Next-generation Internet of Things: Conception of Key Characteristics and Typical Applications

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Abstract: The development of technologies in digitalization and intelligentization has ushered in new areas of opportunities for the Internet of Things (IoT). This paper presents an overview of the evolution trend of the IoT, analyzes and identifies the six characteristics of IoT evolution, and outlines the typical IoT applications, and on this basis delineates the development trend of the next generation IoT. This paper attempts to provide recommendations for the development of the IoT industry and related technical research.

1. Introduction

IoT is an intelligent information service system based on network communication such as Internet and cellular network, which connects the intelligent objects with the ability of perception, communication and computation to realize total perception, reliable transmission and intelligent processing so as to enable interconnections among people or things.

In recent years, the addressable market size of IoT technology has been expanding rapidly. According to IDC, the global market of IoT is estimated to be USD 1.7 trillion in 2020 [1], while McKinsey Co. predicts that the global market of IoT will reach USD 4 to 11 trillion in 2025 [2]. According to GSMA, the global IoT connections will increase from 12 billion in 2019 to 24.6 billion in 2025, at a compound annual growth rate of 17% [3]. The IoT technologies and solutions are accelerating to penetrate various industries around the world. According to the forecasting made by various consulting companies, the fastest-growing IoT verticals are likely to be smart industry, smart transportation, smart health, and smart energy.

The evolution of IoT can be divided into three stages: interconnection, intelligence, and autonomy. The first stage is the establishment of large-scale IoT connections, where network infrastructure, interconnection and management are the core tasks. The second stage is the intelligent stage of the IoT. Thanks to digitalization technologies, the IoT applications will gradually complete digital transformation and upgrading on a global scale. At the same time, the intelligent perception and analysis can be realized by the intelligent processing through machine learning at the terminal, edge or cloud sides. The third stage is the autonomous IoT. By introducing cloud computing and artificial intelligence (AI), the independent analysis and calculation of business logic are realized, and the dynamic real-time self-optimization are achieved. Currently, the IoT has initially achieved the first stage of large-scale interconnection. The massive interconnections will promote the development of data intelligence in various fields. The era of data intelligence of the IoT is emerging on the horizon.

2. Key Enabling Factors for the Development of IoT

Applications: New application requirements are the driving force behind the development of any system. With the rapid development of intelligentization, the next-generation IoT has put forward a new level of requirement for latency and accuracy, and presented new challenges to the basic network requirements such as delay, bandwidth, power, and energy consumption. In addition, management, operation and maintenance of network resources need to be flexible, controllable and predictable in a brand new manner [4]. To this end, besides the enhancement of network capabilities, the most important is to realize mutual awareness between the business applications and the network, where the network has a deep understanding of the application requirements and the application has real-time understanding of the network status so as to realize a deep integration of application and network.

Technology: The revolution of technology is driving the rapid development of IoT. The next-generation IoT is an open network that is deeply integrated with AI, big data, smart sensing, etc. The innovation, evolution and development of the IoT technology will ultimately promote the realization of the business applications. The critical technologies of IoT mainly involve three layers: Perception, which needs to realize ubiquitous perception, using sensors to obtain information about objects anytime and anywhere; Networking, which needs to realize reliable transmission of object information in a real-time and accurate manner through the integration of various networks; and Applications, which need to realize intelligent processing, using various intelligent computing technologies to implement intelligent control of objects.

Data: Data is a cornerstone of the future development of IoT. A great number of IoT devices generate massive amount of data with the aid of AI. Efficient interactions of data poses a huge challenge for the IoT interacting and computing capabilities. It is necessary to achieve reasonable transmission, storage, and allocation of computing resources according to the needs of data interactions. Network elements need to be intelligently constructed, and the routing needs to be flexibly controlled. At the same time, data interactions will bring about a certain increase in business value, accelerate business development, and bring more benefits to the network.

3. Analysis for Evolutional Characteristics of IoT

Taking into account the typical applications and common requirements of the next-generation IoT, the future IoT can be characterized by the following 6 S’ s: (1) Speedy: Quickly realizes the identification, management and optimization of the rich business services of IoT; (2) Syncretic: constructs the highly reliable and high-performance data transmission through the vertical and horizontal integration of heterogeneous networks such as cellular and satellite networks; (3) Synergistic: Implements real-time and accurate analysis of massive data based on collaborative data processing; (4) Security: Realizes the customized and comprehensive security protection for IoT business services; and (5) Simple: Realizes the easy-to-use, easy-to-deploy, and easy-to-manage system for users, developers and operators; (6) Shared: Achieves the sharing of network capabilities and resources based on a unified system architecture. Based on the 6S characteristics of the next-generation IoT, a new era of intelligent IoT is on the horizon, as shown in Figure 1.

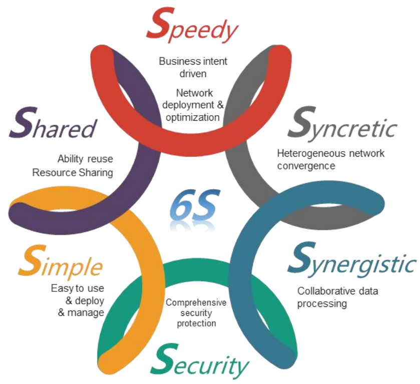

Figure 1: Characteristics of next generation IoT system based on 6S.

3.1. Speedy

Countless business service requirements will be introduced by the rapid development of IoT in the future. Different from legacy IoT businesses, the next-generation IoT business features self-growth, being flexibly generated with the interaction and analysis of data. In order to adapt to the flexible and dynamic nature of IoT business, the next-generation IoT system needs to accurately understand the differences in businesses intentions, and quickly complete the accurate identification of such business intentions. At the same time, the system needs to have the ability to quickly and accurately assess network resources in order to accurately match business requirements with network capabilities. Besides, the system needs to monitor in real time the changes in business requirements, identify network failures in advance, and adjust network resource configurations in time to ensure efficient and dynamic matching of services and resources. In this way, a life cycle closed-loop system is formed with the integration of business intention perception, analysis, decision, and intelligent operation and maintenance, and the flexible adjustment of the network is realized. Many emerging technologies, such as semantic recognition, model base, big data, AI perception, and digital twin can realize business intention understanding and transformation, real-time network status perception, and establish a digital network model. Therefore, the consistency of the network status and business intention can be continuously verified, and predictive maintenance can be performed, thereby forming a complete closed-loop system.

3.2. Syncretic

In the 4G era, although mobile networks cover 90% of the global population, they only cover less than 20% of the global geographic locations. For 80% of the global locations, it is necessary to expand the network coverage to realize environmental monitoring, disaster protection, emergency search and rescues, and national defense monitoring. In order to achieve global seamless network coverage, the land-sea-air-space integrated communication has become the development trend of the next generation IoT. Through the integration of terrestrial wireless communications (e.g. cellular and short-range), drones aerial communications, satellite communications, and overocean communications such as shore-based, unmanned platforms, underwater motion carriers, the next-generation IoT can form a "vertical and horizontal integration" architecture of the network. The “land-sea-air-space” integrated communication can solve the problem of interconnection and intercommunication between heterogeneous networks, and realize end-to-end intercommunication and seamless transmission. As a result, the transmission performance, the availability and reliability of the network are improved, the network coverage is expanded, the resources are fully utilized, the costs of network operators and service providers are reduced, and the diversified business requirements are met. To provide global comprehensive information services, the “land-sea-air-space” integrated communication will gradually realize converged communication based on multiple independently constructed information systems, i.e., land-based, sea-based, air-based, and space-based information system, thereby promoting the formation of a multi-dimensional integration of data, technologies, and products.

3.3. Synergistic

The legacy Internet is designed mainly to solve the transmission of information among people, and the understanding of information and decision-making is completed through the intellects of human beings. Therefore, the intercommunication of information is most important in the Internet era. The era of IoT will not be possible if only to realize the information exchange among things due to the fact that the objects don’t have strong information processing capabilities. How the objects further process the acquired multi-source information requires that objects be endowed with collaborative data processing capabilities. To cope with the ever-increasing demand for massive data transmission, and meet the requirements for computing power of new applications, synergistic needs to be fully implanted into all levels of data processing, and the endogenous intelligence of IoT needs to be defined and realized in terms of perception, storage, and computing. Key technologies such as multi-system fusion perception, multi-protocol fusion, fusion analysis, and “end-edge-cloud” intelligent collaboration will help intelligent genes penetrate all aspects of IoT [5].

3.4. Security

The rapid development of the IoT market and sharp increase in the number of terminals have led to increased security risks. Therefore, security protection will be an indispensable part of the development of the next generation IoT.

The IoT devices are characterized by multiple models, miniaturization, and light weight. These characteristics will become more obvious in future development, therefore the existing coarse-grained and large-scale security solutions will be impractical. At the same time, as businesses are cloudified, the security boundaries are becoming more blurred, and traditional single-point defense methods are hard to work. New types of attacks are complex and concealed, and cannot be effectively identified by traditional passive defense methods, and threat detection and response cycles become longer [6]. Therefore, the security requirements of the next-generation IoT should transform multi-dimensionally from extensive protection to precise protection, from single point protection to overall protection, from passive protection to active protection, and from static protection to dynamic protection.

In order to provide precise, overall, active, and dynamic four-dimensional security protection methods, and build a network-wide active defense system, it is necessary to use network security situational awareness technology to build a complete adaptive security framework and open microservice software architecture and try to establish a system that denies attackers the right to "enter, see, mess up, and walk away", and establish an IoT security system from the perspectives of risk detection, security response, and security operation and maintenance.

3.5. Simple

In order to meet the needs for diversification, globalization, and miniaturization of IoT business development, the next generation IoT systems will introduce many high-precision technologies, resulting in system complexity. However, any efficient and flexible network must be developed by the philosophy of simplification. Simplification can accelerate the development of agile, intelligent, and integrated IoT. Therefore, Simplification is an important goal for the development of the next generation IoT. Through simplified operation, simplified deployment, and simplified operation and maintenance, it is possible to achieve agile and efficient business, unified network bearing, intelligent coordination of computing, on-demand scheduling of resources, and secure policy compliance. These will effectively enhance user experience, improve service deployment efficiency, reduce operation and maintenance costs, and greatly reduce the time and difficulty in network optimization and adjustment, so as to meet the highly dynamic and flexible requirements of the next generation IoT, and create an end-to-end simplicity system architecture of next-generation IoT [7]. Based on the agile analysis of business intention, heterogeneous network interconnection and interoperability, unified end-to-end network protocol and digital twin technologies, it is possible to create an easy-to-operate, easy-to-deploy, and easy-to-manage IoT architecture for users, developers, and operators.

3.6. Shared

The sharing characteristics of the next-generation IoT include the sharing of capabilities and resources. Currently, the vertical applications of IoT are developing in a "stovepipe" manner, with industry applications and closed-loop applications as the mainstay, and to a certain extent belong to intranets and private networks. This model has high construction costs, high repetition, difficult object/information sharing, and difficult interconnection between application systems, and is difficult to adapt to the requirements of scalable and coordinated development, and is difficult to catalyze greater future developments of IoT. Through the sharing of capabilities and resources, effective use of common capabilities and resources can be realized, repetitive construction and the cost of stovepipe collaboration can be reduced, while meeting the needs of the IoT system for data sharing, business componentization, reusability, and flexible expansion. In response to the problems of “reinventing wheels” and “traditional stovepipe architecture of IoT”, the next generation IoT will realize the sharing of capabilities and resources through technologies such as microservices and virtualization.

4. Typical IOT Applications Evolution

The above characteristics will promote the rapid evolution of IoT applications. At present, IoT applications are generally divided into three categories, which are typical applications to individual consumers, such as smart education and smart health; typical applications to industry, such as industrial internet and smart agriculture; and typical applications to city management, such as smart transportation and smart city. The schematic is shown in Figure 2.

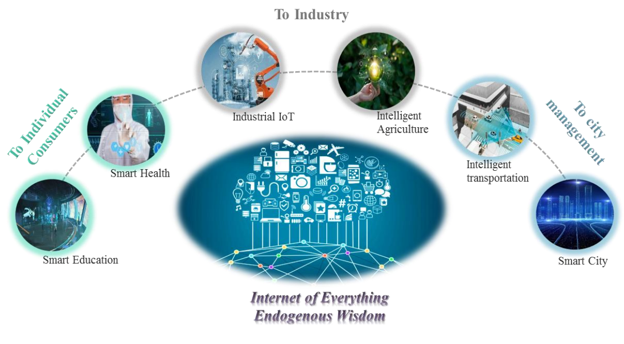

Figure 2: Typical IoT applications.

4.1. Typical Applications to Individual Consumers

Smart Education: With the promotion of education informatization strategy and steady growth of education investment, great progress has been made in education informatization around the world, and the education standards have been continuously improved. It is transforming into an open, shared, interactive and collaborative modern intelligent education, that is more technology-based, network-based and person-based. With the help of IoT, cloud computing, big data, and AI technologies, we will create a new intelligent, perceptual and ubiquitous mode of smart education by personalized, refined and immersive learning and teaching, improving the classroom teaching effect and students' learning interest and learning efficiency. Smart education mainly includes smart classroom, smart teaching and research, smart management and smart campus.

Smart Health: Smart health is the comprehensive application of new generation information technology and biotechnology to integrate medical resources and equipment of health planning departments, hospitals, communities, service organizations and families, to innovate medical health management and services, and establish a holographic whole-course health dynamic monitoring and service system [8].Smart health can be widely used in social health fields such as disease prevention, medical treatment and individual health care.

4.2. IoT Applications to Industry

Industrial IoT (IIoT): IIoT is an emerging business modality and application pattern born of the deep integration of a new generation information and communication technology with advanced manufacturing. In future, industrial production will be deeply integrated with digital twin technology, creating highly-realistic virtual models for physical objects, breaking product life cycle of design, manufacturing and maintenance, and achieving closed-loop digital twin optimization of product. In addition, industrial robots will help build the "unmanned factories", realizing the integration, storage and calculation of massive heterogeneous data, and accelerating the data-driven networked and intelligent construction of factories.

Intelligent Agriculture: Agriculture is an important sector related to national economy and people’s livelihood. Intelligent agriculture is centered around smart production to realize refined, intelligent, intensified, and scientific production by combining information technology with agricultural production, promoting the quality and efficiency of agricultural products. The typical applications include smart planting and farming, UAV plant protection, and autonomous driving of agricultural machinery [9].

4.3. IoT Applications to City Management

Intelligent transportation: It refers to the comprehensive whole-process control of traffic management, transportation, public travel, and transportation construction, etc., to fully ensure traffic safety, improve the operation efficiency and management level of the transportation system, and provide services for unobstructed public travel and sustainable economic development [10]. In the future intelligent transportation system, applications such as unmanned driving, smart aircraft, and zero-emission trains will make significant progress, providing great convenience to people’s living.

Smart city: The construction of future smart cities will aim at achieving sustainable city development, relying on digital twin technology to achieve accurate mapping and real-time interaction between digital cities and physical cities in the fields of city construction and city security, so as to comprehensively improve the quality of life, and promote the transformation of city economic development and the modernization of city governance.

Generally speaking, all kinds of applications of the future IoT will be developed around providing a better life for the people, and meet the diversified needs of human beings. The next generation IoT will aim to achieve full automation without labor. From the connection of things to the intelligent connection of things, it is necessary not only to realize the connection between objects, but also ensure the reliability, flexibility and controllability of the connection, and the accuracy and timeliness of information transmission. It requires comprehensive business perception, heterogeneous network integration, intelligent data processing, terminal intelligent interaction, and information security and controllability in the IoT sensing, transmission, computation, use, and security.

5. Conclusions

IoT is a high integration and comprehensive application of a new generation of information technologies. The next generation IoT is characterized by high dynamics, high flexibility, and high reliability, and has capability requirements such as comprehensive data perception, heterogeneous networks integration, smart business processing, intelligent terminal interactions, and information security and controllability. The introduction of a series of new technologies such as AI, cloud computing, big data, blockchain, and edge computing will enable implementing an end-to-end "speedy, syncretic, synergistic, security, simple, and shared" next-generation IoT and help the IoT technologies to be quickly implemented and deployed in numerous verticals such as education, transportation, medical care, industry, etc

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