ISSN 2278-3091
Volume 9, No.1.3, 2020
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse1291.32020.pdf
https://doi.org/10.30534/ijatcse/2020/1291.32020

Latency Issues in Internet of Things: A Review of Literature and Solution

Mohd Tamizan Abu Bakar[1], Azrul Amri Jamal[2]
[1]University College TATI, Malaysia, tamizan@tatiuc.edu.my
[2]Universiti Sultan Zainal Abidin, Malaysia

ABSTRACT

Currently the issues of latency in resource discovery is still being analyzed and verified. This paper offers a comparison of studies and solutions on the latency issues of the Internet of Things (IoT) in the resources discovery. The purpose is to review resources discovery in terms of how latency could be minimize or remove properly with different IoT solution. We compared and reviewed all latency related literature and solution of the IoT, categorizing all 32 research papers and related commercial results in two different comparison tables. Through this, we are able to provide a general view of the categories of latency, main objectives of the research, techniques, finding and solutions. It has also revealed any trends, gaps and opportunities for how the current IoT issues should be tackled when engaging with the IoT latency problems. Finally we hope this review can provides insight result for every IoT latency sources, suggesting suitable and relevance approaches that can be used to ensure a stable IoT resources discovery in future.

Key words: Internet of Things (IoT), Latency, Network Delay, Network Design, Resource Discovery.

1. INTRODUCTION

There are many definitions of Internet of Things (IoT) in literature by different researchers. Basically IoT is the fastest expending technologies all around us. With the development of Wireless Sensor Network (WSN), Radio Frequency Identification (RFID),cellular lines, Wi-Fi, Li-fi, sensor, Global Positioning System Satellite Network (GPS), Long-Range Wireless (LoRa) and other related techniques, IoT has been widely applied in many applications successfully and plays [1]. IoT helps individuals connect things to improve the quality of life. It also helps organizations and industries improve resource management to become more efficient. The IoT is helping industries, public and private sector organizations to increase operations efficiency. Academies and industries are now increasingly deploying IoT new solutions. Several innovation ideas have already appeared including narrow-band IoT (NB-IoT) [2]. However, this rapid increase in growth has resulted issues of latency, security and new IoT challenges including how to combine the millions of IoT devices from different vendors using specialized applications and how to integrate new things into the existing network infrastructure [3].

According to Cisco System, in three years from now the IoT is expected to become a huge industry with more than 26 billion interconnected devices. Increased number of IoT appliances in daily networking environment results with huge data to manage in the big data area. Of course these traffics make many new IoT devices, applications, protocols, standard, architectures and models are being developed. The fog computing idea was introduced as a bridge between IoT and the cloud [4]. As summarized in Fig. 1, IoT can be divided into two different categories namely Industrial IoT and Massive IoT. Fog Computing is one of the new paradigms of cloud computing that brings several concepts of cloud services to the edge network environment to support it usage [5-9].

2. CHALENGES IN IoT

Today, IoT is the fastest growing technology around us because of the development of communication technologies such as RFID, WSN, LoRa, Wi-Fi, ZigBee, NFC, BLE, LTE, and SigFox. IoT devices are now entering the market using its own data transfer technique. Each of these communication technologies has its own unique and distinct advantages. Some researcher ideas have emerged including the NB-IoT and also the latest high-speed mobile IoTs such as 4G LTE and 5G. However, this rapid increase also introduces new IoT latency, security and challenges especially when it involves IIoT.

Challenges to IoT can be simplified into three different situations. First, the integration of IoT devices from different vendors each using different custom made applications, second the integration new IoT devices to the existing network infrastructure, and third the security of new IoT devices with varying levels of security configured. However, the rapid IoT growth has introduced new challenges, including platform selection matters. IoT platforms provide various capabilities in all environments. Various platforms in network communication will provide several options for IIoT to customize existing technologies with their features. We look forward to LoRa as the best option to support IIoT as some of the factors proposed by previous researchers [10, 11].

Until now, selecting the right IoT platform is the most challenging process for a company. These challenges include how to communicate millions of IoT devices from different vendors and how to integrate new thousands of IoT appliances into current network infrastructure. Selecting the right IoT platform for a given field of application is quiet challenging especially when selection from the mess of different platforms for massive IoT [12].

The implementation of IoT in cloud or fog computing is a difficult task when many parameters are required. IoT mobile cloud and fog research contributions are still limited but can provide a comprehensive overview of the IoT development including the status of the research related areas and help to settle uncover potential and importance research issues, including latency issues in IoT.

There are three IoT domains for long term research including infrastructure, nomadic users and digital economy, so a model for resilience IoT system was proposed to achieve research understanding in dependability, reliability, integrity, ability to fault-tolerant and availability of the IoTsystem [13]. All of the domain and objectives in the domain guiding us to face all challenges with different categories as below:

2.1 Latency in IoT

Network latency issues in IoT will happen when signal cannot be detected, but causes a delay in cloud environment. Many research papers already seem to have discussed the fundamental question of how much IoT network latency leak the information. For sure it is depends on network topologies such as latency in a star topology would leak no information about host’s location and make much noise into the network [20].

2.2 Bottlenecks (Delay) in IoT Technology

Emerging applications that require ultra-low latencies can introduce new challenges beyond just latency requirements. Consider the application of manufacturing, which consists of thousands of sensors deployed within a factory. In such environments, even guaranteeing connectivity can be difficult. Moreover, many sensors are deployed in harsh environments that are highly reflective and absorptive in signal propagation, such as within a metal pipe or inside an injection molding machine. Finally, as nodes are not necessarily connected to power supplies, they need to be ultra-low-power, and may need to harvest energy from environments. This makes low-power communication a necessity in many cases. Also, local control and safety services come with high reliability and regular service requirements, in addition to ultra-low delays [42].

2.3 Efficient IoT Sensing

Today's sensing system has resulted in a large amount of sensor data beyond normal processing capabilities. But a new challenge for both academic research and industrial research are collecting, managing, and processing large IoT sensing data within an acceptable timeframe. When using the real-world IoT applications, the requirements of large size packets, extreme hassle, and high sensor data will bring new technical activities including resource discovery and real-time data managements (such as data collection, data storage, data organization, data analysis, and data publishing)[43] [47].

2.4 IoT Robustness

A robust IoT communication is a critical need for cyber-physical systems and applications. It is important for this application to have practical solutions to use multiple network interfaces, whether homogeneous or heterogeneous with the hope that the lost message probability can be reduced dramatically. Such configurations can be found in many recent application scenarios such as railway control systems, power grid control systems, and any emergency transmission systems [44].

2.5 Energy Efficiency of IoT Equipment

The energy efficiency of IoT equipment has been a growing concern for academic and industrial researchers. All parties are aware that there are many advantages of using green energy, but the disadvantages of the energy source are that energy conversion rates are low and closely related to current weather conditions, so they can be regarded as a very volatile energy generator [45].

2.6 Security Issues

IoT requires security, privacy and trust to ensure its credibility. Unsecured IoT risks or less secure may lead to problems such as unauthorized access, personal information disclosure, leakage of privacy data and data corruption. To date, IoT's safety has been gaining the attention of researchers and they continue to find new efficient techniques to expand. IoT securities issues can be categorized into five situations, confidentiality and authentication, access control, privacy, RFID security and secure routing. For sure, when increasing security issues will definitely increase latency [46].

2.7 Emergence of Software Defined Network (SDN)

The main challenge for Fog Computing is a flexible network architecture design which can be created through the paradigm of SDN. SDN is a new network approach aimed at segregating, designing, implementing and managing the network control plane. It will offer a new concepts of network control functionalities based on network abstraction and OTT are getting bigger and bigger bandwidth usage. [48].

3. LATENCY ISSUES IN IOT

Latency or also known as one-way delay refers to the amount of time for data to move from one point to one direction [50]. Level of latency can be identified with passive or active measurements [51]. As well as data usage in the other field, IoT data is collected from a variety of sources, whether wired or wireless networks like devices, sensors, and services. The IoT data from the various connected things are generated as data streams because the IoT data either structured or unstructured must be organized using the best real time resource discovering method. Refer to the idea of [53] the implementation of Breadth-First Search Technique (BFS) by implementing additional alpha multipliers, shows that it is an example of the most discovery methods and can increase its performances if any suitable element were added to the discovery processes.

Currently, there is an emergence of latency-sensitive and high-volume data in IoT applications, e.g., in the area of robotics, smart hospital, healthcare, smart city, smart vehicles, smart factory, agriculture industries or Industrial Internet of Things (IIoT). Such applications can be categorized as high-volume IoT and have strict latency requirements. The overall latency that goes directly between the two devices within the same network consists of four individual latencies. First; the software latency of the application, second; the software latency in the network application codes or networking stack, third; the hardware latency on media (wire or wireless), and forth; the hardware latency in network devices (access points, gateways, routers, switches, etc).

Hardware latency is relatively invariant or constant, but conversely, latency produced by software is very varied and thus difficult to measure in directly. However, the latency of the software introduced is important for sensitive-latency applications, especially point-to-point latency is the same as the total to all latencies between the two IoT nodes [24].Here, we try to evaluate the implementation of IoT latency, technology bottleneck and some of SDN solutions. Each solutions proposed was experimentally examine its latency performance for service composition in different fields especially in ubiquitous computing. The ability of IoT appliances to support high embeddedness and mobility are critical features for ubiquitous computing. To simplify the latency issue of ubiquitous computing in the IoT area, we should highlight the problem background in Figure 2.

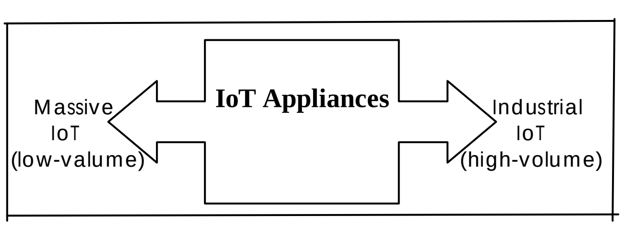

Figure 1: Categories of Basic IoT [4].

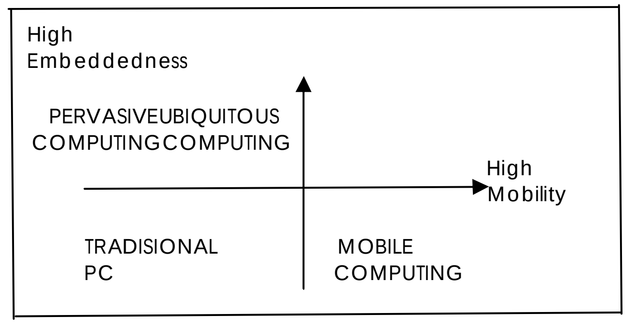

Figure 2: Relationship of Computing System Categories [24]

4. IOT LATENCY SOLUTIONS REVIEW

In this paper, we will discuss the findings in terms of solution either model, prototype or simulation for recovery the latency issues. Here we filtered 22 solutions (research paper 14 to 35) proposed to be reviewed. As a result, table 1 shows the comparison between several research papers in IoT latency solutions. In addition, we also reviewed IoT new products general products, especially in terms of IoT solutions such as QuickTalk - An Association-Free Communication Method for IoT [36], iCarMa - Inexpensive Cardiac Arrhythmia Management [37], Where's The Bear [38] - Automating Wildlife Image Processing Using IoT and Edge Cloud Systems, ParkMaster [39] - low-cost crowdsourcing architecture for evaluate parking availability in cities, Hadoop-Based Intelligent Care System (HICS) - healthcare system applications [40], and Secure Mobile Edge for Hajj [41].

Table 1: Comparison between IoT latency solutions

Research Paper	Objective	Solution
[14]	To propose a new mashup model, known as the IoT mashup that acts as the composition of the IoT source.	Using the Big IoT service which is part of the big data services where the results are used to be explained in turn as a managed integration of various types of data services.
[15]	To perform latency-aware techniques with the goal of resizing the size of packets transmission depending on the packet's incoming rate.	Using special latency-aware software approach for performing packet resizing process with it objective to suite with low-power embedded platforms.
[16]	To reduce overall network traffic and minimizes latency with moving the	The results showed this approach uses virtual resources in the mix of some permission-based block chains to provide

	components of IoT from the cloud onto simpler and faster edge hosts.	IoT services on the edge hosts, for example using the software that IoT components are defined in the form of virtual IoT sources.
[17]	To propose a new modular architecture for the mobile host that is meet compliant and fulfill the architecture of LTE system requirements.	The results proved the advantages of implementing the mobile host in the distributed network with content caching case can reduce level of delay and improve respond time more than 90%.
[18]	To produce low latency VR/AR because of VR/AR is latency sensitive. The experiment results in application of round-trip latency in the IoT network should be short and less than 20 ms inside VR/AR to make sure its best quality in vision movements.	The results showed the Field Of View (FOV) in VR/AR 360° video streaming is required in performing solution at the edge of a mobile network are to optimize the performance of network bandwidth and solve the latency issues.
[19]	To propose a methodology that can arrange server management concept to minimize latency and maximize server utilization.	Both of short latency and very high server utilization can be achieved by using this methodology based on different peak loads for different cells.
[20]	To design low-latency anonymity schemes and at the same time provide protection to the network by observing malicious servers capable of acting as local hackers who are able to see latency of connection networks created via the Tor circuit.	The results showed it can help to reduce the respond time based on average RTT circuit, prevent some of the latency-based attacks, and improve low-latency anonymity schemes efficiency using Tor path selection with latency-aware algorithm.
[21]	To do experiment for semantic reasoning at edge nodes by performing latency and scalability analysis in smart city scenarios.	Experimental results show that edge reasoning can reduce the usage of network bandwidth and reduce the level of latency.
[22]	To measure the level of the latency between Tor nodes especially from a point of view that uses Ting techniques.	The results showed that Ting technique is accurate. The measurements are stable over time, latency data sets that allow Ting to be used in different ways, including faster methods to modify Tor's circuit and efficient long circuit with low point-to-point latency.
[23]	To propose service abstraction framework named as ACACIA, which enables to perform CI applications on edge clouds in mobile networks.	When compared with existing cloud and mobile solutions, results of this implementation shows that ACACIA holistic approach provides a 70% reduction of the application latency level.
[24]	To solve the critical issue of latency in the usage of wakeup receiver (WuRx). This approach is widely used when the remote sensor receivers need to be constant or often to meet latency requirements.	The results showed that it can be produced very attractive for short-range latency-critical IoT application while maintaining low latency outputs and concurrently it worked properly using fully-integrated wakeup receiver.
[25]	To propose a new latency solution at the gateway node named as reply-cache mechanism.	The results showed the improvement of latency management in E2E is around 78.37% and delay arrangement at the gateway node within 41.17% of energy savings.
[26]	To propose a new solution based on dynamic resource reservation scheme using an air-interface slice in arrangement large number of	The results showed that it can achieve the main objectives to reduce the latency rate of air-interface and the drop packets. Their objectives can be achieved using the right

	sensors to support emergency flow in cellular networks.	scheme that allows ultralow latency flow to be transported securely by guaranteed radio link connections.
[27]	To propose an approach to estimate the latency of computer networking software in each individual device without the use of specific and precise hardware to estimate latency in the networking software, bases on a rounded time measurement between multiple devices.	Not using special hardware, the results show the approach offers best results in terms of scalability if the time in latency distribution latency can be assumed. Otherwise, the determination of latency is impossible.
[28]	To prove the evidence of how by using wake-up radios we can abate the data latency imposed by Low Power Listening (LPL) dramatically.	The results showed all parameters that operating at a different frequency than the main radio were investigated including the use of wake-up radios additional low-cost and ultra-low power radios.
[29]	To produce an approach for effective monitoring of the 5G mobile network software defined using an IoT-based framework.	To results showed a framework that gives much better implementation to monitor the mobile network operators system for utilizing the MQTT a unified IoT protocol which is light, data-agnostic, and interoperable.
[30]	To evaluate level of latency in a native-IP wireless communication network for building automation (BA) system with real experimental.	The results showed that the default CoAP retransmission timeout (RTO) is not optimal will degrades the performance of latency and leads to a "Stair Effect".
[31]	To propose a new protocol translator for the IoT that will aim at the inspections of Internet protocol-based	The result shows that the proposed protocol is not a middleware and has its own advantages ie; no design time dependency, transparent, low

	communication protocols to be met the IoT protocol inter-operability, security, and transparency.	latency, secured through authorization and authentication, and used on-demand protocols.
[32]	To use an approach that extends extensively current IoT protocol to support channel aggregation, to ensure low latency service for critical tasks within the IoT network and to improve data transmission rates for critical tasks via simultaneous multiple deliveries.	The results show that the chosen approach reduces the latency of critical tasks is better than traditional approaches and perform optimum relay configurations that minimize the uploaded latency can be obtained within polynomial time.
[33]	To solve problems depends on cloud computing by using distributed cloud service concepts or mobile edge computing in 5G networks due to the communication latency related to physical location of the cloud server away from mobile users	The results show that permissive has good performance while tight systems become degraded when it includes latency of controller communications in the system, but the underestimation system that selects the destination with the lowest latency policies will result in some errors.
[34]	To investigate the model of MAC latency based on mathematical queue theory for MAC slotted superframe structure and to study level of simplicity the software tools based on packet ranking simulation results.	The results indicate that the proposed method can reduce the MAC access latency while meet up the packet generation rates, the number of nodes in the network, and the packet length of each node.
[35]	To measure latency rate for real time IoT appliances and	The result shows that the mechanical scan antenna improves overall system latency

	quality of internet access based on the performance metrics such as scanning rate of the mechanically and electronically steered antennas.	due to the time of sliding needed to change the antenna position from one satellite to another.

5.THE IMPORTANCE OF IOT LATENCY SOLUTIONS

One of the main targets for 5G is to enable IoT critical latency applications. [52]. In the future, we believe that the existence of an IoT environment that requires a small or short period latency will increase. In short, this paper filtered the latency issues in transferring data from the various area of studies from hardware to software. One of the added values of this paper is to consider any missing latency scenario to be evaluated in the future of IoT experiments. As a benchmark, the communication roundtrip latency of industrial IoT applications can be less than 300 ms between countries in the different continents and less than 50 ms between countries in the same continent [49]. For example, some ideas that are widespread in the wired network environment seem to be reasonable to measure the network bandwidth delays. Someone can add a timestamp for each packet before it is being shipped and subtract receipt from delivery time or using Time Trip Round (RTT) probe packet divided by two as a one-way counting. If any timestamps can be added in one pack directly before it is being sent, this method allows us to determine packet delays to be smooth and correct without contingency overhead. [51-54]. To see large variation changes will be highlighted, table 2 shows that every solutions can be classified into four categories of findings, and specifically in the result they are grouped into different types of latency.

Table 2: Area of Studies and Issues to be Further Explored

Group of Research	Finding	Result
[14] [16] [17] [18]	Solve latency issues using application or SDN components.	The edge processing technology produce is suitable to determine the software latency in the network application code or networking stack.
[21] [23] [24] [26] [28] [35]	Solve latency issues using new architecture (hardware/sensor) or prototype.	Several enables processing technologies suitable to determine the hardware latency on media.
[15] [19] [20] [22] [25] [27] [32] [33] [34]	Solve latency issues using latency-aware algorithm, model or technique test by simulator.	Determining the round-trip time between pair suitable to determine the software latency of the application.
[29] [30] [31]	Solve latency issues using new protocol or standard.	Several experiments focusing on comparing latency of different network topology is suitable to determine the hardware latency on media.

6. CONCLUSION

The objective for low latency in IoT resource discovery cannot be achieved by improving only one part of issues or designs. Today we need to think about the future of IoT networks that will be based on some special elements such as SDN to centralize and facilitate the control of the network, NFV to enable flexible and scalable architecture that can be tailored to the needs of some used cases on the same IoT infrastructure, and as well as it can benefits from the local computational power provided by applications running in the mobile edge cloud. Based on this study, all new solutions to determine hardware latency in the IoT network devices and software latency caused by resource discovery factors need to be analyzed.

ACKNOWLEDGEMENT

We are fully acknowledged TATI University College and University of Sultan Zainal Abidin as our employer and sponsor.

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