CHAPTER 2

CONCEPTUAL BACKGROUND

2.1 Internet of Things (IoT)

The IoT is radically rethinking, redesigning and reshaping the ways of doing business by enabling enterprises to develop and improve value-added services with their network of devices. According to Lee and Lee (2015), there are five IoT technologies that are extensively used for the deployment of successful IoT-based products and services. These are including radio frequency identification (RFID), wireless sensor networks (WSN), middleware, cloud computing and IoT application software. The RFID permits data capture and automatic identification by utilizing a reader, radio waves and a tag that could store more data than traditional barcodes. Manufacturing are using active RFID tags. Active RFID tags are able to initiate communication with a reader and to contain external sensors to monitor conditions such as temperature, chemicals, pressure; they are battery-powered. The WSN includes spatially distributed autonomous sensor-equipped devices in order to monitor external conditions such as environmental conditions. The WSN can collaborate with RFID systems to track the status of things, thereby the WSN can be utilized for tracking systems to track location, movements and temperature of things. Then, there is the middleware. With its complex distributed infrastructure including various heterogeneous devices, the IoT is required to simplify the development of new applications and services. The middleware is an ideal solution for this issue due to its ability to enable software developers to perform communication and input/output by hiding the details of various different technologies and only showing relevant software services to the specific IoT application. Lastly, there are cloud computing and IoT application software. Although the devices and networks administer the physical connectivity, they cannot provide device-to-device and human-to-device interactions. Thereby, IoT applications are required to be included on devices in order to enable those interactions while also ensuring that data have been received and acted upon properly in a timely manner. However, the IoT applications require huge data storage, fast processing to enable real-time decision making, and high-speed broadband networks to stream data. The cloud computing is an ideal back-end solution for handling that issue.

There are three main IoT sectors: enterprise, home and government (Lee, 2019). Enterprise IoT is the largest among those three sectors. Enterprise IoT refers to all connected devices used for numerous business purposes in the enterprise setting.

A well-structured, frequently-updated IoT architecture will assist enterprises in developing innovative services. With the development in the IoT, Lee (2019) proposed a five-layer architecture of the enterprise IoT, as shown in Figure 2. 1, that consists of a perception layer, a network layer, a processing layer, an application layer and a service management layer. This five-layer architecture represents an abstract architectural view for a myriad of the enterprise IoT systems. First, the perception layer, also known as sensor layer, addresses communication/sensing functions. This layer consists of various devices such as RFID tags and readers, sensors, video cameras and smartphones that are used to generate huge amount of data from the surrounding environment. Second, there is the network layer, also known as transmission layer that uses Internet getaways, switching, routing devices and communication technologies such as WiFi, LTE, Bluetooth, 3G and Zigbee. These network infrastructures enables the network layer to transmit data collected from the perception/sensor layer to the processing layer. Third, the processing layer, also known as middleware layer, consists of database management, data analytics and cloud computing. After the data from the network layer are received by the processing layer, then the processing layer cleanses, stores, analyses, and process the data. Fourth, there is the application layer that is responsible for data and information integration and presenting them to the users in a user-friendly format. Since this layer consists of a set of problem-specific applications that interact with users and solve problems, it is essential for managers to understand what types of enterprise applications are provided at the application layer. Lee (2019) and Lee and Lee (2015) identified three categories of enterprise IoT applications: (1) operational enterprise IoT to support or improve daily user and customer activities, (2) analytical enterprise IoT to support human decision making and (3) collaborative enterprise IoT to allow different IoT devices to interact and collaborate to achieve specified goals. Lastly, the top layer of the enterprise IoT is the service management layer which is the IoT service business model as its key element. As the starting point for developing a set of enterprise IoT services, the service management layer determines the direction for the other four lower-level layers due to its responsibility to select and deliver the IoT services of the enterprise.

Service management layer
Application/solution layer
Processing layer
Network layer
Perception layer

Figure 2. 1

Five-layer Architecture of the Enterprise IoT

Source: Lee (2019)

Furthermore, there are several important advantages that have been achieved by several manufacturing companies that have adopted IoT (smart meters) for monitoring their energy consumption *at machine level*, as follows: (1) finding and reducing energy waste sources, (2) improving energy-aware production scheduling, (3) reducing energy consumption costs, (4) enhancing maintenance management efficiency, (5) measuring and reducing environmental effect of production processes, (6) supporting decentralization in decision-making at production level to increase energy efficiency, (7) monitoring power quality in factories and (8) supporting cost management by providing real-time data to enable the precise determination of the cost of consumed energy per process/product/order.

Beside the advantages, the manufacturers should pay attention to some disadvantages of the IoT. For instance, the IoT poses a potential risk due to IoT security often tends to lag behind innovation in the marketplace (Rizvi et al., 2020). Moreover, the absence of regulations that oversee the IoT devices also poses another risk of the IoT adoption.

2.2 Energy Management for Cost Efficiency

Lack of awareness of energy consumption behaviour is still a barrier for energy cost efficiency improvement in many factories. In the research conducted by Jagtap et al. (2019), they outlined the lack of awareness of the food manufacturers towards their energy consumption at the machine level. This is due to most of the food manufacturers are still relying on their quarterly or monthly energy bills as the base of their energy cost calculation. Thereby, it is crucial for food manufacturers to understand more-detailed patterns and key data of their energy consumption. According to Shrouf and Miragliotta (2015), there are two categories of methods for calculating expected energy consumption that is usually used in industries: a method based on historical data and a method based on driving factors. Nevertheless, both methods have weaknesses such as long interval time, inability to detect when energy waste has appeared, and inaccurate results when unusual consumption patterns occurred during the preceding period, etc. Therefore, the availability of energy consumption pattern is still a vital issue since manufacturing machines and equipment are generally not metered timely and accurately (Müller and Löffler, 2009).

Weinert et al. (2011) stated that energy cost efficiency are possible to be achievable both from improvements in energy efficiency of specific production processes and also from the utilisation of innovative energy monitoring systems and management approaches. Backlund et al. (2012) proposed that companies shall invest in the inexpensive energy smart metering and monitoring to enhance energy performances rather than financing costly technologies.