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A Survey of Fog Computing and Its Applications

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***Abstract:** We live in a world where consumer products, goods, vehicles, industrial and utility components, sensors, and other everyday objects are being combined with Internet connectivity and powerful data analytic capabilities that promise to transform the way the world works, plays and lives. Through the Internet of Things (IoT), we are generating a humongous volume and variety of data. There is a need for a computing paradigm that allows us to perform computations on the data before it is sent to the cloud, where the opportunity to act on data might be lost. In this paper, we present one such technique called Edge computing, or Fog computing and describe some of its applications.*

***Keyword:** Fog Computing, Edge Computing, Mobile Cloud Computing, Mobile Edge Computing, Cloud Computing.*

I. INTRODUCTION

With the development of wearable computing, smart metering, smart home/city, connected vehicles and large-scale wireless sensor network, the Internet of Things (IoT) has received attentions for years and is considered as the future of Internet. *Fog computing* is proposed to enable computing directly at the edge of the network, which can deliver new applications and services especially for the future of Internet.

The goal of fogging is to improve efficiency and reduce the amount of data transported to the cloud for processing, analysis, and storage. This is often done to improve efficiency, though it may also be used for security and compliance reasons. Popular Fog computing applications include smart grid, smart city, smart buildings, vehicle networks and software-defined networks.

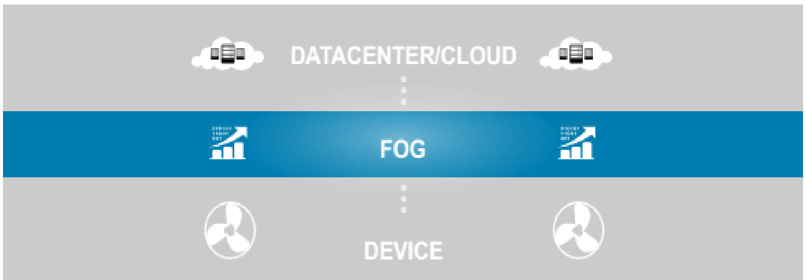

Fig 1: Position of fog between the device and cloud.

The metaphor *fog* comes from the meteorological term for a cloud close to the ground, just as fog concentrates on the edge of the network. The term is often associated with Cisco; the company's product line manager, Ginny Nichols, is believed to have coined the term. "Cisco Fog Computing" is a registered name; *fog computing* is open to the community at large.

The OpenFog Consortium was founded in November 2015 by members from Cisco, Dell, Intel, Microsoft, ARM and Princeton University; its mission is to develop an open reference architecture and convey the business value of fog computing.

II. ISSUES

In this section, we will identify and discuss potential issues in the context of fog computing.

A. Software Defined Networking

Software-defined networking (SDN) is an umbrella term encompassing several kinds of network technology aimed at making the network as agile and flexible as the virtualized server and storage infrastructure of the modern data center. The goal of SDN is to allow network engineers and administrators to respond quickly to changing business requirements. In a software-defined network, a network administrator can shape traffic from a centralized control console without having to touch individual switches and can deliver services to wherever they are needed in the network, without regard to what specific devices a server or other hardware components are connected to. The key technologies for SDN implementation are functional separation, network virtualization, and automation through programmability. There is a challenge of integrating fog computing with SDN.

B. Connectivity

In the case of a heterogeneous fog network, network relaying, partitioning and clustering provide new opportunities for reducing cost, trimming data and expanding connectivity. For example, an ad-hoc wireless sensor network can be partitioned into several clusters due to the coverage of rich-resource fog nodes (cloudlet, sink node, powerful smartphone, etc.). Work proposes an online AP association strategy that not only achieves a minimal throughput but efficiency in computational overhead. Similarly, the selection of fog node from end user will heavily impact the performance. We can dynamically select a subset of fog nodes as relay nodes for optimization goals of maximal availability of fog services for a certain area or a single user, with constraints such as delay, throughput, connectivity, and energy consumption.

C. Reliability

Madsen et al. review the reliability requirement of clustering computing, grid computing, cloud and sensor network towards a discussion of the reliability of fog computing. Normally, reliability can be improved through periodical check-pointing to resume after failure, rescheduling of failed tasks or replication to exploit executing in parallel. But check pointing and rescheduling may not suit the highly dynamic fog computing environment since there will be latency, and cannot adapt to changes. Replication seems more promising but it relies on multiple fog nodes to work together.

	Fog Nodes Closest to IoT Devices	Fog Aggregation Nodes	Cloud
Response time	Milliseconds to subsecond	Seconds to minutes	Minutes, days, weeks
Application examples	M2M communication Haptics[2], including telemedicine and training	Visualization Simple analytics	Big data analytics Graphical dashboards
How long IoT data is stored	Transient	Short duration: perhaps hours, days, or weeks	Months or years
Geographic coverage	Very local: for example, one city block	Wider	Global

Fig 2: A comparison of fog, aggregation and cloud nodes.

D. Resource discovery

Resource discovery and sharing are critical for application performance in fog. Work proposed method dynamically select centralized and flooding strategies to save energy in heterogeneous networks, while there are more constraints to take into consideration in fog computing, such as latency, density, and mobility.

III. APPLICATIONS

A. Smart Cities

Large cities face challenges from traffic congestion, public safety, high energy use, sanitation and in providing municipal services. These challenges can be addressed within a single IoT network by installing a network of fog nodes.

A lack of broadband bandwidth and connectivity is a major issue in establishing smart cities. While most modern cities have one or more cellular networks providing adequate coverage, these networks often have capacity and peak bandwidth limits that barely meet the needs of existing subscribers. This leaves little bandwidth for the advanced municipal services envisioned in a smart city. Deploying a fog computing architecture allows for fog nodes to provide local processing and storage. This optimizes network usage.

Smart cities also struggle with safety and security, where time-critical performance requires advanced, real-time analytics. Municipal networks may carry sensitive traffic and citizen data, as well as operate life-critical systems such as emergency response. Fog computing addresses security, data encryption and distributed analytics requirements.

B. Smart buildings

Building automation demonstrates the need for edge intelligence and localized processing. A commercial building may contain thousands of sensors to measure various building operating parameters: temperature, keycard readers, and parking space occupancy. Data from these sensors must be analyzed to see if actions are needed, such as triggering a fire alarm if smoke is sensed. Fog computing allows for autonomous local operations for the optimized control function.

Each floor, wing or even individual room could contain its own fog node that is responsible for performing emergency monitoring and response functions, controlling climate and lighting and providing a building resident compute and storage infrastructure to supplement the limited capabilities of local smartphones, tablets, and computers.

Fog computing works with cloud computing, so the long-term history of building operational telemetry and control actions can be aggregated and uploaded to the cloud for large-scale analytics to determine operational aspects of buildings. The stored operational history can then train machine learning models, which can be used to further optimize building operations by executing these cloud-trained machine learning models in the local fog infrastructure.

C. Visual security

Video cameras are now used in parking lots, buildings and other public and private spaces to increase public safety. The sheer bandwidth of visual (and another sensor) data being collected over a large-scale network makes it impractical to transport all of the data to the cloud to obtain real-time insights. Imagine a busy airport or city center with many people and objects moving through an area at a time. Real-time monitoring and detection of anomalies pose strict low-latency requirements on surveillance systems. Timeliness is important for both detection and response.

Privacy concerns must be addressed when using a camera as a sensor that collects image data so that the images do not reveal a person's identity or reveal confidential contextual information to any unauthorized parties. Fog computing allows for real-time, latency-sensitive distributed surveillance systems that maintain privacy.

Through fog architecture, video processing is intelligently partitioned between fog nodes co-located with cameras and the cloud. This enables real-time tracking, anomaly detection, and collection of insights from data captured over long intervals of time.

D. Connected car:

The autonomous vehicle is the new trend taking place on the road. Tesla is working on software to add automatic steering, enabling literal "hands-free" operations of the vehicle. Starting out with testing and releasing self-parking features that don't require a person behind the wheel. Within 2017 all new cars on the road will have the capability to connect to cars nearby and the internet. Fog computing will be the best option for all internet-connected vehicles why because fog computing gives real-time interaction. Cars, access point, and traffic lights will be able to interact with each other and so it makes safe for all. At some point in time, the connected car will start saving lives by reducing automobile accidents.

E. Smart Grids:

Smart grid is another application where fog computing is been used. Based on demand for energy, its obtainability and low cost, these smart devices can switch to other energies like solar and winds. The edging process the data collected by fog collectors and generates a control command to the actuators. The filtered data are consumed locally and the balance to the higher tiers for visualization, real-time reports, and transactional analytics. Fog supports semi-permanent storage at the highest tier and momentary storage at the lowest tier.

F. Smart Traffic lights:

Fog enables traffic signals to open lanes on sensing flashing lights of the ambulance. It detects the presence of pedestrian and bikers and measures the distance and speed of the close by vehicles. Sensor lighting turns on, on identifying movements and vice-versa. Smart lights serve as fog devices synchronize to send warning signals to the approaching vehicles. The interactions between the vehicle and access points are enhanced with WiFi, 3G, roadside units and smart traffic lights.

G. Self-Maintaining Train:

Another application of fog computing is self-maintaining trains. A train ball-bearing monitoring sensor will sense the changes in the temperature level and any disorder will automatically alert the train operator and make maintenance according to. Thus we can avoid major disasters.

H. Wireless Sensor and Actuator Networks (WSAN):

The real Wireless Sensor Nodes (WSNs), were designed to extend battery life by operating at predominantly low power. Actuator serves as Fog devices which control the measurement process itself, the consistency and the oscillatory behaviors by creating a closed-loop system. For example, in the lifesaving air vents sensors on vents monitor air conditions flowing in and out of mines and automatically change air-flow if conditions become dangerous to miners. Most of these WSNs entail less bandwidth, less energy, very low processing power, operating as a sink in a unidirectional fashion.

I. Decentralized Smart Building Control:

In decentralized smart building control wireless sensors are installed to measure temperature, humidity, or levels of various gaseous components in the building atmosphere. Thus information can be exchanged among all sensors in the floor and the reading can be combined to form reliable measurements. Using distributed decision making the fog devices react to data. The system gears up to work together to lower the temperature, input fresh air and output moisture from the air or increase humidity. Sensors respond to the movements by switching on or off the lights. Observance of the outlook the fog computing is applied for smart buildings which can maintain basic needs of conserving external and internal energy.

CONCLUSIONS

With the increase in a number of devices that are becoming connected, there is a strong need for a computing paradigm like fog computing which will perform the computations at the edge of the network. This will help in making hard real-time computations on the generated IoT data, without having to send the data to the cloud. With the increasing popularity, it is clear that fog computing is here to stay and will co-exist with cloud computing.

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