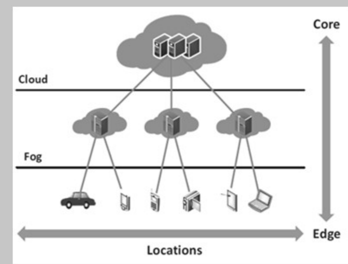
Foggy
Future

Fog Computing
Also called Edge Computing

What is Fog Computing?



Traditional cloud computing, on the other hand, concentrates all applications and data in the cloud.

Fog computing

- **Fog computing** is a paradigm which extends cloud computing paradigm to the edge of the network.
- Terms **Edge Computing** and **Fog computing** are often used interchangeably.
- Similar to Cloud, Fog provides data, compute, storage, and application services to end-user.

Fog
Computing
(AKA edge computing)

Fog computing places processes and resources at the edge of the cloud, often on network devices, while data remains stored in the cloud. This leads to faster processing times and fewer resources consumed.

See Source

Fog computing is a response to some of the issues and problems encountered from regular cloud computing.

Fog Computing : Applications

The Fog vision was conceived to address applications and services that do not fit well the paradigm of the Cloud. They include:

- **Applications that require very low and predictable latency**—the Cloud frees the user from many implementation details, including the precise knowledge of where the computation or storage takes place. This freedom from choice, welcome in many circumstances becomes a liability when latency is at premium.
- Fast mobile applications (smart connected vehicle, connected rail).
- Large-scale distributed control systems (smart grid, smart traffic light systems).

Cloud Computing Issues

[redacted]

- Transmitting and processing data requires bandwidth.
- The more data, the more bandwidth is needed.
- Fog computing reduces the need for bandwidth by:
  - not sending every bit of information over cloud channels
  - aggregating it at certain access points.
- Advantage: By using this kind of distributed strategy, we **can lower costs and improve efficiencies**.

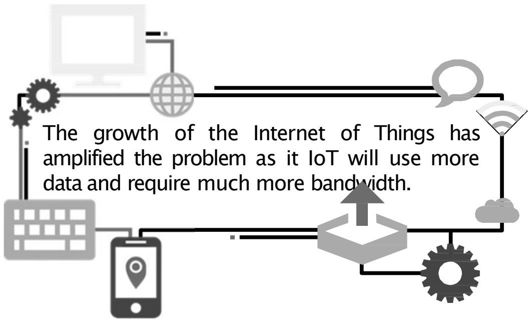
- The emergence of the Internet of Things (IoT) brings a number of use cases of interest that fall in the above categories.
- It also brings **Big Data with a twist**: rather than high volume, **in IoT big is the number of data sources distributed geographically**

Cloud Computing Issues

- Cloud computing has become one of leading technologies in the recent years.
- But it largely depends on servers which are available in a remote location, resulting in **slow response time**.
- Response time plays a crucial role in machine to machine communication and services.

Edge computing platform

The edge computing platform solves the problems by the simple idea of locating small servers called edges servers in the vicinity of the users and devices



The growth of the Internet of Things has amplified the problem as it IoT will use more data and require much more bandwidth.

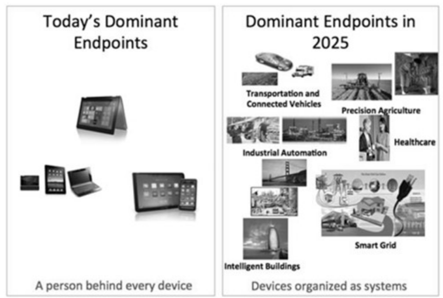
Fog Computing and the Internet of Things

Consequences of IoT

- A number of important IoT use cases, including Smart Cities, pipeline monitoring, Smart Grid, Connected Rail (CR) are naturally geographically distributed
- Support for fast mobility is essential in some very relevant use cases
- Low and predictable latency are essential attributes in industrial automation and other IoT use cases

Internet of Things (IoT)

- The **Internet of Things (IoT)** represents a new world of information and communication technologies (**ICTs**) from anytime, anyplace connectivity for anyone.
- All Things in Internet of things or IoT are uniquely addressable and are connected using standard communication protocols.
- It will consist of connections that will multiply and create entirely new dynamic network of networks.
- In this, objects or things are made as smart so that they will become knowledgeable and their properties will allow them to actively interact in environment



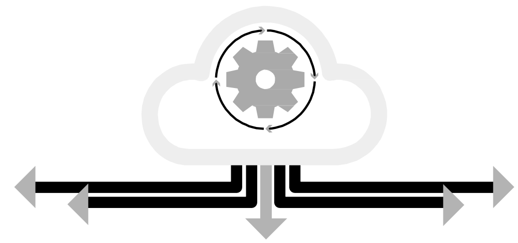
Today there is a person
behind the vast majority of endpoints. The dominant landscape

- The data these devices will generate is going to be really huge.
- The speed with which data can be collected and processed has to definitely increase.

Current cloud computing models can’t keep up with the amount of bandwidth that will be needed.

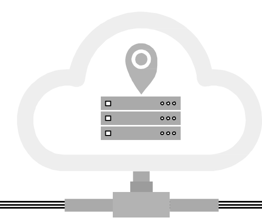
Fog complements the Cloud

- Fog complements the Cloud, does not substitute it.
- Emergent IoT applications demand a platform with novel characteristics.



Fogging basically helps cloud systems by easing the burden of processing data.

- By using the concepts of **fog computing**, data generated can be put to immediate use and deliver a much better user experience.
- Thus fog computing is going to play a big role in internet of things applications



Fog computing goes around the internet entirely by processing data locally.

The characteristics of fog computing like **proximity to end-users**, **low latency**, **location awareness**, and due to its support for yielding better and **more real-time applications** fog computing platform is considered as the appropriate platform for Internet of Things applications and services which include and not restricted to **connected vehicles, smart grid and smart cities.**

Fog computing can also be used in other areas.

Smart Traffic Light System (STLS)

- STLS calls for the deployment of a STL at each intersection.
- The STL is equipped with sensors that
  - (a) measure the distance and speed of approaching vehicles from every direction
  - (b) detect the presence of pedestrians and cyclists crossing the street. The STL also issues “slow down” warnings to vehicles at risk to crossing in red, and even modifies its own cycle to prevent collisions.

Smart Traffic Light System (STLS)

- To be specific, consider some numbers. Let us say that the green wave is set at 64 km/h (40miles/h).
- A vehicle moving at 64 km/h travels 1.7m in 100 ms.
- The policy requires sending an urgent alarm to approaching vehicles when collision with crossing pedestrians is anticipated. **To be effective the local control loop subsystem must react within a few milliseconds—thus illustrating the role of the Fog in supporting low latency applications**

Fog Computing Uses

Smart Traffic Light System (STLS)

- The STLS has three major goals:
  - (a) accidents prevention
  - (b) maintenance of a steady flow of traffic (green waves along main roads)
  - (c) collection of relevant data to evaluate and improve the system.
- Note that the global nature of (b) and (c), in contrast with the localized objective (a).
- Also note the wide difference in time scales:
  - (a) requires real time (RT) reaction
  - (b) near-real time, and
  - (c) relates to the collection and analysis of global data over long periods

Smart Cities

Fog computing helps collect data on city activities from traffic to utilities, ensuring everything is running efficiently

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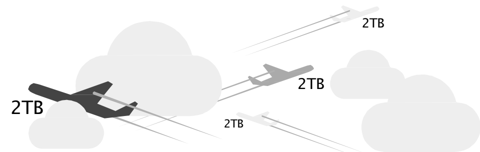

Air Travel

A single engine on a Boeing 747 generates 0.5TB of data. Fog computing can process that data locally and send only the most important bits of information to those who need to see it.

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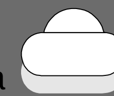
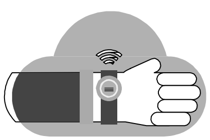
Geo-distribution: A New Dimension of Big Data

- Big Data today is currently characterized along three dimensions: Volume, Velocity, and Variety
- Many IoT use cases, including STLS, Smart Cities, Smart Grids, Connected Rail (CR), and pipeline monitoring are naturally distributed.

Moving the processing to Data



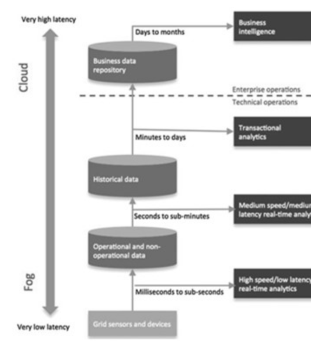
- The call for “moving the processing to the data” is getting louder.
- There is a need for distributed intelligent platform at the Edge *(Fog Computing)* that manages distributed compute, networking, and storage resources.



Wearable Technology

Wearables with virtual interfaces need to process their environment locally to aid the user. Fog computing allows for that processing to happen almost immediately, improving the user experience.

- This observation suggests adding a fourth dimension to the characterization of Big Data, namely, *geo-distribution*.
- Consider, for instance, the monitoring of a pipeline, or the measurement of pollution level (air quality, pollen, and noise) throughout a city.
- The big N in these scenarios is neither the number of terabytes nor rate of data generated by any individual sensor, but rather the number of sensors (and actuators) that are *naturally distributed*, and that has to be managed as a coherent whole



As we climb up the time scale the scop gets wider in coverage.
For instance, the business intelligence level that operates on data collected over months may cover a wide geographical region, possibly a whole country and beyond.
In contrast, the sub-second level refers to more localized loops aimed essentially to keep the grid stable.

Heterogeneous Physical Resources

- Fog nodes are heterogeneous in nature. They range from high end servers, edge routers, access points, set-top boxes, and even end devices such as vehicles, sensors, mobile phones etc
- The different hardware platforms have varying levels of RAM, secondary storage, and real estate to support new functionalities. The platforms run various kinds of OSes, software applications resulting in a wide variety of hardware and software capabilities.
- The Fog network infrastructure is also heterogeneous in nature, ranging from high-speed links connecting enterprise data centers and the core to multiple wireless access technologies (ex: 3G/4G, LTE, WiFi etc.) towards the edge.

- Users are becoming increasingly concerned about the risk of having their private data exposed.
- As a result, besides the technical challenges introduced by the ubiquity of devices, there is another trend that will push for a fog scenario where data is not sent to a few centralized services, but it is instead kept 'in the network' for better privacy.
- Data ownership will be a very important cornerstone of the fog, where some applications will be able to use the network to run applications and manage data without relying on centralized services.

Rogue Fog Node

A rogue fog node would be a fog device or fog instance that pretends to be legitimate and coaxes end users to connect to it.

For example, in an insider attack, a fog administrator may be authorized to manage fog instances, but may instantiate a rogue fog instance rather than a legitimate one.

Authentication

Authentication is an important issue for the security of fog computing since services are offered to massive-scale end users by front fog nodes.

Will fog computing improve privacy?

Today, we constantly leak personal information by using different products, platforms and services

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Security and Privacy Issues

Trust and Authentication

- In cloud computing deployment, data centers are usually owned by cloud service providers. However, fog service providers can be different parties due to different deployment choices:
  - Internet service providers or wireless carriers, who have control of home gateways or cellular base stations, may build fog with their existing infrastructures
  - Cloud service providers, who want to expand their cloud services to the edge of the network, may also build fog infrastructures
  - End users, who own a local private cloud and want to reduce the cost of ownership, would like to turn the local private cloud into fog and lease spare resources on the local private cloud.
- This flexibility complicates the trust situation of fog.

COMPARISON OF FOG COMPUTING AND CLOUD COMPUTING

	Fog Computing	Cloud Computing
Target User	Mobile users	General Internet users.
Service Type	Limited localized information services related to specific deployment locations	Global information collected from worldwide
Hardware	Limited storage, compute power and wireless interface	Ample and scalable storage space and compute power
Distance to Users	In the physical proximity and communicate through single-hop wireless connection	Faraway from users and communicate through IP networks
Working Environment	Outdoor (streets, parklands, *etc.*) or indoor (restaurants, shopping malls, *etc.*)	Warehouse-size building with air conditioning systems
Deployment	Centralized or distributed in reginal areas by local business (local telecommunication vendor, shopping mall retailer, *etc.*)	Centralized and maintained by Amazon, Google, *etc.*

Class assignment

- Define Fog Computing.
- How is it different from Cloud Computing?
- What are the limitations of Cloud Computing that are addressed by Fog Computing?
- Create a table and list compare cloud computing and fog computing (at least 10 with references)
- What are the issues of fog computing (at least 10 with references)
- List down the Applications of fog computing (at least 20 with references)
- Read Paper “Comparison of Edge Computing Implementations: Fog Computing, Cloudlet and Mobile Edge Computing” and differentiate between fog computing, Cloudlet and mobile edge computing.