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INTERNET OF THINGS (IOT): AN INDISPENSABLE TOOL FOR SMART LIBRARY SERVICES IN NIGERIAN UNIVERSITY

Kudirat Abiola Adegoke (CLN)
Department of Library and Information Science,
Faculty of Education and Extension Services
Usmanu Danfodiyo University, Sokoto
Email: adegoke.kudirat@udusok.edu.ng,
kudrat.abiola@gmail.com

Abstract
With the emergence of the Internet of Things (IoT), many libraries the world over now operate a hybrid system of information delivery. Internet of Things has brought about pragmatic methods of managing library resources and services through the use of more dynamic IoT technologies without human interference. IoT technology being a product of the fourth industrial revolution (4IR) uses sensor to collect and transfer data to an object via the Internet. This paper discussed the concept of IoT, its possible areas of application in Nigerian university library services. It also highlighted the merits of using the IoT technologies, problems that hinder speedy adoption of IoT in Nigerian libraries. The paper concluded by recommending that librarians should learn the new technology from those who have effectively applied it to their library operation and services. The paper also lay emphasis on the need for Nigerian libraries to go into full automation as this will hasten the use of smart library service in Nigerian university libraries.

Keywords: *Internet of Things, ICT, Cloud Computing, University Library, Smart Library Services, Nigeria.*

Introduction

The advancement in technology ranging from high-speed Internet for making communication much easier and seamless to the production of higher capacity and intelligent computing devices is affecting life significantly. It is not only making such developments simplify human life but also making modern technology become a part of people's day to day activity. These days, robots are made to acquire and share data among themselves without human intervention thereby cutting down the resources in terms of time, energy, salaries and wages and many more. The application of such technology affects various aspect of everyday life including but not limited to transportation – where a car alerts its owner whenever there is high traffic or danger ahead and recommends an alternative route to follow. The most alarming type of emerging technology is the Internet of Things. Why the name *Internet of Things?* It is the ability to use the Internet for data collection, processing and disseminating information either from robot to robot or robot to human. The robot-to-robot is also known as "Machine-to-Machine (M2M)" Bayani et al. (2018a).

Hahn (2017) defined IoT as the "network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment" which is in line with the assertion of Xu et al; Olson et al; Li et al; Wojick; Liu et al. as cited in Liang (2018). As a "dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual 'Things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network". In a nutshell, the authors were of the opinion that IoT works with smart technologies through users' intelligent interfaces to interact, sense, process and disseminate information to recipients. Thus, IoT works effectively on a touch-based automation system built with a microcontroller that contain wifi, and inbuilt touch sensing input pins with the capability to sense objects and communicate the

exact information to a compatible machine as received.

In a similar view, IoT has been defined by Nag and Nikam (2016) as

> *The use of intelligently connected devices and systems to obtain data gathered by some embedded sensors, actuators in machines and other physical objects. IoT uses connecting media such as wireless sensor networks and physical objects to connect devices and the Internet, with minimal direct human intervention to deliver services that meet the needs of a wide range of academic library users.*

These days, the application of IoT in various organisations such as manufacturing, health, commercial, logistics etc. has revolutionized the way and speed at which data is collected, processed and disseminated. In service-oriented organisations, IoT is being applied to monitor consumers' activities for effective transactions and service delivery. It is likely to play a bigger role in areas like information creation, processing, analysis, automation, traffic monitoring and security control. For example, it is possible to track the movement of products and monitor the interaction between these products through real-time events and sensor-driven analytics.

IoT has been reported to have been used in the health sector to monitor patient's health status using sensors, it can create and send an alarm to the hospital when the need arises and in the education sector for lectures, training and seminars to be conducted and attended by using interactive displays which are embedded with multi-touch, dry-erase and natural writing technology, plus cloud-based lesson delivery software and personalized for mostly educators and students. Clearly the IoT has changed our traditional way of doing things into a more automated manner for smart library service delivery to our end users using smart technologies. Auto insurance companies can introduce vehicle telematics in some smart cars to enable them to assess the drivers' behaviour and accordingly fix the rate of premium based on the risk factors. The same type of implication can be seen in other types of insurance policies, not depending completely on historical information, thus giving a chance for better risk management. IoT will ultimately enable the industry to minimize loss and introduce safety techniques in each and every type of insurance they sell to the public.

Over the years, apart from the afore-mentioned possible areas of implementation, IoT can be applied to various aspects of library in-house operations such as the generation of statistics on the usage of library resources and services, mapping out the most used sections or resources in the library, determining the satisfaction level of users. The Internet of things can also be used in a smart library in which all the resources, facilities and services are interconnected with one another using IoT technologies for effective service delivery. Thus, for IoT to be adopted in the library, it must be able to merge the physical library resources and facilities with the digital services to produce the sustainable smart library we want.

Smart library service delivery means attractive library service delivery to users' communities. What makes library service attractive? The smartness of any library lies in the ability of the library to interconnect books, related data, digital, space and resources through the Internet for easy and remote access.

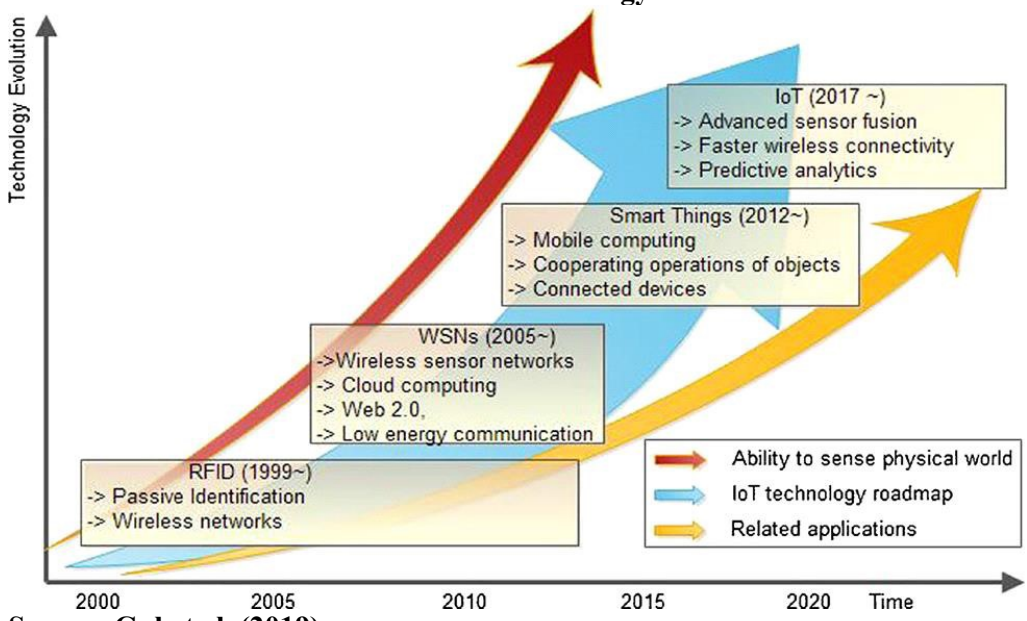
The Concepts of IoT and Technologies

The IoT

The concept of the Internet of Things (IoT) was coined to mean the "Internet" of "Everything" where things could mean a human being walking with a sensor to either monitor the heart performance or general health status of such person, or a motor vehicle using a sophisticated sensor to monitor everything around the vehicle or happenings on the road for effective decision making or it may even be a home placed on surveillance to monitor movements within or around the building or prevent any danger from striking the owners or home itself through the use of smart technologies. The IoT development has over the years gone through several evolutionary stages – the earlier stage which is the first stage used the world wide web (WWW), which is a network of linked HTML for sharing information; the second stage was an advanced version of the WWW which is known as Web 2.0, characterized by the relevant technologies such as social networking site such as LinkedIn, Facebook,

Twitter, blogs, Instagram and delicious, and the third stage which consists of Web 3.0 also known as Semantic Web, which makes the direct communication between machine to machine easy via the Internet. This third stage was responsible for the machine and search engine's intelligence performance which made humans think that machines are intelligent. This stage according to Witmore et al. (2015) has nurtured the IoT which stands as the next evolution of the Internet (Evans, 2011). The trend is moving towards the 5G technologies which is expected to match the needs of the future IoT application (Li, Xu, & Zhao, 2018).

Technology Evolution



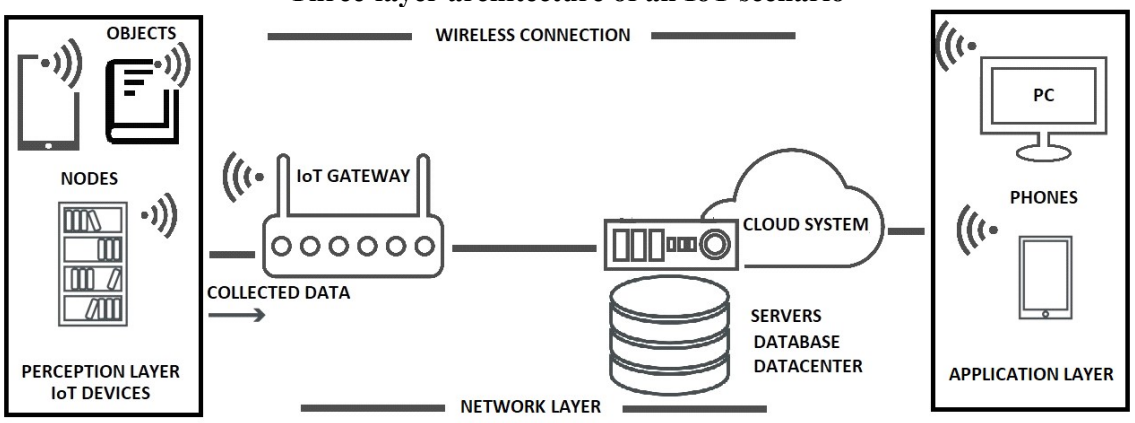
Source: Gul et al. (2019)

Technologies

Thus, no single object can function as a complete system without the support of other components whether in-built or adjunct, so the case of IoT is; for IoT to function as a smart system of service delivery, it needs a set of technology to connect to objects. First and foremost, IoT must have a device for identification which will generate a unique identification code for each object. Then, another device needs to sense the object and measure various aspects of such object. IoT needs another facility to control communication through the Internet or other similar objects. More importantly, there must be a central server where data from all these objects will be collected and analysed by the user of the system.

Amongst such technologies used by IoT to function as a complete system are RFID (Radio Frequency Identification Device), energy harvesting technologies, wireless communication devices (such as Beacons), sensors, cloud computing and advanced Internet protocol (IPv6) (Kudirat & Babalola, 2022). What does RFID do for IoT? It helps to identify and track all data of things, which can sensor, collect and process data to detect the changes in the physical status of an object, energy harvesting technologies help in low energy consumption of associated technologies such as Bluetooth, and the data collected is stored on the cloud for further processing and wireless communication will facilitate communication and interaction between objects to take further course of action.

Three-layer architecture of an IoT scenario



Source: Bayani et al. (2018b)

The authors described the three-layer architecture as follows;

a. The perception layer which is the physical layer includes the sensors (RFID, WSN etc.), the event parameters or the identity existence of the object.
b. The network layer provides Internet connectivity between the objects, network devices, wireless or cable connections, cloud system, database, server system that transmits, and processing of the locally obtained data. It also includes the gateway component to receive the data sensed from the perception layer.
c. The application layer is in charge of providing applications and services to human or non-human users (i.e. Machine to machine case). It can specify various processes, programs, and applications in which the IoT can be positioned as a smart library management system.

IoT in Libraries

According to Qin (2018), IoT can be applied to digital library services and activities. Its application in the library cut across the provision of access to analogue and online collections, consultation, training, information sharing, provision of reference services, and provision of access to space and equipment while its application to activities was viewed in terms of marketing and promotion of library resources; storage; analysis; and selection of record; the gathering of information and processing of information. Bansal et al. (2018) viewed Internet of Things (IoT) in libraries as a mind-boggling association which has inserted constituents connected together and an enormous number of collaborations be it with one man to another or man to machine, machine to man, and with IoT object with object compatibility brings about extraordinary chance. Bayani and Vilchez (2017) listed other services that can be offered by the IoT in digital libraries to include inventory control; theft detection; self-service; book tracking; intelligent alert system; e-copy; smart gate and customer-relationship management (CRM). Similarly, Gupta and Singh (2018) viewed the IoT from the earlier stage of the Internet when the Internet was used in traditional way mainly for browsing and searching for information. It is now utilized in a new dimension - "second life which is called Internet Plus. The word "Internet Plus" was first used by Chinese Prime Minister Li Keqiang in the Government Work Report in March 2015 which has attracted high attention from all walks of life. It is a new concept in which various facets like Mobile Internet, Cloud Computing, Big Data or the Internet of Things are included. "Internet Plus" strategy means integrating the Internet with other industries including traditional industries through Internet platforms and information and communication technologies. It aims at creating a new ecology in new areas". It is believed that IoT is not different from the way cloud computing and big data are used.

Wojcik (2016) developed a theoretical model of IoT application in library service and explored the IoT's potential impact on library services based on the application of IoT in the commercial sector, and proposed that librarians, particularly in academic libraries, can improve library services in innovative ways. IoT can provide more tools and opportunities in sharing information, tracking and

tracing service, and pushing notification service. Massis (2016) explored IoT and its potential impact on the library from the security and privacy points of view and proposed the Security of Things, from security management approaches. Libraries can benefit from IoT in saving staff time, improving patron service, tailored service and recommendation service by collecting real-time data. Pujar and Satyanarayana (2015) posits that IoT as the Internet of things, enables any natural or man-made objects to communicate with each other and transfer data using assigned IP addresses with or without human interventions.

Application of IoT in academic libraries

IoT is an emerging aspect of ICT though still on a trial stage. Libraries still value its potential of value addition towards their service delivery and its ability to enhance library users' experience. Librarians are already familiar with some of its technologies in libraries based on the use of RFID, which does a similar thing of interacting with machines, tags and updates the library management system with entries of books issued to users. However in the case of IoT, the difference is on the Internet's ability to interact with a thing or object such as book and journals with little human intervention. Libraries have books, journals, CDs/DVDs, theses and many more physical objects and IoT can be a blessing in disguise to overcome some of the usual problem of misplacement of objects and their usage (Nag & Nikam, 2016b).

A critical study and application of IoT prove that remote access, low software costs, ease of implementation, in-house support and reduced operating costs, flexibility and adaptability, transparency, global visibility of the library resources and services, ease of use of resources, optimal users' satisfaction, and instantaneous delivery of service and effective utilisation of library resources have been made possible. These and some other benefits of IoT made Bansal et al. (2018b); Bayani and Vilchez (2017) see the technology as an indispensable tool for effective library service delivery. This was corroborated by the proposals of Wang (2011); Yan (2010) that the smart library should be a new model of future library aiming at achieving interconnection, efficiency and convenience through the IoT, cloud computing, and smart devices. Some of the potential areas for implementation of IoT in libraries include but are not limited to the following:

Provision of access to library resources and services

Space and time are becoming worthless in the era of IoT simply because the era is characterised by the Internet of everything where information acquired in the library is made available to users instantly irrespective of the location or state of residence of the patrons. Libraries using a mobile app can create an interface for users to access all the available electronic resources using the Internet, smartphone or touchpad and other relevant technologies such as beacon for easy access.

Provision of smart library security systems

Thesedays, security of life and properties has become individual responsibility; everyone is trying to provide adequate security for himself, business, offices and valuables are secured from unauthorized individuals or groups. This is not different from the way libraries see the security of their personnel, facilities, users and resources, with the advent of IoT, libraries can now secure their facilities and resources with the emerging technologies using the Internet technologies to link their facilities with their handheld devices for easy monitoring and control. Examples of the IoT technologies and their related services provided by the libraries include:

Installation of surveillance camera

Academic libraries can install surveillance cameras using Raspberry pi and a camera to monitor doors, users reading areas, offices and facilities from a smartphone with just a click. Librarians may decide to install surveillance cameras in sensitive areas of the library to remotely monitor everything that happens in those areas through the Internet. For instance, in case of a natural disaster, librarians can alert the security department and request them to expedite action to stop the unforeseen event by opening the library doors from his /her handheld devices irrespective of the location he was at the time of the sad event; with just a touch he/she can use remote control keys to operate their access doors, cars, and systems to prevent unauthorized access to any of their facilities.

Development of facial recognition door

With the new technology, a smart door secures the gateway and ensures that only authorized persons were permitted to enter sensitive areas within the library and its environment. This is an intelligent system made possible by Microsoft API through IoT. For libraries to achieve this, librarians must engage in regular data gathering, training and facial recognition must be taken seriously. Librarians must know Python to code for data gathering; a Raspberry pi camera must be installed for facial detection and recognition training. This, if put in place, it will no doubt strenghten the security of staff offices and other restricted areas of the library popularly tagged as "out of bounds" to all non-library staff.

Development of smart car theft detection

Libraries can build remote control car theft detection that can monitor movement around the car and alert the owner of the car about the unauthorized attempt on the car through their phone. The systems remotely monitor the thief or unauthorized individual around the cars packed within the library premises or parking spaces located outside the library, provided they are connected to the library security control system. The antitheft sensor sends data to the microcontroller, and the microcontroller then makes it a valid signal and moves the camera to take the picture of the intruder, librarians can then see the picture on their phones provided they have installed the App on their phones. The owner can use the remote control to turn or move the car around to prevent theft. This can be made possible through Piezo sensor for movement detection, IoT gecko platform (web-based user interface) and Raspberry Pi microcontroller device.

Design of fire detection alert system

As part of emergency preparedness for the library, IoT based air pollution monitoring system can be designed and used in the library to monitor the different particles present in the air like Sulphur dioxide, carbon dioxide pollen, led and mould spores that may be responsible for air pollution which may later result to fire outbreak or causes diseases in the library environment. The system is capable of detecting flammable gas leaks or smoking through a particle matter detector, and gas/humidity/temperature sensor. Any tick smoke detected around the library will trigger the alarm for a quick emergency response.

Development of IoT-based smart mirror

Libraries as a matter of necessity and recycling can convert all their old LCD or lead monitor television into smart mirrors that can see faces or display real-time, monitor weather and keep notes or tracks of all happenings in the library.

Development of server temperature monitoring system

It is worth knowing that server systems generate a lot of heat when working and by its nature, the system is expected to work round the clock with or without human intervention. There is need to monitor the temperature of the server room to prevent fire outbreak.

Design and implementation of mobile online retrieval system

Libraries using mobile app may provide a virtual library card to their users, which will enable them to gain access to the library facility and use its resources. When a user accesses the library catalogue to locate the required resource(s), the library app stored on his or her mobile phone, will provide a map of the library guiding the user to the location of a resource(s). It can also provide additional information about a resource by connecting to a site such as Amazon, Oakleafbooks and other bookseller websites so that the user has detailed information about the book.

Design of books reservation platform

One of the beauties of the IoT is that a library user can search for a book of his/her choice from the library OPAC through the Internet using his/her smartphone and reserve the book. Then, at that point, the ideal book, accessible in the rack of the library, which is empowered with sensors through the organisation can show a signal or may begin blazing light. This way the actual book will distinguish its area for identification; there will be no need to search through the books on the library shelves searching for the books again. With this alert, the librarian on duty recognizes the book and hands it over to the library officer who will process the book for reservation. With online reservation using the Internet of Things, time and effort is saved from both the user and the library.

Design of IoT-based circulation management system

Library collection with RFID tags on each of the library collection enables their virtual representation, which can be identified using computers and RFID tag readers. Through the integration of RFID tags into member cards, circulation of library material and fine collection can be streamlined. The IoT can tell users about overdue books and how much fine they owe the library, to enable them to return the overdue book and pay the fine online without coming to queue at the library circulation desk for payment.

Provision of inventory control system

Libraries have various other information resources apart from books, journals and magazines. They include microfiche, video, and audio which can also be controlled by fixing sensors on them. With IoT, since the web is included; it gives all the necessary information on the portability of the curator/supervisor and subsequently, better stock control is conceivable. This helps the library to spend less time and effort on stock confirmation. IoT will also help in better inventory management (stock verification) as it will be easy to locate misplaced books.

Introduction of smart digital shelve system

Smart digital shelves may be able to promote the contents based on users' borrowing records and search history. They can also track the movement of the available resources within and outside the library. IoT through its application, allows its users not just to have a virtual visit to the library through their cell phones, but also to keep and track the accessibility of books notwithstanding their geographical location.

Provision of users' orientation system

Information literacy or orientation is offered to fresh users of the library to educate them about the library, its resources and services. IoT may help libraries by providing a self-guided virtual tour of the library. Libraries have set up beacons like wireless devices at various sections of the library; when users visit a particular section, their mobile phone will play a video or audio explaining more about that section and how one can get the maximum benefit out of it. It may even provide an enriched experience of special collections such as manuscripts by providing the digital format of it on their mobile phones as physical access to such resources is always restricted.

Provision of selective dissemination of information services

IoT can use patron's data to suggest selected recommendations, using real-time data, based on the history of their borrowings and activities. When a researcher is searching a database for resources on topic/s of his or her interest, it may suggest other resources, which would be of interest to such users. Even when a user visits the library next time or is close to the library, IoT would be able to inform the user about new arrivals in his or her area of interest or about the availability of a book on loan, which he or she was looking for during his/her earlier visit.

Provision of current awareness services

IoT can provide library users with location-based services. When users create their favourite list on the library catalogue using their account from home or office and walk into the library with IoT-enabled mobile devices, they will be able to get directions for stacks, where favourite books have been shelved. It will also help them to know interesting titles available in their subject area and the status of checked out books. It may also enable libraries to provide the status of availability of reading rooms, discussion rooms, printers, scanners and computers by displaying the peak and non-peak hours of their usage on the library website or users can check it using their library mobile app (Pujar & Satyanarayana, 2016).

Merits of using IoT applications in academic libraries

Cost-saving:

Librarians provide general access for their numerous users through only one subscription platform instead of purchasing many copies of the physical materials for all users. Staff and students do not need to carry heavy books around or buy books and journals for their personal use as the library resources are accessible on their smart devices.

Timeliness

Distance and time have no adverse effect on library service delivery due to smart technologies and services introduced in libraries in some developed countries. Librarians can now monitor

and operate remotely without being physically present in the library; users access and use library resources anywhere they are and visitors see library holdings for effective decision making.

Effective service delivery and global visibility of libraries

With the adoption of IoTs, libraries can now deliver services according to world best practices. Having smart libraries can be possible if libraries automate and interconnect all their physical and digital resources on one platform and provide Internet access to sustain the visibility of those resources.

Conclusion

There is no doubt, that technological advancement has brought about a pragmatic approach to how libraries and information centres generate, process, store and disseminate information. IoT has numerous features that can be used to enhance library service delivery if properly hsrnessed. It may bring effectiveness and efficiency as a value addition to library and information resources and services. The librarians should learn this new technology from those that have effectively applied it to their operations and services to know its pros and cons. Despite the enormous benefits of IoT, the full adoption of the IoT may be a little different in the case of Nigerian libraries since many of these libraries are not fully automated and those automated are still battling with sustainability and maintenance issues. For this to take full shape, all arms of government in Nigeria must support the efforts of the libraries to collectively navigate the digital terrain towards having the desired Smart libraries in the country.

Recommendations

IoT in libraries may turn library buildings into smart buildings but they need to plan ahead by putting into consideration some important issues such as policy, finance, technical know-how, maintenance and above all users' interests. The paper recommends the following:

- Libraries must use information seclusion methods to secure users' data and privacy.
- Libraries should make adequate planning and budgeting before deploying IoT technologies for proper management and sustainability.
- Libraries should give the necessary attention to staff capacity building for effective service delivery and maximum productivity.
- Librarians must update their skills in terms of software and system development; maintenance and configuration.
- Library security personnel must be retrained to make them more productive in the smart environment.
- Library users must be trained on how to effectively utilise library resources from different locations.
- To have smart libraries that we dreamt of, librarians must think outside the box, develop good maintenance culture, up-skill the human resource, and up-scale and re-tool their respective libraries.
- The library should endeavour to install energy designed with an efficient algorithm for the IoT system to function for long hours.

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