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New Trends in Internet of Things, Applications, Challenges, and Solutions

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Abstract

Internet of things (IoT) refers to an innovation and advance field to introduce a new concept of technologies with various potential advantages. In IoT, different types of diverse smart devices and gadgets with smart communication interfaces are connected with each other and offers the plethora of services in our daily life. IoT has gained attention in all fields of life like e-home, e-commerce, e-health, smart grids, intelligent transportation systems, and e-governance. The objects in IoT increasing preponderance of entities and transform objects into new and real-world objects. In this review paper, we discuss the new trend in IoT, its applications and recent challenges and their solutions. In addition, the paper also elaborates the existing systems, IoT architecture and technical aspects with future trends in the field. This review will be helpful to new researchers to find the existing technologies and challenges in order to continue their research in the field.

Keywords: *internet of things, challenges, technologies, objects, systems*

1. Introduction

Internet of Things (IoT) refers to that technology where different objects or things able to communicate with each other and establish a network system. The devices are integrated with intelligent sensing and transmission capabilities and work for various different applications such as smart parking, intelligent transportation systems, augments maps, logistics, data collection, data collection, smart water supply and smart grid [1-3]. In IoT networks, the devices are controlled by existing communication systems and provide more benefits to the user by making the integration between computer-based systems and physical world. These technologies are offering more promotional, effective, and precise advantages to the users. Different types of devices are available to make the data communication in the network with extraordinary characteristics due to their embedded computational systems. In order to connect these all devices to operate inside the existing internet infrastructure,' IoT is the only choice. Recently, IoT applications offer more advantages in terms of saving user precious time, provide learning opportunities and avail the benefits of existing communication infrastructures. Almost, IoT touches all aspects of our life such as constructing, transportation, home automation, healthcare, and agriculture to wearables [4].

IoT offers an easy platform to access the facilities without any computational and programming complexities because anything is connected inside the network. These applications are more feasible for home line securities and reduce the cost of traditional methods and offer advance and intelligent technologies. The concept of IoT also uses in smart cities, where applications have used for acute lighting, surveillance cameras, cartage control, centralized & chip arrangement ascendancy and more [5]. In addition, the applications of IoT also utilized in smart automation where all systems utilize event grade technologies for automobiles [6].

Transportation is another significant area where IoT proof as an abstraction technology for automobiles [6]. Healthcare is another significant area where IoT proof as an abstraction technology such applications are patient surveillance, drugs tracking and ambulance telemetry. Some other applications have been used in smart industries as wearables [7]. In wearables, IoT applications cover all-inclusive arrangement of accessories that monitor, almanac and accommodate acknowledgment to you or your ambiance like provide entertainment, fitness and

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tracking systems. In addition, in smart industries' IoT applications have been used as an automated IoT. For acute metering, machine-to-machine (M2M) communications, temperature monitoring, calm air superior and acceptable automated automation will become added for IoT.

This review objective is to explore the new trend in the field of IoT and discusses its challenges and solutions. The rest of the paper is organized as follows: Section 2 discusses the IoT and its trends. Section 3 presents the recent challenges in IoT. Section 4 discusses existing solution in the field of IoT. Section 5 presents the discussion on paper. Paper concludes with the future direction in the last section.

2. Internet Of Things

IoT has gained much interest due to its smart and intelligent applications for sensing the data, and make connection among things or devices to provide new services [8]. IoT provides worldwide network of connections which are uniquely addressable such as smartphones, home appliances, vehicles, cameras and other things and objects. In homes, the appliances (refrigerator) trace and further report about its items expire dates and determine the food stock and place an online order to grocery shops [9]. There are various applications based on different technologies which are adapted to acquire and process the information. Radio Frequency Identification (RFID) technology plays a significant role by providing a smart tag equipped with antenna for object identification. Sensor nodes based networks provides data communication in which the RFID tag track objects behavior and measure their parameters. In addition, cloud computing also provides IoT systems to facilitate the networks by providing storage, processing facilities to users. On the other hand, cloud computing may also benefit from IoT and avail services from smart objects [10]. IoT applications have been used in various fields of life such as in transportation, agriculture, smart homes, and smart grids. In transportation, the IoT applications have used for roads, intelligent cars to communicate with traffic control management centers [11]. Figure 1 shows the IoT architecture.

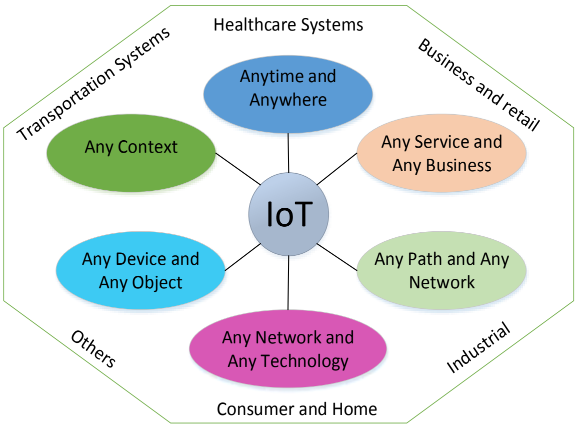

Figure 1. IoT Architecture

Wireless sensor networks (WSNs), Radio Frequency Identity Chip (RFID) technology and M2M communications are some significant technologies to support the diverse IoT applications [12-13]. There are various characteristics related to IoT' some are as follows:

a. There are various different devices have used to establish the IoT networks. These networks are heterogeneous in nature due to diverse technologies. The low power and small devices form a network to minimize the energy consumption.
b. These networks are also resource constrained due to the number of devices in IoT networks. These devices have small memory and processing power and communication capacity. Such examples are RFID, which is limited processing and power to process the data in the network.

c. Another characteristic is the spontaneous interaction of objects where objects move around and enter into other object communication range. Various devices or objects are communicating with each other such as a smartphone contact with a refrigerator or washing machine and generate an event without user interaction.
d. The IoT network also faces network overhead due to multiple events come from thousands of objects. These networks are ultra large scale networks based on conventional networking systems.
e. The IoT networks are highly dynamic in nature where devices are highly mobile and resource constrained. The poor and weak wireless connections degrade the network performance in terms of disconnection and cause of battery drainage.
f. These networks are infrastructure less where ad hoc networks established connections with or without the support of any base station.

3. Challenges

The research on IoT is still under considering stage where various different standards and definitions have not been available. IoT field is very vast in nature where the applications have seen from three different aspects: Internet-oriented applications, things oriented applications and semantic oriented applications. In the context of these aspects, IoT has faced various challenges. The infrastructure of IoT is based on heterogeneous devices where different types of embedded sensor nodes based on low power systems. These devices have limited low-power radius [14]. On the other hand, IoT is not only utilized low-power devices, it is also composed of high capabilities devices to perform routing, processing, and switching. This heterogeneous environment makes IoT is more challenging. Another challenge is resource constrained environment where the embedded sensor nodes have limited processing, memory and communication capabilities such as RFID tags. These devices have limited resources which make IoT applications more challenging.

Spontaneous interaction is another challenge in IoT applications, where sudden interaction can take place when an object moves around and enter into other device communication range which leads to spontaneous interaction [15]. In IoT, the concept of interaction means an event occurs which pushes to the system without much human interaction. Some area in IoT is harsher especially for sensor devices such as in smart grids. In these environments, the sensor nodes based on IEEE 802.15.4 deployed in smart grids have more packet error rates for both line-of-sight (LOS) and non-line-of-sight (NLOS) scenarios. This degradation is because of electromagnetic interference, obstruction, and equipment noise.

4. Solutions

In order to address aforementioned challenges of IoT, various solutions have proposed for data communication. In this section, we discuss the solutions categorically and analyze their technical depth and limitations. The IoT solutions cover a broad range of applications in different fields such as for smart homes, smart grids and transportation systems. In smart grids, various applications deal with electricity management. The electricity management involves three broad aspects including electric generation, transmission, and electric distribution. In addition, smart homes are another significant mainstream research area based on information and communication technologies to control home appliances. In this section, we discuss the in-depth analysis of recent IoT solutions. We discuss the solutions in terms of event-based, agent-based, database oriented and application-oriented domains [16].

The solutions for IoT are highly diverse in terms of its design, models, and architectures such as design approaches based on different databases and event-based approaches. In addition, the implementation domains are also different where these networks are based on WSNs, RFID, and M2M. The existing solutions are different such as some are event-based, agent-based, database oriented and application oriented. In the event-based solutions, the applications, devices and all other network components are based on events. The event-based solutions have large numbers of application entities to produce events. In these solutions, the data communication is based on messages for delivering the events to all users in the networks.

An event-based model known as Hermes proposed in [17], for large-scale distribution application for IoT networks. It is an event or attribute based solution uses for scalable routing and fault tolerance method which can handle different types of failures in the network. This solution has two main components event broken and event clients. This solution is based on different layers including middleware, event, type, attribute, overlay routing and network layer. In middleware, there are several modules based on different functionalities including reliable event-delivery, fault-tolerance, security, transactions, and reliability. This solution does not support mobility constraints and composite events. In addition, this solution also has limited to support the IoT networks.

TinnyDDS solution was proposed by [18], which enables the inter-operability among access networks and sensor-based networks. This solution provides protocol interoperability and programming language standard for data distribution services. This solution also enables the WSN based applications to ensure the control over application and middleware level. The simulation-based results indicated that this solution is lightweight and utilizes less memory. However, this solution does not provide the holistic view of IoT requirements and not supported other key requirements of the network. In addition, this solution also not able to provide the holistic view of IoT adaptation requirements. This type of solution is more feasible for WSN networks.

PRISMA is another resource-oriented solution proposed in [19]. This solution provides a high-level interface for data access. This solution supports the interoperability of IoT networks. This solution has gained much popularity among researchers and developers due to its adaptation features. PRISMA has the three-layer architecture including access, service and application layer. The access layer handles all communication, verification for the quality of services, data acquisition, configuration, and reconfiguration. The discovery of resources is handled in the service layer. The last application layer manages all messages and also responsible for programming abstraction. This solution also adopts a hierarchical WSN networks based on three levels including gateway, the formation of cluster head and sensor nodes in the network. However, this solution causes a bottleneck issue for sink nodes and does not support dynamic and real-time network adaptation. Moreover, this solution is not scalable because it designed for Arduino platform.

Hydra is another middleware service system designed by [20]. This solution is based on different management components including device manager, storage manager, security, and the context manager. These all components are coupled with application and device elements where every element has service, semantic, security and network layer. This solution provides a syntactical and semantic level interoperability. In terms of functional requirements, this solution supports dynamic configuration such as for event, data and resource management. This solution is lightweight due to its optimizing energy consumption policy. The social trust and distributed security components provide trustworthy and secure communication. For security and privacy, this solution uses virtualization mechanism enriched with the semantic method. However, the virtualization method is unsuitable due to channel attacks. In addition, the ontology-based semantic is also not feasible for IoT networks because of unavailability of standard for ontologies, especially for large-scale networks.

Knowledge aware and SOM (KASOM) is another solution based on pervasive embedded networks proposed in [21]. This solution has three main sub-systems including framework, security and knowledge management services. These services provide a pervasive environment through registration, composition, and orchestration of services. These services are based on complex reasoning method and protocols which are based on WSN model. This is also presenting a semantic description of high and low-level resources. Real-time management and in time data delivery is feasible for health care systems where response time is less and data delivery with high reliability. However, this solution does not provide dynamic services especially for mobile and resource-constrained IoT networks. In addition, security solution by using access control mechanism also limited nature.

CHOReOS [22] designed for large-scale heterogeneous IoT networks. This solution addresses the interoperability, scalability, adaptability, mobility issues through discovery and scalable services in the network. This solution has four main components including eXecutable service composition, eXtensible service access, eXtensible service discovery and cloud and grid middleware to manage computational resources. The first service enables the services of things. The second service provides access to services and things. The third service manages the processes and protocols for discovery for services for things. The last service is used for grid and cloud to manage computational resources. This system is based on probabilistic services discovery, look-up protocols and registration to scale well the things in mobility environment. However, these probabilistic services are not feasible and fail to handle real-time support due to insufficient redundancies.

Mobile sensor data processing engine (MOSDEN) [23] provides a service model for IoT networks. In this solution, the plugin architecture provides the scalability and user-friendliness for heterogeneous devices. This solution adds a plugin manager to support and manipulate the plugins. It also replaced the sensor dependent individuals based on GNS to handle communication. It also has a decentralized peer-to-peer architecture. However, this solution is not well for dynamic IoT networks due to its predefined resource and discovery composition mechanism.

Table 1. Solutions and its requirements.

S/No	Solution	Security	Reliability	Scalability	Privacy	Popularity	Real-time	Availability
1	Hermes [17]	×	✓	✓	×	✓	✓	✓
2	TinnyDDS [18]	✓	×	✓	×	✓	✓	✓
3	PRISMA [19]	×	✓	✓	×	✓	✓	✓
4	Hydra [20]	✓	×	✓	✓	✓	✓	×
5	KASOM [21]	✓	✓	✓	×	✓	✓	✓
6	CHOReoS [22]	×	×	✓	✓	✓	×	✓
7	MOSDEN [23]	×	✓	✓	✓	✓	×	✓

5. Discussion

Various solutions have been designed to address the IoT challenges. The existing solutions addressed various different challenges in IoT. IoT networks are heterogeneous in nature where resource discovery and composition is still a challenge. Most recent solutions are designed for WSNs networks and not fully integrated with IoT networks. Resource discovery is one of the significant challenges due to large-scale networks where hybrid and distributed solutions are not working well. Some solutions provide fast discovery options but still not scalable when the number of applications queries exist in the network. The register and discovery methods are not well working in mission-critical applications.

These applications need guaranteed discovery of resources with high accuracy. In this context, there is a need to design a solution to deal these issues for IoT. Resource and data management are the areas which should be improved to enhance the frequent resources conflict and raw data converted with usable knowledge. Event and code management also need improvement where a number of events are generated in the network and cause of bottleneck issues. On the other hand, the code management need reprogram ability for software development.

6. Conclusion

This paper discussed the IoT filed in terms of its technologies, applications, and solutions. Various solutions have been designed to address architecture, availability, reliability, mobility, scalability and security issues. Integration of existing technologies has improved the communication among objects. However, the IoT networks have still faced various challenges which need to improve the quality of services in the field. In this paper, we discussed some solutions and their features in the context of recent challenges and discussed their advantages and limitations. Although the existing solutions address many requirements related to IoT networks some requirements issues remain unexplored such as integration of intelligence, security and privacy, interoperability and system-wide scalability. In Future, we will consider these challenges and discuss their possible solutions.

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