ISSN PRINT 2319 1775 Online 2320 7876

Research paper Journal Volume 11,Iss 12, 2022

Exploring The Management Of Mobility And Heterogeneity In Various Internet Of Things Frameworks

Dr.Sanjay Asutkar
Professor and Head of Department
Electronics and Communication Engineering
Tulsiramji Gaikwad patil College of Engineering & Technology
asutkarsanjay1600@gmail.com,sanjay.ece@tgpcet.com

Abstract: The continued advancement of wireless technology resulted in the enhancement of capacities and capabilities of mobile networks. There was a gradual improvement from the earlier networks which were based on analog switching and offered voice only services with several limitations of quality, capacity, and coverage to the modern digital networks offering great coverage and capacities to connect billions of users and devices while providing a wide range of services. The arrival of new technologies like Long Term Evolution- Advanced (LTE-A) and Fifth Generation (5G) has ushered in revolutionary improvements in terms of data rates, bandwidth, and latency, number of connected devices, network availability, and coverage. The new focus area is the Internet of Things (IoT), Internet of Everything (IoE) ecosystem where billions of mobile nodes, devices, sensors, and other information gathering instruments are connected through a combination of networks using different kinds of technologies. IoT is giving a new meaning to communications and information technology. New applications of IoT in the most diverse areas are emerging at a very rapid pace and it is expected to witness exponential growth in the near future. Some of the application areas where IoT has been successfully implemented include smart cities, smart transport, energy management, healthcare systems, environment monitoring systems, smart monitoring and control in industries.

Keywords: wireless, Internet of Things (IoT), Internet of Everything (IoE), Fifth Generation (5G), smart cities, smart transport, energy management, healthcare systems

Introduction

The invention and growth of the internet have brought very fundamental changes to society and it has completely changed the way we live and function. Internet is used for our everyday communication needs, almost in everything we do like ordering food, doing shopping, keeping ourselves entertained by watching a movie or playing online games, keeping ourselves updated on current affairs and news. It has become almost necessary for us to be connected to the internet to do the very basic day-to-day tasks. In the last two decades of the 20th century, the scope of the Internet widened and it grew exponentially and became the largest computer network in the world comprising thousands of sub-networks and millions of users. The emergence of social media and mass communication tools in the first decade of the 21st century contributed further to the popularity of the internet. The advent of the Internet of Things (IoT) has taken the application and importance of the internet to altogether a different level. IoT is giving a new meaning to communications and information technology. IoT is a network of physical 'things' which communicate with each other. IoT comprises billions of connected components like sensors, various types of instruments and actuators, etc., supporting a vast number of applications[1][2]. New applications of IoT are emerging at a very rapid pace and it is expected to witness exponential growth in the near future. Implementation of IoT in the field of healthcare enables real-time monitoring collection of critical data of medical patients. Parallel to the growth and expansion of the internet, there has been a continuous evolution of wireless communication network technologies that enabled us to always stay connected through mobile devices, without the capability of mobile connectivity such a spectacular growth of the internet and related applications would not have been possible. The continued advancement of wireless technology resulted in the enhancement of capacities and capabilities of mobile networks, the modern digital wireless networks of today connect billions of users and devices while providing a wide range of services like high-quality voice and video calling, high-speed data, high definition video streaming, advanced multimedia applications, high-resolution 3D and real-time interactive gaming, live navigation support, and countless other applications[3]. The arrival of new technologies like LTE-A and 5G has ushered in revolutionary improvements in terms of higher data rates and bandwidth, negligible latency, number of connected devices, high availability, and greater coverage. As the next-generation wireless networks are focused on massive IoT ecosystems and mission-critical communication applications, it becomes imperative to provide for seamless connectivity with minimal delay. Another important requirement is to protect the user privacy and security of personal data. In other words, a mobile node needs to be Always Best Connected (ABC) whether it is stationary or on move without compromising on security. Heterogeneous wireless networks (HWN) are based on the integration of various kinds of networks supported by different technologies, all of the constituent networks in an HWN combine to provide vast coverage and immense capacities to connect billions of users and devices. HWN needs to be dynamic in order to fulfill the connectivity and capacity requirements of new technologies and diverse applications of IoT. Seamless connectivity and Quality of Service (QoS) based on the specific needs of the mobile user or device needs to be ensured at all times in order to support such a vast variety of applications with different needs in terms of bandwidth, data rates, latency. When a mobile node roams in an HWN environment, it is imperative to ensure that it is always connected to the most reliable network available that is capable of catering to the needs of the application running on the mobile node[5][6]. Hence our focus is on developing a robust handoff mechanism capable of providing efficient and secure handoff and reliable authentication to provide seamless connectivity, QoS, and security in the HWN environment.

Fifth Generation of Mobile Communications (5G)

5G works on Orthogonal Frequency Division Multiplexing (OFDM) principles and 5G uses 5G New Radio (NR) air interface. 5G uses shorter frequencies and wider bandwidth technologies. Smart 5G Core Network enables 5G technology to cleverly use network slicing where slices of the network are customized for explicit purposes and act as independent networks while making optimal use of available resources. In addition to revolutionary improvements in terms of higher data rates (up to 10 Gbps), negligible latency (1 millisecond), greater bandwidth, a greater number of connected devices, high availability, a big reduction in network energy usage, greater coverage the 5G technology is focused on massive IoT ecosystem and mission-critical communications applications where networks cater to the communication needs of billions of connected devices.

Mobility Management

With the development of generations of networks and with IoT and IoE coming up rapidly [5], mobility of devices connected to the internet becomes a vital feature, thus mobility management plays an important role in wireless communications. Mobility management is the fundamental technology based on which next-generation wireless networks are being established [6]. The necessity of having seamless connectivity for various advanced services like real-time services (including video streaming and voice data) or non-real-time services (like web browsing and email) has made mobility management an important aspect of wireless communications. Therefore, the basic structure of mobility management should include sport for all kinds of mobility for a variety of real-time as well as non-real-time applications while the user is mobile. As the next-generation wireless networks are focused on massive IoT ecosystem and mission-critical communication applications where networks cater to the communication needs of billions of connected devices, it becomes vital to provide for seamless connectivity with minimal delay when the user is moving within the same or different administrative domain of a heterogeneous wireless network. Mobility management consists of all those functions that are sustained by a wireless network to facilitate subscriber mobility. In other words, mobility management helps the network to track of the mobile node's status and its location to deliver messages or calls. Mobility management is a blend of two related functions- location management and handoff management[6].

Location Management

Location management deals with identifying the location of the mobile node so as to direct or deliver calls/data to that mobile node. It is a two-stage process. In the first stage, location updating or registration is done by the mobile node by updating the network about its new access point and revising the user’s location profile[7]. The next stage is known as call delivery. The network checks the mobile node’s location profile and locates the mobile host with respect to its current location. Many studies are being conducted on architecture, protocols, and various issues related to location management[8].

Handoff Management

Handoff or handover management is related to the mobile node’s connectivity while it is moving and changing its access point in the network. It is a three-stage process. In general, a handoff is a process of changing the network connection while the mobile node is moving and a call is in progress. This research work is based on handoff management which will be elaborated on here forth.[9]

ISSN PRINT 2319 1775 Online 2320 7876

 Journal Volume 11,Iss 12, 2022

Handoff Initiation or Decision Information Gathering Phase

In this phase, the handoff is initiated after the evaluation as and when required. Parametric information for certain parameters like RSS, power consumption, user preferences, and network load, link speed and bandwidth, etc. is gathered. Also, information about the available networks and the user is collected and evaluated. Information about available networks consists of QoS-specific information like available bandwidth and latency and network information like security level, RSS, and load[10]. Mobile device information like battery power level and speed of the mobile device and user-related information like user preferences and service requirements is also collected. These collected parameters form the basis for deciding the need for a handover and once the handover is triggered all of the vital information is forwarded to the handover decision system[11]

As the next generation wireless networks are focused on massive IoT environments and mission-critical communication applications, it becomes imperative to provide seamless connectivity with minimal delay when the user is moving within the same or different administrative domain of a heterogeneous wireless network. Another important requirement is to protect the user privacy and security of personal data[12]. In other words, a mobile node needs to be Always Best Connected (ABC) whether it is stationary or on move without compromising on security. A handoff mechanism capable of providing efficient and secure handoff and reliable authentication is required to provide seamless connectivity, Quality of Service (QoS), and security in the Heterogeneous Wireless Networks (HWN) environment. HWN is basically formed by the integration of various types of networks that are not only based on different technologies but also differ in terms of parameters like bandwidth, reliability security, and latency, etc. It is a challenge to provide seamless and uninterrupted connectivity while ensuring user privacy and security in such a diverse environment. In order to cater to the needs of mobility management in the HWN environment, the Handoff Optimization using Priority Ranking (HOPR) algorithm is proposed. The HOPR algorithm works in three phases[13].

In the first phase of HOPR, parameter selection is done by using an expert's opinion. Six parameters namely Received Signal Strength Indicator (RSSI), bandwidth, delay, packet loss, bit error rate, and line cost, are selected for this proposed work. It is ensured that the parameters are selected from all the three categories- Network related, Terminal or Mobile related and User related parameters. After the parameters are finalized, priority ranking for each parameter is done with respect to each traffic class i.e., voice, video, best effort, and background. Thereafter, Multi-Criteria Decision Making (MCDM) techniques namely Fuzzy Analytic Hierarchy Process (FAHP) and Entropy are used for weight calculation[14]. Keeping in view, the vast variety of applications a user or mobile node uses these days, each calculation is done for various traffic classes. For a proficient mobility management framework, the best suitable network needs to be selected from a pool of candidate networks.

Ranking of candidate networks Wireless Fidelity (Wi-Fi), Worldwide Interoperability for Microwave Access (WiMAX), LTE-A is done in phase-II of HOPR using Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Fuzzy Technique for Order Preference

ISSN PRINT 2319 1775 Online 2320 7876

Research paper© 2012 IJFANS. All Rights Reserved, Journal Volume 11,Iss 12, 2022

by Similarity to Ideal Solution (FTOPSIS) MCDM ranking methods. Due consideration and importance are given to the network and user security before the execution of handoff in the proposed handoff authentication protocol. This protocol establishes a secure connection between the mobile node and access point by executing mutual authentication through the authentication server. Performance analysis is done to prove the efficiency of the proposed algorithm. Diverse types of applications such as video streaming, voice calls, multimedia gaming, etc., are considered in various types of networks and practical scenarios[15].

The Internet of Things (IoT) is a transformative paradigm that connects a vast array of devices and sensors, enabling them to communicate and share information seamlessly. This interconnected network of physical devices, vehicles, buildings, and other objects is designed to collect and exchange data. One of the key challenges in managing IoT ecosystems is dealing with the mobility and heterogeneity of devices within these frameworks.

Mobility in IoT:

Mobility refers to the capability of devices to move within the IoT network. This includes mobile devices such as smartphones, wearables, and even vehicles. Managing mobility is crucial in scenarios where devices are constantly changing their location, creating dynamic and ever-evolving networks.

Challenges: Addressing issues like handovers, seamless connectivity, and efficient routing becomes vital in a mobile IoT environment.

Heterogeneity in IoT:

Heterogeneity in IoT encompasses the diversity of devices, protocols, communication technologies, and data formats within the network. IoT ecosystems involve a wide range of devices with varying capabilities, power constraints, and communication protocols.

Challenges: Interoperability, data standardization, and ensuring seamless communication between heterogeneous devices are significant challenges in managing IoT systems.

Frameworks for Managing Mobility and Heterogeneity:

Several frameworks and protocols have been developed to address the challenges posed by mobility and heterogeneity in IoT. Some notable examples include:

MQTT (Message Queuing Telemetry Transport): A lightweight and efficient messaging protocol that supports real-time communication among devices, accommodating heterogeneous devices with different capabilities.

CoAP (Constrained Application Protocol): Designed for resource-constrained devices, CoAP enables efficient communication and is well-suited for IoT applications with diverse devices.

5G Networks: The advent of 5G technology introduces capabilities such as low-latency communication and high data rates, addressing some challenges associated with mobility in IoT.

Edge Computing: By bringing computation closer to the devices, edge computing helps in reducing latency and efficiently managing data generated by heterogeneous IoT devices.

Security and Privacy Concerns:

ISSN PRINT 2319 1775 Online 2320 7876

Research paper© 2012 IJFANS. All Rights Reserved, Journal Volume 11,Iss 12, 2022

Mobility and heterogeneity introduce new security and privacy challenges in IoT. Ensuring secure communication, data integrity, and privacy protection become critical aspects of IoT frameworks.

There has been unprecedented growth in the wireless networks and range of services provided by them in recent times, there has also been a continuous evolution in network technologies aimed at achieving higher speeds, security, reliability, and quality of service. The arrival of Next Generation Networks (NGN's) have revolutionized wireless data and multimedia services and work is being done at a rapid pace to enhance the performance of fifth-generation (5G) networks for better Quality of Service (QoS) and Quality of Experience (QoE). Integration of heterogeneous networks is a must to achieve the objective of providing the best quality of services to a mobile user without delay or disruptions. On the other hand, the birth of the Internet of Things (IoT) has created not only a ubiquitous and heterogeneous environment to work upon but also deal with challenges like mobility management and reliability[16][17][18]

Mobility Management in IoT

The Internet of Things is a network of connected devices with unique identifiers in the form of an IP address that have embedded technologies or are equipped with technologies that enable them to sense, gather data and communicate about the environment in which they reside. The integration of various platforms and technologies has paved way for IoT for various applications like Smart homes, smart healthcare, smart transportation, etc. leading to the birth of Smart cities. But with the advent of smart cities issues like reliable mobility management have come into the picture. In IoT, most of the objects are mobile and therefore require a mobility management protocol for maintaining IP mobility. Also, the users carrying mobile gadgets like cell phones, laptops or smartphones, etc. want to remain connected to the network services all the time while they are on the move (i.e. moving from one network to another). In order to provide the mobile users uninterrupted services or to track the signaling from moving objects, there is a need for mobility management schemes.[19]

Issues and Challenges

The paradigm shift in wireless technologies and IoT scenarios has led the researchers to focus more on mobility management so as to ensure reliable and seamless connectivity to IoT applications. Researchers are coming up with enhanced models of mobility management framework but still continuous and result-oriented studies are needed for a better IoT world. Many issues and challenges are faced and a number of challenges are coming up in the said field. A few of the challenges are:

➢ Access to multimedia applications: With the evolution of NGNs, services, and applications have changed very rapidly. User applications require real-time data and this imposes the challenge of delivery of data to be on time. Thus, this indicates that work should be focussed on factors like throughput, delay, etc. Multi-criteria need to be assigned weight according to their priority or requirement in the environment

ISSN PRINT 2319 1775 Online 2320 7876

Mobile user's profile prediction: It is important to study the system behaviour and generalize the situation which can exist during user movement. Decisions are being made on the basis of incomplete or partial information available. Many researchers have not considered velocity, direction, throughput, etc. for making handoff decisions which suffer from plenty of limitations. As the node is mobile most of the time, thus it becomes necessary to consider mobility-based parameters to provide the optimum solution for providing QoS and QoE in the heterogeneous environment accurately, seamlessly, and well-timed[20].

➢ Providing Network Intelligence: A number of the algorithms have failed to provide intelligent information. Also, considering real-time traffic there has been very little focusing on Network Intelligence. This may result in congestion and thereby resulting in loss of data. Therefore, there is a need to find a solution for efficient handoff decision making that helps in unfolding the hidden information. Techniques like fuzzy logic, artificial neural networks, and genetic algorithms are the generalized mechanism of Network Intelligence.

➢ Providing priority multi-criteria based decision making: The current research has been based on equal priority and mobile priority which significantly degrades the network performance in terms of call blocking and the number of handovers. Providing priority based multi criteria's on the basis of the application running on mobile and user preferences can improve the average blocking probability.

➢ Providing seamless communication between various applications: It is difficult to provide a seamless flow of information between various applications like desktop, business, and mobile applications. Standing at the verge of ambiance intelligent smart cities, seamless communication is the main issue. Therefore, work has to be done to provide a seamless mobility framework for the IoT environment.

➢ Providing security and reliability to secure user's information: In today's scenario when IoT is being propelled highly by the technology, every node is communicating with almost every other node. During this communication, lots of information or messages are exchanged which may contain user's or network's crucial data. So it becomes the need of the hour to work on techniques that help in maintaining the security and reliability of the information being exchanged or stored

➢ Focussing on traffic classes: The up-gradation of technology and ease of availability of the resources like mobile devices, the internet, and multimedia applications has taken the usage of services to next level. Nowadays, every mobile device user runs multiple kinds of applications and believes in multi-tasking as well. While playing a multimedia game, it is common for the kids to stay on voice call as well or while watching a video, the user might be downloading emails as well. During the execution of these kinds of applications, the user expects the best QoS and QoE as well. Thus, it becomes essential for the mobility management framework to take into consideration the type of service being used or traffic class being used by the mobile node at the time of handoff.

ISSN PRINT 2319 1775 Online 2320 7876
 Journal Volume 11,Iss 12, 2022

Mobility Management Based on Application Aware Handoff Decision Making

When the world is moving onto the "world of the internet of things", it becomes necessary to check the reliability of the connection node. When a mobile node moves into an HWN with an IoT environment, the handoff performed should be reliable and authenticated. This chapter elaborates on the reliable and efficient framework developed for such an environment. The framework consists of two sections – Priority Ranking based parameter selection for weight elicitation and efficient network selection with reliable handoff authentication protocol for an IoT environment. For over a decade, researchers have been working on developing an efficient algorithm for network selection. Techniques like user-centric based, fuzzy logic based, Markov process based decision, game theory based decision, etc. have been used in these studies [21]. In this framework, MCDM techniques have been employed to find out the best network from the candidate networks and then perform a handoff. Further, an authentication protocol has been designed to make the handoff more reliable and secure.

(1). Priority Ranking of the Parameters The proposed work is based on multiple parameters chosen through a blended approach. As already stated, various types of traffic classes have been used for the study. The requirement of each traffic class (w.r.t. the parameters) varies in an HWN for e.g., for a voice call good signal strength has to be prioritized over other parameters like bandwidth or bit error rate. On the contrary, for a video traffic class bandwidth should be given a higher priority over the rest of the parametric. To make this proposed work a multi-parametric study and to choose the right parameters, a blended approach of expert opinion survey and literature review has been used. Around fifty experts from the field of wireless networks were asked to rank the parameters on the basis of a questionnaire. Then parametric priority ranking has been combined with the reviewed iterative outcomes to finalize the selected parameters.

(2). Working on all the four traffic classes From the exhaustive literature survey, it has been found that only a few studies have considered all the four traffic classes. The proposed work uses all the four traffic classes namely voice, background, video, and best effort for the network selection. The usage of traffic classes for the study not only helps in enhancing the work done by previous researches but also improves the efficiency of the algorithm for network selection as the it will be based on the type of application a mobile node is using.

(3). Fuzzy and Non-Fuzzy MCDM techniques used MCDM techniques like Entropy, FAHP, TOPSIS, and FTOPSIS have been chosen for an efficient network selection. A mobile node travels in different kinds of the heterogeneous wireless network. It becomes imperative to consider the fuzzy or vague values of the network parameters in such an environment. Thus, the proposed work ranks various networks by using both non-fuzzy as well as fuzzy MCDM techniques. For calculation of the weights of the selected criteria, Entropy, a non-fuzzy method, and FAHP, a fuzzy method – have been used. These weights are later used by TOPSIS, a non-fuzzy ranking method, and FTOPSIS, a fuzzy ranking method to rank a network.

(4). Parameters chosen from the three parametric categories A heterogeneous wireless environment has multiple parameters on the basis of which a handoff can be triggered. These parameters are divided into three categories namelynetwork-based parameters, mobile-based

 Journal Volume 11,Iss 12, 2022

parameters, and user-based parameters. Literature survey shows that all the studies which use multiple parameters have a limited number of parameters and these studies rarely concentrated on choosing the parameters from all these three categories. The proposed work has selected six parameters with at least one parameter from each of the three categories. Such a selection helps in improving the reliability of the handoff process.

(5). Reliability checks while performing handoff An IoT healthcare environment has been chosen as a case study (Chapter 6). The handoff performed by the mobile node while moving in an IoT healthcare environment is supposed to be reliable and secure. To ensure this, a suitable handoff authentication protocol has been proposed while connecting to the best network selected by the MCDM techniques used. The literature reviewed so far indicates that very few of the studies have used such network selection techniques along with the reliable handoff authentication protocol.

(6). Different performance evaluators chosen The comparative analysis done for the literature review shows that only a few studies have worked on multiple performance evaluators like ping-pong rate and a number of handoffs while ignoring call blocking probability. The proposed work includes call blocking probability as a major performance evaluator for the results obtained from both fuzzy and non-fuzzy techniques used.

With the growing integration of heterogeneous wireless environments with IoT devices, IoT has found its application in almost every walk of life like automobiles, industries, home automation, healthcare services , etc. The heterogeneity of the wireless networks in which these applications are working, calls for handoff procedure whenever the mobile node, which is using IoT devices, moves from one network to another. Further, these HWN are openly accessible to intruders which may be internet operators, peer nodes, or even third-party technologies. Such an intrusion may lead to a security breach of user's data leading to the illegitimate use of user's data as well as the exploitation of QoS appreciated by the authorized user's. This demands a reliable and authenticated handoff mechanism in an IoT environment. A handoff authentication model typically has three main entities: Mobile Nodes (MNs), Access Points (APs), and the Authentication Server (AS) . In general, MN is a registered user of AS, who has the right to use its subscribed services through a connection to any AP. An AP acts as a patron for assuring an MN as an authentic subscriber. As the MN moves out of the network area of the current AP (e.g. APc), it tries to establish a connection to a new AP (e.g. APn) as shown in figure 1. The APn will initiate the handoff authentication process to recognize the MN. Once the authentication is successful, a session key is created between the MN and APn to verify the MN's later access. Else, the request to access the network will be rejected by APn.

ISSN PRINT 2319 1775 Online 2320 7876

 Journal Volume 11,Iss 12, 2022

Figure 1: Handoff Authentication for IoT

Conclusion

To address our research issues, this section focuses on the findings of our research to draw a conclusion. With the findings of this research, reliable and secure handoff decision making can be practiced. Choosing a suitable network and performing handoff authentication can help any mobile node to transfer information or use an application with continuous, uninterrupted, and secure connectivity. A variety of applications (like multimedia applications) and environments (like IoT and IoE) are being used or coming up, giving rise to demands related to wireless networks, devices, and techniques to handle various challenges related to them. The intent of this research work is to provide a systematic methodology to provide a reliable framework which deals with issues related to handoff in mobility management and providing a secure handoff authentication protocol before the execution of handoff while a user roams around in an IoT environment. The objectives are prioritized during the initiation of this thesis to make scientific and strategic movements during our studies.

References

[1]N. R. Council., The Evolution of Untethered Communications. The National Academies Press. https://doi.org/10.17226/5968., 1997.

[2] "Evolution of wireless technologies 1G to 5G in mobile communication - RF Page." [Online]. Available: https://www.rfpage.com/evolution-of-wirelesstechnologies-1g-to-5g-in-mobile-communication/.

[3] Mobile Communication, C. Concept, N. American, and A. Cellular, "Cellular Communications " The International Engineering Consortium, pp. 1–23.

[4] T. S. Rappaport, The Cellular Concept —System Design Fundamentals. 2001.

ISSN PRINT 2319 1775 Online 2320 7876

 Journal Volume 11,Iss 12, 2022

[5] D. J. Langley, J. van Doorn, Irene C. L. Ng, S. Stieglitz, A. Lazovik, and A. Boonstra, "The Internet of Everything: Smart things and their impact on business models," Journal of Business Research, vol. no. 122, pp. 853–863, 2021.

[6] J. Z. Sun and J. Sauvola, "Mobility and mobility management: A conceptual framework," Proceedings 10th IEEE International Conference on Networks (ICON 2002), Towards Network Superiority, pp. 205–210, 2002.

[7] A. Ahmed, M. Boulahia, and D. Ga, "Enabling Vertical Handover Decisions in Heterogeneous Wireless Networks : A State-of-the-Art and A Classification," IEEE Communications Surveys & Tutorials, 16(2), pp. 1–36, 2013.

[8] R. Deb, M. Islam, J. Uddin, and K. R. Islam, "Performance Improvement of Seamless Vertical Handover in Heterogeneous Wireless Network," The 2nd International Conference on Machine Learning and Computer Science (IMLCS'2013), pp. 21–25, 2013.

[9] K. C. Foong, C. T. Chee, and L. S. Wei, "Adaptive network fuzzy inference system (ANFIS) handoff algorithm," International Conference on Future Computer and Communication Proceedings, ICFCC 2009, vol. 1, no. 2, pp. 195–198, 2009

[10] B. R. Chandavarkar and G. R. M. Reddy, "Survey paper: Mobility 186 management in heterogeneous wireless networks," Procedia Engineering, vol. 30, no. 2011, pp. 113–123, 2012.

[11] M. Kassar, B. Kervella, and G. Pujolle, "An overview of vertical handover decision strategies in heterogeneous wireless networks," Elsevier Comput. Commun., vol. 31, no. 10, pp. 2607–2620, 2008.

[12] A. Kammoun and N. Tabbane, "Fuzzy Utility Decisional Vertical Handover Algorithm For Enhancing Network Performances," 5th International Conference on Multimedia Computing and Systems (ICMCS), 2016, pp. 337- 343, 2016.

[13] J. Marrquez-Barja, C. T. Calafate, J. C. Cano, and P. Manzoni, "An overview of vertical handover techniques: Algorithms, protocols and tools," Computer Communications, vol. 34, no. 8, pp. 985–997, 2011.

[14] N. S. Yan Xiaohuan, Ahmet . Y, "A survey of vertical handover decision algorithms in fourth generation heterogeneous wireless networks," Elsevier Computer Networks 54, pp. 1848–1863, 2010.

[15] M. Drissi, M. Oumsis, and D. Aboutajdine, "A Multi-Criteria Decision Framework for network selection over LTE and WLAN," Engineering Applications of Artificial Intelligence, vol. 66, no. February, pp. 113–127, 2017.

[16] R. K. Goyal, S. Kaushal, and A. K. Sangaiah, "The utility based non-linear fuzzy AHP optimization model for network selection in heterogeneous wireless networks," Applied Soft Computing, vol. 67, pp. 800–811, 2018.

[17] Kevin Asthon, "That ' Internet of Things ' Thing," RFID Journal, p. 4986, 2010. [18] P. Brous, M. Janssen, and P. Herder, "The dual effects of the Internet of Things (IoT): A systematic review of the benefits and risks of IoT adoption by organizations," International Journal of Information Management, vol. 51, p. 101952, 2020.

[18] S. Kumar, P. Tiwari, and M. Zymbler, "Internet of Things is a revolutionary approach for future technology enhancement: a review," Journal of Big Data, 187 vol. 6, no. 1, 2019.

[19] Z. K. Zhang, M. C. Y. Cho, C. W. Wang, C. W. Hsu, C. K. Chen, and S. Shieh, "IoT security: Ongoing challenges and research opportunities," IEEE 7th International Conference on Service-Oriented Computing and Applications Proceedings, pp. 230–234, 2014

[20] M. Zekri, B. Jouaber, and D. Zeghlache, "A review on mobility management and vertical handover solutions over heterogeneous wireless networks," Computer Communications, vol. 35, no. 17, pp. 2055–2068, 2012.