From the Cloud to the Edge: The Technical Characteristics and Application Scenarios of Fog Computing

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Fog Computing, the Response to the Massive IoT Trend (Fog Computing)

International Telecommunication Union clearly defines IoT (Internet of Things) as “a phenomenon where every standalone object is connected”, this shows that as connectivity and communications technology gradually mature, various linking devices and equipment will be able to connect and create a more rich and diverse service scenario. However, as this trend is being established, these connected devices will produce large amount of data, which in turn will cause two problems that need to be solved: first, the increasing number of connected devices will lead to data congestion. The current solution is to process data in batches to divert data flow, but this will still result in latency and inability to respond to the issue immediately; second, with the advent of more wireless and cable-connected devices, service operators will have to invest more into the installation of cloud infrastructure. Aside from the initial installation, follow-up maintenance will also require huge costs, bumping up service prices.

In response to the problems with the IoT, the structure of edge computing called “fog computing” was created. It can be defined as “an emerging method of computing with the main goal of shifting computing and connecting units from the cloud to the edge or near-edge position to help devices preemptively and autonomously process information and data created by connected devices, creating a computing structure that can operate without relying on the center”.

Technical Characteristic of Fog Computing that Combines Vertical Division and Horizontal Linkage

Other than fog computing, there are actually other solutions that are expected to solve the resource deficiency problem in cloud computing, such as mobile edge computing and mobile cloud computing. However, these solutions are different in network structure, topology, and even position of computing units (core). Careful comparisons show two characteristics of fog computing: First, fog computing can be designed for any IoT object, and focuses on processing data communications (Datacom) instead of telecommunications (Telecom) service issues; second, because of its network topology, in addition to emphasizing the cooperative connection between the cloud, fog, and object, it also emphasizes the flat layered structure (such as the fog-and-fog interface), this way, the structure can help devices on the same level instantly and quickly conduct data sharing and collaboration.

Figure 1. Structure Type of Fog Computing.

Table 1. Analytical Comparison between Fog Computing, Mobile Edge Computing, and Mobile Cloud Computing.

Characteristics	Fog Computing	Mobile Edge Computing	Mobile Cloud Computing
Network and communication properties	Datacom + Telecom	Telecom	Datacom
Corresponding scenario	Massive IoT	5G	Mobile device computing resource limits
Computing location	Fog Nodes & Network	Edge Servers	Cloudlets(Small sized cloud)
Network Structure	Internet + cellular network	Cellular network	Cellular network
Main corresponding object	Various connected equipment	Mobile phones, cars	Mobile phone
Main driving force	IEEE	ETSI	NIST
Main service type	Public and private hybrid service	Public services	Private services
Network topology	Hierarchical Structure + Flat layered structure	Hierarchical Structure	Hierarchical Structure
Main solutions	Fog-cloud computing cooperation mechanism, flexible fog node distribution provide computing services	Combine edge servers with cellular base station for hierarchical distribution	Configure small cloud servers that provide computing resources and application service

From this standpoint, fog computing not only emphasizes cloud-and-fog, fog-and-object interfaces, but also emphasize the fog-and-fog horizontal interface. In other words, not only does it focus on the information technology end, but more importantly, it also relies on software defined technologies or flexible deployment of equipment to integrate with the operational technology end. This type of system of systems structural design idea is actually more suited to the IoT service scenario, and the

feature that separates fog computing from other similar solutions.

For Application Scenarios of Fog Computing

Continuing from the aforementioned technical characteristics of fog computing, it can be discovered that fog computing is a solution designed for the heterogeneous service scenario of IoT, and can be flexibly deployed according to different sub-system numbers, demand for network latency, amount of data transmission, and other demands in different scenarios. Continuing from the types of different demands, they can usually be categorized into four application scenarios: “standalone and semi-enclosed”, “dependent on sub-system cooperation”, “key decisions in the cloud”, and “remote and special applications” (Table 2).

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Table 2. Comparison between the Four Application Scenarios of Fog Computing.

	<i>Standalone and Semi-Enclosed</i>	<i>Dependent on Sub-System Cooperation</i>	<i>Key Decisions in the Cloud</i>	<i>Remote and Special Applications</i>
<i>Application Scenario</i>	This usage scenario demands a higher level of information security; less dependent on the cloud (needed for price function only); at the same time, the equipment used in this scenario has very different tolerance for network latency; requires immediate collaborative response.	This usage scenario involves two or more heterogeneous systems (such as production/logistic systems) where the main operation relies on system cooperation; at the same time, heterogeneous systems have a higher tolerance for cloud latency, and can be extended to hours or days	The terminal equipment used in this scenario has more homogeneity; the physical scale of nodes and systems are scattered wider, but the fog system have a lower tolerance for cloud latency, and requires immediate reaction.	This usage scenario lacks general communications, electronics basic infrastructure (or cost considerations), making it hard for class deployment; the equipment has lower demands for network latency, passively responding to the information demands from the center, and it is more simple
<i>Solution</i>	Technical solutions include distributed database systems and SDN to reconfigure the equipment's former data traffic	Technical solutions such as P2P and middleware support hands decision-making to the cloud, and control or immediate response to the fog	Technical solutions such as SDN reconfigures the device's former data traffic, and the cloud center must also rely on gig data technology decisions	The cloud needs better data fusion abilities, and the terminal device needs to possess smart module technology that can be adjusted flexibly
<i>Main Fields (Industry)</i>	Smart healthcare system, smart factory, semi-telepresence robot, ATM system, and military application fields	Smart retail, smart office, smart architecture, and smart logistics	City emergency electricity monitoring system, city water supply monitoring system, city notification network	Smart agriculture, remote weather stations, marine ship management, and large-scale GPS

Comparing these four application scenarios shows how the deployment type and main computing location of fog computing can be flexibly adjusted according to the type of IoT, or even geological scales, but in every scenario, the goal is to realize low latency, high information safety,

and continuous computing services, which is why it is stressed again and again how fog computing is a solution more suited to IoT.

The Development and Prospects of Fog Computing

Figure 2. The Paradigm Shift Signal of Fog Computing.

The emergence of fog computing will influence the ecosystem of the current industry. Key developments can be roughly put into three categories:

First, more 'flexible' IaaS basic structure (Flexible Virtual Network)

There is no need for the user end of the cloud computing service to install servers or network equipment, but as the speed of data processing increases, part of the data between future users and the cloud will be processed and stored by the "near edge" fog node, changing the existing data transmission and storage models, and even the existing network computing prices.

Second, more 'customized' network computing service (Customizable Domain-Specific Computing)

"Customization" is currently based on user flexible pricing; fog computing emphasizes layered, and flexible horizontal structures, which can help client deploy computing structures based on different needs (such as different latency of connected devices, bandwidth, and service quality), especially to solve the issue of sub-system collaboration with heterogeneous access (Heterogeneous access).

Third, terminal devices with embedded intelligence

Devices not only provide data transmission functions, but also provide terminal information filter (promote Edge AI, embedded SoC...etc.) for the 'intelligentization' of the next level Gateway and Device, which will become the first battleground of information electronics; Taiwanese companies can further enter this market through the hardware 'microprocessor' or software 'edge management software platform'. The emergence of the fog computing structure does not mean the replacement of cloud computing, or other similar decentralized computing technology. However, one thing for sure is that, as IoT connected technology continues to mature, making interconnection between devices

possible, IoT will have more fusion options to choose from. In other words, within the next five years, different technologies will co-exist, but it can be certain that the emergence of fog computing means two technical demands that must be resolved: First, computing units must be moved to the edge or half-edge positions, which is closer to the data generation point, to resolve network latency issues and implement a more timely service scenario; second, the increase of IoT not only means the increase in equipment and devices, but also increase of sub-systems. As a result, the integration of different heterogeneous systems and reduction of cooperative problems caused by the increase of heterogeneous systems has become the core problem.