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Research paper

Emerging Paradigm of Edge Computing in the Context of Iot

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Abstract

Centralised Cloud computing is having many challenges with the rapid increasing in IoT(Internet Of Things) applications. The challenges are high latency, low spectral efficiency (SE), and non-adaptive machine type of communication. In order to solve these challenges have moved to the concept of new computing concept that is nothing but edge computing, which calls for moving the data at the edge of the network. Edge computing has the possible to deal with the concerns of battery life constraint, response time requirement, data safety, bandwidth cost saving and privacy. In this paper, we started the explanation with IoT and solution of IOT i.e. edge computing, followed by several case studies, ranging from cloud offloading to smart home and city, as well as collaborative edge to materialize the concept of edge computing.

Keywords: *Centralised IoT, Edge computing, Fog Computing, Internet of Things (IoT).*

1. Introduction

IoT means different things to different people. In general classical internet was designed to build a network of computing devices and network equipments like PCs, servers, switches, modems, routers, load balancer, etc. As shown in the figure 1. IoT (Internet of Things) has a internet has a network of physical devices in everyday life. This physical device may include door locks, taps in your home, windows or traffic signals in the city, etc. As shown in figure 2. In short IOT is nothing but when physical things are augmented with connectivity, computing, sensors and actuators then it becomes IoT[1].

a) Why do we need IOT?

While connecting them we can monitor things 24/7 analyse their usage and conditions to be able to control them in a better way. So that we can provide more values of the outcome to their users. Additionally these physical things can also connect, sense, collaborate each other by creating a greater intelligent outcome to bring more value to the users of those things. In this scenario the beneficiaries are users and manufacturers/ Administrators.[2] Here the users can monitor and control things remotely and they can use the things more efficiently, see the extended service of life, with the integration and collaboration of things we can improve experience as well as to a certain extent things can operate in an autonomous way. Second type of beneficiaries are the manufacturers/ Administrators of these things.[3] They can get real time insights into device location, their operating condition, usage and performance by using this kind of information they can improve the future products or we can find new opportunity to monetize value added services around this products. It also helps in providing infield product upgrades for extended lifecycle.

b) Classification of IOT

Broadly IoT is classified into three categories:

1. **Consumer IoT**: This relates to connected devices aimed at the consumer market. This includes personal and pet monitoring; everyday objects like kitchen appliances, door locks, etc. can be connected together.

2. **Industrial IoT**: Different machines in a particular factory can be connected together.

Ex: Medical devices in private hospitals are connected and they can also be managed in a better way.

3. **Civic IoT:** It includes smart public services like transportation, Electricity supply grid in the city, and water supply system in the city anything which is public service within the city.

c) What does it take to build these IoT solutions?

Technically IOT is a convergence of many technologies which are existed. For example sensors/actuators are for monitoring and controlling of things requires single board computers to add the computing power. Embedded programming will be required to program the single board computer or Micro controllers, intelligent devices like smart phones are used for the user to operate things remotely [4]. Internet is used for connectivity of those things. For data connection and business application cloud computing can be an option For handling the analytics around large amount of data that is collected big data technologies, Analytics and Artificial intelligence became a key factor to the IOT solutions.

d) Architecture of IOT

The root level of the network is various things which are producers of the data and it sends the data to the gateway which is next level in the network. Now Gateway will send all the received data to the centralised cloud and here gateway do not have any processing power in typical IoT architectures. At the cloud the data is stored, processed, and analysed and based on the analysis decisions are made. Accordingly necessary instructions for control actions are sent back to the gateway which in turn forwards to the appropriate things. Part of the data are sent to the end user over smart personal devices like mobiles, PCs, Tablets and this will be required for the users to monitor, control and take decisions and accordingly initiate the instructions to the smart devices.

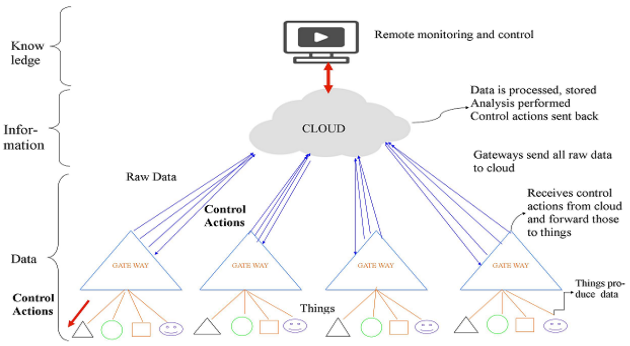


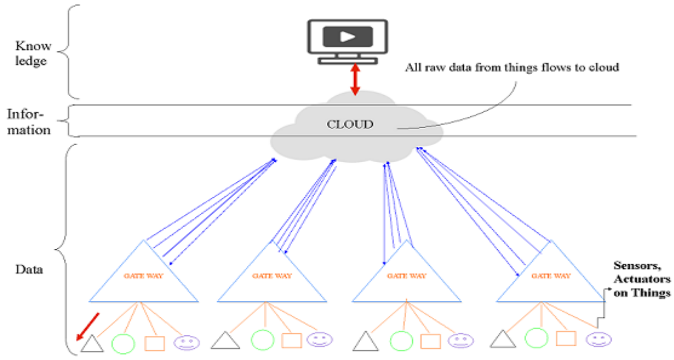
Figure 1 : ARCHITECTURE

e) Challenges in IOT

- Edge computing works at the individual device, fleet, or plant level. Among its benefits are:
- Real-time or near real-time data analysis as the data is analyzed at the local device level, not in a distant data center or cloud;
- Lower operating costs due to the smaller operational and data management expenses of local devices vs. clouds and data centres[5];
- Reduced network traffic because less data is transmitted from local devices via a network to a data center or cloud, thereby reducing network traffic bottlenecks;
- Improved application performance as apps that don't tolerate latency can achieve lower latency levels on the edge, as opposed to a faraway cloud or data center.

2. Insights in Centralised IoT

When we look at the architecture all the data that is created by things are sent directly to the cloud and the processing will start from here. Sending the data to the cloud becomes a challenge by analysing it and creating insights out of it is another challenge in real time.



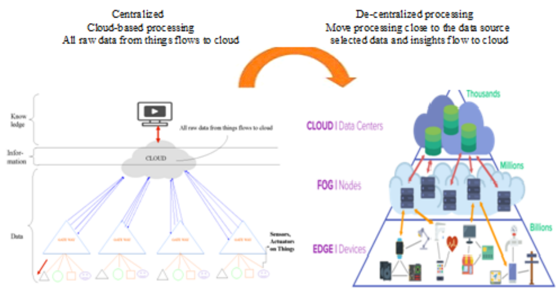
The Data Challenge: For example Connected car can produce 4TB of data per day because every car has more than 200 sensors. Similarly weather data can be up to 5PB/ day, airlines will produce 2.5TB/Day the amount of data that is produced by private cloud or hybrid cloud [5].

a) Data processing challenges:

1. Intermittent connection is a problem
2. Insufficient bandwidth is also a problem when the things are in the remote location.
3. Here the data is in Tera Bytes then we can't send the data in time to the users and the data may perish.
4. Security and compliance is also a problem.

Here the solution is Distributed or Decentralised processing Edge / Fog Computing unlike the earlier model the raw data was send to the cloud directly. We now send only the selected data to the cloud. Gateway is the networked device which is connected already to the internet. Gateway will process the raw data and then it takes the decision how much data is required to send to the cloud and how much data is allowed to do processing locally. Intermediate nodes i.e. fog and edge nodes [6]. Here the data processing starts from edge node itself and part of the data is done by edge and some by fog and the remaining insights is from the cloud.

3 Solution – Edge / Fog Computing



In the given figure the edge will collect all the data from things and edge will do the critical part in the real time and next is fog it may or may not be in the business control. For ex Fog could be intermediate nodes of the network. Whatever the data is processed by latency can be dedicated to the cloud something which is required in the future are stored in the cloud. In edge primary insights are flowing here only limited space is their so it is not able to store all the historical data [7]. The next layer is cloud wherein whatever data is processed with latency can be dedicated to the cloud. The data which is required in the future can be left up to the cloud. Fog and edge don't have that much heavy lifting capacity.

Edges are the first nodes where primary insights start flowing because edges are geographically located and they are very nearby things and the edges will have little storage capacity. Edges can store the data for some limited days according to that the edges will draw insights to that limited data.

a) Examples of Edges

1. **Smart phone** – The first edge device.
2. **Power Grid, Mobile Networks**

Power grid will have own network of distribution of power. They have multiple Points of Presence nodes managed by businesses from cloud to the data sources. They can leverage as fog/edges

3. **Smart City –** Any smart applications are distributed across geographically.
4. **Factories, Oil Rigs, Ships, Aircrafts**

These are On-premise infra managed by business and here there is no direct access to intermediate network nodes.

b) Edge or Cloud

"Edge does not replace cloud. It simply complements cloud"
For training machine learning applications we require lot of historical data so cloud is the only place the data is existed and that's why edge does not replace cloud it complements for sure by giving real time analytics capabilities [8].

c) Advantages

1. It will make big data into smaller data.
2. Nearest compute capacity leveraged.
3. It will process the data very closer to the edge.
4. It has Low latency.
5. Data stays at source, only insights flow.
6. It will take near real time decisions
7. If possible it will take the instant actions.

d) Capabilities needed at Edge

- Compactness – The devices which will do computing on edges can be various kind of range of sizes it could be wall or rack or shelf mountable depending upon the space, computing power.
- The edge devices are ruggedness for out-door, harsh environmental conditions (shock, vibrations, high ambient temperature, pressure etc.).
- Security is a major concern because IoT devices are wide spread devices geographically [9].
- Remote administration, monitoring and control are also required because when more devices are deployed remotely and when we want to launch or when we want to upgrade we have to do in a centralised manner.
- Modularity for easy subsystem replacement and upgrade.

3. Enablers for edge

More compact, powerful converged solutions are required for the fulfilment of edge requirements and some of them are,

a) Processors and accelerators – We have a broad range of processing devices. Some of the examples are
Examples : Atom 16 which require low power and high compute.
Xeon E5, Xeon E5 which requires high power and it is high computing devices.

Accelerators: The computational resources cannot be met by the processors alone.

Examples: 1) FPGA – Field Programmable Gate Arrays

- Reprogrammable for new problems of ever-shifting technologies and business models.
- Up to 1500 GFLOPs still less energy-hungry.
  - Used in Intel's driver-less cars platform
  - Underpins neural network execution for Bing and Baidu search.

2) ASIC – Google's Tensor Processing Unit (TPU)

- 15 to 30 times faster neural networks in less power.
- Saved Google cost of 15 new data centers.
- Costly, permanent in nature, not programmable.
- Google, Face book need AI chip on personal devices to run neural networks

b) Advanced SoCs which are powerful enough to run fully fledged Operating systems or complex algorithms [10].

c) Converged Systems which have compute, Storage and Network combined into one module.
Converged Infrastructure – In order to heavy lift the processing of IoT data deluge, Edges have to be build like clouds. Example is converged servers for gateways which is having the following properties.

- Compute, storage, network and virtualization components grouped together in a package.
- Compact in size
- Rugged for harsh edge conditions.
- Optimized for low energy consumption.
- Engineered to optimize performance and cost.
- Ready to commission.

Storage : We can store data in the following

1. 1 IB SSD M.2 U form factor
2. Intel 'Ruler' SSD which can store up to 1 PetaByte, it is same like server rack
3. IBM Tape which can store upto 330 TB and it is Palm size

It also requires complete Edge software stack which is capable of doing Analytics / Machine learning libraries.

Examples : IBM Watson IoT, AWS Greengrass, Azure to IoT Edge, Predix, Apache Edgent, Edge X Foundry, Open Whisk, android things, ForgHorn Open Fog, Etc.

a) The data has to be stored for few days or few months so it requires some Micro datacenters like capabilities at the edge.

b) DATACENTERS at edge

Microdata center : Which is Stand alone rack – level systems. It contain all of traditional data center in one box. It is designed mainly for specific workloads.
Modular datacenter : A modular datacenter connected to the powergrid at a utility substation.Modules can be shipped to be added, integrated or retrofitted as required.
Portable modular data center : Which is 20 to 40 feet container size.

c) In addition to that, billions are devices are connected so we require 5G, Software Data Networking (SDN) and Network Functioning Virtualization (NFV) are some of the options.

4. Compute for things-to-cloud

Here how the data is moving from things IoT to edge
Microcontrollers : Which is Small in size and consumes low power and it is low cost. High performance apps like DSP(Digital Signal Processing), Sensor fusion, motor control.
SoC : Server class SoC with ARMv8 64bit contain 54 cores 3.0 Ghz,upto 1TB memory, 100Gbps I/O bandwidth, 10 to 100 GbE. Integrated hardware accelerators for security, Storage, Networking and virtualisation.

Gateway : Gateway contains Intel Atom / i5 dual-core.1.46/ 1.9 GHz, On-board GPU, 4-8 GB RAM, 32- 64GB SSD, 1U / 2U form factor. It is also rugged for harsh edge.
Server : Server contains Intel E5-26xx V4 family. 64 to 176 cores. 32GB to 2TB RAM 9.6 – 460 TB storage, 12M + IOPS , 60GB/s transfer rate. Rugged for harsh edge.
Processor :10s of processors in a single 19 in 15U to 30U rack. Rapidly deployable indoor, outdoor. Designed to withstand in rugged, high risk zones.

5. Challenges at edge

1. Replication of data – when, What , How
2. Security at resource constrained edge devices
3. Storage limitations
4. Creating analytical model in one place and executing in multiple places.
5. Creation and exchange of ML models with in the nodes.
6. Complexity management.
7. Peer to peer communication requires mature standards.
8. Depend on progress in communication network and related infrastructure.

6. Conclusion

These days the data and services are moving from cloud to edge because the processing data at the edge guarantee the good reliability and less response time. By this we can also save bandwidth as the data is possibly be handled at the edge instead of directly uploaded to the cloud. The increasing of IoT changed the role of edge in the computing paradigm from data consumer to data producer/consumer. It would be more efficient to process or massage data at the edge of the network. In this paper, we came up with our understanding of edge computing; with the rationale that computing should happen at the proximity of data sources. Then we list several cases whereby edge computing could flourish from cloud offloading to a smart environment such as home and city. We also introduce collaborative edge, since edge can connect end user and cloud both physically and logically so not only is the conventional cloud computing paradigm still supported, but also it can connect long distance networks together for data sharing and collaboration because of the closeness of data. At last, we put forward the challenges and opportunities that are worth working on, including programmability, naming, data abstraction, service management, privacy and security, as well as optimization metrics. Edge computing is here, and we hope this paper will bring this to the attention of the community.

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