

Dynamic Bandwidth Allocation for Internet of Things System Using Elastic Wireless Local Area Network

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Abstract—Rapid technological development, triggering various applications development that are increasingly innovative. One of them is the Internet of Things (IoT) system that makes human works easier and more effective. Along with sensor technology development in monitoring and controlling through IoT systems, a mechanism is needed to manage bandwidth so that IoT system can function optimally, especially in buildings designated as public areas. Smart building supported by various integrated sensors to maintain safety and comfort in the area. This study proposes the application of Elastic Wireless Local Area Network (WLAN) as a model for dynamic bandwidth management in IoT systems. In this model, IoT bandwidth changes automatically according to the number of traffic measurements for each IoT connected to the network. As an effort to determine the performance of the elastic WLAN mechanism, this study succeeded in developing a prototype IoT device that implements elastic WLAN on an Access-Point Raspberry Pi by using two temperature sensors placed in separate locations. The system successfully allocates bandwidth to each IoT according to the amount of data input from each temperature sensor installed. The higher the amount of data captured by the sensor, the system will automatically allocate the higher bandwidth to the sensor system, and vice versa.

Keywords: *bandwidth allocation, bandwidth management, elastic wlan, internet of things*

Abstrak—Perkembangan Teknologi yang pesat, memicu perkembangan berbagai aplikasi yang semakin inovatif. Salah satunya sistem *Internet of Things* (IoT) yang memudahkan serta mengefektifkan pekerjaan manusia. Seiring dengan perkembangan teknologi sensor dalam memonitor dan mengontrol melalui sistem IoT, maka dibutuhkan mekanisme untuk mengelola bandwidth sehingga sistem IoT dapat berfungsi optimal terutama pada bangunan yang diperuntukkan sebagai area publik. Sistem bangunan pintar yang didukung oleh berbagai sensor yang saling terintegrasi untuk menjaga keamanan dan kenyamanan di area tersebut. Penelitian ini mengajukan penerapan *Wireless Local Area Network* (WLAN) elastis sebagai model untuk melakukan manajemen *bandwidth* secara dinamis pada sistem IoT. Pada model ini, *bandwidth* IoT berubah secara otomatis menyesuaikan dengan jumlah pengukuran lalu lintas setiap IoT yang terhubung ke jaringan. Sebagai upaya untuk mengetahui kinerja dari mekanisme WLAN elastis, penelitian ini berhasil mengembangkan purwarupa perangkat IoT yang mengimplementasikan WLAN elastis pada *Access-Point* Raspberry Pi dengan menggunakan dua buah sensor temperatur yang ditempatkan terpisah. Sistem ini berhasil mengalokasikan bandwidth ke masing-masing IoT sesuai dengan jumlah input data dari setiap sensor temperatur yang dipasang. Semakin tinggi jumlah data yang ditangkap maka secara otomatis sistem akan mengalokasikan bandwidth yang semakin tinggi ke sistem sensor tersebut, demikian juga sebaliknya.

Kata Kunci: *alokasi bandwidth, manajemen bandwidth, wlan elastis, internet of things*

I. INTRODUCTION

The development in the field of Information and Communication Technology (ICT) is very rapid and has covered almost all areas of public life. One part of the technology that has been widely used by people in the world is wireless local area network technology. The use of Wireless Local Area Network (WLAN) is very fast spreading in the community because of the ease in the installation process and the development of wireless-based

service applications that provide flexibility for its users. Currently, WLANs are widely applied to support services in the fields of education, health, government, business, agriculture and so on.

Along with the support of this technological development, various innovations are also being developed. One of them is innovation through the application of Internet of Things (IoT) technology. In its current development, IoT is used to monitor and automate a lot of work using a variety of sensors. With the existence

of the internet network, the application of IoT has been developed to become more attractive by applying it to smart-house systems, smart-building, smart cities, smart health, agriculture, electric vehicles, and various other fields.

Increasing the development of the use of IoT devices raises problems related to the allocation of bandwidth that should be allocated to each sensor or IoT device connected to a network. An example is the application of IoT in an area to monitor its environmental conditions. For this system, of course, it needs to involve many sensors in it. So, it is necessary to allocate adequate bandwidth to each sensor so that the data or information generated by each sensor can be conveyed properly to the device controller. This has become a very important issue that has been discussed in many studies [1].

In this study, the mechanism of bandwidth management for the IoT devices is attempted using the elastic WLAN system. This system allows dynamically controlling the active Access Point (AP) based on environmental conditions and the number of connected devices to the network. Elastic WLAN is a network that adapts to changes in the environment. This is very beneficial for energy efficiency, reliability, and improving network performance [1].

According to the research conducted in [2], elastic WLAN is intended to minimize power usage in the IoT networks. This also will cause a reduction in the workload of the network. Elastic WLAN also improves Transmission Control Protocol (TCP) fairness for devices or hosts that are connected concurrently to the AP in which implements transmission delay based on Received Signal Strength (RSS) of the hosts [2]. Sudibyo *et al.* [3] used delay parameter and node-red to adjusting bandwidth allocation in micro-smart-home for each IoT network. Adjusting bandwidth is useful to reduce delay transmission, latency also the traffic load on IoT networks.

In order to show the function of the elastic WLAN system, here is developed an IoT prototype device that utilizes two human body temperature sensor devices, each

of which is placed separately. The Hierarchical Token Bucket (HTB) approach used to assign bandwidth to each IoT in this research. This approach is aided by the deployment of a Raspberry Pi AP, which can dynamically adjust bandwidth allocation using Linux command according to the traffic that each IoT receives.

A dynamic bandwidth allocation mechanism is implemented in the developed IoT prototype. It is intended that the adjustment of the required bandwidth for each IoT will be more appropriate if the bandwidth is set based on the number of measurements taken by the IoT.

The rest of this paper is organized as follows: Section II Literature Review. Section III Method. Section IV presents result of bandwidth allocation for IoT using elastic WLAN. Finally, Section V concludes this paper.

II. LITERATURE REVIEW

In this section will be described research and literature related to the proposed research.

A. Elastic WLAN

Elastic WLAN is a WLAN system that allows dynamic control of APs according to their network environment. The higher the number of data traffic requests, the more active APs are required. This elastic WLAN system's application is adaptable to network changes, which is essential for energy-efficient, dependable, and high-performance wireless communication services. Fig.1 shows an example of Elastic WLAN Topology.

Elastic WLAN dynamically improves network configuration depending on the traffic needed to lower energy consumption. There is unfairness in a WLAN network caused by Modulation and Coding Scheme (MCS) as well as the TCP window size between two AP's that communicate simultaneously [2]. In the study, Islam *et al.* [2] performed a TCP fairness control method for two hosts communicating on elastic WLAN using Raspberry Pi as an AP.

Furthermore, Hu, *et al.* [4] performed dynamic mobile AP placement in an active AP configuration algorithm to meet strict traffic needs. The research was conducted using several scenarios for AP configuration algorithms used in elastic WLAN. Scenarios are performed using three types of AP with different speeds and topologies.

Configuring elastic WLAN in AP based on Raspberry Pi usually uses Linux operating systems. Mamun *et al.* [5] conducted research to implement Linux-PC for elastic WLAN system design. The research conducted the AP aggregation algorithm as the basis of its elastic WLAN. Several commands applied to Linux operating systems to turn Linux-PC into an AP. Raspberry Pi could be able to measure the quality of service of some network [6].

There was research about temperature sensors developed by [7]. It used MLX90614 as a temperature sensor for thermometers and STM32F107 as the microcontroller. The software was programmed using Keil C and debugged

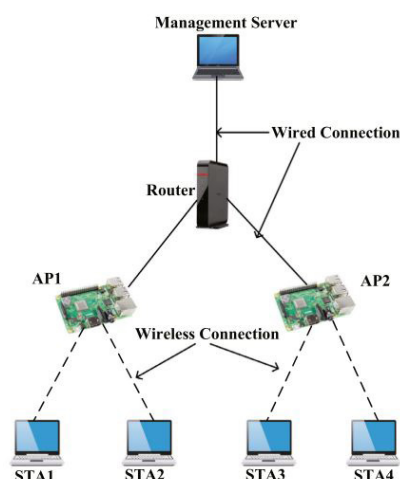


Fig.1 Example of elastic WLAN topology [2]

with KeilVision4 MDK V4.22, as well as studied the effects of temperature on different bottles with different shapes and materials.

Another research for MLX90614 was conducted by [8]. The research used MLX90614 with Arduino for the microcontroller and HC-SR04. The result of the research was suitable for indoor installation in a fixed position, for example at the entrance of an office building.

B. Internet of Things (IoT)

IoT is a network of physical objects such as devices, instrumentation, vehicles, buildings and other embedded electronic components, circuits, software, sensors, and network connectivity that allows these objects to collect and exchange data [9]. IoT allows objects to be remotely perceived and controlled across network infrastructure, creating opportunities to integrate directly from the physical world into a computer-based system [10], also improve efficiency and accuracy [11] [12]. IoT can communicate without human intervention [13].

IoT does not have a universally agreed architecture, therefore IoT architecture varies depending on the researcher. IoT architecture must be adaptive to allow devices to interact dynamically with others and support communication between them. In addition, the IoT must be decentralized and heterogeneous [10]. Farhan *et al.* [14] grouped IoT architectures into three and five layers. Another architectural form of IoT proposed in [15] inspired by the processing layer of the human brain that causes intelligence, human ability to think, to feel, to remember, to determine decisions, and react to the surrounding environment.

The development of the IoT affects the activities of human life in the world. IoT provides many benefits to the world [16]. Examples of IoT use include health or e-health, smart environment [17], smart-city, smart energy meter [18], smart-home [19] even in vehicles already applied by IoT [20]. The example about the use of IoT in health can create a health application that can monitor a patient's blood sugar levels in real-time and automatically [21].

IoT usually uses several devices such as microcontrollers or microprocessors. The microcontroller commonly used in the IoT systems is ESP-32 [22] or ESP8266 [23], and the microprocessor often used in IoT development is the Raspberry Pi [24].

III. METHOD

In this study, we proposed the allocating bandwidth for IoT systems connected to Raspberry Pi AP using elastic WLAN systems. We used a prototype body temperature detection device as IoT, then the IoT device was connected to the Raspberry Pi AP. IoT devices detect people's body temperature and send measurement data to a database. Bandwidth settings programs are executed based on the amount of measurement data of each IoT device.

The elastic WLAN mechanism is applied to Raspberry

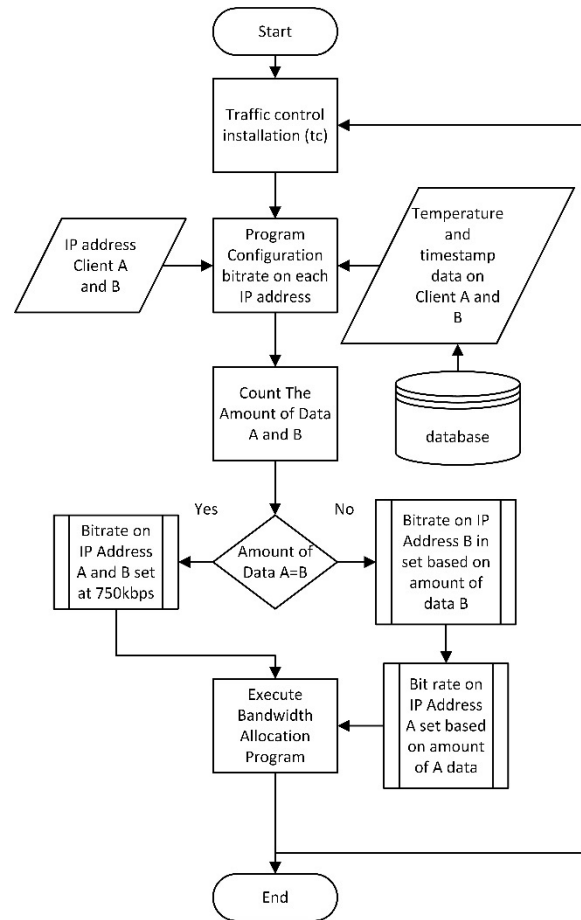


Fig.2 Bandwidth allocation flowchart

Pi AP by creating a program that executes an algorithm managing bandwidth for both IoTs according to the IoTs environment. IoT environment scenarios were built according to Fig.2.

Bandwidth management program based on (1) is used to divide the bandwidth. The number of measurements of each IoT will be compared to get the bandwidth allocation value. The bandwidth allocation equation is as follow:

$$IoT_{bandwidth} = \frac{a}{T} \times B \quad (1)$$

where is the allocation bandwidth (Mbps) to each IoT, a is the number of measurements done by each IoT (times), T is the total number of measurements of the entire IoT (times). B is the available bandwidth (Mbps).

The bandwidth management program was constructed using Python programming language and adapting Linux commands based on HTB to develop the application of bandwidth allocation. This research workflow flowchart is shown in Fig.2.

Based on the Fig. 2 the first thing to do is installing traffic control software on Raspberry Pi. Traffic Control (TC) is a regulatory mechanism for manipulating a network in the Linux kernel consisting of shaping, scheduling, policing and dropping [25]. Then, the program retrieves the IP address as well as a lot of data of each IoT from the database. Each amount of data is compared, if the amount

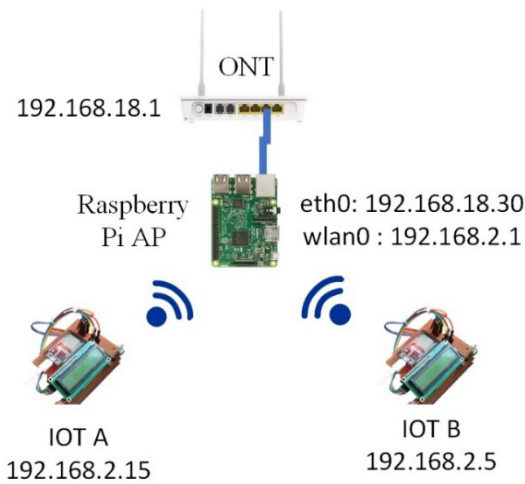


Fig.3 System topology

of data is the same then the bandwidth is divided equally. If the amount of data is not the same, then the bandwidth is divided based on the amount of data each IoT. The program then executes bandwidth sharing commands and manipulates the bandwidth for each IoT

Fig.3 shown the topology used for the experiment. There are several models of devices that are also used shown at Table 1

In the research conducted, the entire device is placed as in Fig.4. The experiment was performed by doing measurements using IoT devices. Each IoT device gets a variety of measurement traffic over a fifteen-minute span.

The workflow mechanism of the allocation system is illustrated in Fig.5. Two temperature sensors are placed each in two different gates. The temperature checks are conducted on several persons at different gates as well as with different numbers of persons. After performing the measurement, each IoT sends the measurement data to the database, and the Raspberry Pi AP executes a bandwidth allocation program based on the measurements.

IV. RESULT

This section shows the results obtained from the experiments. The setting scenario is to measure the body temperature directly with the number of each measurement on the IoT generated using a random number generator program. Each IoT receives random traffic for fifteen minutes to see if the application is running properly.

Bandwidth will vary dynamically depending on the number of measurements received by IoT. The maximum bandwidth in this scenario is 1.5 Mbps. The maximum

Table 1. Used device model

Device	Device Model
Router	Huawei EG8245H5
Access Point	Raspberry Pi 3B
IoT	ESP32 with obstacle sensors and mlx90614 sensors

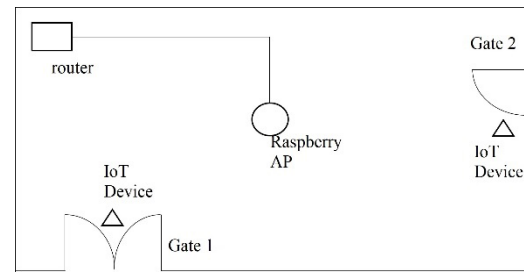


Fig.4 Device placement

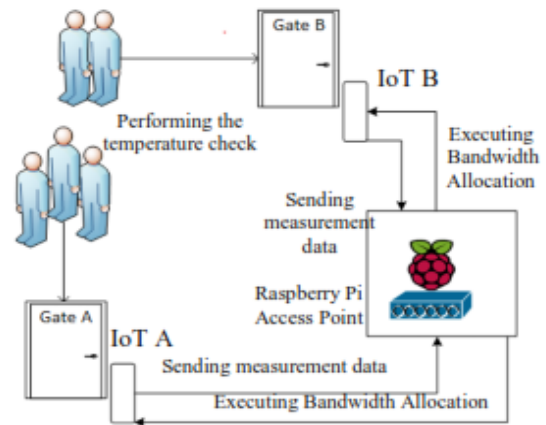


Fig.5 System workflow

bandwidth on IoT will be achieved if one of the IoT does not take measurements or is idle, the bandwidth value will be divided in two if the number of measurements performed by both IoT is the same.

The program retrieves data on the database at any one-minute time interval. Fig.6 shows the measurement traffic performed by IoT as well as bandwidth settings that run for 15 minutes. Based on these images, each IoT gets a different and random number of measurements traffic. The use of elastic WLAN mechanism in this research is to regulate bandwidth allocation for each IoT depending on the environment in which the measurement traffic. So, Fig.8 shows the results of allocating bandwidth for each IoT. Fig.7 shows the bandwidth without elastic WLAN.

Based on Fig.8, the traffic and bandwidth obtained by each IoT are changes every time. If the IoT starts to perform the measurements, the measurement graph will increase so

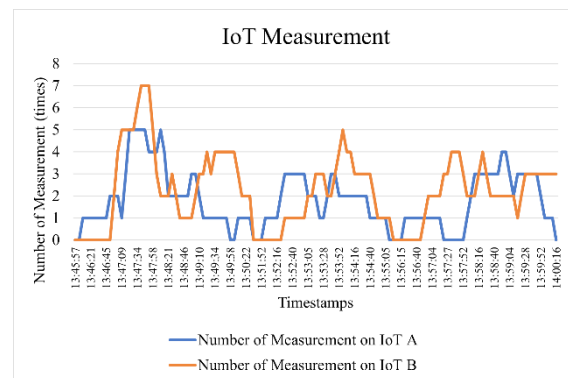


Fig.6 IoT measurement result

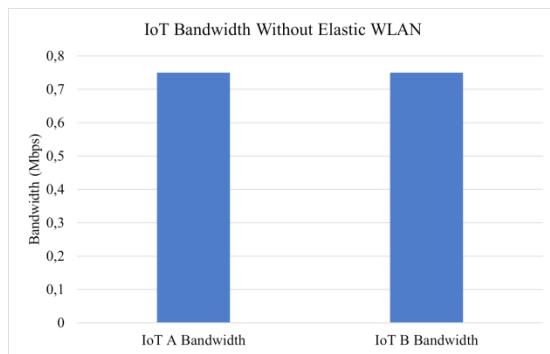


Fig.7 Bandwidth before elastic WLAN implementation

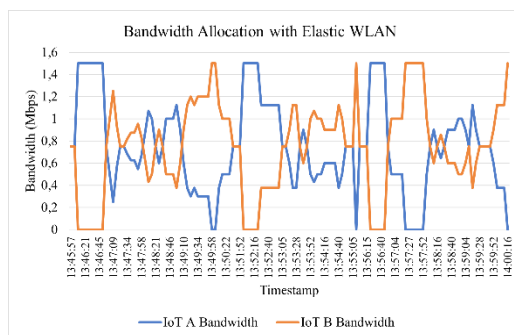


Fig.8 Bandwidth after elastic WLAN implementation

that IoT starts to get traffic, therefore bandwidth increases. When the IoT starts to enter in idle then the graph tends to decrease, so the traffic obtained by IoT begins to decrease so that bandwidth will decrease. Therefore, the bandwidth obtained by IoT is directly proportional to the traffic.

Based on these experiments, the allocation of bandwidth for IoT dynamically changes depending on the measurements performed, this is in accordance with the purpose of elastic WLAN which is to create an adaptive network depending on the environment obtained on the network. So that the available bandwidth can be allocated according to the IoT needs

V. CONCLUSION

The method of dynamic bandwidth allocation in IoT systems using elastic WLAN has been successfully developed. Implementation of elastic WLAN on the prototype of the IoT system based on the Raspberry Pi which is connected to two human body temperature sensor networks. The results of measuring the bandwidth capacity allocated to each of the temperature sensor networks have succeeded in providing a bandwidth allocation that changes dynamically and automatically in accordance with the amount of data or traffic generated by each sensor. The higher the traffic generated by the sensor, the system will allocate a higher bandwidth and vice versa. For future research, it can be developed by adding the number and types of sensor networks that are integrated into the model with the elastic WLAN to develop a more optimal and reliable IoT system.

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