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Scalability in Internet of Things: Features, Techniques and Research Challenges

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Abstract

Internet of things (IOT) is one of the most rapidly emerging fields in today's scenario. IOT is basically a network of objects that are connected to each other through the internet and are also capable of transferring and modifying data with the help of embedded sensors. IOT is becoming the next phase of internet which has the ability to collect, analyse and spread data that can be turned into information and knowledge. With the growing idea of IOT we face a major challenge of "scalability in IOT". Scalability is the ability of a device to adapt to the changes in the environment and meet the changing needs in the future. It is essential feature of any system which has the capability to handle the growing amount of work. It is a desirable attribute of a system or a network whose lack can cause a poor system performance and the necessity of reengineering of the whole system. In this paper we present the definition, features to be considered for scalability, techniques to achieve scalability, types of scalability and research and challenges.

Keywords: Scalability, Internet of things(IoT), horizontal scalability, vertical scalability, "thing"

INTRODUCTION

With the enhancement in technology in this fast advancing world, the number of devices that connect to the internet is increasing exponentially, which also increases the amount of data that is being transferred over the web. Also, with the growth of technology in various areas, people use the internet for a wide range of things such social media platforms, communication, playing games, online banking, e-commerce, online shopping, etc. As more and more gain access to this network of interconnected networks, we have achieved a bigger goal of making machines, remote devices and smart objects capable of being connected to the internet. This quintessential shift gives rise to new visionary benefits. This inter-networking of devices or "things" opens new gateways for devices to communicate with each other perpetually and makes everyday life "smart" [1]. In other words, this perfect specimen is called the "Internet of Things" (IoT). The integral purpose of this is to contrive a configuration that facilitates the formation of a "smart" network comprising of these immense number of devices, systems and equipment. Another primary intention of IoT is to expand the network in order to incorporate any "thing" that can be remotely located an identified without the need of a communication intermediary between these "things". Furthermore, as this new technology progresses to an altogether different level, it becomes inevitable to make the device more scalable both horizontally and vertically. Horizontal scalability deals with expanding the network so that increasing number of hardware devices or software entities can be accommodated in the network. Whereas, vertical scalability is concerned with the capability to build up the efficiency of the already existing software or hardware by affixing more number of resources.

On a larger scale, IoT can be listed as a worldwide framework that promotes the connection of any "thing" by manipulating extracted data and their communication abilities. The entire existing and emerging structure of networks is considered to be a part of this progressively accelerating IoT framework. The fundamental property of an IoT framework is that it will provide exclusive recognition of each "thing" and its virtual personification for the progress and development of usefulness and applications. Scalability is a very crucial aspect that comes into being with the new and progressive technology advancements that happen every day. As more and more number of devices or "things" are being connected to the internet, it is a matter of utmost concern to consider various complications that arise as a result of this. There are innumerable aspects that need to be kept in mind for scalability in IoT. Some of them are listed below.

A. Features for scalability:

Scalability is a mega-phenomenon which is driven by smaller and more specialized processes. A very crucial aspect for scalability is the features that need to be kept in mind for scalability. These include features such as business, marketing, hardware, software and network.

B. Techniques for scalability:

A device or a system may be scalable in various ways. But to attain unmitigated scalability, we must follow a well framed series of steps which will facilitate scalability. These steps are formally referred to as techniques for scalability. In our paper, we will be focussing on techniques such as controlling the IoT data pipeline, three axis scaling approach, automated bootstrapping, developing microservices architecture, etc.

C. Research challenges and issues:

With the advancement and progress in today's fast-moving world, there come few hindrances in the process. Research challenges and issues constitute of the probable hindrances or obstacles that we may face while undertaking the process of scalability. We have focussed on various challenges such as protocol and network security, identity management, privacy, trust and governance, fault tolerance, etc.

TYPES AND IMPORTANCE OF SCALABILITY

An IOT system connects a huge amount of sensors, actuators, and other devices to provide with information sharing and a large number of applications via internet. It challenges the design and the growth of the system to meet scalability and adaptability to the changing environment and needs of the people. Scalability means flexibility that allows us to better address and achieves the specific needs as they arise. The main objective of making the device scalable is to meet the changing demands and they can never be static since the interest of people and taste changes with time as well as the environmental conditions. It is vital as it contributes to competitiveness, efficiency and quality. The importance of scalability is that it helps in the system to work gracefully without any undue delay and unproductive resource consumption and makes a good use of the available resources. In a scalable system, if the memory requirements of the system increase as there is an increase in the amount of data then it does not grow to insupportable levels [2]. Moreover, the device operates smoothly and with speed in spite of the fact that whether the device is large or small in size. Hence it is important to make a device scalable to make it more efficient for the present and the future use. [3]

Here we tend to define the different types of scalability in context to IOT.

A. Vertical Scalability:

It is also referred to as scaling up which is the ability to increase the capacity of existing hardware or software by adding more resources to it. For instance, we add processing power to a server to increase its speed. Moreover, we can scale

a system vertically by expanding it by adding more processing, main memory, storage, and network interfaces to the node in order satisfy more requests per system. Hosting services companies surmount by increasing the number of processors. It means to add resources to a single node in a system which involves the addition of CPUs or memory to a single computer. Such vertical scaling of current systems facilitates them to utilize virtualization technology more productively.

The main advantage of vertical scalability is that it consumes less power if we compare to running multiple servers, reduces administrative efforts as we need to handle and manage only one system. Moreover, the implementation is easier, reduces software costs and application compatibility is retained.

As there are advantages there are also disadvantages of this type of scaling which include greater risk of hardware failure which will cause bigger outages, severe vendor lock in and the cost of the overall implementation is high.

B. Horizontal Scalability:

It is also referred to as scaling out which is the ability to increase the capacity by connecting the multiple hardware or software entities so that they can work together as a single unit. Horizontal scalability can be achieved by adding more machines into the group of resources and adding more nodes to a system for instance adding a new computer to a distributed software application.

The examples of this can be SOA systems and web servers which scale out by adding more and more servers to the load-balanced network so that the incoming requests can be distributed between all of them. Cluster is a familiar term for describing a scaled-out processing system.

An example might include scaling out from one Web server system to other three systems. System architects may set up swarm of small computers in a cluster to obtain cumulative computing power that many-a-times exceeds that of computers based on a single traditional processor.

Application scalability indicates the improved performance of running applications on a scaled-up version of the system.

FEATURES TO BE CONSIDERED FOR SCALABILITY

Scalability is an important factor that goes hand in hand with the ever-growing modern infrastructure of devices called the “Internet of Things”. By the year 2020, the IoT network will have around 24 billion devices that could connect to it. It is also a diverse phenomenon which deals with numerous aspects of an IoT application such as network and security, identity management, data privacy, big data, massive scaling, etc. Each of these factors are pillars that contribute to the overall anomaly of scalability [4]. We

shall be focussing on few main factors which are as below:

A. Business:

The system should be able to store the increasing amount of data in the database to make it scalable. For example, if the company is storing small amount of data and if it increases to a higher level in the near future so it should not become obsolete and should be able to provide a platform for the increasing amount of data. If the system is not scalable, then it will not be able to support forthcoming expansion when shifts in technology occur. This may result in loss of businesses and they may be left with unusable systems and devices that must either be interchanged or augmented and both are expensive prospects.

B. Marketing:

The device should be suitable to all the environments and it can work in any environment as required according to the need of the customer. The device should be easily understandable and should be easy to use for a customer and if the customer requires any of the changes related to the device so the changes can easily be made without disrupting the working of the system.

C. Software:

A scalable system should have the feature of moving from a smaller to a larger system and take the full advantage of the larger system in terms of performance (user response time). It should have the ability to support an increasing number of connected devices, users, and application features and analytics capabilities without any degradation in the quality of service.

D. Hardware:

Devices need to be uniquely identifiable remotely. Masses of analogous devices corresponding to various customers should only be allowed to use their customer-specific data. Devices need to connect to their respective backend systems in a secure fashion as the information they relay is often private or sensitive, it is necessary to encrypt the data before it leaves the device. Stolen, lost or compromised devices need to be easily quarantined. No one would be willing to pay the bill of previous tenants after vacating.

E. Networks:

A scalable network must have the ability to adapt when failures occur and it must also remain mostly operational until the issue is repaired. It does not require complete deployment in order to function which allows for gradual rollout and tweaks along the way. Align network and device longevity. It should be heterogeneous i.e. it should be able to connect computers and other devices

with different operating systems or protocols. It is also used in wireless networks using different access technologies. For example, a wireless network which affords a service by the means of wireless LAN and is capable of maintaining the service when switching to a cellular network is called a wireless heterogeneous network. HNet often indicates the use of multiple types of access nodes in a wireless network. [5]

TECHNIQUES FOR SCALABILITY

Internet of Things (IoT) is an explosively developing field and scalability is considered to be an important factor that facilitates it. This ascertains that IoT application must be made capable to support a gigantic number of connected devices or "things", various types of users and application features. A short description of few techniques is given below. [6]

A. Using automated bootstrapping:

As the number of devices increase, manual functions such as bootstrapping, software and security configuration, device registration and upgrade are no longer feasible. Thus, any mechanism that involves human interaction and facilitation starts becoming obsolete and impractical. Hence, all these services must automate the aforementioned processes in order to save time and act more efficiently. Devices must have in-built facilities with required bootloaders, security keys and other necessary features that will promote the process of automation when a remotely located device starts up for the first time. [4]

B. Controlling the IoT data pipeline:

IoT devices generate and transmit tremendous amount of data that needs to be processed and organized in a required format for it to be usable. There is an indispensable need for a data processing pipeline that is made up of front-end collected and a specific set of data and content curation functions in IoT applications. There functions are appropriately applied on the data stream that is being transferred between various systems and "things". With increased number of devices that contribute to generating and transmitting data, these data pipelines must be designed in such a way that they can handle sudden surge in the rate of flow of data and performance issues. The capacities of these data streams must be adjusted based on valuable parameters such as the number of simultaneously connected devices or data streams. Therefore, it is crucial that there be control in the data pipeline as required by a particular service. [6]

C. Applying the three-axis approach for scaling:

IoT applications can be scaled along the three fundamental axes: X axis – scale by cloning, Y axis – scaling by splitting different things and Z axis – scale by

splitting similar things. X-scaling is associated with utilizing more resources to distribute the incoming demands amongst various servers, in such a way that all servers are capable of handling requests. It is beneficial to incorporate servers that preserve state information from one request to another. It is easy to scale up such servers. Scaling in Y-axis perpetually means distributing the tasks at hand based on processes. Scaling in the Z-axis means allocating the responsibilities on the basis of the incoming request or response data. Thus, scaling in various directions plays an eminent role as a technique for scalability. [7]

D. Developing microservices architecture:

Microservices is a contemporary architectural approach in which intricate applications are comprised of individualistic micro-processes disseminating with each other with the help of language-agnostic APIs. It is useful to divide each application into several independent instances which are often called functional units each of which performs a separate function. Each of these functional units should work independently and executed. These Functional units can send messages to each other and hence is called microservice architecture. [8]

E. Adopting multiple data storage technologies:

An IOT system has different parts of applications which require different techniques for their storage rather than using one common technique for all. These applications are required to be built on the best suited technology components that are available and hence each of the microservices that we are using should use that component that is suited for its needs. Moreover, the data query and the retrieval requirements should determine their choice of data storage technology or in other words their choice of database. [9]

F. Create a system that can be easily expanded:

As more and more devices are added to the system it should have the capability to easily expand. The device should be designed by analysing the future needs and designing the device according to it. [10]

G. Making sure that the devices that are on the network can be operated for many years without needing any service. [10] The maintenance results in the lowest operational cost for the device as well as the network in long term view.

RESEARCH CHALLENGES AND ISSUES

A. Protocol and network security:

A protocol is primarily referred to as an access method used a standard to define

a scheme for exchanging data over various computer networks such as Local Area Network or LAN, Intranet, Internet, etc. Thus, with this comes the evident urgency to secure the networks against various malicious practices. Protocol and network security is a predominant factor leading to scalability as with the increase in number of "things" that connect to the internet, we must define new protocols that accommodate and remotely identify each and every "thing" [11]. Hence, it is greatly essential to incorporate cryptography algorithms that can provide high throughput.

B. Identity Management:

Identity management is a field of study which deals with security. It is concerned with giving access to authorized personnel only and it also controls their access to various resources. In the recent days, we come across many incidents where third party sources access unauthorized data and cause trouble in identity management. Such complications are on the rise with the voluminously increasing number of "things" that are being made capable to connect to the internet. Hence, universal authentication is very important. Authorization is another important aspect. If there is no control over who can access data, everything will be accessed by everyone, which is not realistic. Simple in centralized IoT architecture but comparatively difficult in distributed architecture.

C. Privacy:

Privacy aids in maintaining anonymity and individuality of the users or "things". Privacy in IoT is of utmost concern as it is necessary to protect the information of individual "things" or persons from disclosure to the IoT environment. As "things" in IoT disseminate data unrestrictedly, they also function in affiliation with other "things" and interact with them. Interoperability in an IoT network is indispensable because it helps in maintaining concurrency between various elements of the network. [9] The large amount of data the IoT devices can muster is mind-boggling, which gives rise to more and more access points for hackers, leaving sensitive information at stake. As a matter of fact, manufacturers or hackers could utilize a connected device to virtually invade a person's home. All such issues can put a wrong impression in the consumers' minds about connected products, which will hamper the growth of IoT to its true potential.

D. Trust and governance:

Trust and governance are obligatory in order to realize trust between the various entities or "things" and also from the user's point of view. To gain trust from the user, IoT must maintain a trust management system to ensure trust between the user and the system. From the system perspective, governance is crucial

where policies should be contained and where policies vs. control is taken care of. If there isn't a proper trust management system, there is a possibility of breach of confidence between entities or between an entity and a thing. Hence, this is one of the major research challenges.

E. Fault tolerance:

The primary aim of fault tolerance in IoT is to readily adapt with the ever-changing environments and build up trustworthy redundancy. Since billions of devices are now producing and consuming services, IoT will be more prone to attacks [9]. Immensely constrained devices will be the ones that are most liable to attacks and malicious systems might try to pursue control over other devices either directly or in an indirect manner. Thus, due to this, fault tolerance can be a probable issue in scalability.

F. Access control:

Access control permits only accredited users to access various resources of an IoT system. For example, an administrator will have a wider access as compared to traditional users. The emerging IoT technology calls for access control challenges in a singular way because of the low bandwidth between the IoT devices and the internet, low power requirements of IoT devices and also because of the distributed architecture followed in the system. Thus, we must scrutinize the conventional access control methods before incorporating them in IoT. In the future, there will be various IoT systems with different types of architecture. Hence, this might act as a challenge in the near future.

G. Creating knowledge and big data:

Big data and IoT can be expressed as two side of the same coin. IoT receives and compiles data from multitudinous sensors which is then categorized, formulated and utilized to take programmed judgements. Generating data from IoT devices can pose as one of the biggest threats in the future. Devices are designed in a way to serve a particular purpose rather than a variety of applications combined and incorporated into one device. In some situations, rather than using sensors for each and every small application, it is feasible and more suitable to collect information by inference. IoT devices are increasing by leaps and bounds and this means that the data being produced by IoT devices is also reaching a new high. Hence, there can arise a difficulty in managing such myriad amount of data and extracting required information from it. The biggest obstacle that IoT faces is the relevance of obtained data with the actions or behaviour of the user. Hence, the data thus collected might be of no use ultimately. [4]

CONCLUSION

The IOT in the forthcoming years may see a gigantic leap and hence it is necessary to make the systems that are scalable. Scalability has become an important aspect in the consideration of any IOT system which will make the device more efficient and reliable. The device will be adaptable to any changes in the environment and the needs of the people.

In this paper, we have presented the detailed overview study and importance of scalability. The different types of scalability have been shown. The various features that a scalable device should have has been presented in detail accompanied by the various techniques through with the scalability can be achieved. We have also provided the overview of all the issues while many any iot device scalable. A number of research challenges has been identified and examined which are expected to become major research trends in the next coming years.

Through this paper, we have provided a detailed understanding about scalability will help the readers to realize that how important scalability is in any IoT system and how to achieve it.

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