Internet of Things (IoT)

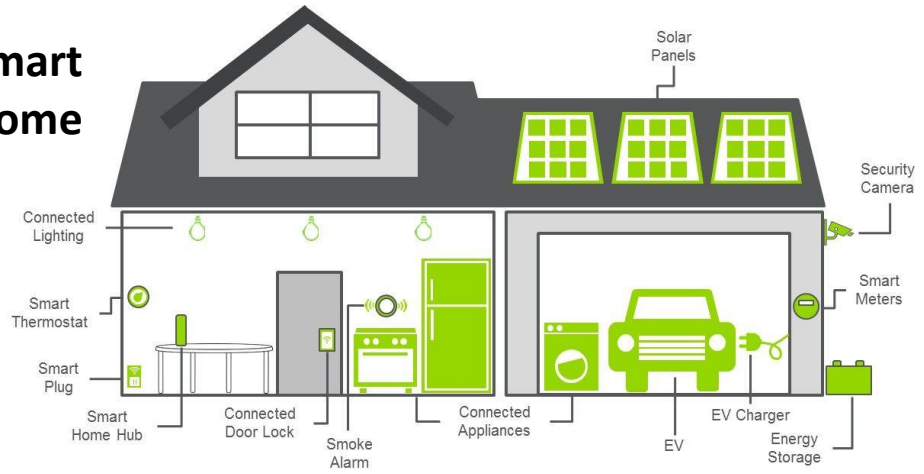
IoT Architecture

Dr. Manas Khatua
Associate Professor
Dept. of CSE, IIT Guwahati
E-mail: manaskhatua@iitg.ac.in

What is Architectural Plan?

- In present days, networks run the modern business
- So, it should never be built without careful planning

Smart Home

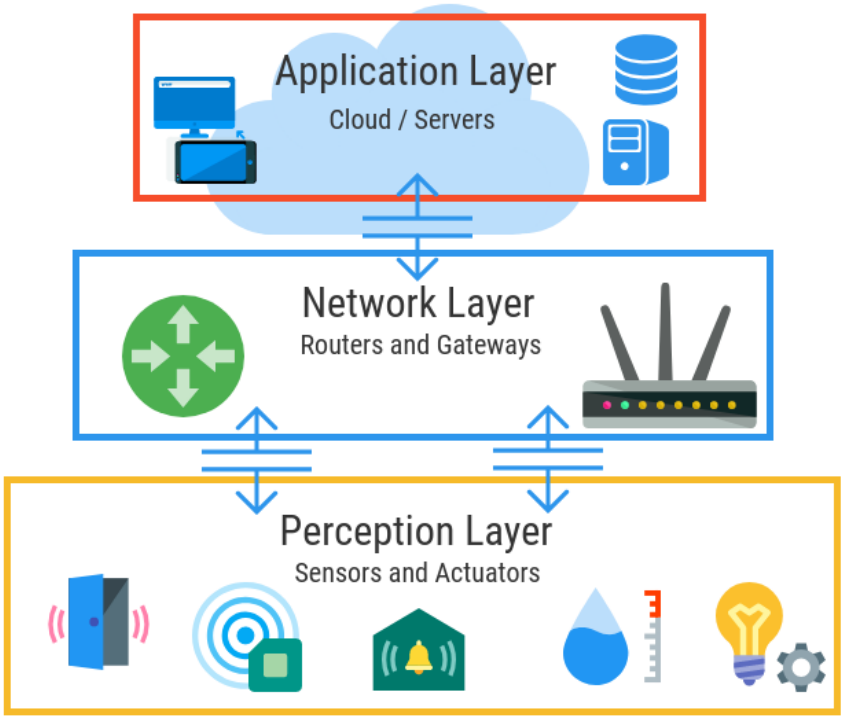


- Architecture is <u>how you design</u> your application or solution.
- Essence of IoT architecture:
  - how the data is
    - transported,
    - collected,
    - analyzed, and
    - ultimately acted upon.

Driving forces:

- Scale
- Security
- Constrained devices
- Massive data
- Data analysis
- Support to legacy devices

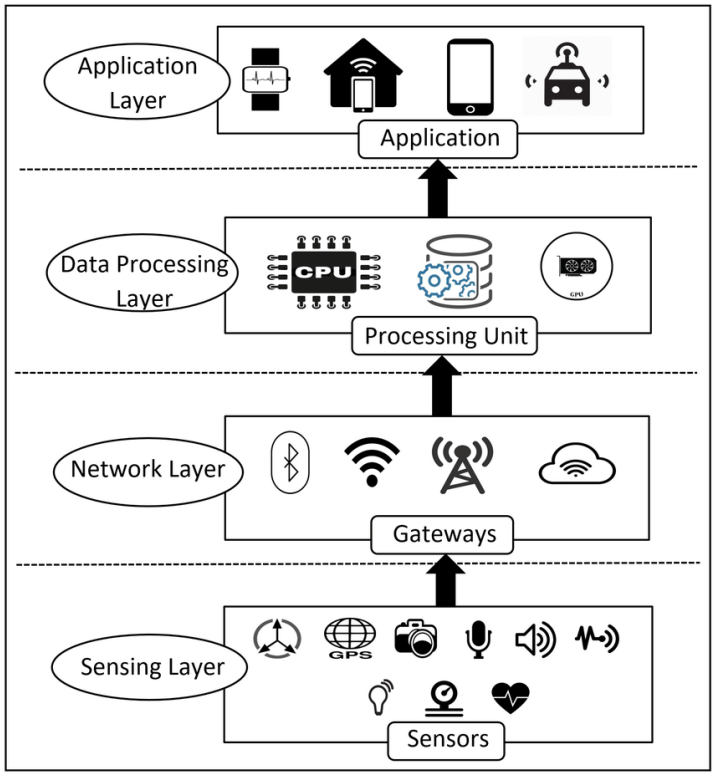
Basic 3-Layer architecture



- **Perception layer** is the physical layer, which has sensors for sensing and gathering information about the environment.
- **Network layer** is responsible for connecting to other smart things, network devices, and servers. Its features are also used for transmitting and processing sensor data.
- **Application layer** is responsible for delivering application specific services to the user.
  - For example, smart homes, smart cities, smart health, etc.

Source: https://www.pinterest.com/pin/641129696942354756/

Commonly used 4-Layer architecture



- **Sensing layer:** This layer includes sensors and actuators that are placed in the environment to gather information
- **Network layer:** It includes protocols and technologies that enable devices to connect and communicate with each other and with the wider internet.
- **Data processing Layer:** It includes a variety of technologies and tools, such as data management systems, analytics platforms, and machine learning algorithms, to extract meaningful insights from the data and make decisions based on that data.
- **Application Layer:** It includes various software and applications such as mobile apps, web portals, and other user interfaces that are designed to interact with the underlying IoT infrastructure.

Source: Sikder *et al.*, "A Survey on Sensor-based Threats to Internet-of-Things (IoT) Devices and Applications" *IEEE Communications Surveys & Tutorials*, 23(2), pp. 1125 - 1159, 2021.

Emergence of Standard IoT Architecture

- However, the basic 3-layer or commonly used 4-layer architectures did not address many issues.
- In fact, IoT did not have any standard defined architecture of working which is strictly followed universally.

Few Existing Issues:

- Highly fragmented marked with limited vendor-specific applications
- Each application vertical contains its own technologies without interoperability
- Incompatibility for seamless integration between heterogeneous applications and devices
- Did not consider security aspect in design

- So, in the past several years, few architectural standards and frameworks have emerged
- Two best-known architectures:
  - oneM2M architecture
  - IoT World Forum architecture

Source: https://onem2m.org/using-onem2m/developers/basics

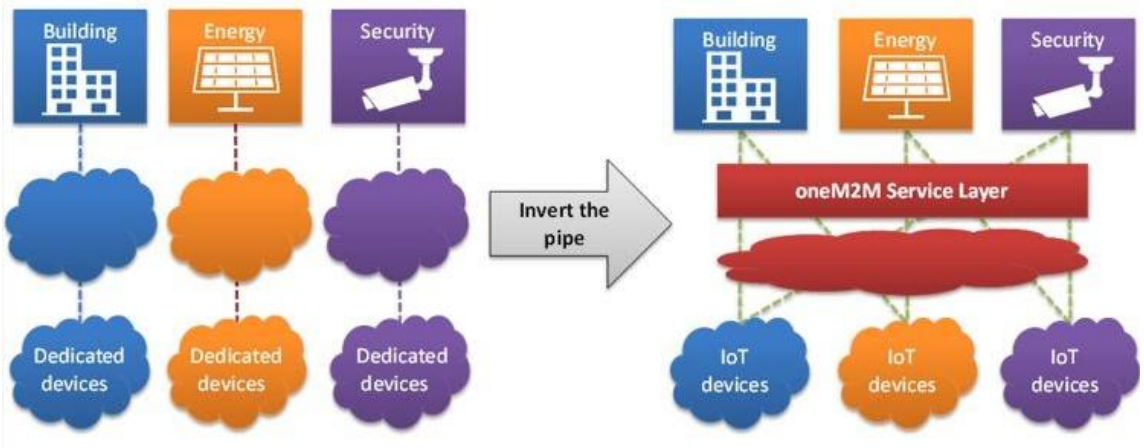
oneM2M Architecture

Goal of **oneM2M** architecture:

- to create a common services layer, which can be readily embedded in **field devices** to allow communication with application servers.

Challenges in IoT Architecture:

- heterogeneity of devices,
- heterogeneity of software,
- Heterogeneity of access methods



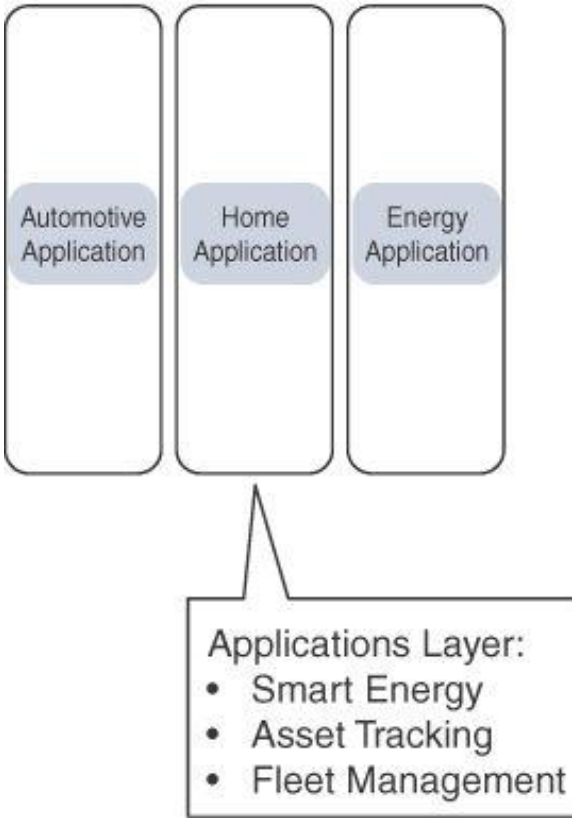
- Using the smart building use case, a security application can detect when nobody is in the building.
- It could then trigger lights to be switched off and for the HVAC system to operate on a reduced setting.

Image Source: https://onem2m.org/using-onem2m/developers/basics

oneM2M Architecture

- Proposed by Européen Télécommunications Standards Institute (ETSI)
- oneM2M architecture divides IoT functions into three major domains.

First



- Defines **application-layer protocols**
- Attempts to standardize **northbound API**

  API (Application Programming Interface)

  Note: Interface can be thought of as a contract of service between two applications or parties. This contract defines how the two communicate with each other using requests and responses.

- A northbound interface allows a particular component of a network to communicate with a higher-level component.
- Applications have their own sets of data models

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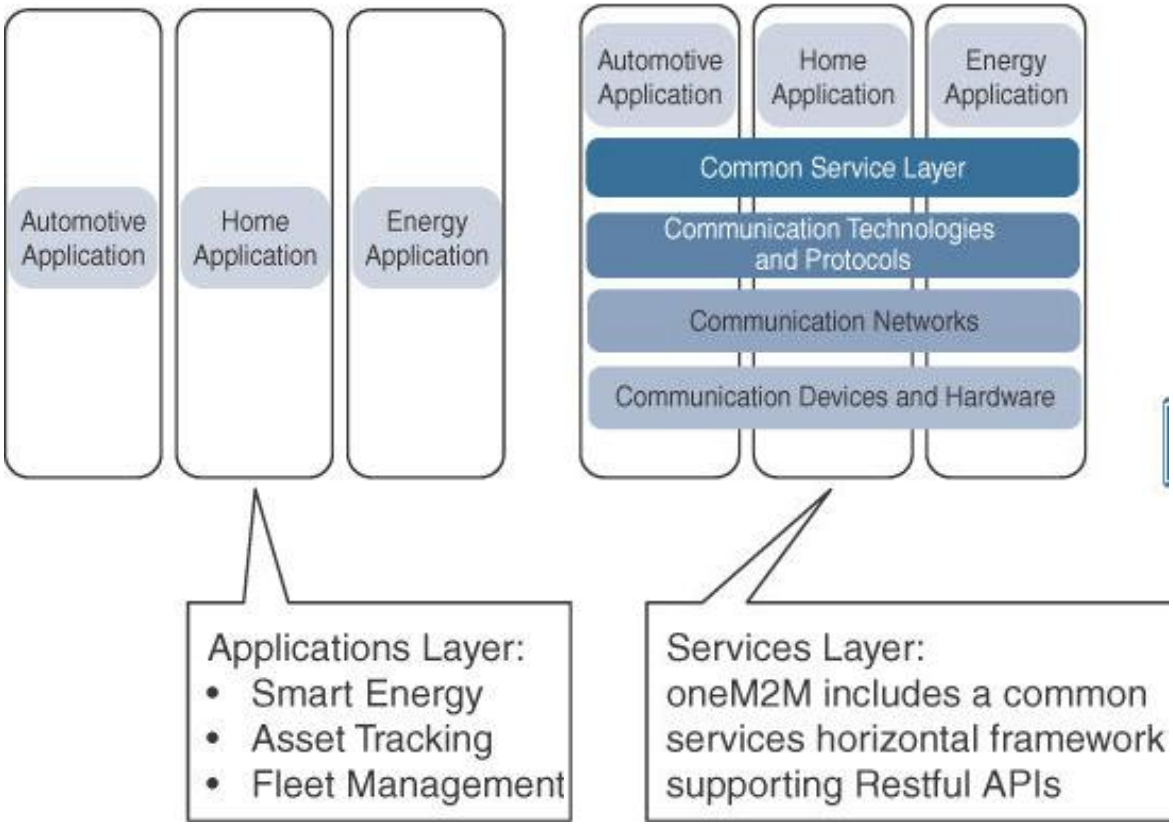
First **Second**



- horizontal framework across the vertical industry applications.
- Include:
  - the physical network that the IoT applications run on. (e.g. backhaul network)
  - the underlying management protocols
  - the hardware

cont…

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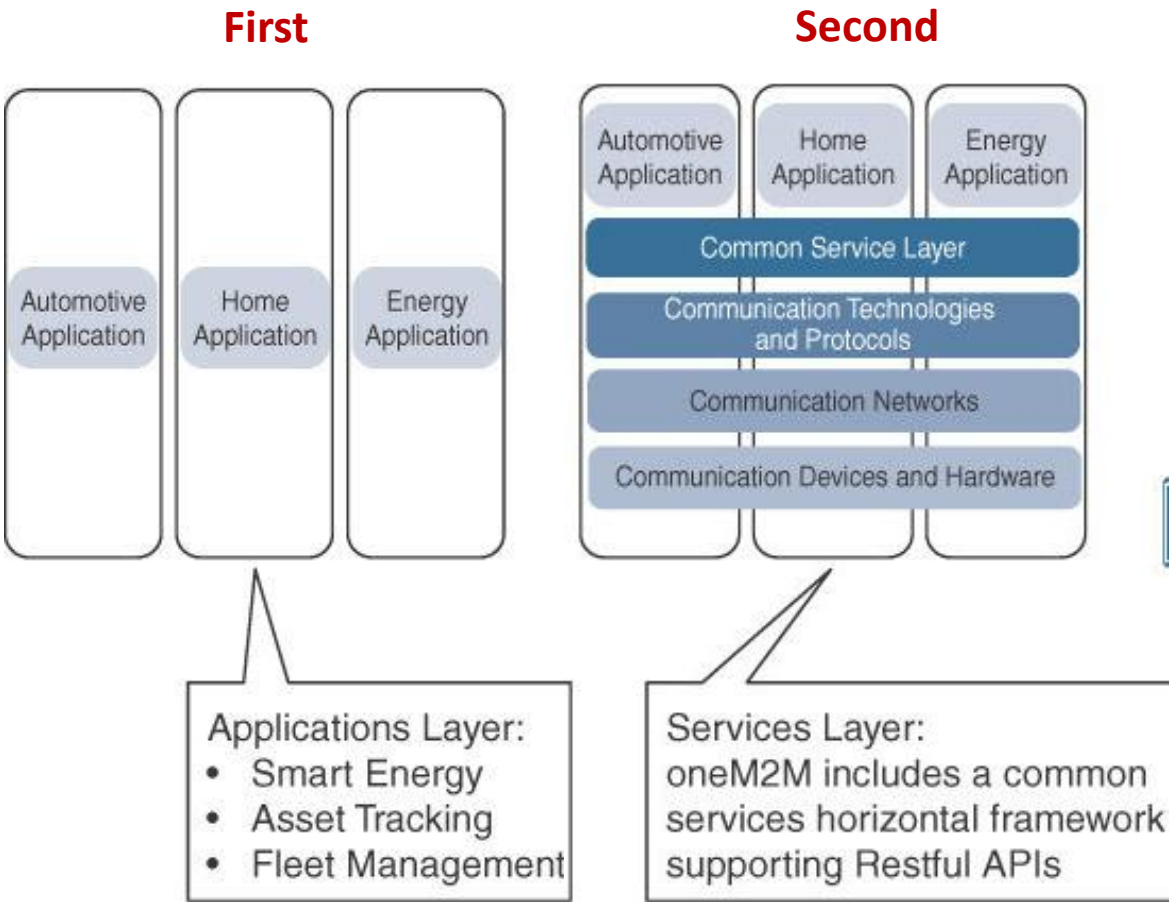

- top is the common services layer
- This layer **adds** APIs and middleware supporting third-party services and applications.
- Service layer can be readily embedded within various hardware and software nodes
- A **RESTful API** uses HTTP requests to GET, PUT, POST and DELETE **data**.

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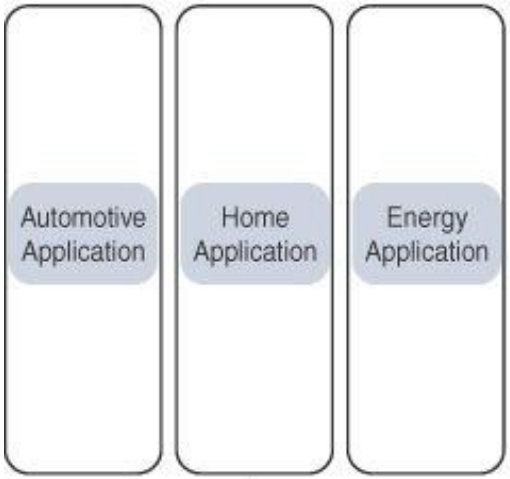
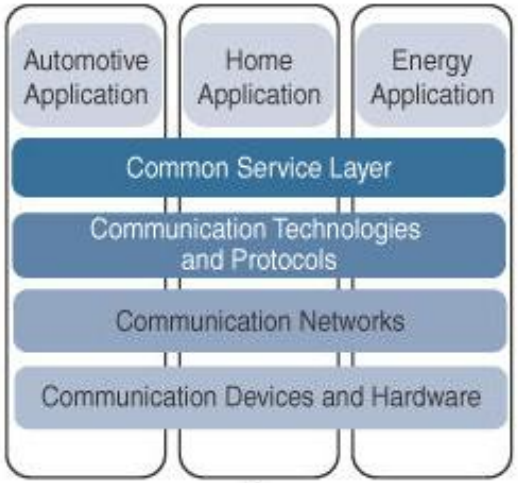


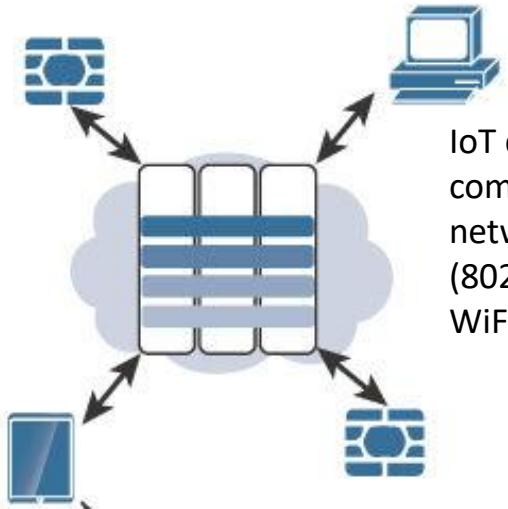
Applications Layer:
- Smart Energy
- Asset Tracking
- Fleet Management

Second



Services Layer:
oneM2M includes a common services horizontal framework supporting Restful APIs

Third



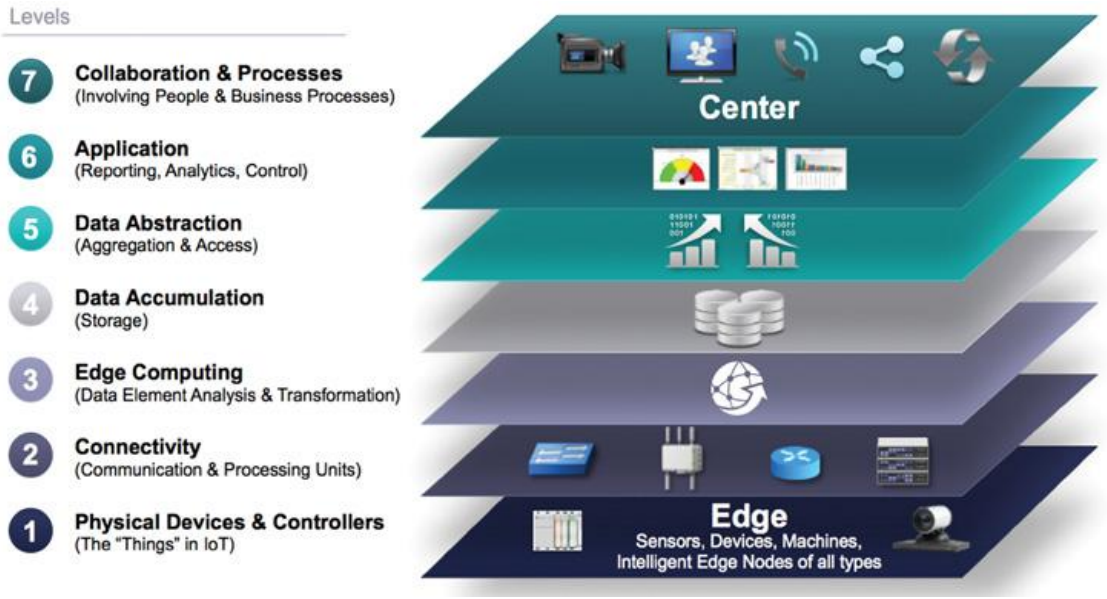
IoT devices, & communication network (802.15.4, LoRa, WiFi)

Network Layer:
Applications talk to the APIs to communicate to sensors

IoTWF Architecture – 7 Layer Stack

IoTWF architectural committee (led by Cisco, IBM, Rockwell Automation, and others) aims to -

- ✓ offers a clean, simplified perspective on IoT
- ✓ includes edge computing, data storage, and data access
- ✓ concise way of visualizing IoT from a technical perspective



- Decompose the IoT problem into smaller parts
- Identify different technologies at each layer
- Different parts of a system can be provided by different vendors
- Tiered security model enforced at the transition points between levels
- Define interfaces that leads to interoperability

Layers 1 & 2

Layer 1: Physical Devices and Controllers Layer

- home of the “things” in IoT
- “things” can be from a microscopic sensors to giant machines in a factory
- primary function is generating data
- capable of being queried and/or controlled over a network.

Layer 2: Connectivity Layer

- focus is on connectivity

② **Connectivity**
(Communication and Processing Units)

Layer 2 Functions:

- Communications Between Layer 1 Devices
- Reliable Delivery of Information Across the Network
- Switching and Routing
- Translation Between Protocols
- Network Level Security

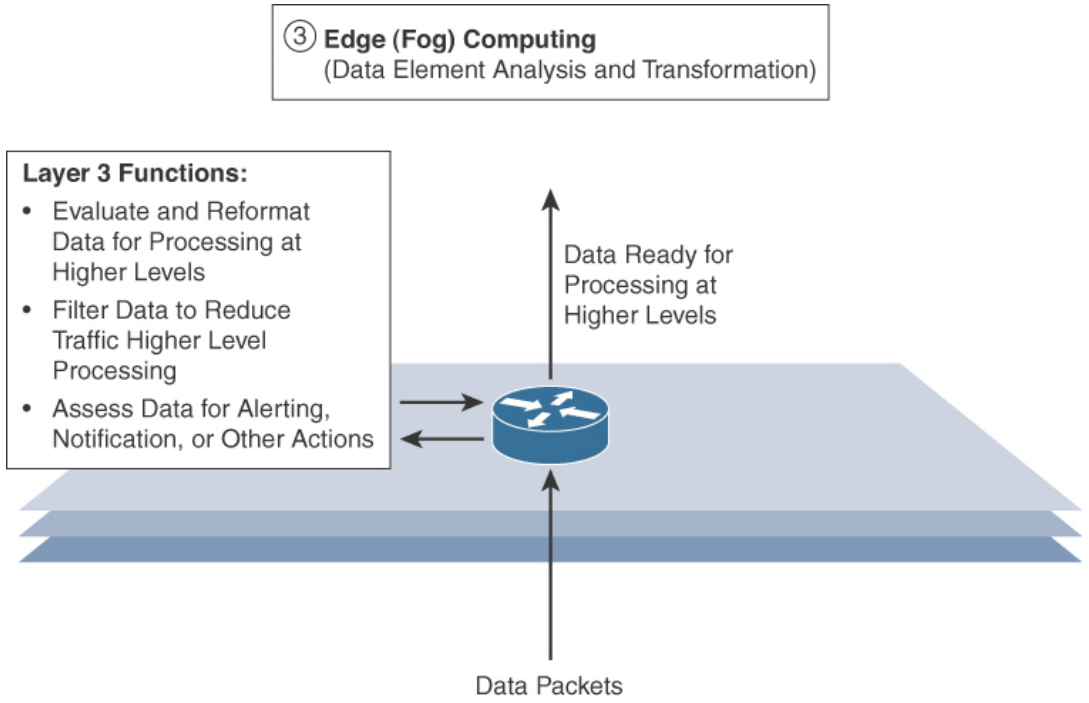
Layer 3 : Fog Layer

Layer 3: Edge Computing Layer

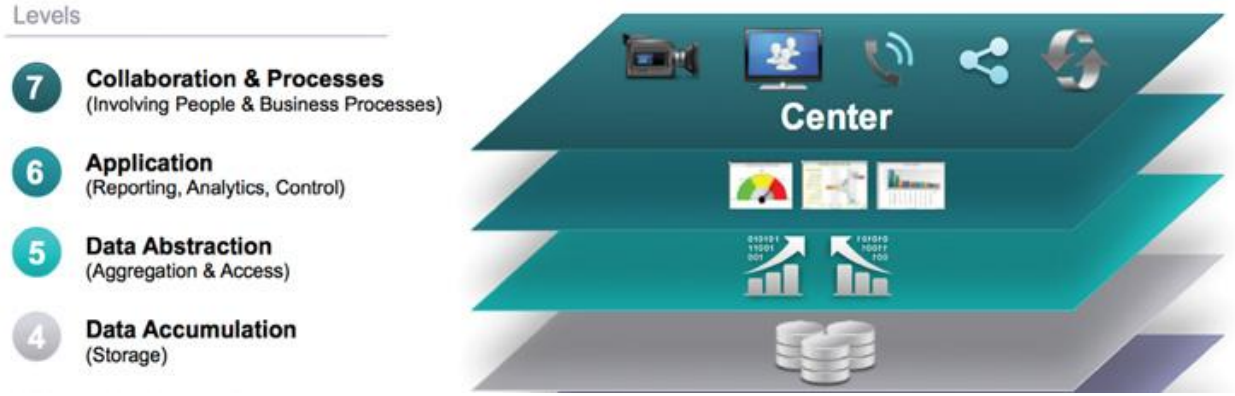
- often referred to as the "fog" layer
- emphasis is on
  - Data reduction by filtering and cleaning up
  - Reformatting and compressing data
  - Initial processing of data (e.g. alert generation, data validation, etc)

Basic principle:

information processing is initiated as early and as close to the edge of the network as possible.



Upper Layers: Layers 4–7

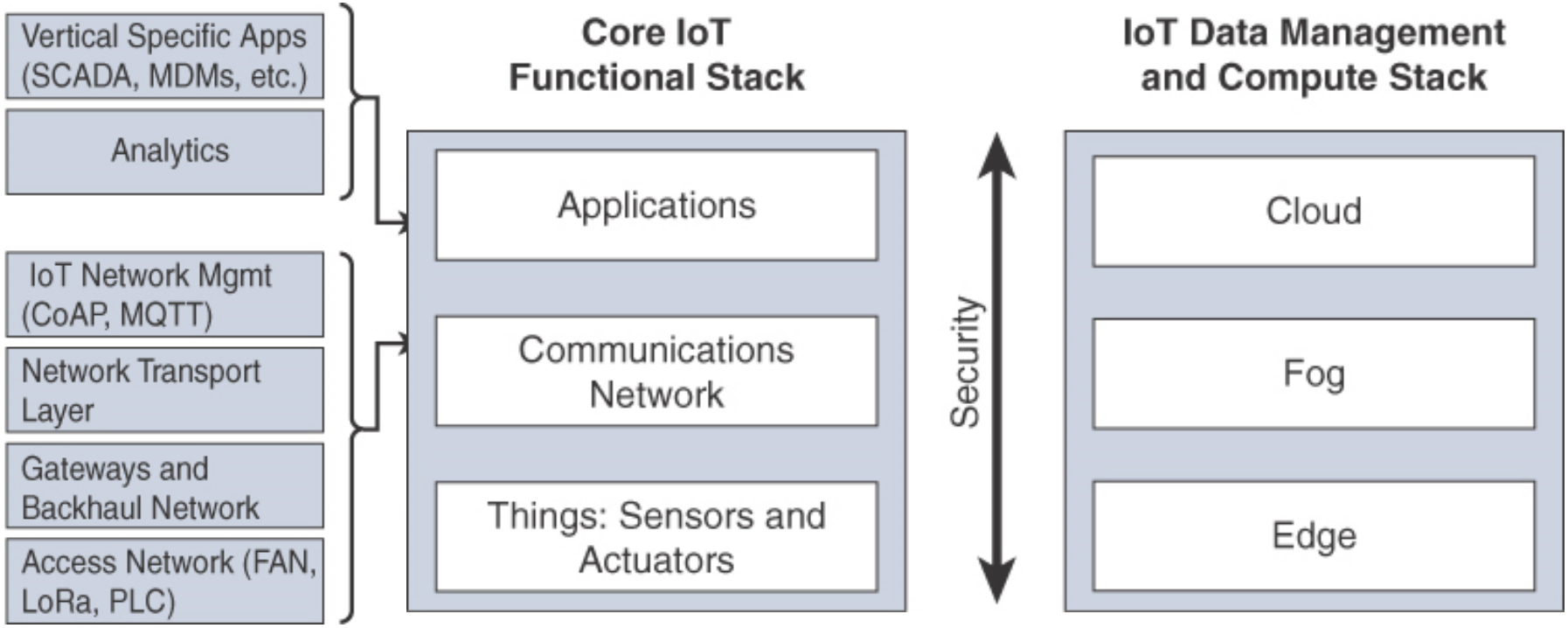


Layers	Functions
Layer 4: Data Accumulation	• Captures data and stores it for applications • Convert event-based data to query-based processing
Layer 5: Data Abstraction	• Reconciles multiple data formats • Ensures consistent semantics for various data sources • Confirmation about dataset completeness
Layer 6: Application	• Interpret data using software applications • Applications may monitor, control, and provide report based on analysing the data
Layer 7: Collaboration and processes	• Consumes and shares the application information • Collaborating and communicating IoT information

Unified IoT Architecture

- It highlights the fundamental building blocks that are common to most IoT systems and which is intended to help in designing an IoT network.

- IoT architectural framework is presented as two parallel stacks
  - Core IoT Functional Stack
  - IoT Data Management and Compute Stack



Lessons Learned

- ✓ What is the need of IoT architecture?
- ✓ 3-Layer and 4-Layer IoT Architectures
- ✓ About oneM2M architecture
- ✓ About IoT WF architecture
- ✓ Unified IoT Architecture

Thanks!

Figures and slide materials are taken from the following sources:

1. David Hanes *et al.*, “IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things”, 1st Edition, 2018, Pearson India.