Edge Computing Platform Management: Design for F2C and F2F for Small Businesses to Reduce Costs

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***Abstract*—With a focus on edge computing and the cloud, IoT and connected devices require both edge computing platform management for real-time decisions and cloud computing for optimization. From a business's perspective, this requires further investments in keeping devices updated. Big players in edge computing have proposed new devices and concepts for industries, resulting in the likelihood of increasingly expensive devices going forward. However, small businesses and factories cannot afford such investments. Thus, this paper proposes a simple and low-cost implementation of an edge computing platform for small businesses to automate their business in real time. Furthermore, having the perspective of historical performance enables real-time optimization of the entire business process.**

Keywords*—*Fog Architecture; Fog Computing; Small Business; Smart Factory; Raspberry Pi 3B+; Low Cost; F2C; F2F

I. INTRODUCTION

According to a report by Gartner, there will be 8.4 billion connected things (IoT devices) in 2017, and Gartner forecasts that the number will reach 20.4 billion by 2020. In addition, IHS Markit predicts that IoT devices worldwide will jump 12 percent on average annually from 2017 to reach 125 billion in 2030 [1, 2]. We already understand that cloud services offer a platform with storage and other resources such as business analytic systems, IoT passes, network control, and management systems through the internet from a remote data center. Cloud services are established as ideal solutions for several kinds of businesses. For example, they provide data and applications to workers no matter where they are in the world with extreme reliability. Moreover, they improve collaboration between people and between IoT devices, enabling the easy sharing of information in virtually real time. However, a huge number of applications and IoT devices operate on the cloud, leading to severe loads and latency on cloud infrastructure. Many companies use cloud computing to increase their agility by allowing authorized customers to access their applications, data, and analytics anywhere there is internet access.

Current cloud computing presents certain issues because of the latency and limited bandwidth caused by the ever-increasing number of devices connected to the internet. Moreover, failing data production mechanisms present security concerns.

In this paper, we propose a simple and low-cost implementation of an edge computing platform for organizations that use fog computing because fog computing operates on the edge of networks.

The paper is organized as follows. Section 2 describes related work that consists of basic fog computing concepts, key ingredients for fog design implementation, and fog computing structures. Section 3 proposes a fog system architecture for small businesses. Section 4 discusses modeling and designing fog systems when implementation and performance are a challenge for businesses because we need to identify the dependencies between system components such as IoT-to-fog, F2C, and F2F and understand how their failures impact system operation.

II. IDENTIFYING FOG-TO-CLOUD ARCHITECTURE

This section depicts primitives and prior work suggested by other researchers for basic concepts in fog computing.

From a basic model of the Internet of Things Reference Model by CISCO and related work [3, 4, 7], the information flow of an IoT system has 7 layers as shown in Figure 1.

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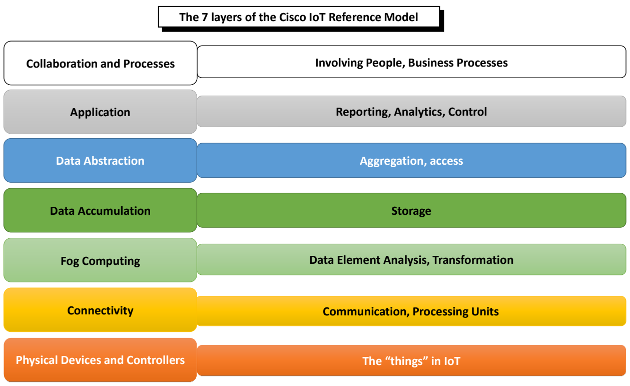

Fig 1. CISCO's Internet of Things Reference Model

CISCO defines standard terms for the interaction of IoT management systems that help industries and the education sector to more easily understand the design of new digitized systems. In this paper, we try to design the structure of fog computing on the basis of this layer concept.

A. Fog computing basic concepts

Fog computing is an architecture that extends services offered by the cloud to IoT devices. Fog features are quite similar to those of a cloud infrastructure. It has provisioning of computing, storage, analytics, and network management. Fog systems do not work on a cloud; they are deployed at the edge of networks, so the fog is faster and closer to end devices than the cloud is. The advantages of the fog are as follows [3, 4, 5].

- Fog supports real-time interactions better than cloud.
- Fog computing supports interactions with cloud and analytic services.
- Fog enables data management and processing at the edge of networks.
- Fog supports mobility because of its proximity to end users.
- Fog provides data processing, analysis, and storage.

B. Fog computing scenarios and key ingredients

Yannuzzi et al. [6] proposed that an edge computing platform must:

- "*Support rapid mobility patterns, even requiring in some cases high throughput on demand for short time periods.*
- *Support systems requiring reliable sensing, analysis, control and actuation, in scenarios subject to poor or unreliable connectivity to the Cloud and/or requiring very low latency.*
- *Be able to manage a large amount of geographically distributed "things" (either physical or virtual), which may produce data that require different levels of real-time analytics and data aggregation.*"

As shown in Figure 2, a fog system is a decentralized computing infrastructure; it exists in the middle to bring the IoT to life by a distributed infrastructure in which certain application processes or services are managed at the edge of the network. Fog systems extend cloud computing and services by bringing the advantages and power of the cloud closer to where data are created and acted upon at the edge of the network.

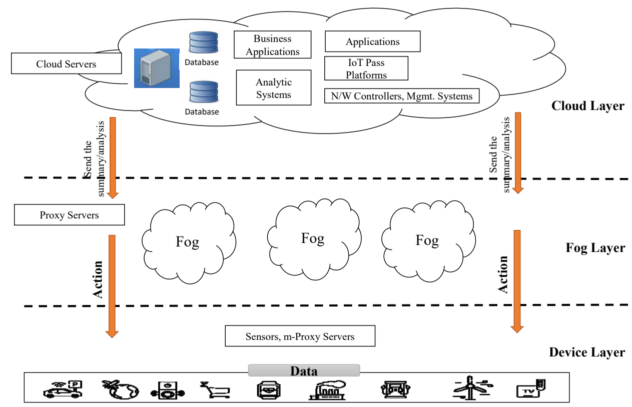

Fig 2. Overview of fog system architecture [7]

The key components of fog infrastructure are the network, middleware, and data center infrastructure. Fog architecture is usually enabled by short-range means, for example, Wi-Fi, Bluetooth, sensors, RFID, cellular, or low-power wide area networks. For a middle device, we need to consider connecting devices that have a high ability to communicate with other devices within the network. In addition, at the cloud layer, the cost of use is based on data and is also based on security and privacy requirements.

In summary, fog computing in general supports IoT applications and facilitates the operation of computing storage and networking services between end devices and cloud computing data centers.

C. Fog computing structure

Fog computing involves three basic jobs: switching networks, pushing services, and core services [8, 9].

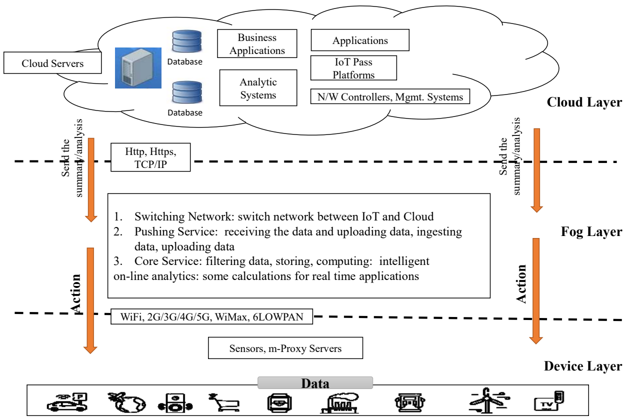

Fig 3. Three basic jobs of a fog system [9]

As shown in Figure 3, IoT devices generate a large amount of varied and incomplete data. Thus, these data need to be processed and responded to in a short time in order to be sent to an edge device for directing an operation. Moreover, in this scenario, the physical distance between users leads to transmission latency.

In such scenarios, fog computing provides a solution. From the three basic jobs, the fog gets a data feed from IoT devices such as sensors in real time, ideally in milliseconds, and then stores the data temporarily. In addition, at the fog node, data are filtered and aggregated in accordance with provided policies, and online analysis is conducted before data are sent to the cloud in accordance with conditioned policy. Fog systems are implemented to minimize the amount of data sent to the cloud, save bandwidth, reduce data latency, improve data security, and improve system response time in remote mission-critical applications. The corresponding fog nodes might be gateway devices, PCs, or micro data centers.

Figure 4 depicts a recently proposed concept called fog vehicular computing (FVC) that augments the computation and storage power of fog computing [10]. The FVC architecture has three main layers: application and services, policy management, and abstraction.

The first layer provides a variety of real-time applications for end users. This layer consists of information and entertainment as services, the network as a service, storage as a service (STaaS), and computation as a service.

The second layer is policy management, which consists of three sub layers: first is the policy sub layer, which interconnects with both the fog and vehicular cloud sublayers to assign tasks and resources dynamically. The components in this sub layer are load balancing, quality of service, configuration, repository, security and privacy, service DB, and the decision manager. The second sublayer of policy management is the fog. At this layer, the main components are the fog capability DB, fog task scheduler, and fog service manager. The final sublayer of the policy management is the vehicular cloud. This sublayer consists of the vehicular capability DB, vehicular task scheduler, and vehicular resource manager.

From the FVC architecture, the last layer is the abstraction layer. The main duty of this layer is to protect security and privacy.

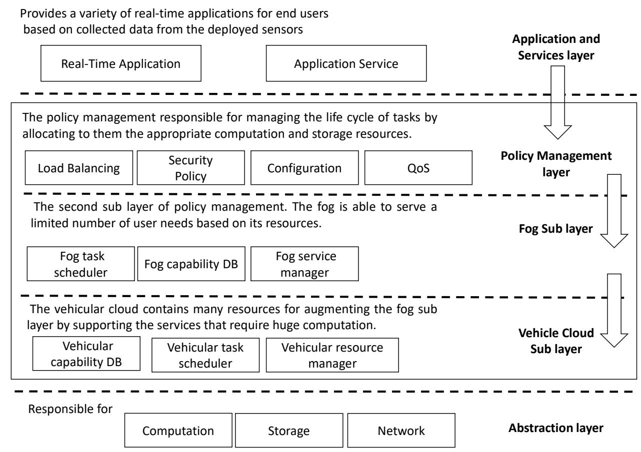

Fig 4. General architecture of FVC [10]

Moreover, Name et al. explained in their paper that the fog system normally comprises devices such as routers, gateways, switches, and access points. Devices at fog nodes have an ability to execute and temporarily store user requests for quick analysis. In addition, they can understand beforehand the required resources for executing any task/application request from the terminal nodes and send the data to another system such as another fog node or IoT gateway on the LAN for performing higher-level processing and analysis. Devices at fog nodes also do data filtering, analyzing, and processing before data transmission to the cloud or WAN at a later date [11].

Another example of fog computing is the architecture for e-health systems based on IoT devices using the fog and cloud [12].

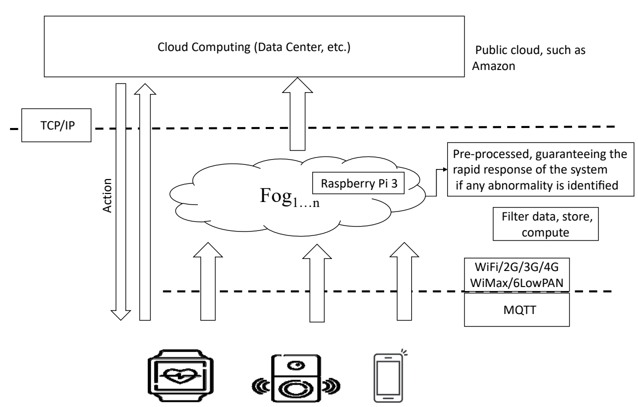

Fig 5. E-health system based on IoT, fog, and cloud computing [12]

As Figure 5 shows, this proposed system is quite simple and is a good example of a design that small businesses can implement. The system highlights a relatively low-cost fog architecture that can improve the management of end of life care and post hospital care by detecting human falls, cardiac arrhythmia, or epilepsy attacks in a timely manner. A Raspberry Pi 3 is used at the fog layer for collecting sensor data and negotiating the sending of information to the cloud.

However, this system has a weak point in comparison with the architecture of the FVC as mentioned before in terms of policy and security management. In addition, if we consider the core basics of fog computing, this design lacks a network switching function.

Thus, from the literature review in Section II , we use a WBS to design a fog system architecture for small businesses and provide guidelines for data transmission for F2C and F2F.

III. ARCHITECTURE PROPOSAL OF FOG SYSTEM FOR SMALL BUSINESSES

In terms of information flow, we decided upon a hierarchy of functions for each level and interaction layers as shown in Figure 6.

From Figure 6, the "parent" part of the hierarchy is "IoT devices," while the "child" parts consist of "connectivity" followed by "fog computing." The "child" parts of "fog computing" consist of "data accumulation," "data abstraction," "application," and "collaboration and processes."

As for the white boxes (before the cloud box), for example, "data accumulation" is responsible for collecting data from the IoT devices. "Data abstraction" is responsible for protecting security and privacy. "Application/visual" is responsible for providing a variety of real-time applications for end users. Finally, "collaboration and processes" is responsible for the internet connection inside a service network of an organization.

We propose this concept of a system hierarchy into our edge computing platform management so that we can provide a scheme for arranging key components in providing services to a small organization.

Figure 6 is a virtual platform that provides a view of each layer starting from receiving data from IoT devices with accessibility by an available network at a location service. Then, at the fog layer, processing is done, reserving networking services for the device to a cloud computing data center. However, in this diagram, not all data are processed at the fog layer; some data may be sent directly to the cloud in regards to security and privacy on the basis of the policy stored in "data abstraction."

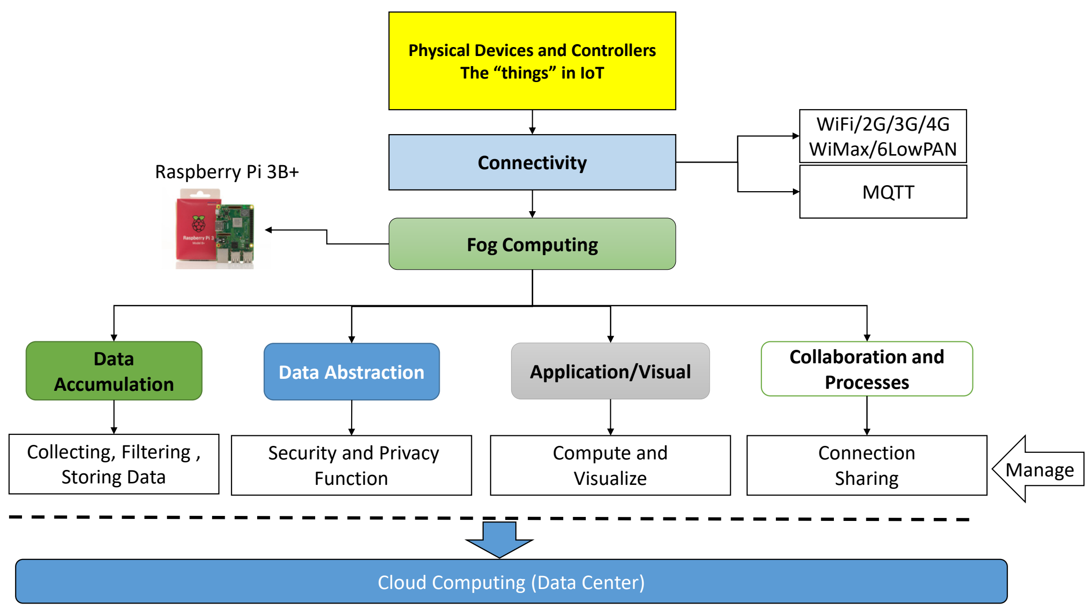

Fig 6. System hierarchy of F2C and F2F for small businesses

As shown in Figure 7, the platform is divided into three layers; the first layer is physical devices such as IoT devices, sensors, smartphones, and wearable devices. Generally, in small businesses and smart factories, IoT is used for tracking raw materials, finished goods, or parts and for predictive maintenance by analyzing the historical data of machines for improving product design such as that of sensors in smart watches (for gaining insight on customers' usage), for dynamic route planning, and for identifying quality, etc. [13].

At this layer, sensor data are collected for getting real-time information regarding those mentioned activities. For communicating with the fog layer, these data and devices need a reliable connection made through Wi-Fi, 2G, 3G, 4G, or otherwise to enable them to communicate seamlessly without any uninterrupted data flow and within a safe and productive environment.

At the fog layer, there may be several fog nodes. We propose low cost fog nodes in this paper, such as the Raspberry Pi 3B+ with RFID. We propose these devices because they are not only cheap but can be accommodated without impacting network performance and reliability, and they can easily be moved within their environment to maximize functionality. However, with the Raspberry Pi 3B+, businesses need support from programming teams to operate the systems in Figure 7 to follow the IoT reference model. The functions in the Pi must have the following system functions.

1. Collecting, filtering data, storing, computing
2. Security policy and privacy
3. Task scheduler
4. Small visualization
5. Internet connection sharing, collaboration and processes

For all five functions, we can use Python to code a command to process and compute on the Raspberry Pi 3B+; however, the most difficult part is network switching functions. This task may need an additional device such as a router or switch and an RFID reader to cover all areas in a business or factory.

Considering the simple requirement of edge computing for small factories [14, 15], the basic components of the edge gateway are as follows (excluded IoT devices).

1. Edge gateway device
2. Commercial source license
3. Development cost
4. Customer support
5. Internet Bandwidth per Month

For these basic components, if SMEs use a subscription plan, they have to pay from 18,191 Baht (63,119 yen, 606.36 dollars) per month, which is 218,292.00 baht (757,432.32 yen, 7,276 dollars) per year, respectively. As for buying devices, for the Dell Edge Gateway 300, it costs 27,820 Baht for general purpose automation. This cost now includes tasks no. 2–5 as mentioned above, whereas the price of the Raspberry Pi 3B+ Starter Kit with 16 GB is just 2,709 Baht (812.7 yen, 90.3 dollars), and SMEs can hire one developer for coding the five functions as presented in Figure 7. From the price list, we contrast general fog computing provided by software vendors and self-provisioning by SMEs. We can see that the configuration described is cheaper for small businesses and factories.

Finally, at the cloud layer, only large data that do not need real time processing and secured data must be sent to the cloud directly.

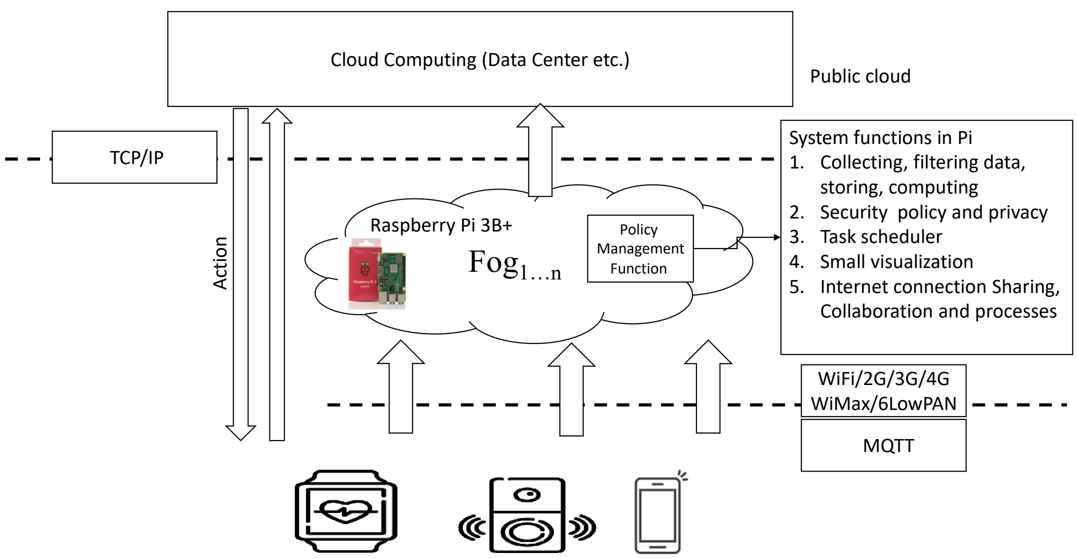

Fig7. System diagram of F2C and F2F for small businesses

IV. Discussion

The use of IoT devices in industries is steadily increasing. These devices can be used for monitoring tasks and improving the efficiency of day-to-day work. A Raspberry Pi 3B+ can be used as a fog device in conjunction with other devices at a low cost for small businesses and factories. The proposed platform enables the remote monitoring of raw materials, parts, and equipment and inventory control. Moreover, it can help in terms of analytics such as providing statistics on livestock and produce. For manufacturing and retail industries, collaboration with connected supply chains can easily be established by IoT. IoT devices can help drastically cut the cost of production and inventory as well as reduce waste products.

However, besides considering low costs, implementing IoT in businesses or factories requires that all devices are connected securely and privately. The cost of hardware is continuously falling, while computational ability is increasing. With current technology, hardware-, infrastructure-, and application-wise, multiple tasks can be done on a single device such as the Pi.

V. CONCLUSION AND FUTURE WORK

In this paper, we proposed a simple and low-cost implementation of an edge computing platform for small businesses to automate their business in real-time. Furthermore, having the perspective of historical performance enables real-time optimization of the entire business process. In conclusion, security and privacy are still the essential points of IoT platforms—all businesses must protect their data and their customers' data to secure their corporate reputation and the reputation of their business services.

Our future work is to evaluate the proposed platform in selected businesses. Future experiments will involve installing IoT devices for evaluation of security and privacy. In addition, the final results will be used to modify the fog platform, recommended devices, networks, and a privacy framework to achieve the ideal platform for small businesses and factories. Furthermore, we will evaluate the effect of cost reductions.

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