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Article

Significance of Fog Computing in IoT

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A B S T R A C T

The idea of Fog computing or Edge Computing is to extend the cloud nearer to the Internet of Things (IoT) devices. Through the internet of things (IoT), we can generate a numerous volume and variety of data. With the increase in the number of internet connected devices, the increased demand of real-time, low latency services, data security are the biggest challenges for the cloud computing framework. In order to overcome above challenges, Fog Computing came into picture. The computing reduces the predictable latency in the latency-sensitive of IoT applications such as healthcare services which is primary objective of this computing. The paper argues that the Fog Computing is the best platform solutions towards this goal for a number of critical IoT services and applications, namely, Connected Vehicle, Smart Grid, Smart Cities, and in general, Wireless Sensors and Actuator Networks (WSANs).

Keywords: Fog Computing, Cloud Computing, IoT, Latency Sensitive, Smart Grid, Connected Vehicles, WSANs

Introduction

Fog computing is the term coined by CISCO. The computing is an intermediate layer between the cloud and IoT devices shown in figure 1. The term 'fog computing' is also termed as 'edge computing', which essentially means somewhat than hosting and working from a centralized cloud. Fog system operates on network ends. The computing can be processed locally in smart devices rather being send to the cloud processing. As IoT is emerging, number of sensors have been employed in various devices which combines information and computing processes to control very large collection of different objects (Clinton, 2014) which are rapidly leading to an increasing amount of data generation. Cloud computing is providing 'pay as you go model' which is an efficient way to have data centres rather than having private data centres for customers for having their web applications, batch processing and other processes. Therefore, the cloud computing reduces the burden of specifications and details for an enterprise. This is because deviceswhich have computing capacity estimate the environment by interacting with networking devices and basic property of network connectivity.

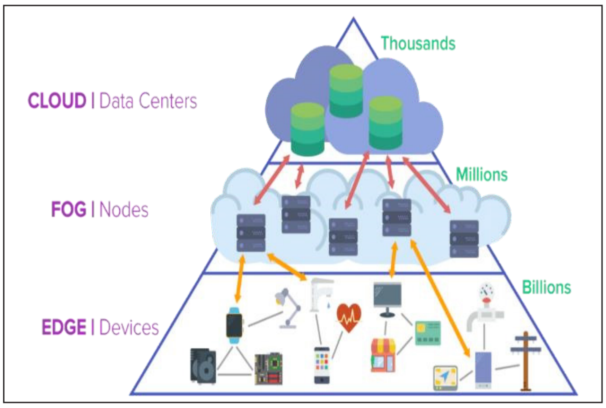

Figure 1.Fog Nodes Between Edge and Cloud

Cloud Computing Architecture and the Need of Fog Computing

The section explains why the collected task of the current cloud model is insufficient to handle the requirements of IoT.

- The volume of the data that are produced by the IoT devices.
- The latency that means the time that it takes for a sense data to go to thecloud and sent back commands.

- The bandwidth , which means that how much channels are going to be occupied because of this communication of all these data of IoT devices.
- The traditional computing architecture of Cloud is shown in Fig.2. IoT devices are used to sense the physical phenomena occurring around them, which sends the data to the cloud and get an action or command book or action required. To reduce this particular time, fog computing is required. Large amount of time is required because the clouds might be physically located even a continents away from the users, this physical limitation introduces a large latency in communication. If we talk in terms of volume, it is estimated that by 2020, about 50 billion IoT devices will be online. Presently billions of devices produce Exabyte of data every day and this is a very big data. So, much of unusual amount of data are going to be produce because of the introduction of IoT. Hence, the device density is still increasing every day and the current cloud model is unable to process this amount of data.

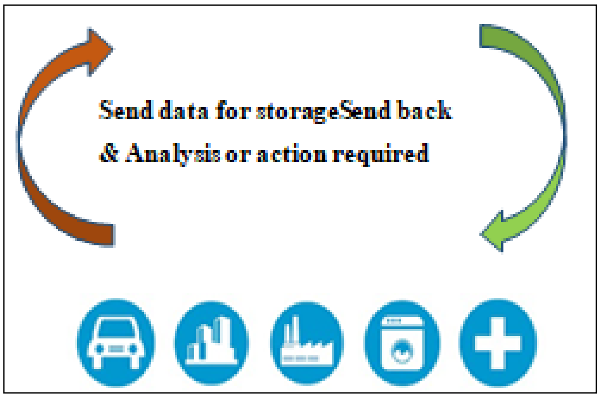

Figure 2.Cloud Model

The private firms, factories, airplanes companies produces huge amount of data every day. There is a need to send all of these data to the cloud for further storage and processing. Unfortunately, the current cloud model can not basically store all of these data. Also this data in its raw form has to be filtered before the data is sent to the cloud. This has to pick process to filter before it is distinct for storing and processing on the cloud. In terms of latency, IoT of time has been taken by a data packet for a round trip. On important aspect for handling a time sensitive data, is to handle the issues of latency, because if it is time sensitive, it is a real time data. So time is important and that is the reason why the latency has to be handle with special internists. If the edge devices send time sensitive data to cloud for analysis and wait for the cloud to give a proper action, then it can lead to many unwanted results. So while handling time sensitive data, a millisecond can make huge differences. In proposed Figure 2, the edge devices or healthcare services or vehicles are generating the time-sensitive data in nature. Hence, the process has to be fast so as to use the stored data in a meaningful manner. There requires the processing of such data to be very fast like in medical healthcare services. Latency increases because data goes from the edge devices to the cloud and has to come back again as shown in equation 1.

$$\boldsymbol{LATENCY} = \mathrm{T}\,fromdeviceto\ \mathrm{cloud} + \boldsymbol{T}\,dataanalysis + \mathrm{T}\ fromcloudvice\ (where\ \boldsymbol{T} = TotalTime) \qquad (1)$$

When the action reaches to the device accident may occur in an emergency situation. Hence, the 'fog computing' is very important for the IoT. Bandwidth is bit-rate of data during transmission. If all the data generated by IoT devices are send to cloud for storage and analysis, then the traffic generated by these devices will be simply gigantic. So, these IoT devices are going to consume almost all the bandwidth. Consequently, handling this kind of traffic will be simply a very hard task because billions of devices are consuming bandwidth. When all the devices become online even IPv6 will not able to provide facility to all devices.

Requirements of IoT

Due to change in scope of internet there is a requirement to make physical world smarter. In an estimation, it is evaluated that within 5 years, 50 billion devices will be online. Internet of Things (IoT) is going to sustain a $14 trillion market by fulfilling following criteria's :

Reduction in Latency of Data

Appropriate action at right time prevents major accidents machines failure. Hence a minute delay while taking a decisions make a huge difference and latency can be reduced by analysing the data close to the data source.

Data Security and Privacy

IoT data must be secured and protected from intruders. Data are required to be monitored24 X 7 so that an appropriate action should be taken before the attack causes major harm to the network.

Operation Reliability

The data generated from IoT devices are used to solve real time problem. The problem of integrity and availability of the data must be guaranteed. Unavailability and tempering of data can be hazardous.

Processing of Data at Respective Suitability Place

Data can be divided into three types based on sensitivity

- Time sensitive data
- Less sensitive data
- Data which are not time sensitive

Extremely time sensitive data should be analysed very near to the data source and the data which are not time sensitive will be analysed in the cloud. So time sensitive data should be closer to the IoT devices and Non-Sensitive data send it to the cloud.

Monitoring Data Across Large Geographical Area

The location of connected IoT devices can be spread across a large geographical region like monitoring the railway track of country or state and the devices that are exposed to the harsh environments conditions.

Features of Fog Computing

- Low latency and location awareness: To support endpoints with rich services at the edge of the network, includes applications with low latency requirements.
- Wide-spread geographical distribution:Fog technology delivers high quality streaming to moving vehicles by using proxies and access points that are installed along highways and tracks.
- Mobility: Fog supports LISP protocol 1 to decouple identity of host from its location identity. This requires a distributed directory system.
- Very large number of nodes: Due to wide geo - distribution very large number of nodes are required. For example; numerous nodes in sensor networks and in smart grid.
- Predominant role of wireless access.
- Strong presence of streaming and real time applications:More focus on real time processing rather than batch processing.
- Heterogeneity:Fog components interoperate, and services are federated across domains. For example: streaming of service.

Importance of Fog Computing in IoT

Fog plays major role in three scenarios of interest. These are the connected vehicle, smart grid, and wireless sensor and actuator networks (WSAN).

Connected Vehicles (CV)

The vehicles started communication with the physical world in 1996. To make best communication with the physical world there are so many sensors are used in connected vehicles to sense the physical properties. It is very hard to believe that self-driving vehicleswill generate up to 1 terabyte of data per second. The main aim of connected vehicles is to provide the road safety of the vehicles from accidents, it provides the comfortable drive,it decreases the consumption of fuel and traffic congestion.If the data is to be leveraged, then the board on the vehicle should be used and enriched before it can be broadcasted. Even devoted Short Range Communications (DSRC) such as Wanet,Manets, can be profitable from the rich data. Cellular and other data transfer methods are not the solutions themselves because the data volumes are still being prepared in 5G networks. So the connected vehicles demonstrate the connectivity and interaction between the one access point to another access point, vehicles to access point(Road side Unit[RSU], Wi-Fi, 4G, LTE, Smart Traffic Light) and vehicles to vehicles. The fog a large number of fog nodes which make it the ideal platform to deliver the large scale of smart connected vehicles services for road safety, traffic control and support,geo-location(every cities, along road) mobility and location awareness, support for real-time interaction, low latency. The STL (Smart Traffic Light) node locally contacts the sensors, which detects the presence of foot-passenger, bikers and it measures the speed of the vehicles. These STL nodes also make an interaction with the neighbour traffic lightfor the traffic signal's wave. On the basis of this information the STL sends the alert signals to approaching the connected vehicles network. The flow of data and information modifies its own cycle to stop accidents. These data are the real-time analytics (changing, the timing of the cycles in response to the traffic conditions). The data from the group of smart traffic lights are sent to the cloud for long time analytic.

Wireless Sensor and Actuator Network (WSAN)

The original Wireless Sensor (Bowman et al.,1993) is shown in Figure 3. WSN is designed to operate at extremely low power to extend battery life or even to make energy harvesting feasible. Most of these WSNs involve a large number of low bandwidth, low energy, low processing power, small memory motes, operating as sources of a sink (collector) in a unidirectional fashion. Sensing the environment, simple processing, and forwarding data to the static sink are the duties of this class of sensor networks, for which the open source Tiny OS2 is the defecto standard operating system. Motes have proven useful in a variety of scenarios to collect environmental data (humidity, temperature, amount of rainfall, light intensity, etc). Energy constrained WSNs are advanced in several directions like multiple sinks, mobile sinks, multiple mobile sinks, and mobile sensors. All these were proposed in successive incarnations to meet the requirements of new applications. Yet, they fall short in applications that go beyond sensing and tracking, but require actuators to exert physical actions (open, close, move, focus, target, even carry and deploy sensors).

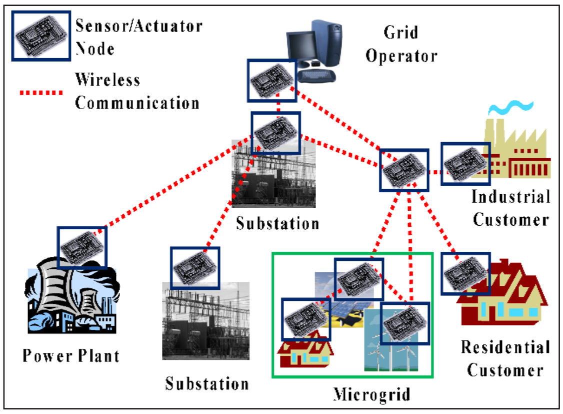

Figure 3.Architecture Wireless Sensor and Actuator Network

Actuators, which can control either a system or the measurement process itself, bring new dimensions to sensor networks. The information flow is not unidirectional (from the sensors to the sink) but bidirectional (sensors to sink, and controller node to actuators). In a subtler, information flow becomes a closed-loop system, in which the issues of stability and potential oscillatory behaviour cannot be ignored. Latency and jitter become a dominant concern in systems that require rapid response. Contributors of Wireless Sensor and Actuator Networks (WSANs) pointed out that WSAN architecture consists of two networks: a wireless sensor network and a mobile ad hoc network (MANET) (Fröhlich et al., 2000). Author concluded that emergent applications demand a higher bandwidth, collaborative sensing environment T. Banka et al (Tavel P, 2007). Their experience is rooted in the CASA (Collaborative Adaptive Sensing of the Atmosphere) project. CASA (Sannella M, 1994), a multi-year, multipartner initiative led by UMASS, deployed a network of small weather radars, integrated with a distributed processing and storage infrastructure in a closed loop system to monitor the lower troposphere for atmospheric hazards like tornados, hailstorms, etc. Technical details of the deployment of fog is stated by S.S. Kashi and M. Sharifi (Fröhlich et al., 2000). The characteristics of the Fog like proximity and location awareness, geo distribution, hierarchical organization makes it the suitable platform to support both energy constrained WSNs and WSANs.

Smart Grid

Several issues were encountered in the smart grid while addressing the smart grid by the cloud computing. The major issue that was seen in the privacy of the massive amount of data of smart grid. The latency during the parallel processing to make smart decisions. Sothere was an urgent need to big pool of computing and data storage requirements for smart grid. To overcome these needs under the favour of scalability and distribution skills of cloud computing, Anothercloud computing architecture is purposed i.e; Fog Computing. Which resolves all the essential issues of cloud computing to increase utility and security of smart grid. It also resolves the issue of parallel processing is used to make smart grid decisions. So further cloud computing was enhanced by cloud-client computing with multi-agent technology where the micro grid is divided into three tiers of network. Some of this data regards to protection and control loops that requires processing (from milli-seconds to sub seconds). It is an electrical grid that is integrated with a computerised two-way communication network. Also for first-class fog, machine to machine interaction, selection, processing data and issues to control commands to actuators. Smart grid filters the data that is consumed locally and sends the rest to the higher level. The second and third tiers deal with visualization and reporting(human -to-machine interaction) as well as systems and process (M2M) (to deal with second and third level). the time scales of these interaction with the all node of the fog. Range from second to minute (real time analytical). Consequently the fog must suppose several type of storage from ephemeral at the lowest level to semi- permanent at the highest level .

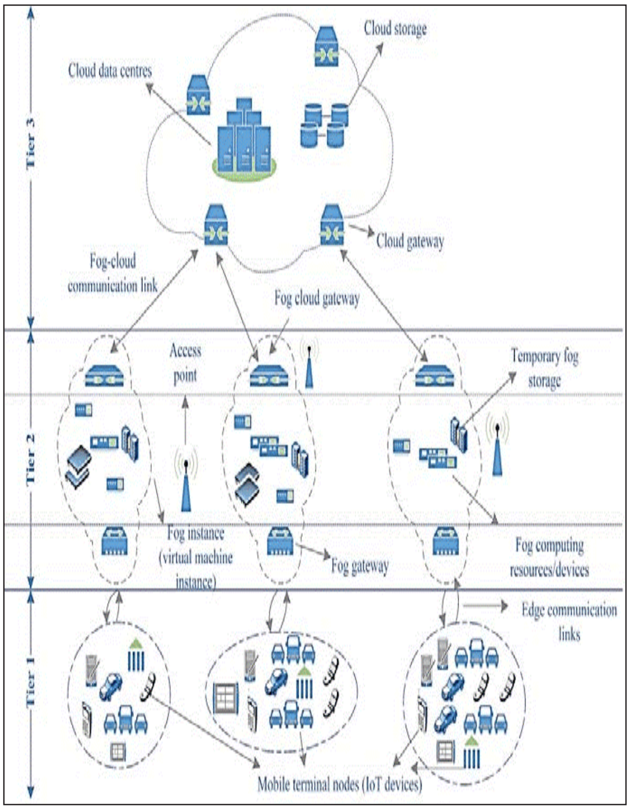

Figure 4.Tiers of Fog Computing for IoT

Design Issues for Fog

In this section, main key issues to create an open fog architecture of heterogeneous platforms is discussed:

- Architecture Issue: An open architecture based on seven principles including management of ecosystem, extensible service provisioning and cloud quality. Cloud computing Open Architecture (CCOA) could be the architectural foundation in the cloud value chain (Zhang et al., 2009).
- Platform Issue: the interoperability issue among heterogeneous platforms suggests solutions connected with it for various cloud service deployment models.
- Implementation level Issue: The business issues are further divided into financial and reliability and security and performance issues are dealt under technical branch.
- Business Related Issue: A clearer direction for a promising future for Cloud considers in facilitating customers to select a reliable cloud provider using some trust and reputation models.
- Technical Issue: Security consciousness and concerns

arise as soon as one begins to run applications beyond the designated firewall and move closer towards the public domains.

Strength of Fogging in IoT

Although cloud computing is still in scenario but when it comes in IoT applications it loses its significance for computing emerged as a most promising viable option because of following reason:

- It provides better security, fog nodes can use the same security, policy and the operation cost is low.
- Data are processed in fog nodes before sending to cloud, which reduces the bandwidth consumption and further the most important thing o IoT is that the data determine through the analysis can be executed in this kind of model.
- The IoT devices are implemented in some safety critical platforms like; industries, where the safety is primary concern. So in such cases, it is process fast, the data have to process very fast the sensing of sensors.
- For better privacy, every industry can analyse their data locally to store confidential data in their local servers or they can send those data which can be shared to the cloud.
- Business agility also improves fog application can be easily developed according to tools available, that can be deployed any where according to the customers need, the fog node supports mobility because of node can nodes can join and leave network anytime.
- The solutions that fog platform can be deployed in remote places and they can be subjected to harsh environmental continent condition for the environment monitoring in open environment, Under Sea, railway track, vehicles, factory floor etc.
- Fog computing have better data handling because of it can operate with less bandwidth, data can be analysed locally and that would reduces the risk of latency.

Application Areas

The section discusses several fascinating applications that will provide benefit from fog computing.

- We can perform real time health analysis using fog technology where the patients with electronic scan can be monitor in real time for the patients undergoing STROKES or any kind of medical emergency and alerts the respective doctors immediately.
- Historical data analysis can be predict in future dangers of patients.
- It is intelligence power efficient system, it reports detail power consumption report every day and suggest economical power usage plan.
- Real time rail monitoring is another application, where the fog nodes can be deployed to railway tracks for real time monitoring of the track conditions for high speed train and sending the data in cloud for analysis is in efficient manner, fog nodes provides fast data analysis so, that is going to improve safety and reliability of railway system.
- Pipeline optimization for Gas and Oils are transported through pipelines. So the real time monitoring of pressures, flow compressor is necessary in such kind of gas pipeline system.
- Terabytes of data are created and sending all this to cloud for analysis and storage is not efficient, so the fog becomes solution in such a scenario because network latency is not acceptable.

Conclusion

Fog computing or Edge computing is a perfect partner for cloud and IoT devices, it can sit in between Internet of Things and cloud computing to help Internet of Things (IoT) in the different function that it has to perform. It also solves the primary problems faced by cloud while handling Internet of Things (IoT) data, which reduces the latency overall. It benefits extends from an individual person to large firms just only because of real time analysis and monitoring.

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