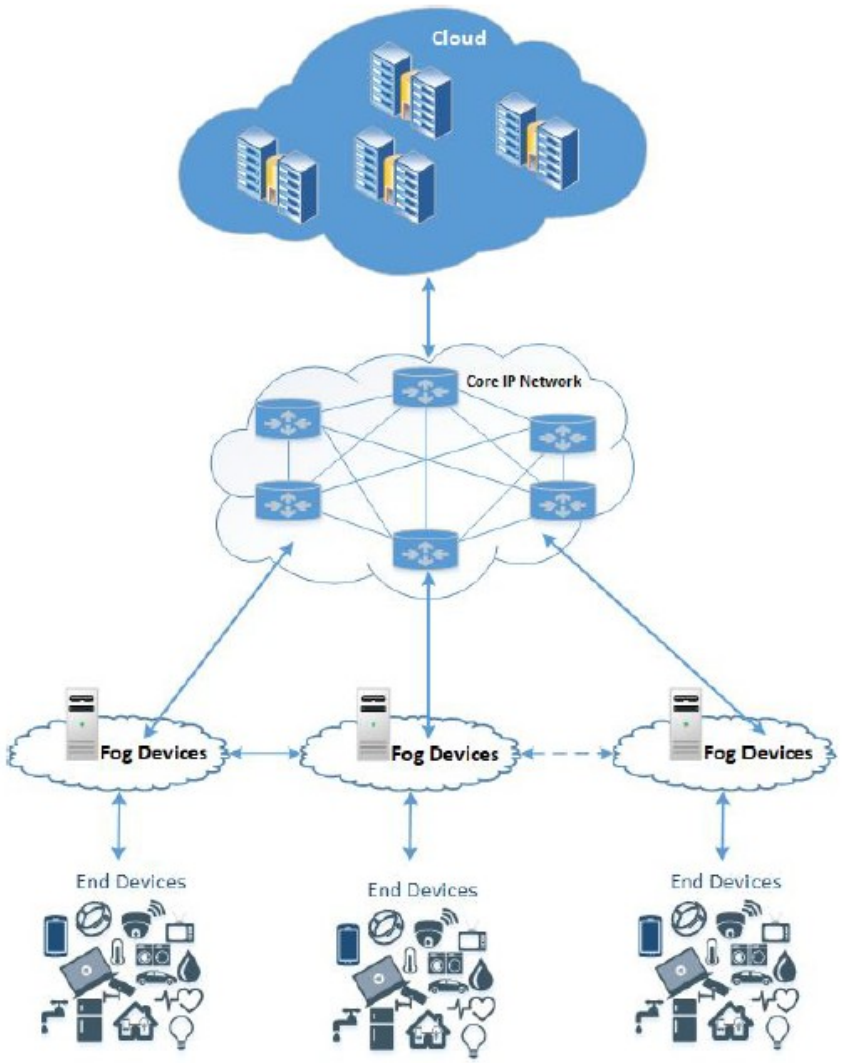
Why isn't cloud computing sufficient for some applications?

- **Latency** – Real-time interaction
  - Video Streaming – Movies, Video Conferencing
  - Gaming – Role playing games
  - Augmented Reality – Pokémon Go
- **Geographical Distribution** – Widely distributed deployments
  - Massively Multiplayer Online Real-time Games
  - Route Planning / Traffic
- **Mobile Deployment** – Nodes will be moving
  - Cell phones
  - Vehicles
- **Large number of Nodes**
  - Networks of sensor nodes

Fog Computing

Fog platform provides low-latency virtualized services and is linked to the Cloud Computing infrastructure.

Edge devices request compute, storage and communication services from the Fog. The Fog provides local, low-latency response to these requests and forwards relevant data for computationally intensive processing.



Exemplars: Content Delivery

Netflix – evolving business model.

- 1998: Initially mail order DVDs, competing with Blockbuster brick and mortar stores.
  - Order on-line
  - DVDs delivered by mail
- 2007: Started deliver content via internet
- 2011: Development of Open Content Delivery – a network set up to move content closer to the consumer

- Business Model:
  - Subscription Service
  - Delivery of the content you want, when you want it.

- Cloud computing supported– Billing, Content Delivery Network, big data analytics, understanding usage patterns and where content needs to be placed for fast delivery.

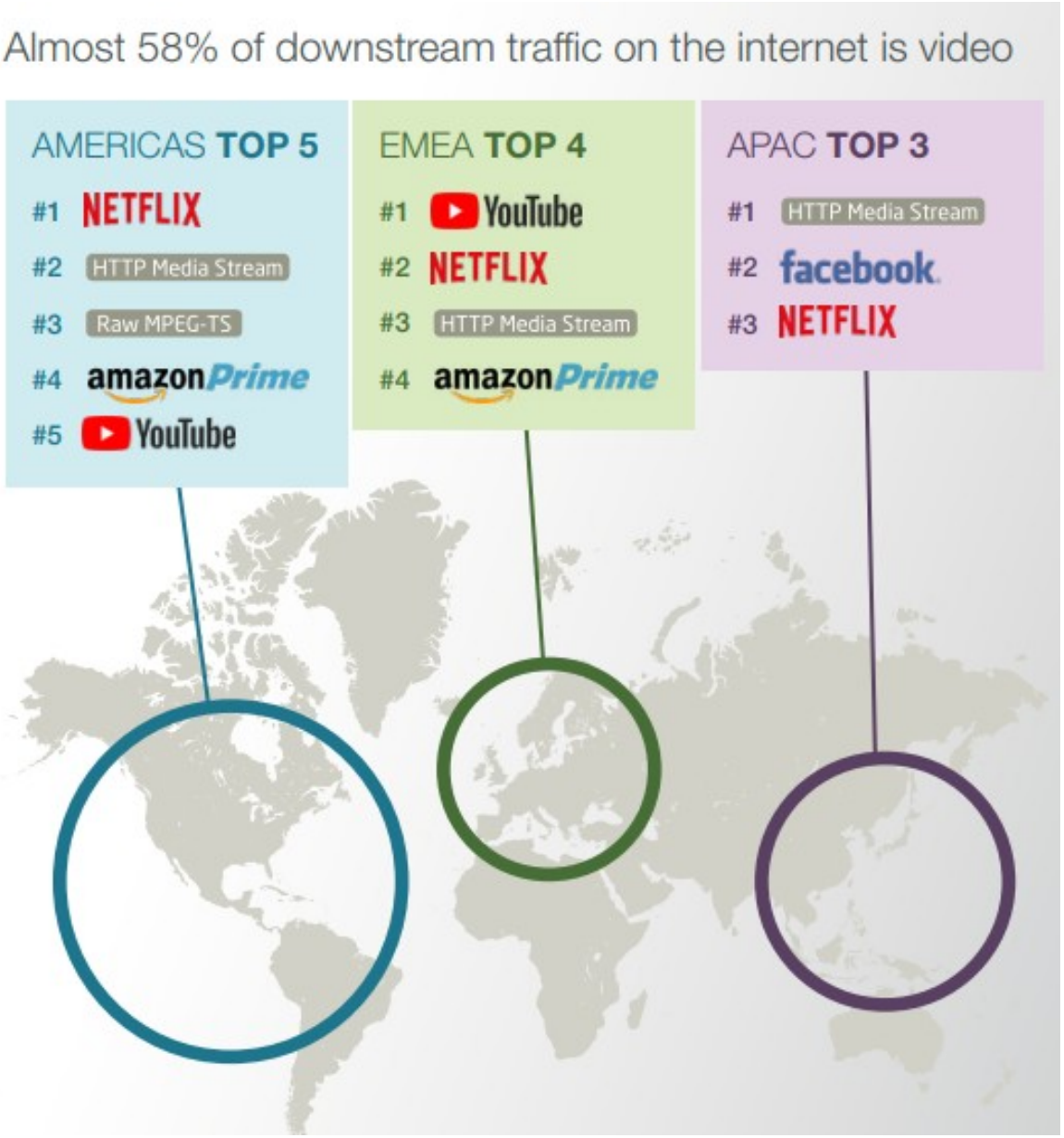
How do you scale this?

Back Office Support can still be done in the cloud.

But how do you do content delivery?

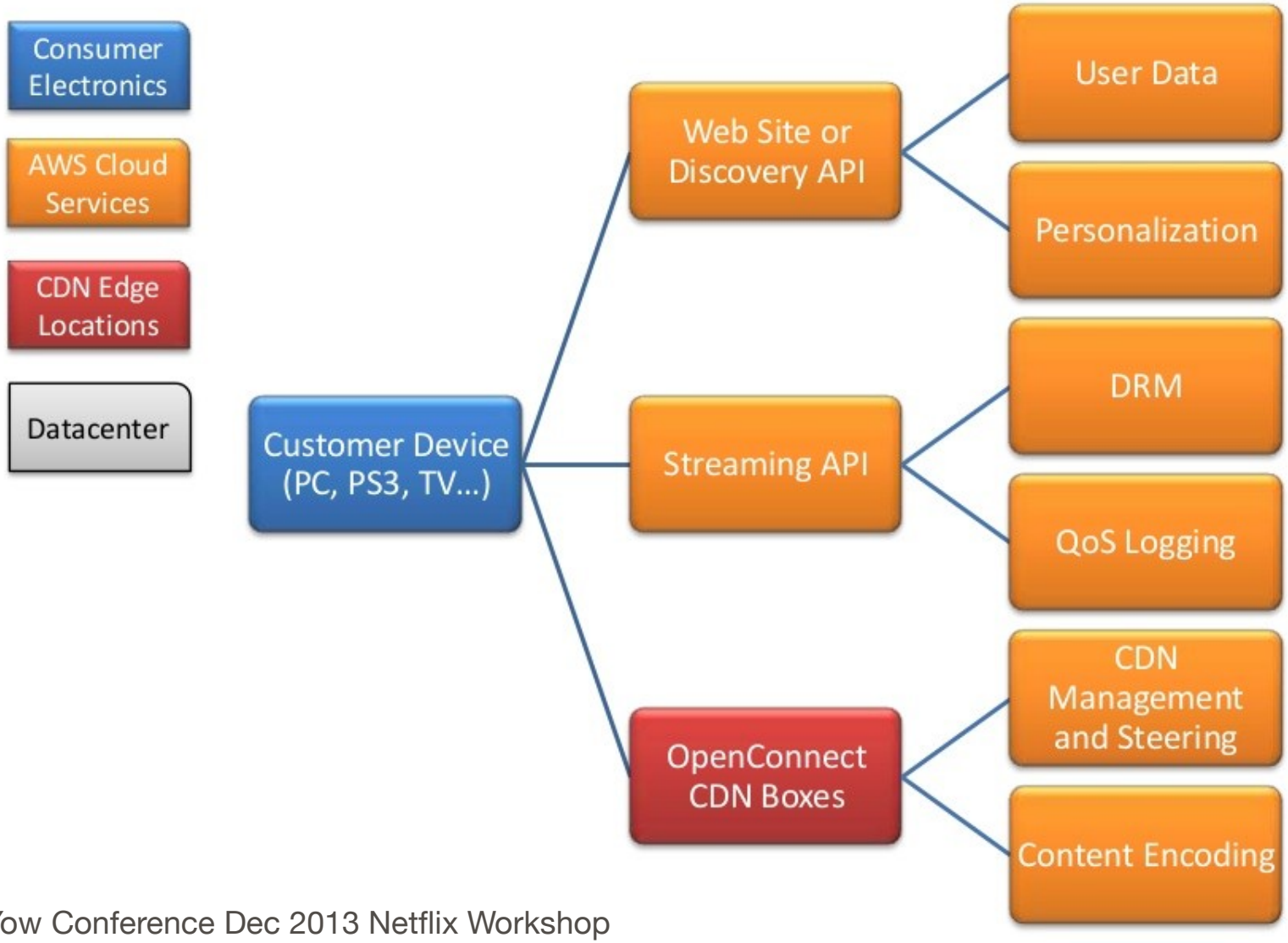
GLOBAL APPLICATION TRAFFIC SHARE

1	NETFLIX	14.97% ⬇	2.92% ⬆
2	HTTP MEDIA STREAM	13.07% ⬇	4.84% ⬆
3	YOUTUBE	11.35% ⬇	3.03% ⬆
4	RAW MPEG-TS	4.39% ⬇	4.11% ⬆
5	HTTP (TLS)	4.06% ⬇	2.06% ⬆
6	QUIC	3.87% ⬇	1.43% ⬆
7	AMAZON PRIME	3.69% ⬇	0.87% ⬆
8	HTTP DOWNLOAD	3.69% ⬇	1.45% ⬆
9	HTTP	3.22% ⬇	4.80% ⬆
10	PLAYSTATION DOWNLOAD	2.67% ⬇	0.45% ⬆

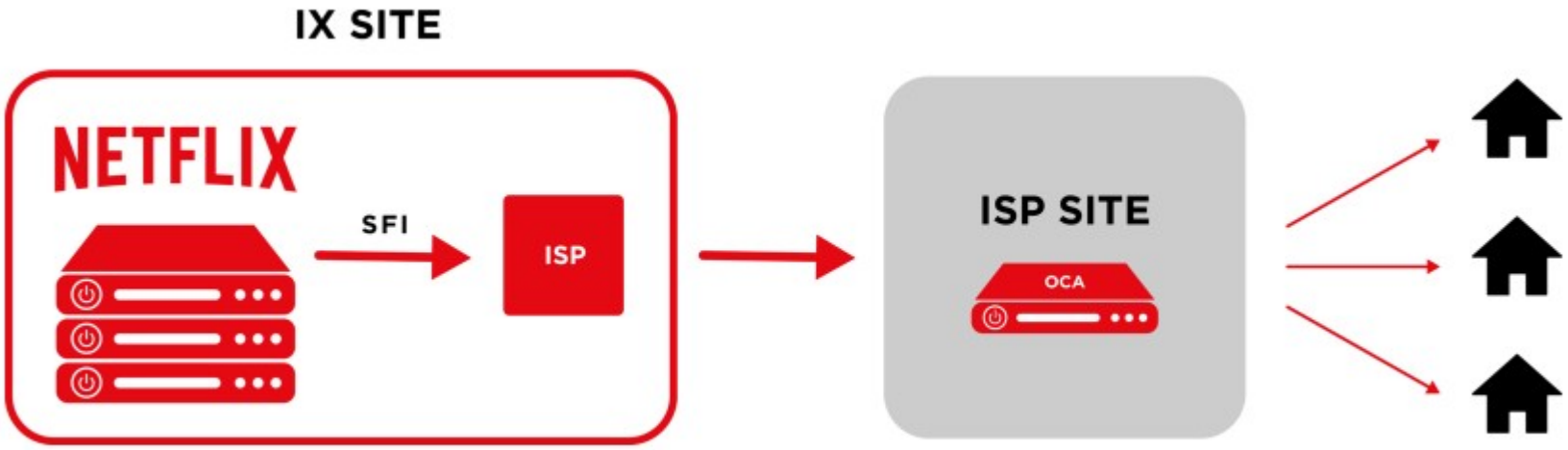


https://www.sandvine.com/hubfs/downloads/phenomena/2018-phenomena-report.pdf

How Netflix Streaming Works Today



Netflix



IX – Internet Exchange Points
SFI – Settlement Free Peering
OCA – Open Connect Appliance

Exemplars: Real-time Mapping

Initially, Maps were static. You generated a map with directions and printed it.

2005: Google Maps introduced.

2007: Real-time traffic data integrated

2007: Street View added

2008: Android App released w/ turn by turn navigation

Interesting article about putting the data into Google Maps:

- How Google Builds Its Maps

Fog Computing Characteristics:

- **Low Latency** – Video Delivery, Navigation Information
- **Location Awareness** – Traffic Lights, Navigation, Sensor Networks
- **Wide-spread Geographical Distribution**
- **Mobility** – Fitness Trackers, Phones and Vehicles

Fog Computing Characteristics:

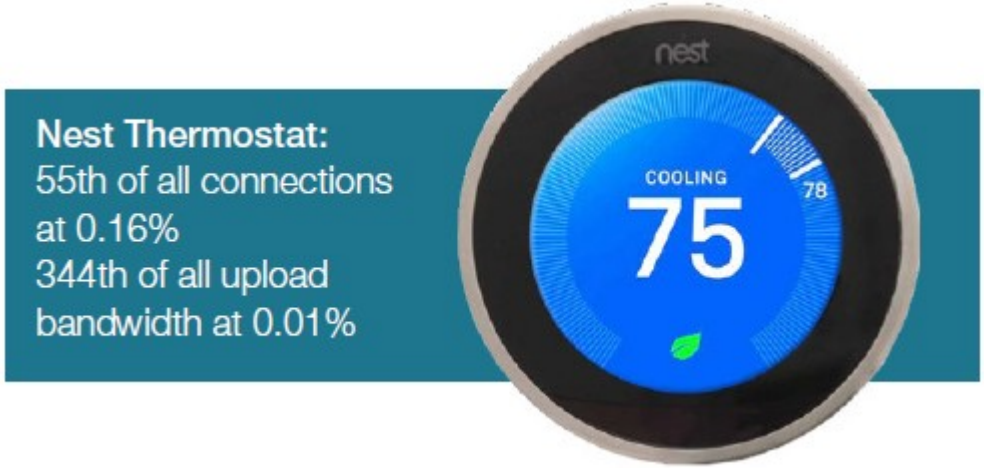
- **Very Large Number of Nodes**

IoT Device Connections

https://d110erj175o600.cloudfront.net/upload/images/06_2017/170615153722.pdf

Fog Computing Characteristics:

- Predominance of **Wireless Access**



- Strong presence of **Streaming** and **Real-time Applications**
- **Heterogeneity**

www.sandvine.com/hubfs/downloads/phenomena/2018-phenomena-report.pdf

Architectural Drivers

Low Latency / Real Time Response – Device will want near real-time response for content delivery and actionable information

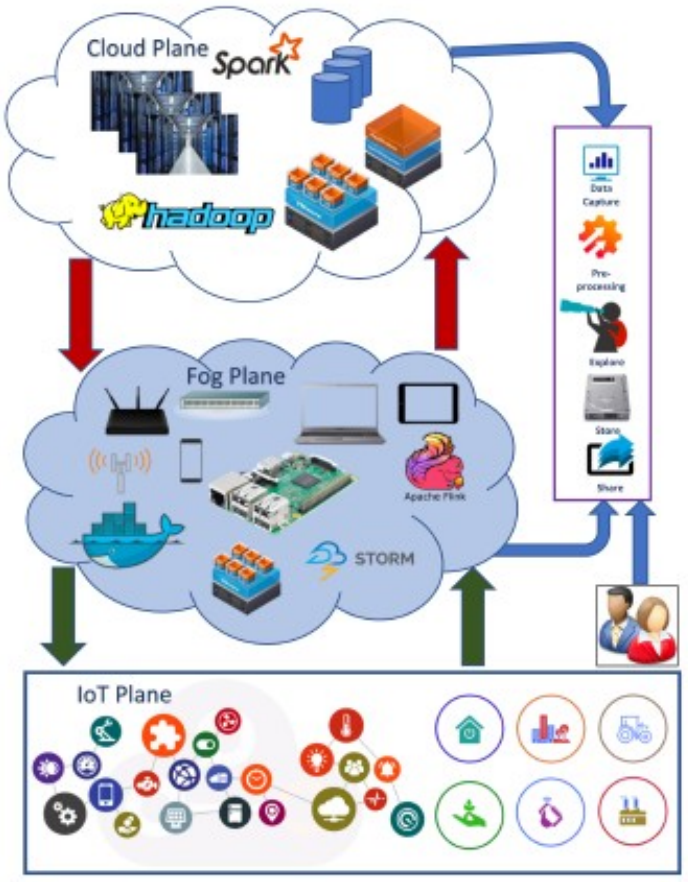
Dynamic Number of Nodes -- Number of devices within the Fog is dynamic. System must be able to handle large number of devices joining and leaving the Fog

Highly Mobile Nodes – Nodes will be entering and exiting the Fog and the Fog must adapt and continue to perform

Diverse Set of Failure Modes – Wide range of devices with varying levels of sophistication mean there will be many failure modes that need to be seamlessly handled

Security – Access control

Layered Pattern for Fog Computing:



Application
- IoT
- WSN
- CDN
- Autonomous Vehicle
- Traffic Network

Security
- Encryption
- Privacy
- Authentication

Resource Management
- Resource Allocation
- Scheduling
- Energy Savings
- Reliability
- Scalability

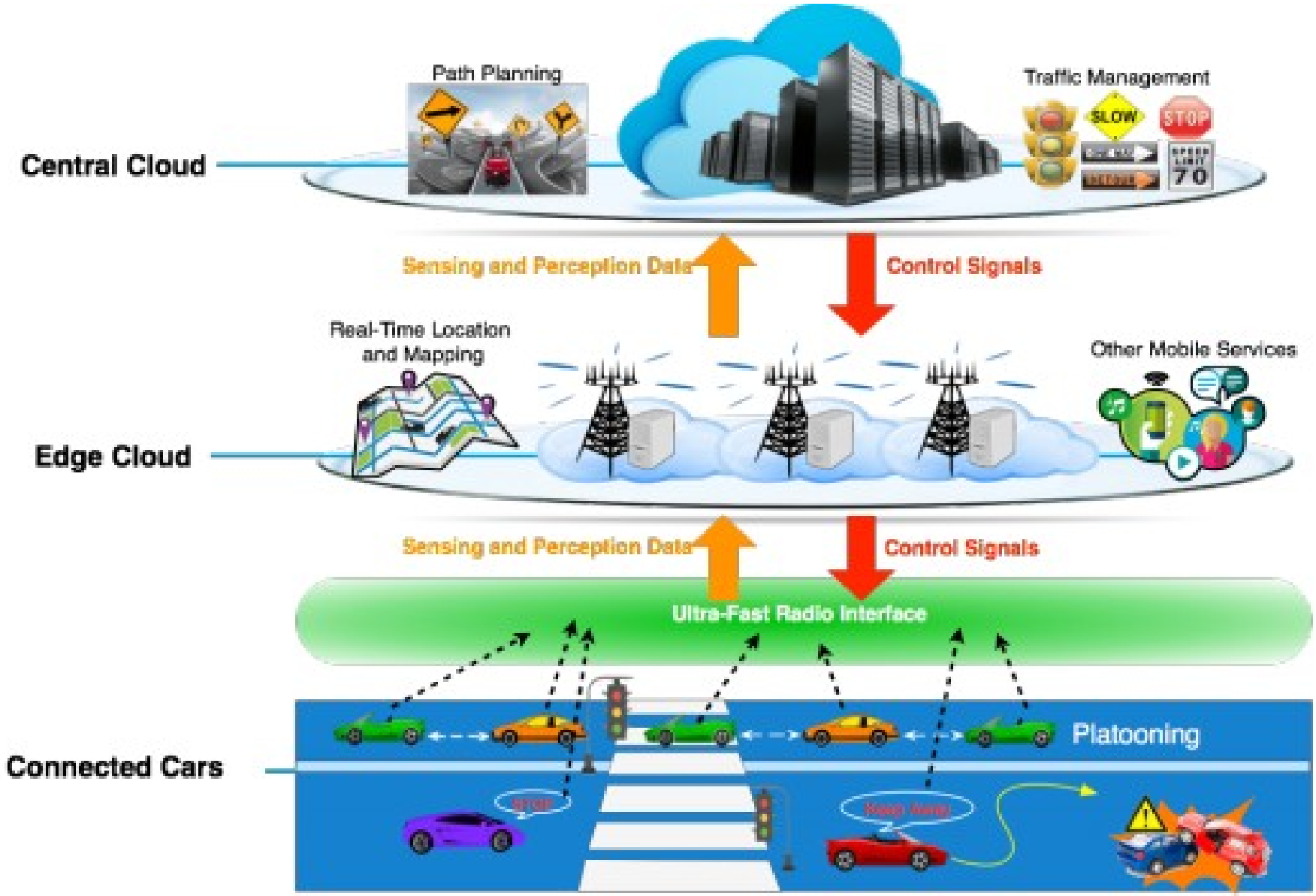
Storage
- Data Backup
- Storage Virtualization

Pre and Post-Processing
- Data Analysis
- Data Filtering
- Data Flow
- Data Trimming
- Data Reconstruction

Monitoring
- System Monitoring
- Resource Demand
- Performance Prediction

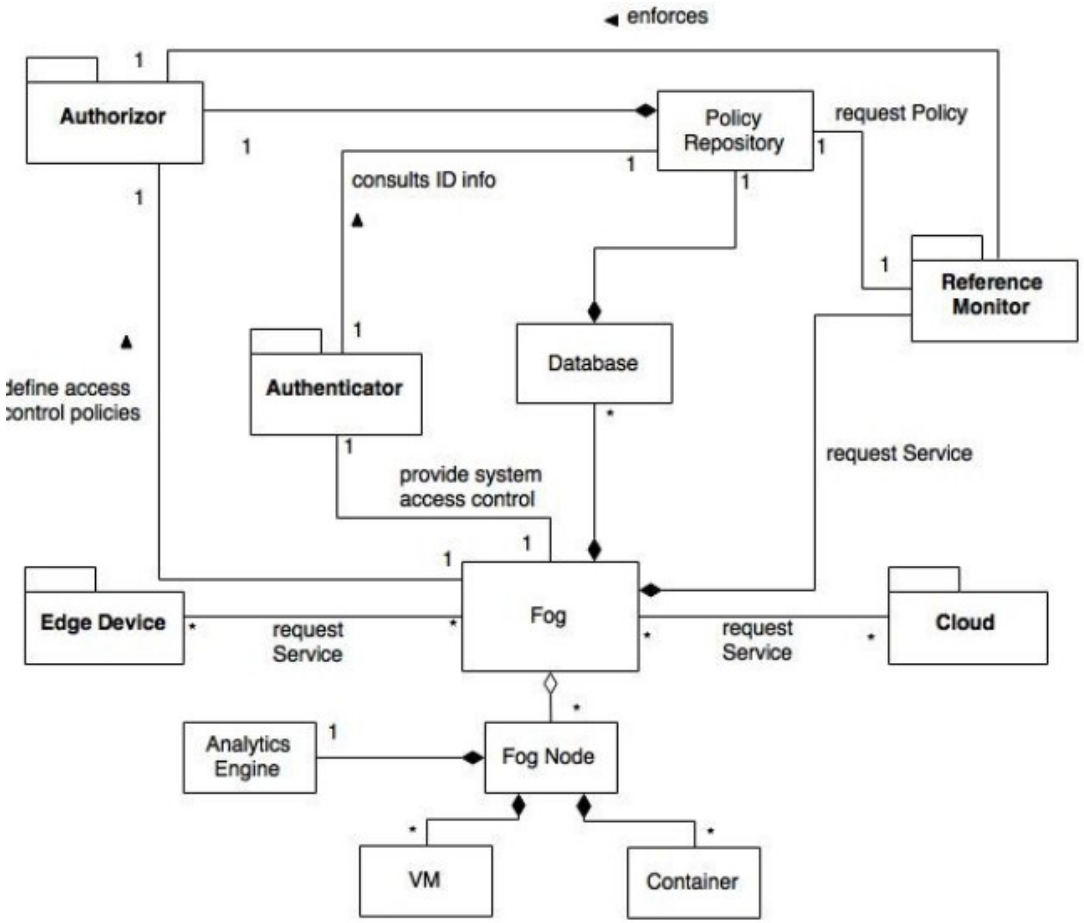
Fog Device, Server & Gateway
- Device Configuration
- Storage Configuration
- Connectivity
- Computation Requirements

Physical
- Physical Sensors
- Virtual Sensors



https://arxiv.org/pdf/1701.01090.pdf

Fog Computing Pattern:



Reading Assignment:

A Pattern for Fog Computing:
https://www.researchgate.net/publication/314101893_A_Pattern_for_Fog_Computing

Be prepared to address a couple questions about this paper on Friday, November 13.