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Internet of Things (IoT): Applications and Challenges in Libraries

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ABSTRACT
Internet of Things (IoT) has emerged as one of the boons in the lives of human beings. There is no area where the internet and its other devices are not used in various functions and applications. Libraries are also no exception to using Internet and Internet of things. This article presents an overview on the Internet of Things (IoT) and its possible applications in libraries along with the challenges and solutions to overcome the problems in using IoT.

KEYWORDS: Internet, Internet of Things, IoT, Libraries.

1. WHAT IS IoT

The term "Internet of Things" (IoT) was first used by Kevin Ashton in a presentation to Proctor & Gamble in 1999 that was a new topic of technical, social, and economic significance. Most people think of it as tying objects to the Internet and using that connection to give them some sort of helpful remote control or monitoring (Chase, 2013). Thus, Internet of Things is a network of real-world items that are linked to the internet and have the ability to speak with one another. Sensors, software, and other technologies are built into Internet of Things devices so they may share data with other systems and devices.

Since IoT uses the internet to connect numerous objects, it is thought to be the most significant and all-encompassing phenomenon of present time. It makes it possible for digital or physical objects or devices that are embedded with sensors, electronics, software, and other types of hardware to act intelligently. It also gives them the ability to gather and share data so they can make decisions on their own, with or without human assistance, using internet connectivity (Alagumalai and Natarajan, 2020).

Real-time communication between users and self-reporting devices is the aim of the Internet of Things. In order to comprehend customer preferences, make necessary adjustments, and send out notifications, IoT devices can gather data from their environment.

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2. DEVELOPMENT OF IoT

J.C.R. Licklider, the head of the Defense Advanced Research Projects Agency (DARPA), in 1962 envisioned a galactic network of an interconnected set of computers. His concept later evolved into the Advanced Research Projects Agency Network (ARPANET) in 1969. By 1980, ARPANET was commercialized for public use, and thus the internet was born.

In 1989, David Nichols and his colleagues at MIT invented the first IoT device, and this was shortly followed by John Romkey and Simon Hackett creating the Internet Toaster in 1991. The Internet toaster was a big milestone, as Romkey and Hackett successfully connected a toaster to the internet and managed to turn it on and off remotely.

Chase (2013) further adds that before the term "Internet" was coined, manufacturers were already connecting devices to the network. By the middle of the 1990s, embedded products were starting to include Web servers. For almost 15 years, modern M2M manufacturers have been incorporating Internet-connected technologies into services like fleet management, alarm systems, and tracking valuable assets. Some of these M2M systems are based on industry standard protocols, although they are difficult to construct. However, when more potent processors are added to the end nodes, integrating M2M systems is becoming simpler. Additionally, these processors allow the platform to utilize intelligent frameworks since they enable high-level operating systems (OSes) and languages. Network operations centers (NOCs) are in charge of these systems, which are usually connected to premium business service layers.

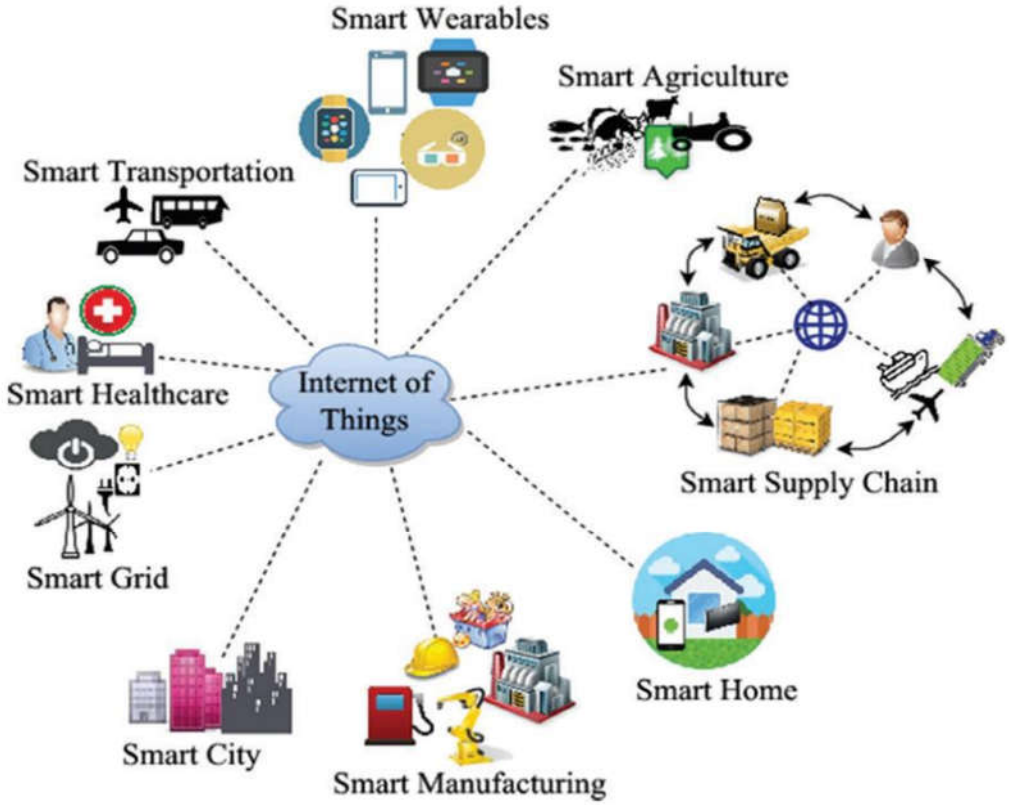

Figure 1: Uses of Internet of Things
(Source: Samaila et al, 2018)

However, a boom in Internet connectivity in both consumer and business markets was seen during 1990s, while its application was still constrained due to the network interconnects poor performance. Many

applications adopted Internet connectivity in the 2000s, and many consumer, business, and industrial items now come with built-in information access features as seen in figure 1. Nonetheless, these gadgets are still largely online objects that need greater human contact and oversight via applications and user interfaces.

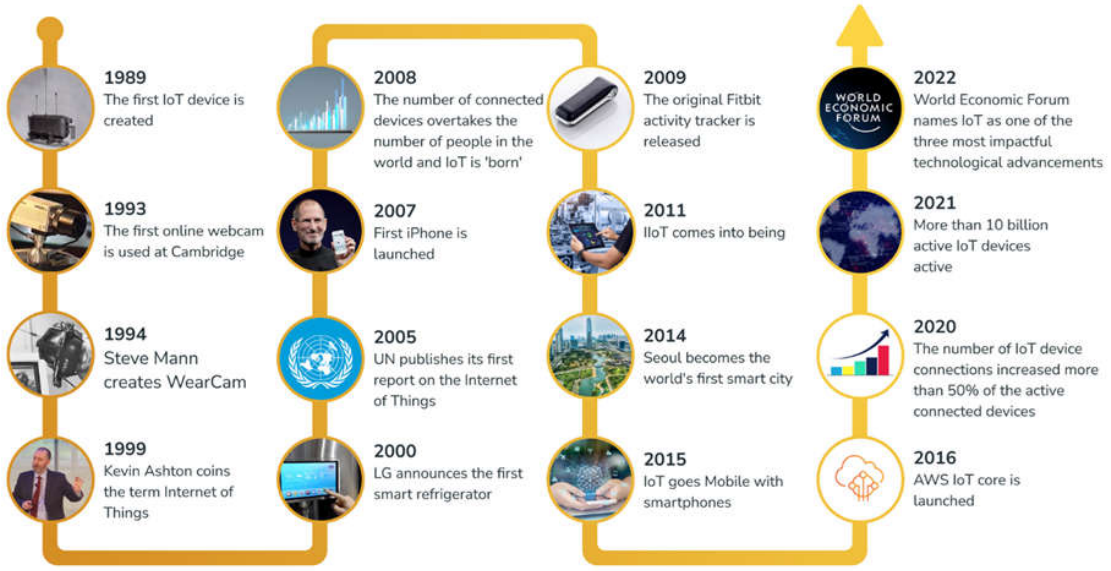

Figure 2: Development of Intenet of Things
(https://bytebeam.io/blog/a-brief-history-of-internet-of-things/)

Further, figure 2 briefs the developmental phases of the IoT over the time very well in pictorial format. But the goal of the Internet of Things is to create self-reporting devices that can communicate with consumers and one another in real time. IoT devices can collect data from their surroundings, evaluate it to ascertain user preferences, make the required corrections, and sound an alarm.

Today's, the thermostat, energy meter, lighting control system, music streaming and control system, remote video streaming box, pool system, irrigation system, and more are already connected by consumers. In order for a user to control these devices using a conventional Web browser or a smartphone app that serves as a personal NOC, the majority of these systems have some connectivity via a website. Figure 3 also depicts the connectivity development that took place with the passage of time for IoT and other things.

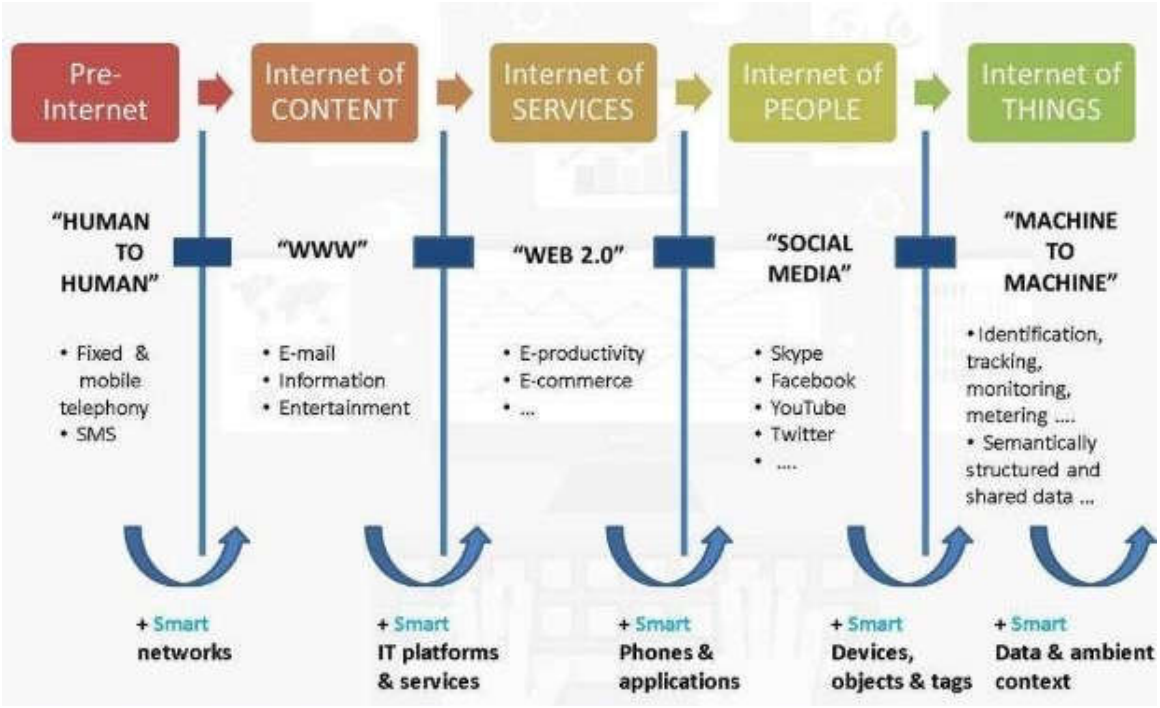

Figure 3: Evolution of IoT
(Dash, Pal and Hegde, 2018)

Further, the popularity of the Internet of Things can be better understood through figure 4 where the pillars show prognosis of worldwide spending on IoT from 2018 to 2024.

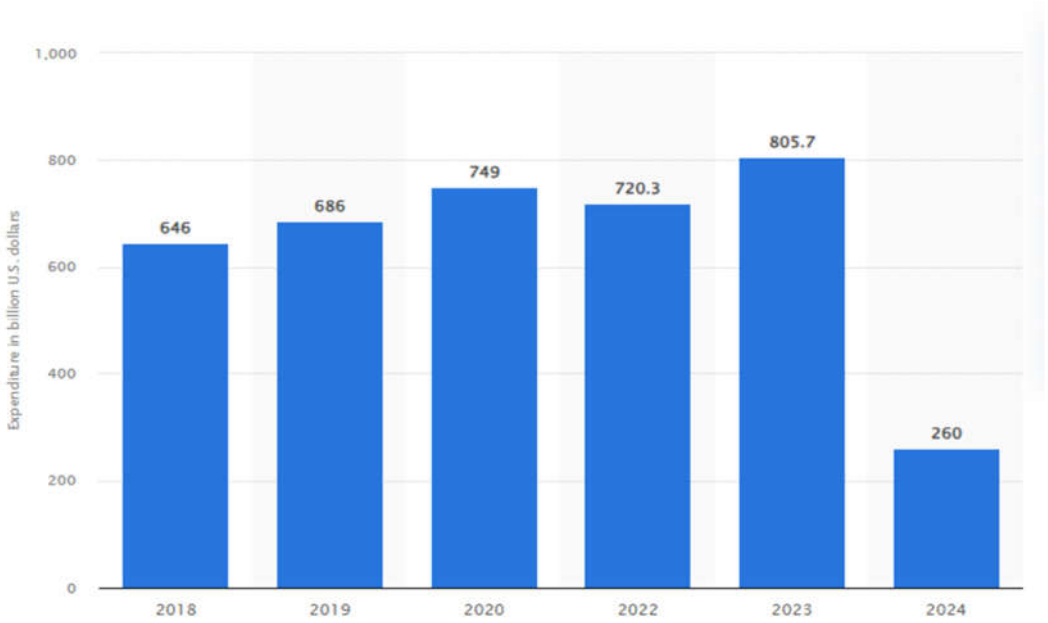

Figure 4: Year by Year Increased Expenditure of IoT Use
(Source: Vailshery, 2024)

3. MODELS OF IoT

In an Internet of Things system, there are a number of models that can be utilized to communicate between the system and a server. However, Publisher-Subscriber, Push-Pull, Exclusive Pair, and Request-Response models are the popular models. The descriptions of each of them is given below (https://www.geeksforgeeks.org/communication-models-in-iot-internet-of-things/ and https://snscourseware.org/snsctnew/ files/1710350183.pdf).

3.1. Request & Response Model

A client-server architecture is used in this model.

- The client asks the server for the information as necessary. The encoded format is often used for this request.
- Due to the independent handling of each request and the lack of data retention between them, this paradigm is stateless.
- The server classifies the request and retrieves the resource representation and data from the database. This information is transformed into a response and sent to the client in an encoded manner. In turn, the response is sent to the client.

However, under the Request-Response communication model, the client makes a request to the server, and the server replies. Upon receiving the request, the server determines how to reply, retrieves the necessary resources and data, produces the response, and then forwards it to the client.

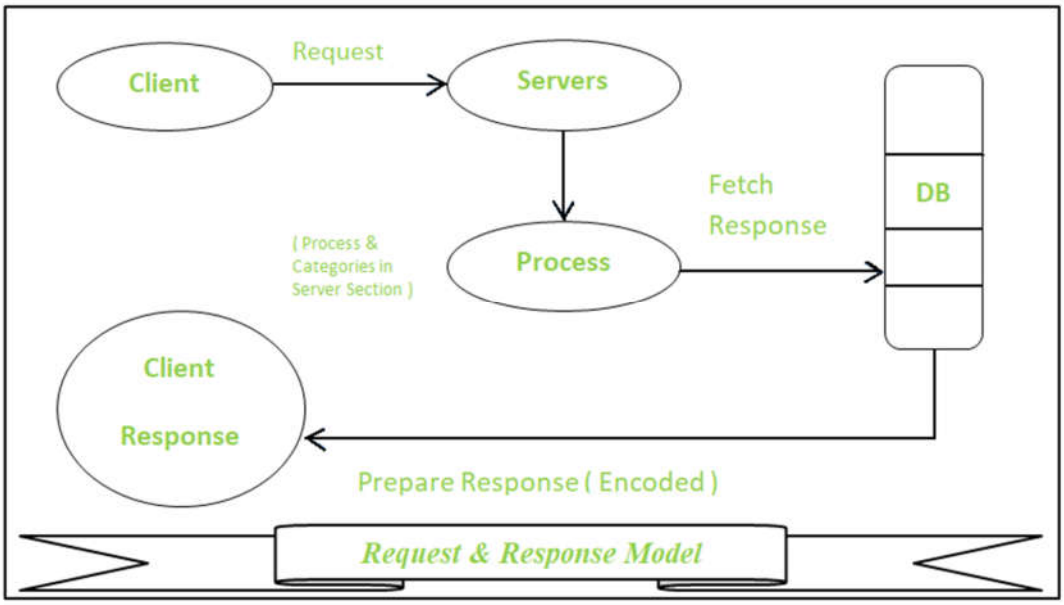

Figure 5: Request & Response Model

Example: When a query on a browser is made then the browser submits an HTTP request to the server and then the server returns a response to the browser (client).

3.2. Publisher-Subscriber Model

Three entities make up this model: publishers, brokers, and the consumers.

- The publishers are the data source. The data are sent to the topic that the broker is in charge of but they have no idea who the customers are.
- The topics that the broker oversees are subscribed to by customers.

Thus, the brokers are responsible for receiving data from publishers and forwarding it to the relevant customers. The broker only possesses consumer information that pertains to a certain topic and that the publisher is not aware of.

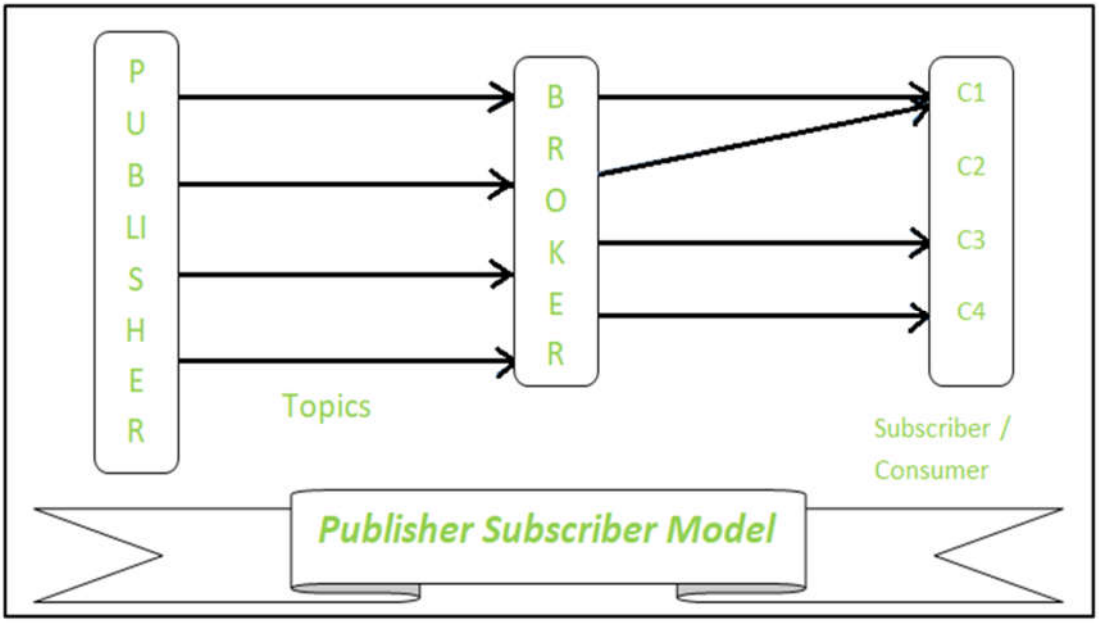

Figure 6: Publisher – Subscriber Model

Example: Email address on the website to sign up for their mailings is used frequently. These email addresses are controlled by third-party services. If a new article is posted on the website, it is sent straight to the broker, who then distributes the updated information or post to all of the subscribers.

3.3. Push-Pull Model

The data queues, data publishers, and data consumers make up the push-pull model.

- Consumers and publishers are not familiar with one another.
- The data or message are published by publishers and added to the queue. The customers, who are on the opposite end of the line, remove the data. When the rate at which data are pushed or pulled by a publisher and a consumer differs, the queue serves as a buffer for the message.

However, the message between the producer and the consumer is decoupled with the aid of queues. In cases when the rate at which consumers draw data and the rate at which producers put data differs, queues also serve as a buffer.

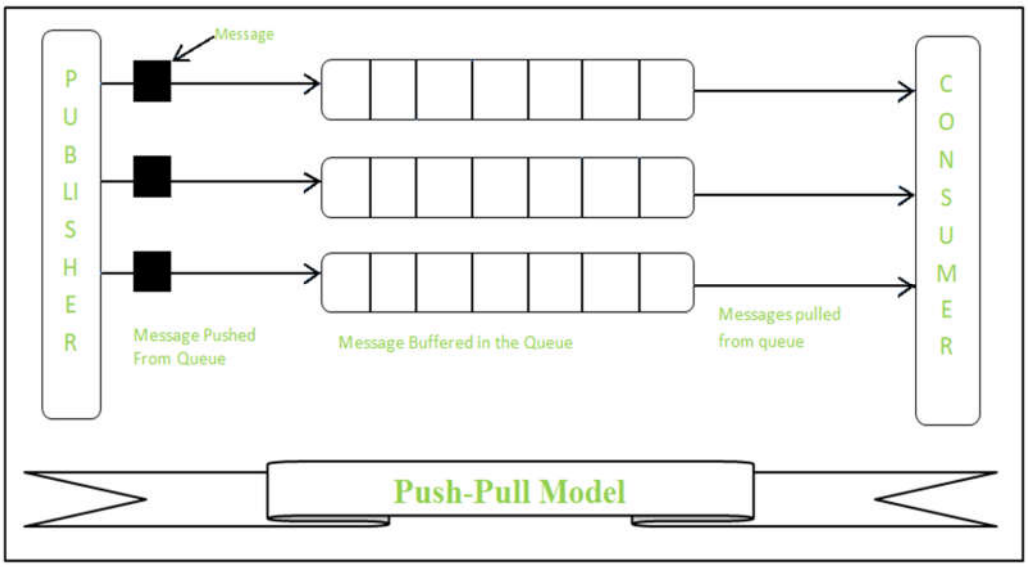

Figure 7: Push-Pull Model

Example: Upon visiting a website, a queue of published posts is presented. Thus, based on the needs, a post is selected and begin reading it.

3.4. Exclusive Pair Model

Exclusive Pair is a bi-directional paradigm that allows full-duplex client-server communication. Until the client requests that the connection be closed, the connection is stable and stays open.

- The server maintains a record of every connection that has been established.
- Since this connection model is state-full, the server is aware of every connection that is open.

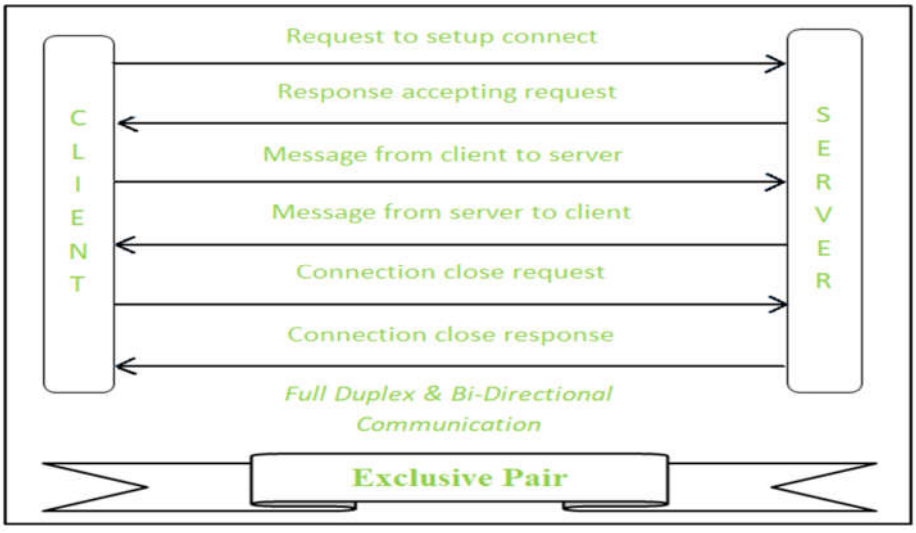

Figure 8: Exclusive Pair Model

Example: The entire foundation of a Web Socket-based communication API is based on this concept.

4. INTERNET OF THINGS IN LIBRARIES

Libraries are just one of the many industries that have seen tremendous breakthroughs because of the Internet of Things (IoT). Although there are many advantages to IoT applications in libraries, it is important to take data privacy concerns into account. Libraries may improve user experience and expedite operations thanks to the Internet of Things. By ensuring ideal conditions for preservation, environmental monitoring with IoT sensors helps safeguard priceless library resources, according to Balram, Ashish, and Pal (2013).

But the IoT applications for libraries are about linking objects or things and enabling data transfer and communication to accomplish a task. As service providers, libraries offer both print and electronic information resources, including books, journals, online databases, and more. Kaba and Ramaiah (2019) mention that the libraries also have facilities and equipment such as computers and printers, study and discussion rooms, tables and chairs, shelves and racks, and more. However, the following are some possible areas where libraries could use IoT (Pujar and Satyanarayana, 2015) and (Kaba and Ramaiah, 2019):

4.1. Access to Library and its Resources

Libraries can provide their patrons with a virtual library card that allows them to access the library and utilize its services through a mobile application. The library app on a user's smartphone will show a map of the library leading them to the resource or resources they need when they enter the catalogue to find them. It may also connect to websites like Amazon to provide more information about a resource, giving the user comprehensive knowledge about it before borrowing it.

4.2. Collection Management

Every item in the library collection has an RFID tag, it may be virtually represented and recognized by computers and RFID scanners. RFID tags can be integrated with member cards to streamline fine collection and item circulation. In order to allow patrons to return overdue books and pay the fine online without having to wait in line at the library circulation desk, the Internet of Things will be able to inform users about overdue books and the amount of fine they owe the library. Smart digital shelves might be able to advertise the content depending on users' Internet search and borrowing histories. It will be simple to find lost books thanks to IoT, which will also aid in improved stock verification.

4.3. Information Literacy

Information literacy or orientation is provided. IoT could assist libraries in offering self-guided virtual tours to inform new users about a library, its resources, and services. Libraries may place beacons, or wireless devices, in different areas of the library. When patrons enter a specific area, a video or audio recording describing the area and how to get the most out of it will play on their mobile device. It might even be possible to offer users an enhanced experience of unique collections, such manuscripts, by delivering them in digital format on their smartphones by giving the limited physical access to such resources.

4.4. Recommendation Services

Using real-time data and the history of the patron's borrowings, IoT can make personalized suggestions. Other resources that might be of interest to the researcher can be suggested when they search a database for materials on the subject of their study. IoT would be able to notify the user about new arrivals in their area of work or about the availability of a borrowed book that they were seeking for during their last visit, even if they are close to the library or come on a subsequent occasion.

4.5. Location-Based Services

Libraries could offer location-based services with the use of IoT. Upon entering the library with an IoT-enabled mobile device, a user who may create a list of their favourite books using their account from home or the office can receive directions to the stacks where their favourite books are kept. They can also be informed about the status of checked-out books and other interesting titles that are available on the subject. By showing the busiest and slowest times for their use on the library's website or through their mobile app, patrons may be able to verify the availability of reading rooms, discussion rooms, printers, scanners, computers, and the other resources.

4.6. Appliance Management

IoT might assist libraries and its patrons in controlling their available appliances more effectively, which would save energy expenses. Although some libraries have implemented such measures, they may expand the authority to include both library employees and patrons. An IoT-enabled smartphone could be used to manage the lighting, air conditioning, Wi-Fi, and other features when a person entered a library and used a cubicle or reading table, are considering examples.

5. CHALLENGES OF IoT IN LIBRARIES

Bradbury (2015) and Greenberg (2015) pointed out that the Internet of Things presents important obstacles that may prevent its full potential. Technical difficulties still exist, and new political, legal, and development issues emerge in addition to the attention-grabbing headlines regarding internet device hacking, surveillance issues, and privacy concerns. The Internet of Things is a complicated subject to comprehend because of this "promise versus risk" debate, the dissemination of information through popular media, and marketing.

Interoperability and data non-availability are the common issues specific to IoT adoption in libraries. However, the deployment and use of technologies cannot be accomplished without a number of hurdles, difficulties, and barriers, even though the Internet of Things has positively contributed to innovations and the transformation of library resources and services. These challenges and hurdles may include financial and administrative difficulties, concerns about privacy and security, and failure and inaccuracy, as are covered below (Kaba and Ramaiah, 2019).

5.1 Challenges of Financial and Administration

The deployment of IoT necessitates significant financial investment to purchase all the equipment required for this new technology. So, it is best to draft an implementation budget before taking any further action. Librarians typically have no trouble coming up with this kind of plan or coming up with original, imaginative ideas but frequently, they are unable to secure decision-makers' and stakeholders' consent to put their ideas into practice. One of the possible causes of those suggestions' rejection is a lack of expertise in persuading decision-makers of the value and advantages of novel concepts.

However, the financial standing of an organization, particularly in the private sector, prevents decision makers from supporting these novel concepts. This is due to the fact that the majority of IoT implementations require significant financial outlays for device acquisition, implementation, and ongoing device maintenance (Bansal et al., 2018).

5.2. Challenges of Security and Privacy

One of the main concerns while using IoT is privacy and security. Connectivity, communication, and data transfer between items are necessary for IoT operation. Consequently, a patron of an IoT-enabled library must enable mobile connectivity. This connectivity is regarded as a privacy violation since it gives library employees access to the contents on the patron's mobile device (Welbourne et al., 2009). However, as IoT technology relies on networking and communication between various things, hackers can easily access user profiles, enable services in the library, and make it accessible to unauthorized users. It is intriguing to learn that the threat posed by hackers is a worldwide occurrence that compromises security in libraries as well as other IoT-enabled service providers, including financial, healthcare, and commercial organizations (Stolpe, 2016; Shim et al., 2017). Regretfully, the threat posed by hackers is predicted to grow as IoT devices get smarter, complicated, and advanced (Makori, 2017).

5.3 Challenges of Inaccuracy and Failure

Any ICT equipment, including Internet of Things systems, is occasionally susceptible to errors and malfunctions brought on by human error or technological issues. Inaccuracy and system failure can be extremely expensive, both monetarily and physically. For example, providing traffic, health care, and feeding systems with erroneous instructions could result in numerous fatalities. As a result, IoT consistency, conformance, and reliability across mobile networks and through to remote control devices are now of greater interest to technology professionals (Abo-Seada, 2019).

6. FUTURE OF IoT IN LIBRARIES

Librarians should be prepared to accept more IoT-enabled gadgets in libraries as more items and things are thought to be IoT-enabled devices in the future (Abo-Seada, 2019). Hahn (2017) asserts that the IoT devices available today are insufficient to comprehend how patrons interact with library resources and services. He thinks that more in-depth information on how physical library rooms are actually used should be available through future IoT devices. Librarians will be able to report space utilization properly and make evidence-based decisions as a result. Upala and Wong (2019) have suggested an Internet of Things method to help with library space management. Without assistance of the librarians, the results and analysis of the suggested IoT solution, according to those writers, will speed up the process of making library rooms available.

Using IoT technology to make library reading tables smart is another potential change. To enable patrons to access library resources and services while reading in the library without getting up from their seat, the smart table ought to be outfitted with Internet of Things technology. For example, users can browse online databases, read e-books, e-journals, e-magazines, e-newspapers, write, draw, and edit documents, and print and scan documents while seated at the smart table for complete account access. Active learning and creativity will be encouraged by the availability of such intelligent facilities. According to Varnum (2017), making an investment in active learning can help the library become a more useful resource for patrons.

The use of IoT in libraries undoubtedly helps with collection management, facilities, equipment, and appliance management, user education and access to library resources and services, despite the fact that there are many obstacles to overcome. Because of this, it helps librarians to make more effective and efficient decisions, improve user happiness, boost staff productivity and performance, and have more productive interactions with the users. Hopefully, the industry can overcome the current issues with current technology to introduce many smarter IoT devices, allowing all libraries to employ them to offer their patrons greater services.

7. CONCLUSION

Thus, it is seen that the libraries have a lot of promises with IOT. If executed properly, it could yield the intended outcomes and enhance the value of library resources and services. In addition to the potential implementation areas listed above, IoT may eventually expand into more library areas and provide data on resource usage, a map showing the most popular library areas, user satisfaction levels, and the times when students become dissatisfied with library resources and return to Google. Though, it is still in its infancy; therefore, it makes sense for librarians to get knowledgeable about this new technology and hold off on implementing it in libraries until it is more widely acknowledged, adopted, and accessible. At the same time, it would be fascinating to pick up tips from early adopters and come up with better strategies to optimize the advantages of IoT adoption in libraries. Since libraries have a history of change, the Internet of Things (IoT) is expected to be the next big thing after the Internet. This will bring about a lot of changes to the library industry, especially in the way that libraries connect and communicate with their users.

It is therefore predicted to change the way a man work, play, and live. The Internet of Things is expected to impact every aspect of our lives, from home appliances and wearable body sensors to industry automation and car connectivity. Wearable technology-based gadgets have also started to be used in libraries for various purposes (Jagdev and Dhiman, 2023). Our lives will be "authored" by the networks that surround us, which are always changing and evolving in response to inputs from other systems and our environment. Our lives will be more environmentally friendly thanks to lighting systems that change according to how much daylight enters through the windows. With wearable technology that can identify heart attacks and strokes before they occur, our lives will be healthier. However, the 2020 Internet of Things is a long way off, but there is no doubt that it will be fantastic, but libraries must anonymize and safeguard the information they gather to preserve user privacy and adhere to data protection laws.

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