Using the Internet of Everything for Data Centers

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Abstract. With the new infrastructure in recent times, the data center is relevant to all lives. Whether an individual, a small company, or a large corporation interested in education, finance, telecommunications, retailers, or social networking services, data centers provide a convenient and efficient platform for storing and computing data. In other words, data centers connect users, administrators, servers, data and information, different machines, and devices. This expresses the concept of the Internet of Everything (IoE). In this paper, the authors analyze the profound connection between data centers and the Internet of Everything concept from three aspects: the historical development of data centers, the current development pattern, and the future development trend. Hence, the development of data centers is inseparable from the Internet of Everything concept, and many of the design ideas of data centers fit well with the Internet of Everything concept.

Keywords: Internet of Everything · data centers · people-to-people (P2P) · people-to-machine (P2M) · machine-to-machine (M2M)

1 Introduction

In today's rapidly evolving connected world, the Internet of Things (IoT) [1] is no longer a new word. Its significance is to connect independent physical devices to the internet or other devices, thus interconnecting machines and devices. But the Internet of Everything (IoE) as a recent concept is beyond this understanding because its connectivity is more comprehensive than devices and the internet. It has expanded to physical devices, people, processes, data, and other elements [2, 3], just like its name – 'everything'. In this context, almost everything is online and connected via the internet, while data transfers (almost) occur in real-time.

Moreover, due to content-based communication, artificial intelligence (AI) [4], and machine learning [5], every interaction helps IoE devices become "smarter" [1]. Therefore, IoE covers a broader range of areas, plays more roles, and is more adaptable to the rapid development of technology. The current widely used data centers can also be seen as a reflection of the concept of the Internet of Everything.

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Data centers are the basic physical unit that carries data, a specific device network for global collaboration to deliver, accelerate, display, calculate, and store data information on the internet. Generally speaking, data centers are mainly composed of several parts: a computer room (building itself), power supply and distribution system, refrigeration system, network equipment, server equipment, storage equipment, etc. They could be applied in all aspects of production and life, essential to the digital transformation of various industries, and promote the rapid development of the digital economy [6]. There are three primary forms of data centers: physical data centers, IDC (internet data centers), and cloud computing data centers. In a 2021 report on digital infrastructure, real estate giant CBRE found that new data infrastructure in the U.S. broke ground and increased by 42% year-on-year, with data center service providers making several large land purchases this year to prepare for the next phase of development [7]. The result of data centers plays a crucial role in this era.

Data centers' primary function is to provide a space for companies like education, finance, telecommunications, retailers, and social networking services that process much information daily to carry all the data calculations. These generate and use data companies directly in data centers of virtual space and cloud computing resources pool to run their business. Therefore, they do not need to undertake new civil engineering room, cabinets, UBS, precision air conditioning, jumper, and so on room environment construction of the server, storage, network equipment procurement, and shelves, as well as the development of a business system, and deployment, availability reliability, and security operations [8]. This aligns with the concept of people in the Internet of Everything linking with machines, devices, and data through the internet [6]. In addition, from the perspective of the composition of data centers, many servers connect through the internet and constitute a large computer room environment for data storage and computing. It also reflects the close connection between the data and its equipment.

This paper aims to outline the historical development of data centers and the concept of the Internet of Everything, the operation mode of data centers in the present era, and the development trend of data centers in the future, and illustrate the inseparable relationship between data centers and the concept of the Internet of Everything. That is, data centers are a concrete embodiment of the Internet of Everything.

2 Background of Data Centers and IoE

Table 1 provides a brief history of data centers in the IoE context. With the introduction of the Electronic Numerical Integrator and Calculator (ENIAC), the first fully automatic electronic data computer in the 1940s, a new era of human computing was revolutionized, and the evolution of the "Data Centers" went with it began.

In the 1960s, the prototype of data centers began to emerge. Computer systems, storage systems, power equipment, and other related components had been discovered, but there needed to be a systematic connection between them; they were placed in the same space. The nascent data center was called a "Server Farm" to house computer systems, storage systems, electrical equipment, and other related components. At this time, the concept of interconnection was just beginning to emerge, as the first distributed control network, the Apha network, was first constructed in 1968 [9].

Table 1. History of data centers and IoE

Years	Machine	Stage meaning
1940s	Electronic Numerical Integrator and Calculator	A new era of computing
1960s	Server Farm	A prototype data center
1968	ARPANET	The first distributed control network
1990s	Client-server	The prototype of a traditional computer room
1990s	DC-IDC	The data center as Enfo eService
2005	IoT	Networked devices that sense and share data
2006	Cloud Data Centers	The rise of cloud computing

In the early 1990s, with the development of communications technology and the widespread use of computers, the micro-computing industry (servers) saw a boom, and the data centers concept began to develop. Connected network devices replaced the older generation of PCs, and the emergence of the client-server technology model [10], in particular, led to the creation of a separate room for servers, with simple equipment wiring, linking, and layering, using the term 'data centers' to name the space. At that time, the term 'data centers' became popular and was the earliest form of the traditional server room we have today. By the mid-1990s, the rise of the internet had a significant impact on the market. Internet connectivity has become a must for businesses to deploy IT services. Network providers and colocation providers were widely developed in creating hundreds of data centers, and most companies accepted data centers as a service model. At this point, the idea of relying on the internet for human-to-machine and machine-to-machine connectivity in IoE has begun manifesting itself. With the advent of mobile devices and wireless technology, fixed devices, which were difficult to move, have evolved into easily portable and mobile devices. The connection between man and device has also changed from one where people follow the device to one where the device follows people [2].

Since the beginning of the 21st century, the internet has seen explosive growth, driving the rapid development of data centers and showing a diverse trend. With the rise of global internet companies such as Google, Baidu, Tencent, and Sina, the PC boom required uninterrupted networks, promoting the rapid development of data centers, which became more professionally built and costly to maintain compared to before. It was not until 2005 that the data center's design, construction, and operation developed steadily. And it was in this year that China Telecom launched its highly industry-recognized server room design standard, namely: China Telecom - 2005 IDC Product Specification [11]. At the same time, the US telecom industry also promulgated the "TIA942 Standard" [6], which classifies server rooms into four levels, Tire1-Tire4. These two standards have played a normative and guiding role in developing data centers.

Furthermore, with the rise of cloud computing technology, cloud data centers are gradually coming into the limelight, integrating the computing, storage, and network

layers into a single hardware device to achieve data centers management through a hyper-converged architecture, which has been called "hyper-converged architecture data centers." Furthermore, in 2005, the Internet of Things (IoT) concept was also introduced [12, 13]. Today, IoT refers to connected devices that can sense and share data, i.e., machine-to-machine connections (M2M) in the Internet of Everything concept [14].

3 Impact of IoE on Data Centers

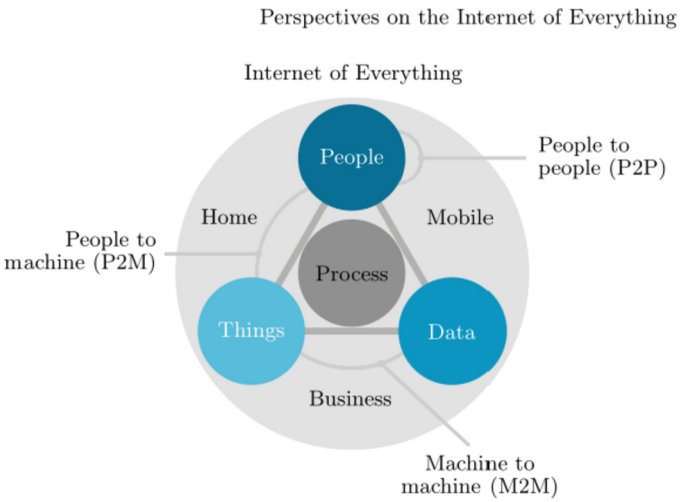

Fig. 1. The components of the Internet of Everything (IoE) [1, 2]

As shown in Fig. 1, IoE mainly comprises five components: personnel, machinery, equipment, data, and process, connected through the internet. Compared with the Internet of Things, which only emphasizes the connection between machines and devices (M2M), the Internet of Everything adds the relationship between people (P2P), the connection between people and machines and devices (P2M), and these ideas are correspondingly reflected in data centers [1].

For establishing the connection between people, machines, and equipment, the storage and calculation of data by the user or company with the help of data centers fall under the concept of P2M. The connection between data centers and users can be divided into three types according to the platform model the data center delivers to the user [15]. The first one, Infrastructure as a Service (IaaS), mainly provides the lowest level of resource services, such as servers, storage, and networks. After enterprises or users rent these resources, they can customize their business systems according to their needs, which is considered the closest connection between people and machines and the equipment itself; the second one, Platform as a Service (PaaS), which is pre-built based on the second type, PaaS, is built on top of this with all the environment related to development, testing, operation, and maintenance. Individuals or enterprises can focus on their

business logic and do not have to care about the underlying operating environment. The third type, Software as a Service (SaaS), is more straightforward, providing ready-made software or application services, such as email services. This is more universal in nature, as individuals and enterprises of any size need to use ready-made software of all kinds, providing a way for people to connect with various software facilities. SaaS provides a way for people to communicate with multiple software facilities. And on top of the user-based platform of data centers, certain connections exist between users and users and users and administrators.

The exchange of data between different users or companies through a pool of resources in a data center falls under the people-to-people (P2P) concept. The resource space provided by data centers can be divided into three categories according to how data centers resources are deployed [8]. The first category, the public cloud, refers to the vast number of users who rent help from the resource pool on demand to meet their needs [16]. Users pay for the actual resources they use over time. This model's ownership of the underlying resources belongs to the service provider, and the right to use them belongs to the customer. This reflects the sharing of resources in the resource pool by the users on the one hand and also the connection between the service provider and the customer. The second category, private cloud, refers to how some large enterprises structure themselves and deploy themselves self-sufficiently. It no longer shares the resource pool with all users. Still, it isolates the space resources for its use, which is well suited to the security operation and maintenance management of large enterprises.

The service and ownership of the underlying resources in this model belong to the customer. The third category, hybrid cloud, is a combination of the first two, where the cloud service provider helps you maintain your own cloud facilities or multi-cloud interoperability so that you can privatize the highly secure data and publicize the less essential parts, meeting security needs and saving costs, which is the mainstream deployment model at present [17]. These models embody the data exchange and connection between people through the internet in the Internet of Everything. In the Internet of Everything era, the relationship between people will be diversified and not limited to the initial physical contact, the connection is unavoidable, and the concept of the Internet of Everything can provide us with thoughts on how to find a suitable P2P approach. The idea of the Internet of Everything can provide us with a direction to think about how to find the right way of P2P.

For the existing M2M in the Internet of Things concept, there is more embodiment in data centers. On the one hand, from the perspective of the composition of data centers, the hardware of data centers is divided into two categories, namely, the leading and supporting equipment. Among them, the top equipment refers to the IT computing power equipment represented by the network and server, the communication equipment represented by switches, routers, and firewalls, and the supporting equipment refers to the underlying essential support equipment (such as power supply system and refrigeration system) to ensure the regular operation of the leading equipment, which are closely connected through data centers network to realize data interaction and collaborative work, which is the M2M concept in the Internet of Everything. Only when these machines and equipment are connected to their ability can they support the continuous operation of these massive data centers. On the other hand, as a single data center has been difficult

to adapt to the business needs of the new era, the interconnection of data centers and data centers has also begun to be considered. To meet the cross-regional operation, user access, and the demand of the different disaster scenarios, more and more organizations and enterprises in other regions deployed multiple data centers in the same industry, and various industry enterprises often need data sharing and cooperation, which requires different enterprise connectivity between data centers [18]. The communication of data in other data centers is also a need for M2M in the Internet of Everything. In the Internet of Everything era, if the data is independent and unshared, and an effective connection needs to be established between different data centers, it is difficult for data centers to maintain their data storage and management advantages.

4 Development Trends of Data Centers and IoE

There are currently two dominant trends in data centers. One is to achieve interconnection between different data centers, as mentioned in Sect. 3. The number of data centers in the world today has proliferated, and the number of data centers is already large enough and widely distributed. However, how to achieve data exchange and sharing between data centers is now a significant consideration for mainstream data centers. From the Internet of Everything perspective, it is crucial to build on what was originally a relatively simple machine-to-machine connection for servers in close geographical proximity and develop it into a connection between different data centers across geographies. To meet data center interconnection requirements, Huawei CloudFabric Data Centre [19] relies on two key technologies, VXLAN and EVPN, to provide customers with a minimalist operational experience covering the entire lifecycle of cloud-based data center networks.

Second, it solves the energy consumption problem of data centers. According to the China "New Infrastructure" Development Research Report [8], data centers will account for the largest share of global energy consumption, up to 33%, by 2025, so how to save energy has become one of the issues on the minds of data centers today [20]. One is to choose a suitable environment for data center construction, such as subsea data centers or Arctic data centers, to save energy by using the environment to assist the cooling system. This not only keeps the energy required for cooling and heat dissipation but also widens the distribution of data centers, enabling the interconnection of everything through data centers [21]. The other is the intelligent management of the various facilities in data centers by monitoring the power consumption within the processor. This also embodies the interconnection between data centers, the environment, and humans.

5 Conclusion

From the history of data centers, the development of data centers is in line with the many ideas of the Internet of Everything; the development of data centers also complements the development of the Internet of Everything concept. The two have something in common. Judging from the current development of data centers, many existing service modes and construction methods of data centers are very compatible with the Internet of Everything P2M, P2P, and M2M. From the future trends of data centers, some of the existing future development directions are also very much in line with the Internet

of Everything concept. We have reason to expect that the future of data centers will be better connected to the Internet of Everything concept, develop a new form of data centers, and the idea of the Internet of Everything.

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