

IoT App Development



IoT Architecture

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Associate Professor

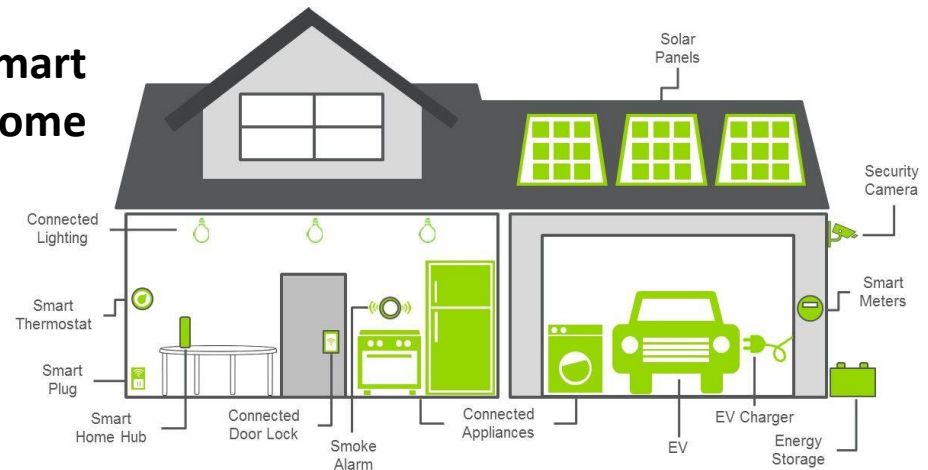
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What is Architectural Plan?

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

Smart Home

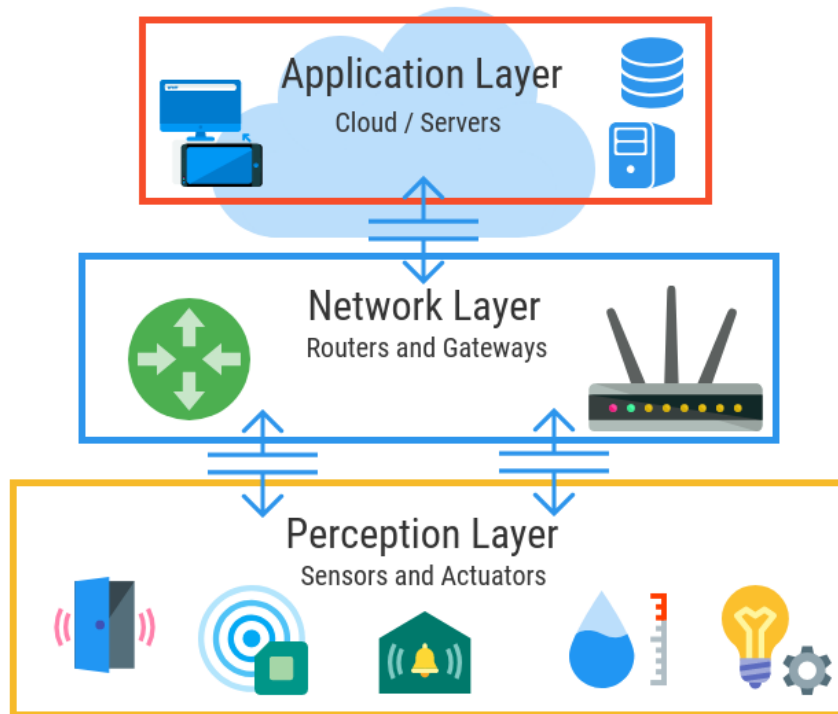


- Architecture is how you design your application or solution.
- **Essence of IoT architecture:**
 - how the data is
 - transported,
 - collected,
 - analyzed, and
 - ultimately acted upon.

Driving forces:

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

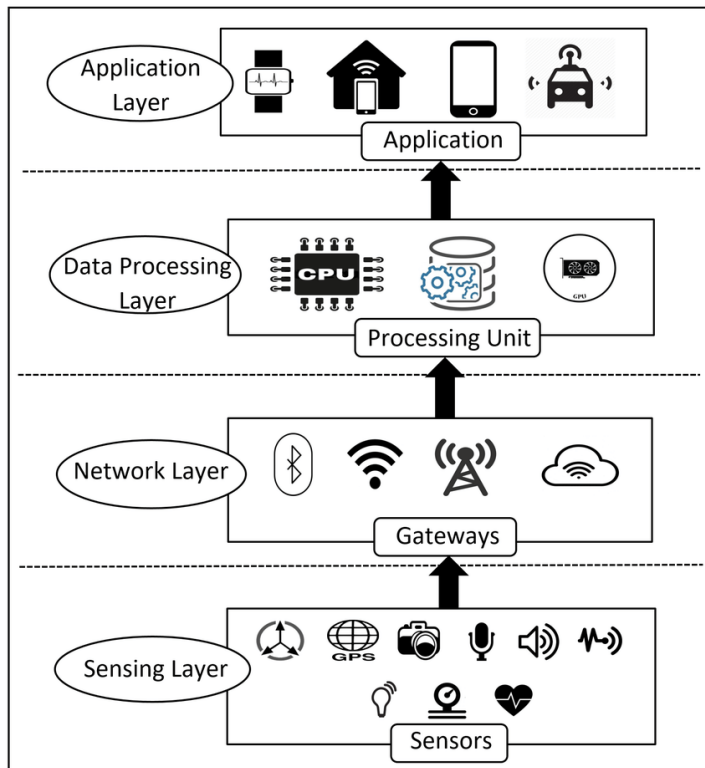
Basic 3-Layer architecture



- **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>

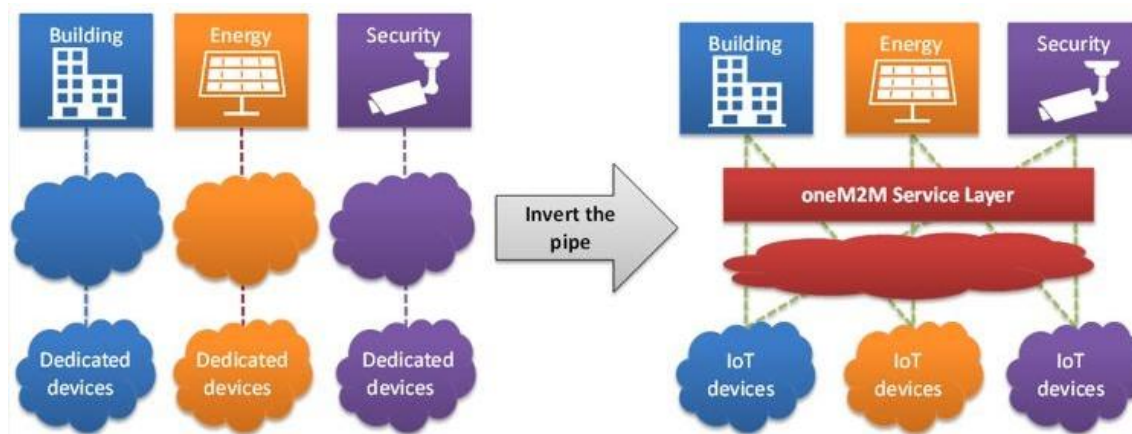
oneM2M Architecture

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



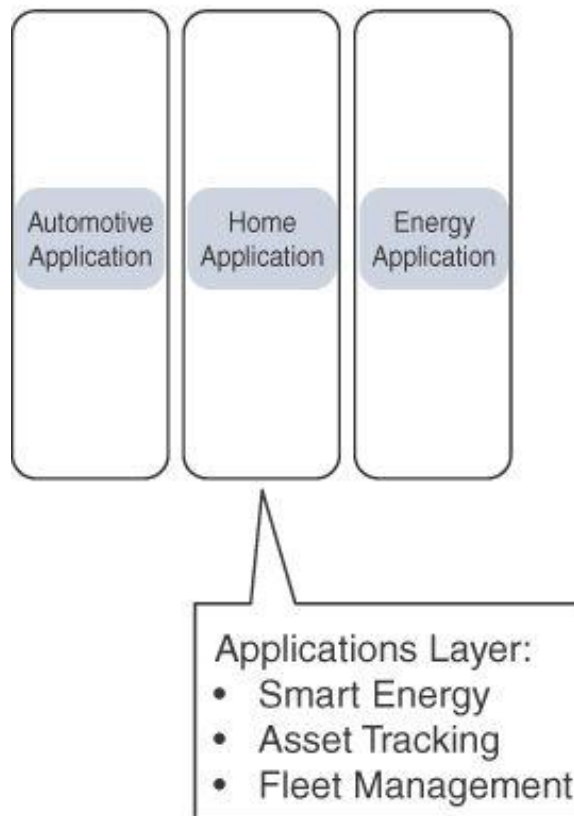
- Using the smart building use case, a **security application** can detect when nobody is in the building.
- It could then **trigger lights** to be switched off and for the **HVAC system** to operate on a reduced setting.

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



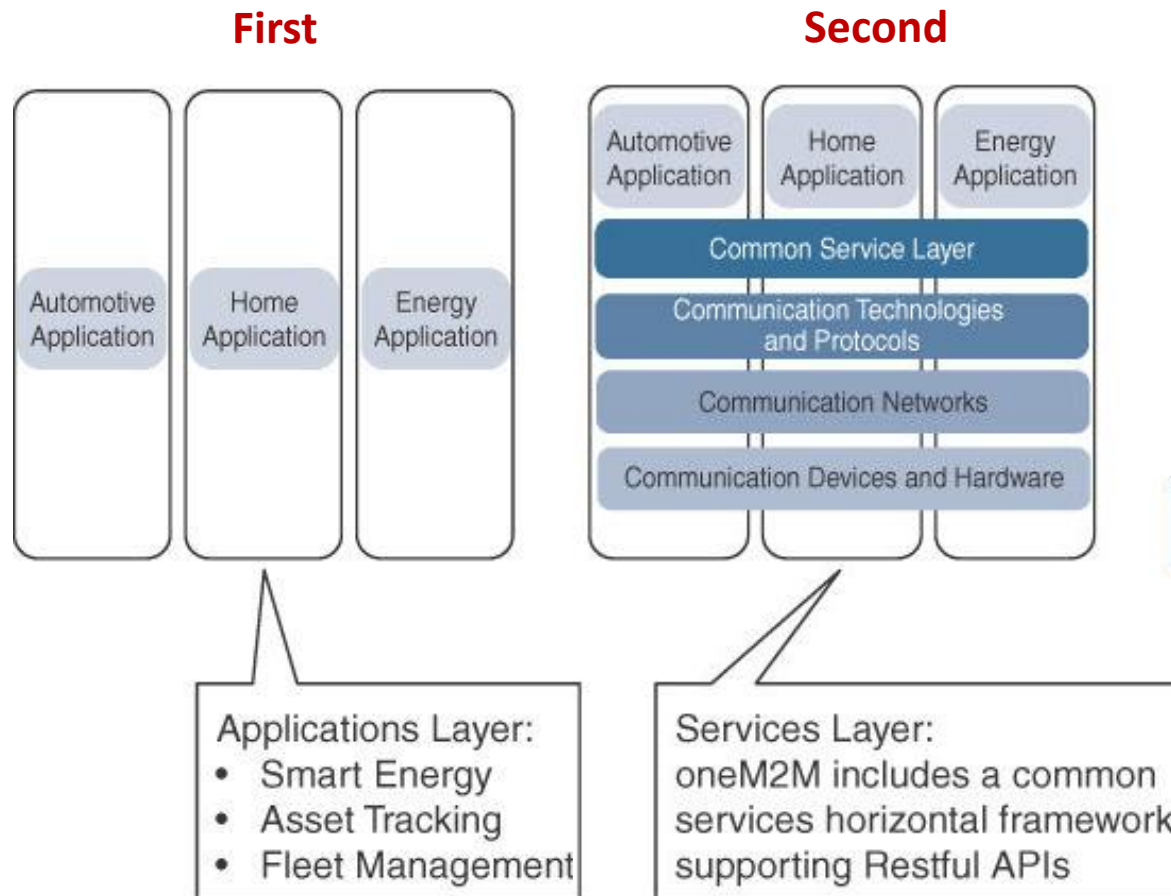
- Defines **application-layer protocols**
- Attempts to **standardize northbound API**

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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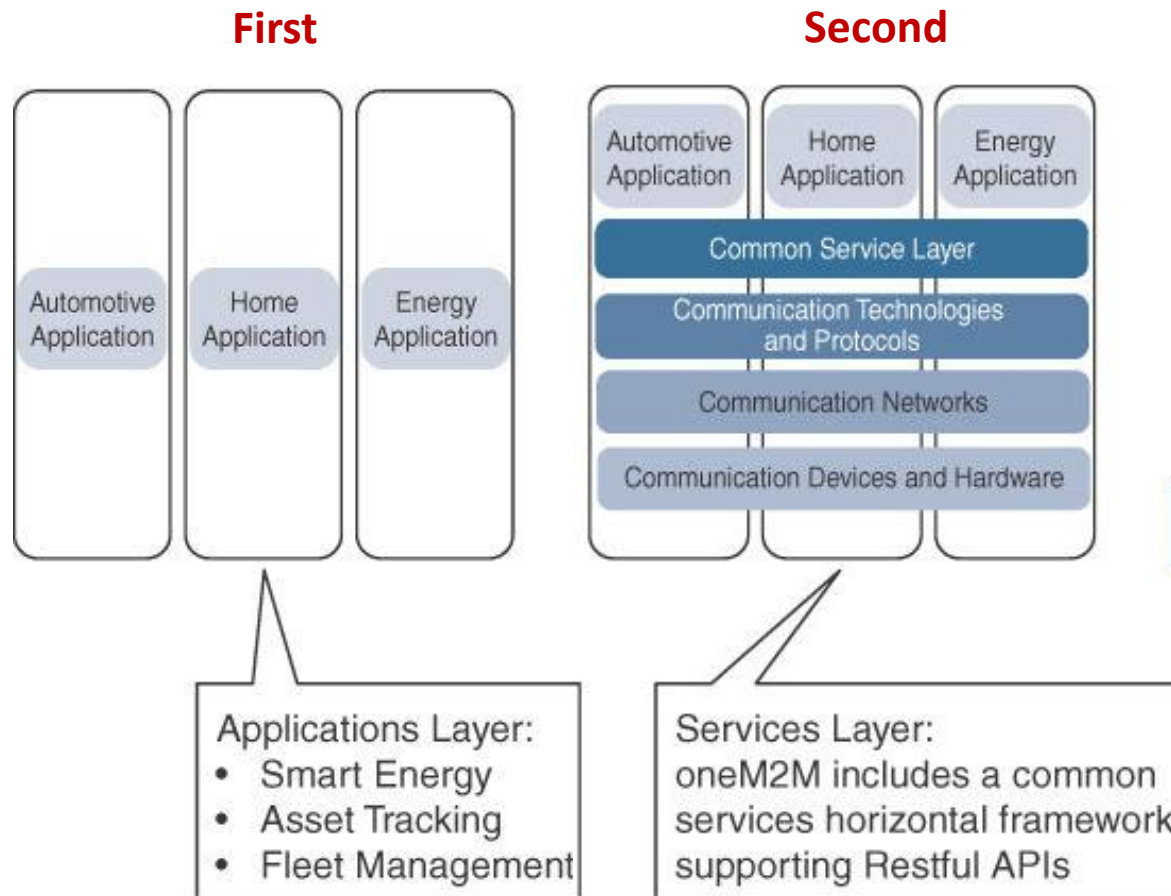


- horizontal framework across the vertical industry applications.
- Include:**
 - the **physical network** that the IoT applications run on. (e.g. backhaul network)
 - the underlying management **protocols**
 - the **hardware**

cont...

oneM2M Architecture

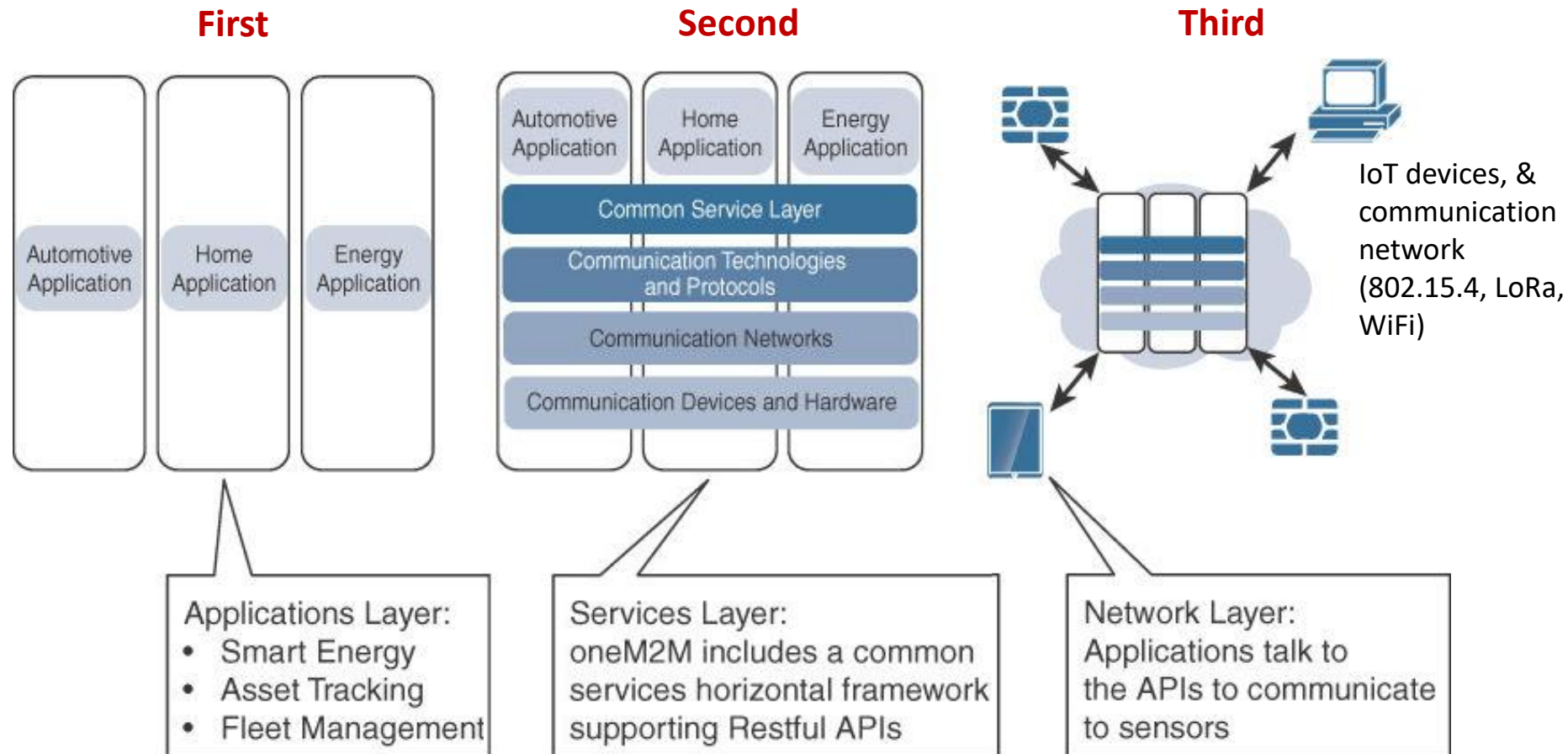
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- top is the **common services layer**
- This layer **adds APIs and middleware supporting third-party services and applications**.
- Service layer can be **readily embedded** within various hardware and software nodes
- A **RESTful API** uses HTTP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

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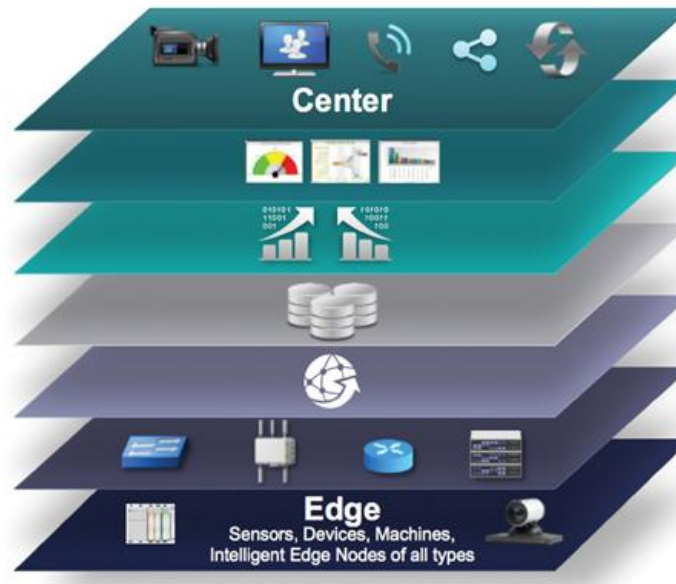
IoTWF Architecture – 7 Layer Stack

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**

Levels

- 7 Collaboration & Processes**
(Involving People & Business Processes)
- 6 Application**
(Reporting, Analytics, Control)
- 5 Data Abstraction**
(Aggregation & Access)
- 4 Data Accumulation**
(Storage)
- 3 Edge Computing**
(Data Element Analysis & Transformation)
- 2 Connectivity**
(Communication & Processing Units)
- 1 Physical Devices & Controllers**
(The "Things" in IoT)



- 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 : Edge Computing Layer

Basic principle:

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

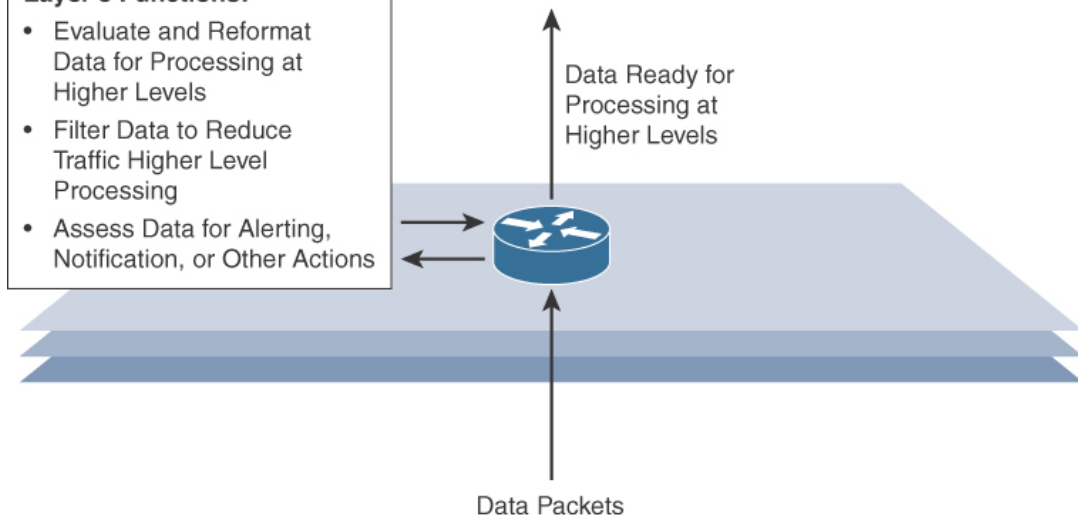
Layer 3: Edge Computing Layer

- 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)

③ **Edge (Fog) Computing**
(Data Element Analysis and Transformation)

Layer 3 Functions:

- Evaluate and Reformat Data for Processing at Higher Levels
- Filter Data to Reduce Traffic Higher Level Processing
- Assess Data for Alerting, Notification, or Other Actions



Upper Layers: Layers 4–7

Levels

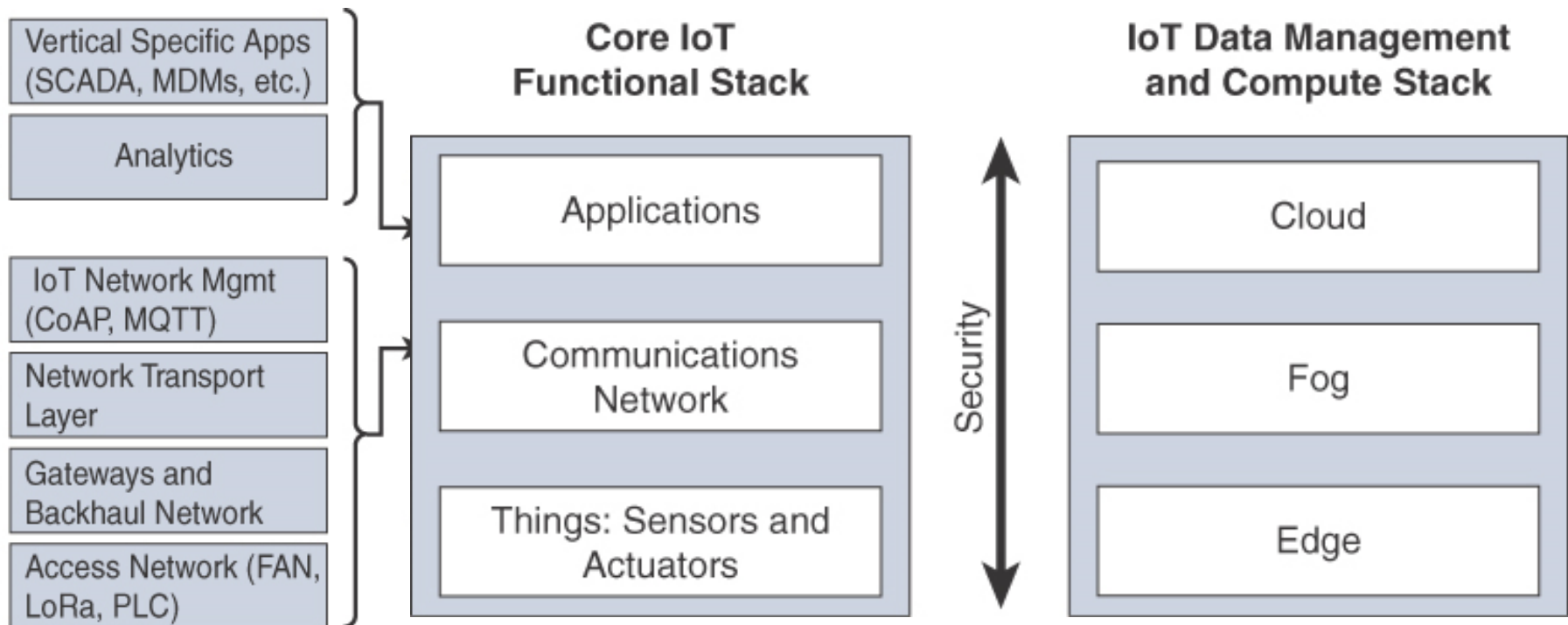
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Layers	Functions
Layer 4: Data Accumulation	• Captures data and stores it for applications • Convert event-based data to query-based processing
Layer 5: Data Abstraction	• Reconciles multiple data formats • Ensures consistent semantics for various 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.