MODULE 2:
FOG COMPUTING

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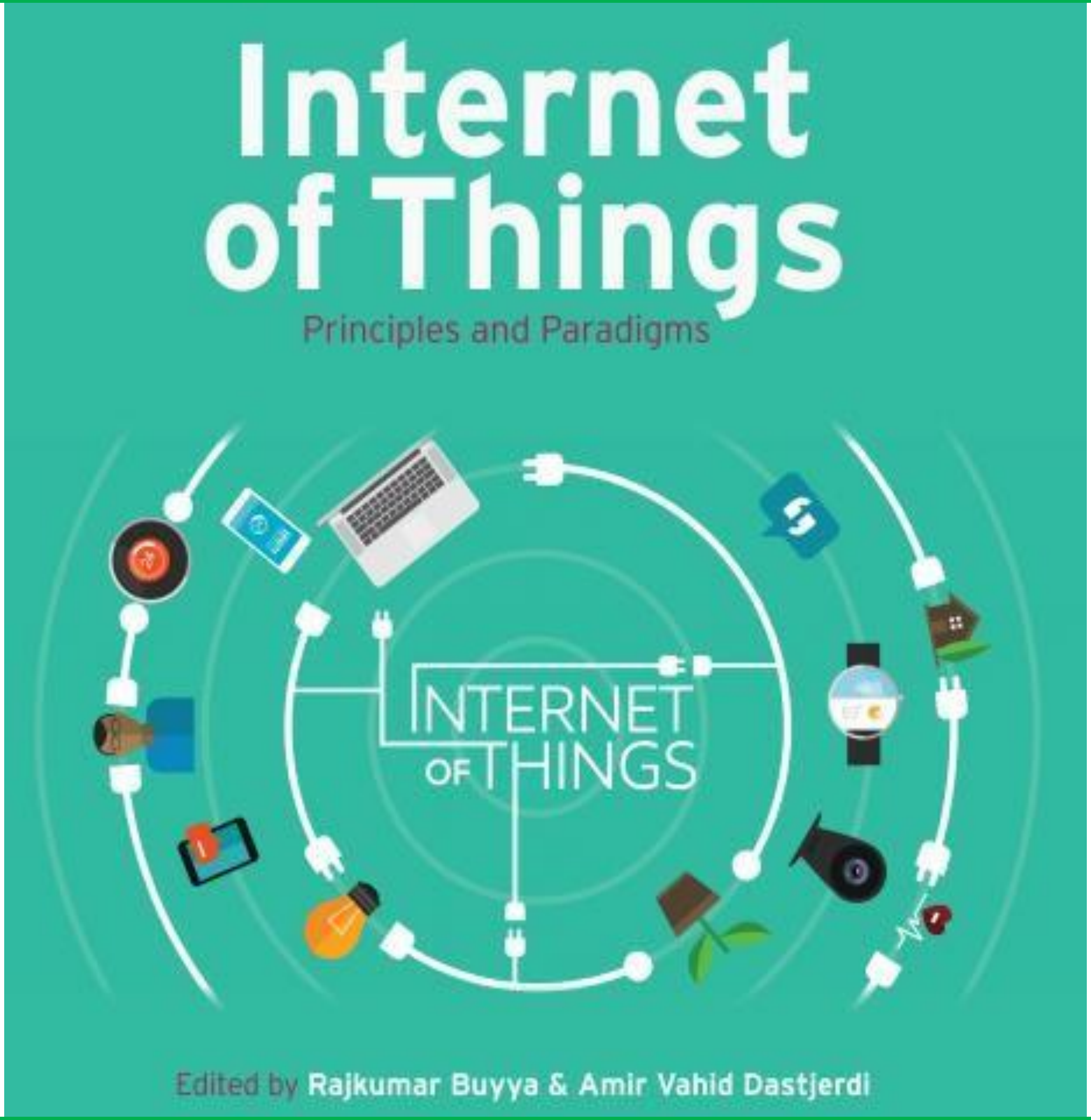

Internet of Things
Principles and Paradigms
INTERNET OF THINGS
Edited by Rajkumar Buyya & Amir Vahid Dastjerdi

FOG COMPUTING:

PRINCIPLES,ARCHITECTURES AND APPLICATIONS

Introduction

- Internet of Things (IoT) environments consist of loosely connected devices that are connected through heterogeneous networks.
- The purpose of building an IoT environment is to **collect and process data from IoT devices** in order to

➢ mine and detect patterns

➢ perform predictive analysis or optimization

➢ make smarter decisions in a timely manner

...Introduction

Data in an IoT environment can be classified into two categories:

- **Little Data or Big Stream:** transransient data that is captured constantly from IoT smart devices
- ***Big Data*:** persistent data and knowledge that is stored and archived in centralized cloud storage
  - Need both **Big Stream** and **Big Data** for effective real-time analytics and decision making.

...Introduction

- Data is collected and aggregated from IoT networks that consist of smart devices,
- Data is sent to cloud servers, where it is stored and processed.
- Cloud computing enables highly scalable computing platforms that can be configured on demand **to meet constant changes of application requirements** in a pay-per-use mode, **reducing the investment** necessary to build the desired analytics application.
- However, when data sources are distributed across **multiple locations** and **low latency** is indispensable**, in- cloud data processing fails to meet the requirements.**

Motivating Scenario

Motivation behind the need for an **alternative paradigm** that is capable of bringing the computation to more **computationally capable devices** that are geographically closer to the sensors than to the clouds, and that have connectivity to the Internet :

- Centralized cloud servers **cannot deal with flows with high velocity** in real time.
- Some users, due to **privacy concerns**, are not comfortable to transfer and store activity-track-data into the cloud, even if they require a statistical report on their activities.

…Motivating Scenario

Cloud limitations:

- Latency
- Limited Bandwidth
- Data Protection Mechanism
- Internet Connectivity

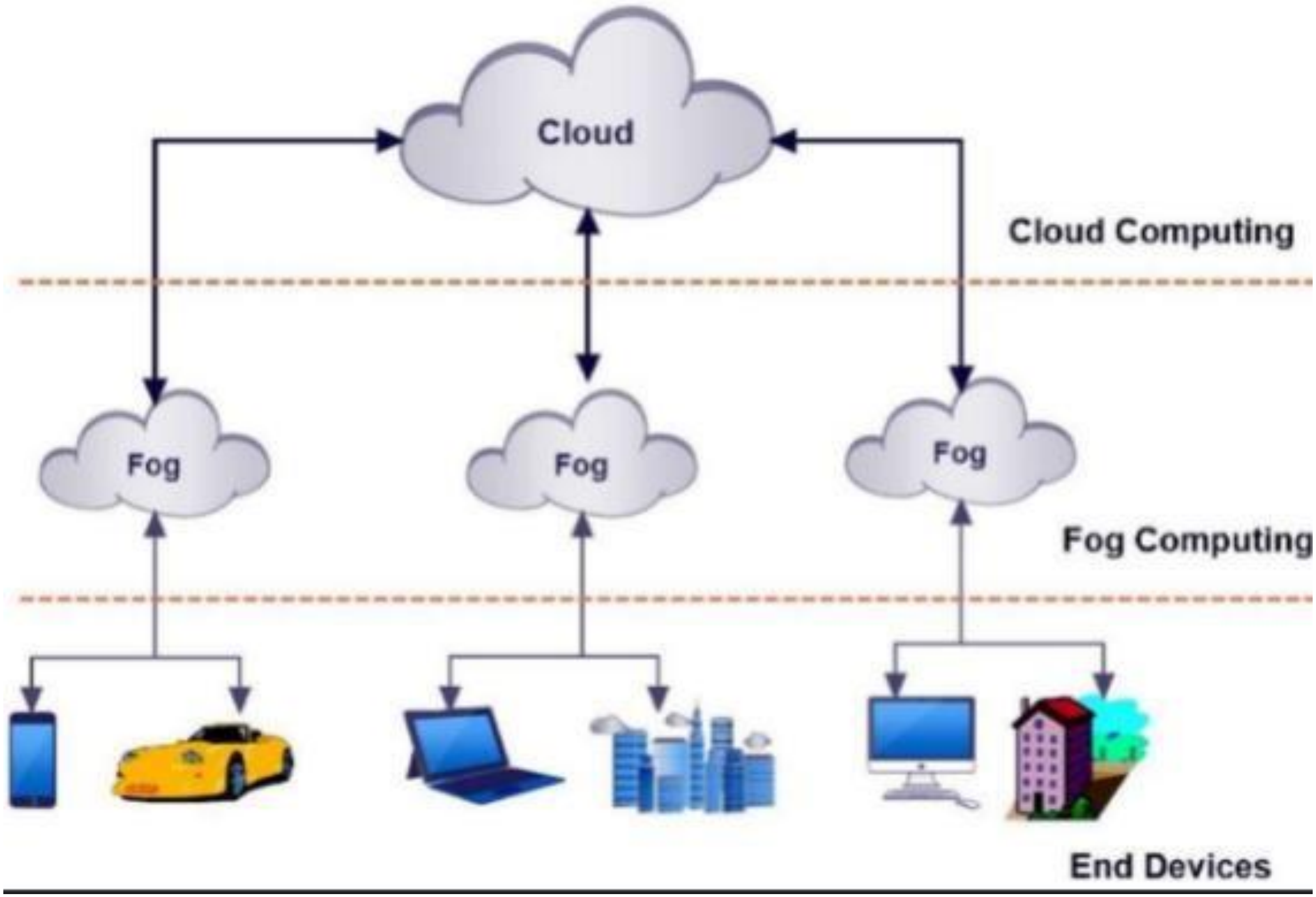
...Motivating Scenario

- This motivates the need for more computationally capable devices that are **geographically closer to the sensors** than to the clouds, and that have connectivity to the Internet.
- These computationally capable devices are at the **edge of the network** and therefore referred to as **edge devices ,** which can

➢ build local views of data flows

➢ aggregate data to be sent to the cloud for further offline analysis.

Thus **Fog computing** has emerged.


Cloud
Cloud Computing
Fog
Fog
Fog
Fog Computing
End Devices

Fog Computing

- **Fog computing** (fog networking or fogging) is an architecture that uses edge devices to carry out a substantial amount of computation, storage and communication locally and routed over the Internet backbone.
- It is a **Decentralized computing structure** located **between** the **cloud and devices** that produce data.
- It extends the concept of cloud computing to the network edge , making it ideal for **IoT** and other applications that require **real-time interactions**.

...Fog Computing

- Fog computing is **a distributed computing paradigm** that fundamentally **extends the services provided by the cloud to the edge of the network.**
- It facilitates management and programming of compute, networking, and storage services between data centres and end devices.
- Fog computing involves components of an application running both in the cloud as well as in edge devices between sensors and the cloud(smart gateways, routers, or dedicated fog devices).

...Fog Computing

- Fog computing supports:

➢ Mobility

➢ Computing resources

➢ Communication protocols

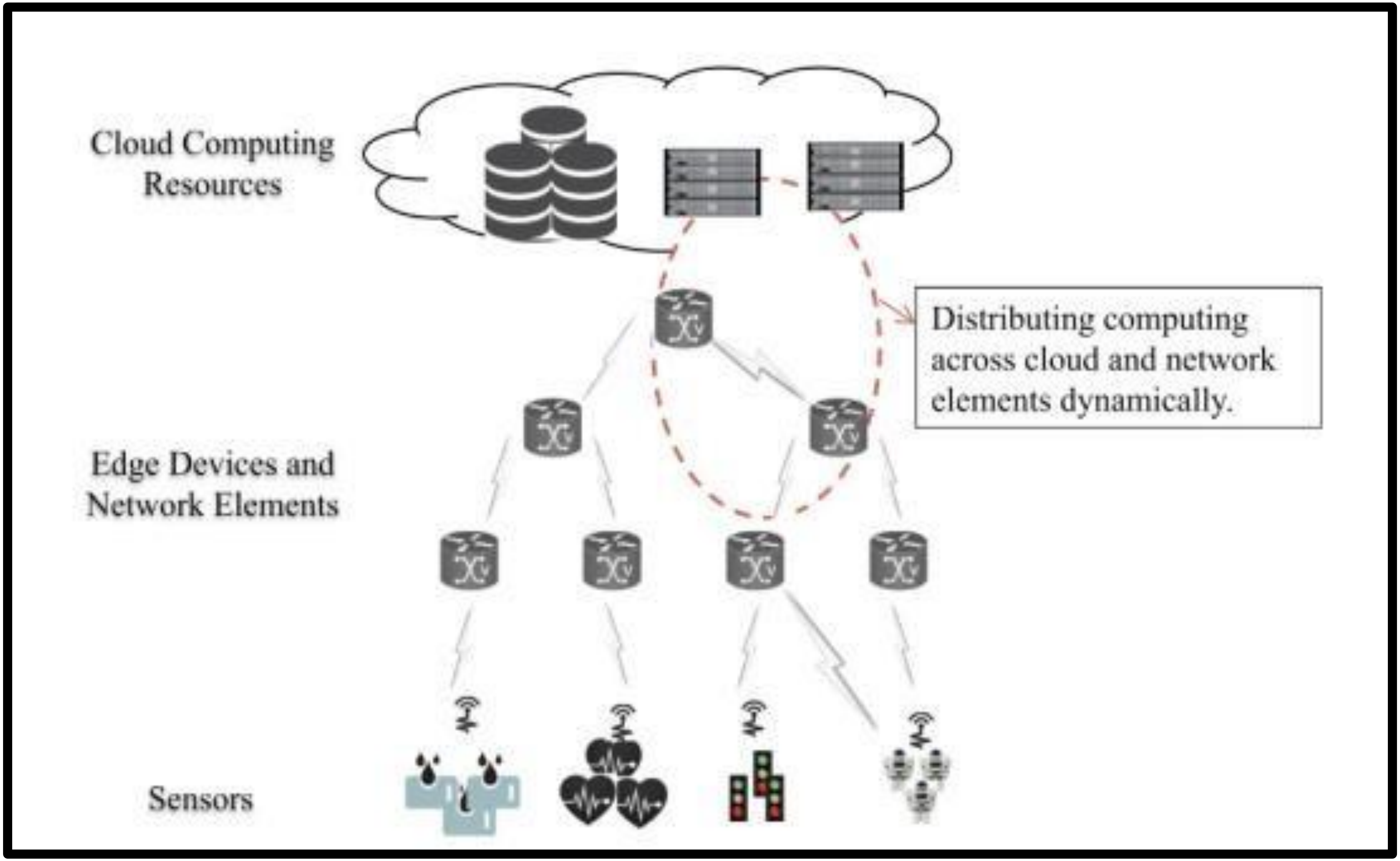
➢ Interface heterogeneity

➢ Cloud integration

➢ Distributed data analytics

❖ to address requirements of applications that need low latency with a wide and dense geographical distribution.

Fog Computing is a Distributed Computing Paradigm That Extends the Cloud Services to the Edge of the Network



Advantages of Fog Computing

- **Reduction of network traffic***:*

- it is neither efficient nor sensible to send all of the raw data to the cloud as there is billions of mobile devices that has the computing capability.
- Fog computing benefits by providing a platform for filter and analysis of the data generated by these devices close to the edge, and for generation of local data views.
- This drastically reduces the traffic being sent to the cloud.

...Advantages of Fog Computing

❖ Suitable for IoT tasks and queries

- With the increasing number of smart devices, most of the **requests pertain to the surroundings** of the device, such requests can be served without the help of the global information present at the cloud .
- **Local nature of some requests** made by certain application, makes sense that the requests are processed in fog rather than cloud infrastructure (eg: smart-connected vehicle which needs to capture events only about a hundred meters from it)
- Fog computing **makes the communication distance closer to the physical distance** by bringing the processing closer to the edge of the network

...Advantages of Fog Computing

❖ Low-latency requirement:

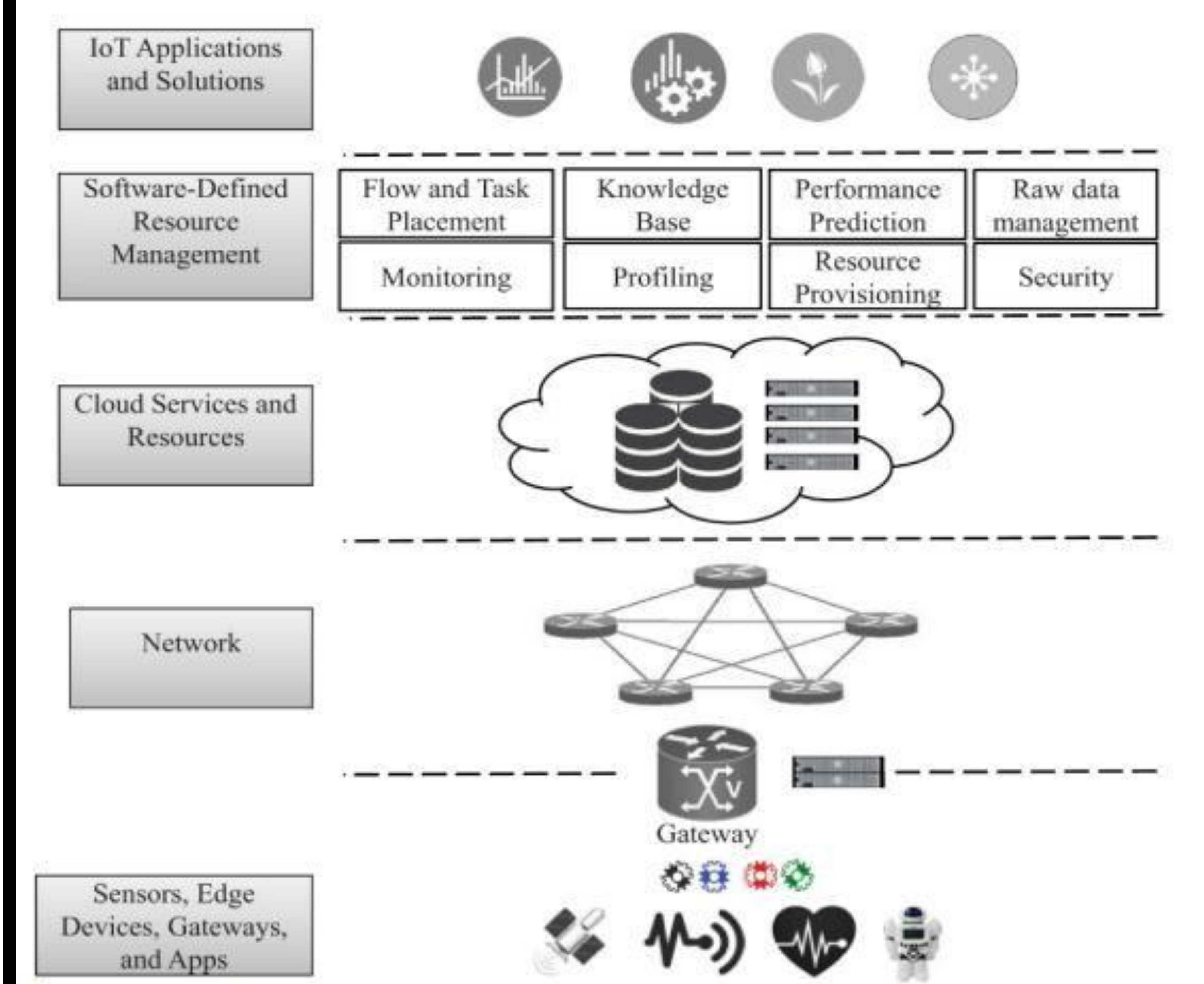
- Mission-critical applications require real-time data processing.(eg: cloud robotics)
- Having the control system running on the cloud may make the **sense-process-actuate** loop slow or unavailable as a result of communication failures.
- Fog computing helps, by performing the processing required for the control system very close to the device, thus making real-time response possible.

...Advantages of Fog Computing

❖ Scalability:

- The cloud may become the bottleneck if all the raw data generated by end devices is continually sent to it.
- Since fog computing aims at processing incoming data closer to the data source itself, it reduces the burden of that processing on the cloud.
- Thus it addressing the scalability issues arising out of the increasing number of endpoints.

Reference Architecture Of Fog Computing



Fog Computing Reference Architecture

- **Bottommost layer** : **End devices (sensors), Edge devices** and **Gateways** – it also includes **apps** that can be installed in the end devices to enhance their functionality.

- **Network Layer:** for communicating among themselves, and between them and the cloud.

- **Cloud services and Resources Layer:** support resource management and processing of IoT tasks that reach the cloud.

- **Resource management software Layer:** manages the whole infrastructure and enables QoS to Fog Computing applications.

- **Topmost layer** : contains the applications that leverage fog computing to deliver innovative and intelligent applications to end users.

Software-Defined Resource Management layer

- It implements many middleware-like services **to optimize the use of the cloud and Fog resources** on behalf of the applications.
- The goal of these **services is to reduce the cost of using the cloud** at the same time that performance of applications reach **acceptable levels of latency**, by pushing task execution to Fog nodes.

Software-Defined
Resource Management layer

- **Flow and task placement:**

➢ It keeps track of the state of available cloud, Fog, and network resources to identify the best candidates to hold incoming tasks and flows for execution.

➢ It communicates with the Resource-Provisioning service to indicate the current number of flows and tasks, which may trigger new rounds of allocations if deemed too high.

… Services of Software-Defined Resource Management layer :

- **Knowledge Base:** stores historical information about application demands and resource demands that can be leveraged by other services to support their decision- making process.
- **Performance Prediction:**

  It utilizes **information of the Knowledge- Base service** to estimate the performance of available cloud resources-This information is used by the Resource Provisioning service to decide the amount of resources to be provisioned, in times where there are a large number of tasks and flows in use or when performance is not satisfactory.

- **Raw-Data Management:**

➢ This service has direct access to the data sources and provides views from the data for other services.

➢ views can be obtained by simple querying (eg, SQL or NOSQL REST API) or with more complex processing (eg, MapReduce).

➢ Method for generation of the view is abstracted away from other services.

- **Monitoring:** This service keeps track of the performance and status of applications and services, and supplies this information to other services as required.

- **Resource Provisioning:**

➢ **This service is responsible for acquiring cloud, Fog, and network resources for hosting the applications.**

➢ **This allocation is dynamic**

➢ **The decision on the number of resources is made with the use of information provided by other services and user requirements on latency, as well as credentials managed by the Security service.**

- **Profiling:** This service builds resource and application profiles based on information obtained from the Knowledge Base and Monitoring services.
- **Security:** This service supplies authentication, authorization, and cryptography, as required by services and applications.

Applications of Fog Computing

- **There are variety of applications benefiting from the Fog- computing paradigm.**
- ***Major applications are,***

➢ **Healthcare**

➢ **Augmented Reality**

➢ **Caching and Preprocessing**

Healthcare

- **Monitor fall for stroke patients**: a set of fall-detection algorithms, including algorithms based on acceleration measurements and time-series analysis methods, and filtering techniques to facilitate the fall-detection process. A real-time fall-detection system based on fog computing that divides the fall-detection task between edge devices and the cloud.

…Healthcare

- **Three-tier architecture** for a smart-healthcare infrastructure, comprised of **a role model**, **layered-cloud architecture**, and **a fog-computing layer**, in order to provide an efficient architecture for healthcare and elderly-care applications.

  The fog layer improves the architecture by providing **low latency, mobility support, location awareness, and security measures.**

Augmented Reality

- **Augmented reality applications** are highly latency-intolerant, as even very small delays in response can damage the user experience. Hence, fog computing has the potential to become a major player in the augmented reality domain.
- **Augmented Brain Computer Interaction Game** employs both fog and cloud servers, a combination that enables the system to perform **continuous real-time brain-state classification at the fog servers**, while the classification models are tuned regularly in the cloud servers, based on the EEG readings collected by the sensors.

...Augmented Reality

- In a **Wearable Cognitive Assistance system based on Google Glass devices** that assist people with reduced mental acuity , the **compute-intensive workloads of this application need to be offloaded** to an external server -Offloading the compute intensive tasks to the cloud incurs a considerable latency, so making use of nearby devices. These devices may communicate with the cloud for delay-tolerant jobs like error reporting and logging.

Caching

- The fog device performs a number of optimizations that reduces the amount of time the user has to wait for the requested webpage to load.

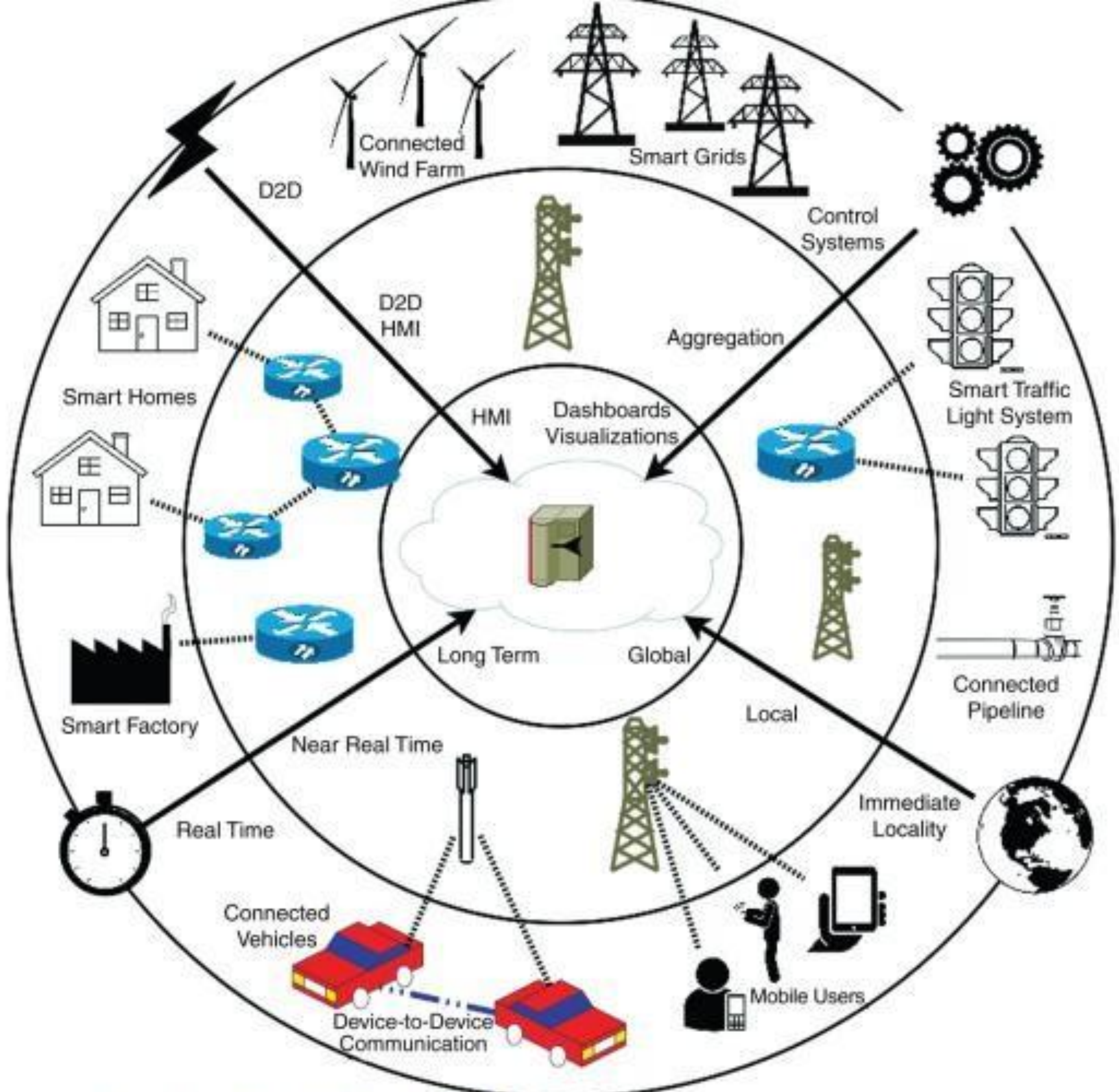
- In case of network congestion, the edge device may provide low resolution graphics to the user in order to reach acceptable response times.

Preprocessing

- One of the major advantages of fog computing is linking IoT and cloud computing. This integration involves challenges like **data trimming**.
- The trimming or pre-processing of data before sending it to the cloud will be a necessity in IoT environments because of the huge amount of data generated by these environments.
- Sending huge volumes of raw data to the cloud will lead to both core-network and data-centre congestion.
- To meet the challenge of pre-processing, can use a smart gateway-based communication for integrating IoT with cloud computing.

…Preprocessing

- Data generated by IoT devices is sent to the smart gateway, either directly (one-hop) or through sink nodes (multi-hop).
- The smart gateway handles the pre-processing required before sending the data to the cloud.
- The smart gateway is assisted by fog-computing services for operations on IoT data in **a latency-sensitive and context-aware manner.** Such a communication approach helps the creation of a richer and better user experience for IoT applications.



Range of Applications Benefiting From Fog Computing

RCB

Thank you