IoT Data Management and Compute Stack

- How data will be processed
- Where data will be processed

- Fog Computing
- Edge Computing
- The Hierarchy of Edge, Fog, and Cloud

IoT Challenges

1. **Scalability**
2. Security -> Chapter 8
3. Privacy
4. **Big Data and Data Analytics**
5. Interoperability

IoT Data Management and Compute Stack

1. The exponential growth of IoT devices, predicted to surpass 50 billion by 2020, demands new network architectures as traditional IT networks cannot handle this scale. (IoT's Impact on Network Architecture)

2. The vast amount of data generated by IoT sensors **is largely unstructured** and often lacks immediate utility, posing a major challenge in building effective IoT systems. (Big data)

3. While **raw sensor data** like smart meter polling **has limited value on its own**, it can provide critical insights when analyzed alongside other data sources, such as weather reports and grid demand. (Big data analytics)

IoT Data Management and Compute Stack (cnt.)

1. In most cases, the **processing location** is the **cloud**. Smart objects need to connect to the cloud, and data processing is **centralized**.

2. One advantage of this model is **simplicity**.

3. Objects just need to connect to a central cloud application. That application has visibility over all the IoT nodes and can process all the analytics needed today and in the future.

4. This structure has its limitations.

    a. Huge data volume, irrelevant data processing

    ✓ Need data analysis to preserve resources, bring data analysis closer to IoT system

Why bring data analysis closer to IoT system?

- New requirements-
    - **<u>Minimizing latency</u>**: Milliseconds matter for many types of industrial systems, such as when you are trying to prevent manufacturing line shutdowns or restore electrical service. Analyzing data close to the device that collected the data can make a difference bet^{n} averting disaster and a cascading system failure.
    - **<u>Conserving network bandwidth</u>**:– It is not practical to transport vast amounts of data from thousands or hundreds of thousands of edge devices to the cloud.
    - **<u>Increasing local efficiency</u>**: Collecting and securing data across a wide geographic area with different environmental conditions may not be useful. The environmental conditions in one area will trigger a local response independent from the conditions of another site hundreds of miles away. **(sensitive data handling)**

Traditional IT Cloud Computing Model

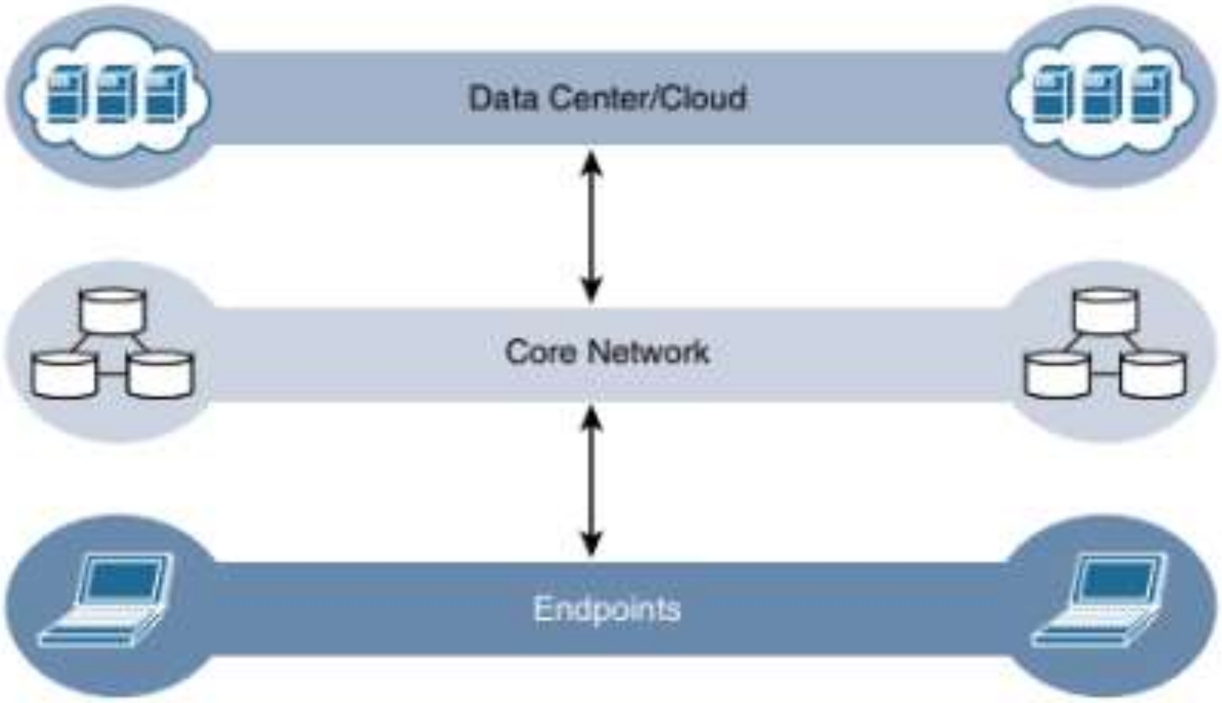

Figure 2-14 *The Traditional IT Cloud Computing Model*

- Hence IoT systems function differently many data-related problems arise-

1. Bandwidth limited
2. Latency High
3. Need fail secure operation (network backhaul can be unreliable)
4. Huge volume of data, Big data

Fog Computing

1. Solution of previous mentioned challenges is- distribute data management throughout the IoT system as close to the edge of the IP network as possible

2. Any device with **computing, storage, and network connectivity** can be a **fog node** i.e. industrial controllers, switches, routers, embedded servers, and IoT gateways**.**

3. **Analyzing IoT data close to where it is collected –**

   a. **minimizes latency**
   b. **offloads gigabytes of network traffic from the core network**
   c. **and keeps sensitive data inside the local network**

Fog Computing (cnt.)

- fog node has contextual awareness of the sensors it is managing because of its geographic proximity to those sensors.

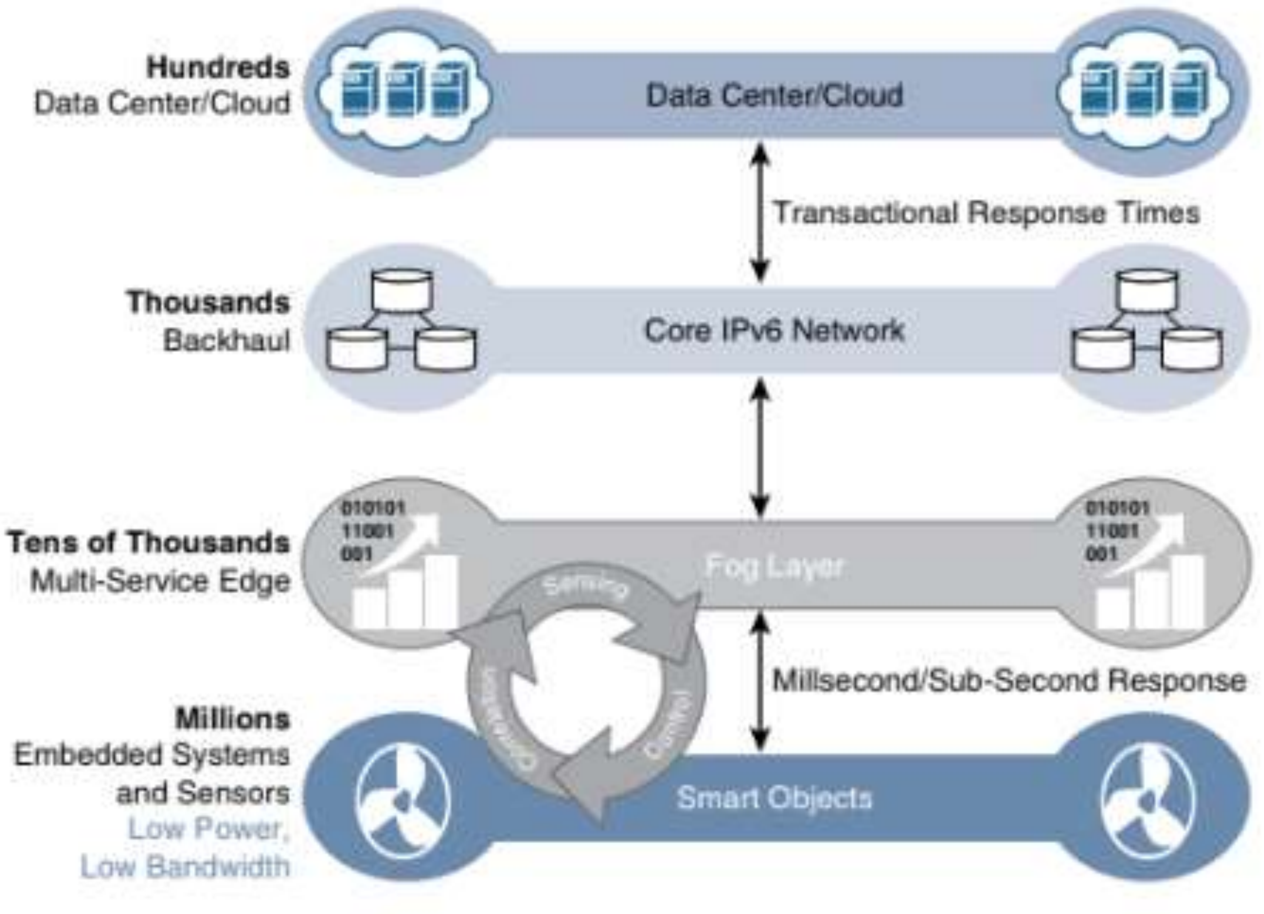

Figure 2-15 *The IoT Data Management and Compute Stack with Fog Computing*

Characteristics of Fog Computing

1. **Contextual location awareness and low latency:** The fog node sits as close to the IoT endpoint as possible to deliver distributed computing.

2. **Geographic distribution**

3. **Wireless communication between the fog and the IoT endpoint**: Fog nodes are typically deployed in the presence of a large number of IoT endpoints.

4. **Use for real-time interactions:** Important fog applications involve real-time interactions rather than batch processing.

Edge Computing

1. Things/ Devices/ sensor connected/collects data also processes it

2. Some new classes of IoT endpoints have enough computing capabilities to perform at least low-level analytics and filtering to make basic decisions. For example, consider a **water sensor on a fire hydrant**. -> able to quickly generate an **alert of a localized problem**

The Hierarchy of Edge, Fog, and Cloud

1. Edge or fog computing in no way replaces the cloud. Rather, they **complement each other** and require strong cooperation between layers.

2. Edge and fog computing layers act as a first line of defense for filtering, analyzing, and otherwise managing data endpoints. This saves the cloud from being queried by every node for each event.

3. At each stage, data is collected, analyzed, and responded to when necessary, according to the capabilities of the resources at each layer. The latency becomes higher as data needs to be sent to the cloud. The advantage of this hierarchy is that a response to events from resources close to the end device is fast and can result in immediate benefits, while still having deeper computing resources available in the cloud when necessary.

The Hierarchy of Edge, Fog, and Cloud (cnt.)

- From an architectural standpoint, fog nodes closest to the network edge receive the data from IoT devices. The fog IoT application then directs different types of data to the optimal place for analysis:

  a. **The most time-sensitive data** is analyzed on **the edge or fog node** closest to the things generating the data.

  b. Data that **can wait seconds or minutes** for action is passed along to an **aggregation node** for analysis and action.

  c. **Data that is less time sensitive** is sent to the **cloud for historical analysis**, big **data analytics,** and **long-term storage**. For example, each of thousands or hundreds of thousands of fog nodes might send periodic summaries of data to the cloud for historical analysis and storage.

  In summary, when architecting an IoT network, you should consider the amount of data to be analyzed and the time sensitivity of this data.

Simplified IoT Architecture

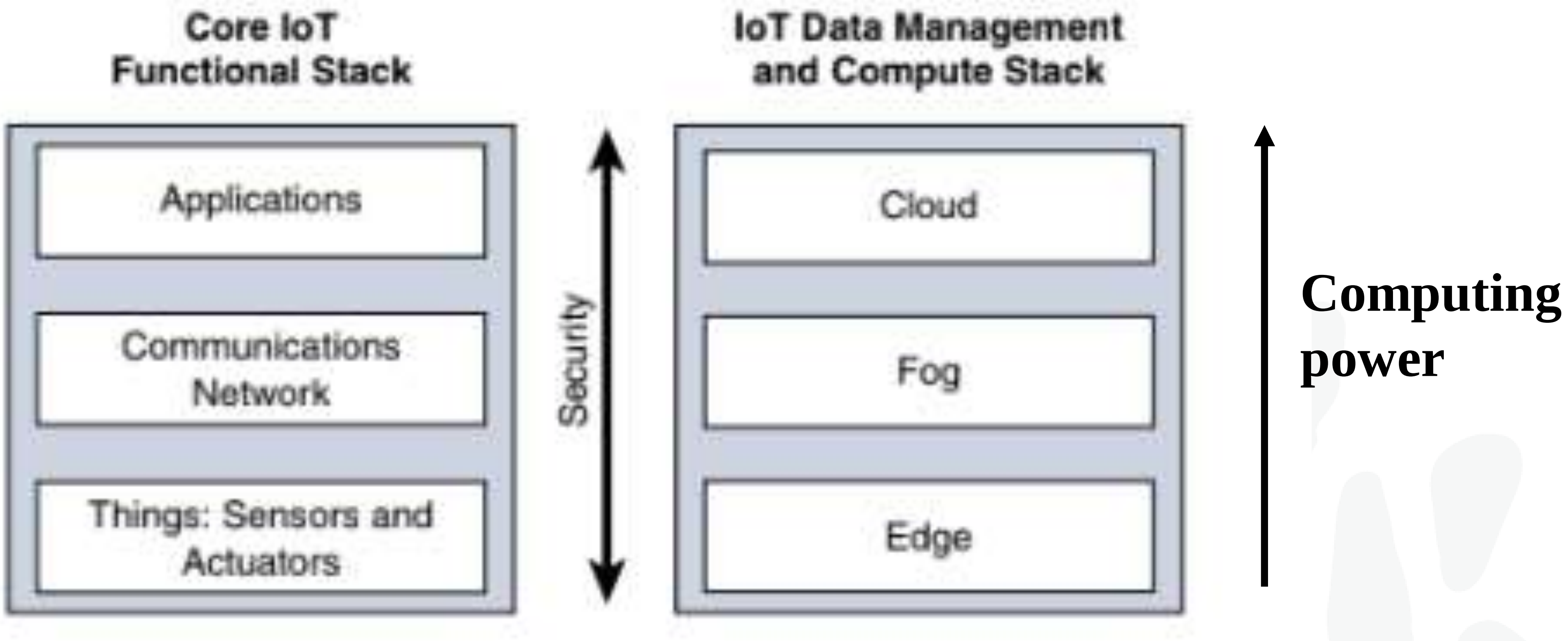

Figure 2-6 *Simplified IoT Architecture*

References

- IoT Fundamentals Book Chapter-2