CZ4171 Term Paper

Applications of IoT in Singapore Context

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1. Introduction

1.1. Background Information

Internet of Things (IoT) can be defined as an open and interconnected network of smart objects that are capable of self-organization, sharing information, data and resources, while responding and adapting to changes and challenges present in the environment they're in [1]. The motivation behind the introduction of IoT is to enable human activities to be done more efficiently with higher productivity. Users are able to obtain real-time data from the devices connected in the IoT network, thus being able to make well-informed decisions faster, resulting in higher efficiency and productivity.

IoT can complement the Smart Nation Initiative of Singapore. The Smart Nation Initiative is a program launched in 2014 which aims to "support better living, stronger communities, and create more opportunities, for all" [2]. The Smart Nation Initiative can be divided mainly into two sections which are improving the livelihood of the citizens and boost the economy of the country by increasing the productivity and opening up new business opportunities to leverage on. According to Statista, the total number of IoT device connections has increased from around 29.94 million devices in 2018 to 75.35 million in 2023[3]. This trend is shown in Figure 1 below. Thus, showing the increasing usage of IoT systems in Singapore.

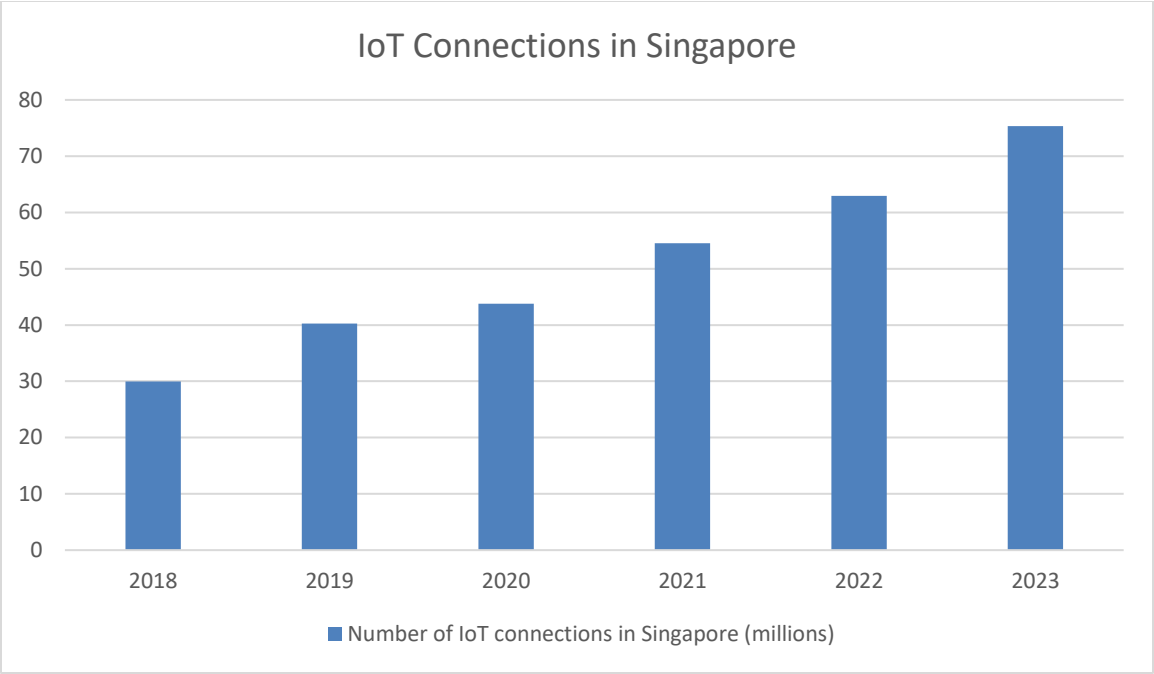

Figure 1: Number of IoT connections in Singapore

In Singapore, IoT has been used in many fields such as transportation, medical, e-commerce and others. In this paper, we will be looking at some examples of applications of IoT in Singapore, which are transportation, smart factories, urban farming and smart textiles.

2. Applications

2.1 Transportation

Public transportation such as Mass Rapid Transport (MRT) and SMRT buses are a vital part of Singapore's economy. According to The Straits Times, in 2023, only around one-third of the Singaporean population, which consists of Singaporeans and Permanent Citizens, own their own personal cars [4]. Thus, around 4,534,563 people out of 5,917,648 people living in Singapore including foreigners, or 77% of all residents in Singapore [5], relies on public transportation as their main mode of transportation around Singapore as shown in Figure 2.

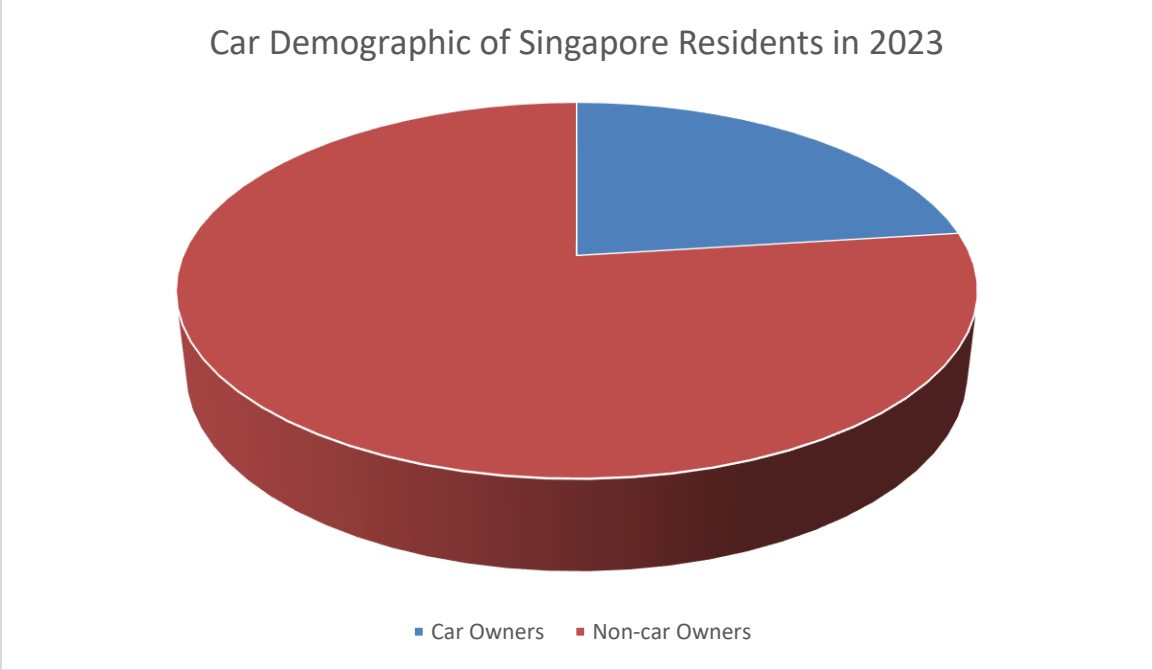

Figure 2: Car Demographic of Singapore Residents in 2023

One of the methods IoT can be utilized is by providing users with information required for their travel journey. Users can access information such as the position of the bus or MRT, the time taken for the bus or MRT to arrive to the said location, and the time taken for the journey from the start to the destination based on the method of travel. Using IoT, users are able to obtain close to real-time information which they can use to plan out their travel method. Bus tracking applications utilize the GPS system to obtain the location of the buses in Singapore. GPS

devices, installed on every bus, continuously tracking the location of each bus via satellite. This location data is then transmitted to a secure server or database. The bus tracking application periodically obtains the data from the server or database, providing accurate and up-to-date information on the whereabouts of each bus [6].

For example, Singabus bus tracking application obtains their information regarding the location of the SMRT buses in Singapore from Land Transport Authority of Singapore (LTA) and other sources to provide highly accurate information on the location and timing of the buses from the bus stop the user is currently located at as shown in Figure 3 [7].

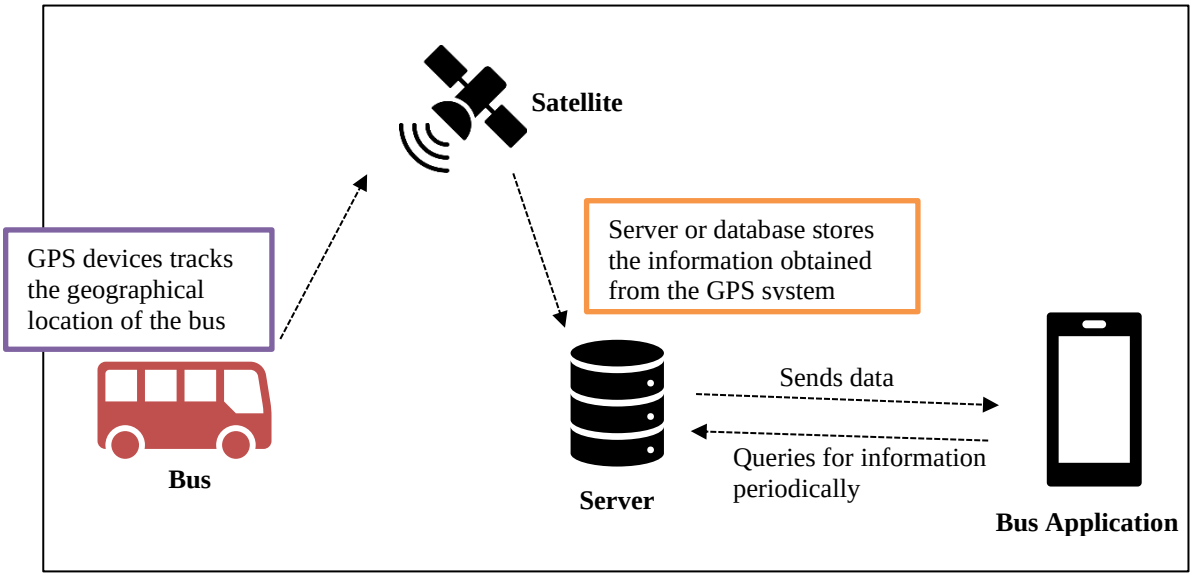

Figure 3: Bus Tracking Application System

Applications such as MyTransport.sg also tracks not only the location of the buses, but also the bus loading information, which is whether the bus is crowded or not [8].

In addition, another implementation of IoT in transportation is through the use of RFID readers. When passengers alight on the bus, or enter through the gantry in the MRT station, they tap their EZ-link card on these readers. When a passenger taps their EZ-link card on the RFID

readers, the reader takes note of the location and the time in which the passenger alight the bus or enter through the gantry in the MRT station. This data is stored in the LTA server to use for calculating the travel fares. Travel fares are calculated based on the total distance travelled in a journey. However, there are also some other conditions such as the maximum duration between the time the passenger first taps to use the bus or MRT to the time the passenger exits the bus or MRT by tapping again is 2 hours [9]. The data of the passenger such as location and time is stored in the server managed by the transportation operators and LTA such that they can charge the correct price for the travel journey, as well as use the data for further planning to improve the transportation system and routes in the future. The data can also be used to penalize those passengers which are not following the rules. Such as if they keep lingering around the bus or MRT station without exiting then they will pay for the maximum fare despite the distance travelled. The maximum fare will also be charged to passengers which forgot to tap out when exiting the bus, reminding them to always tap out to avoid being penalized.

In conclusion, the use of IoT in the public transportation system in Singapore has brought about significant benefits for both passengers and transportation operators. By utilizing GPS tracking systems and RFID readers, passengers can enjoy more accurate travel information, better travel planning, and more convenient fare payment. At the same time, transportation operators and the LTA can obtain valuable data on passenger behavior and travel patterns, which can be used to improve the efficiency and effectiveness of the public transportation system.

2.2 Smart Factory

Furthermore, in accordance to the Smart Nation Initiative, Smart Factories are another method of utilizing IoT to boost Singapore’s economy by increasing productivity and opening up new opportunities for Singapore businesses to leverage on in the digital economy. Smart Factories are powered by the implementation of IoT and Cyber-Physical Systems (CPS). By utilizing IoT

and CPS, manufacturing systems become more capable, making them able to facilitate the management of complicated and flexible systems to cater to the rapid boost in the product volumes and customizations [10]. These allow users and other machines to be more context-aware, having better understanding of their environment, which assists them in making informed decisions as well as in the execution of their tasks in the factories. One example of such use recently is by Star Living, a furniture brand in Singapore. Star Living opened up a new IoT driven factory, which includes a new headquarter, a warehouse and a showroom, in Sungei Kadut on the 24th of October 2023. The motivation behind using IoT for their new factory is to quicken and simplify industrial processes, while also improving operational productivity and storage capacity by 50 percent [11]. The method in which IoT is utilized in this smart factory is by utilizing autonomous-guided vehicles to locate and lift the heavy furniture in the building, as well as utilizing motorized mobile shuttles to carry the furniture around the factory space as shown in Figure 4. By utilizing these autonomous devices or vehicles in the warehouse, one benefit is that there is less intervention required by human employees on these processes, these frees up the time of the employees to focus on other tasks while also keeping them safe as they are not directly involved with the heavy furniture in the warehouse. Furthermore, by improving the efficiency of their processes, it also gives Singapore's companies like Star Living, an

opportunity to expand outside of the Singapore market into the international market.

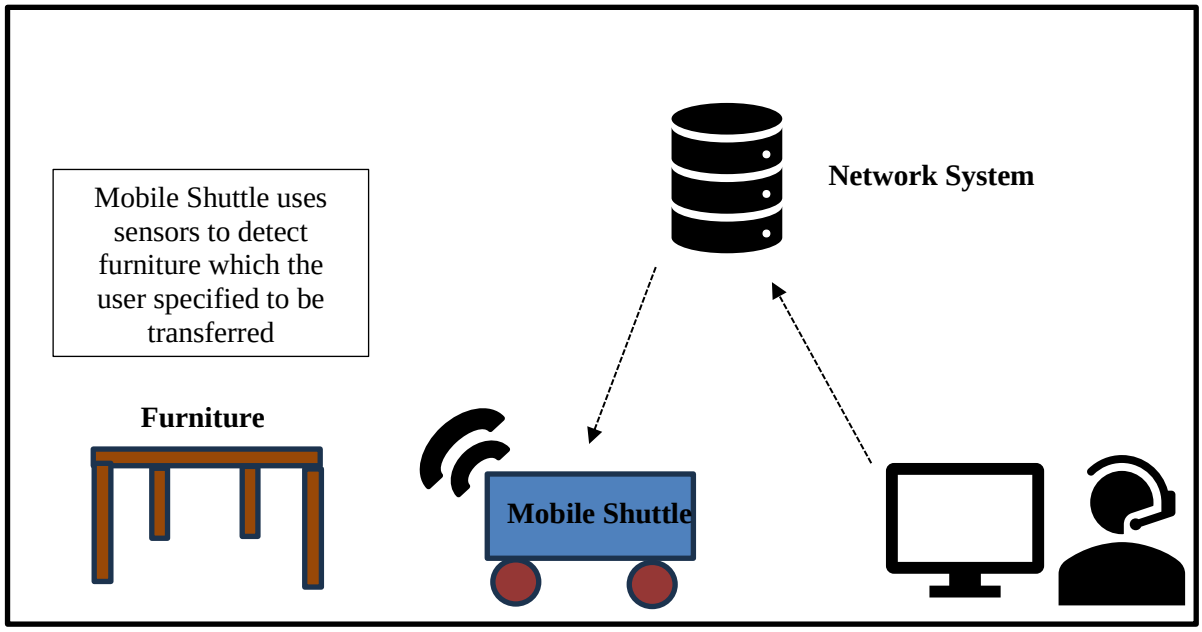

Figure 4: Example of IoT usage in Smart Factory in context of Star Living warehouse

Another example of Smart Factories in Singapore is by ST Engineering. The utilization of IoT, or in this case Industrial IoT (IIoT) which is a concept under IoT which focuses more on industrial processes, which requires higher level of precision and accuracy as compared to the commercial IoT. The uses of IIoT in the context of ST Engineering is mainly divided into 4 sections, which are Manufacturing Simulation Centre, Operations Centre, Robotics and Automation, and Integrated Supply Chain Management [12]. For Manufacturing Simulation Centre, ST Engineering utilizes a virtual twin environment to prepare for production and validate processes beforehand. The virtual twin environment provides comprehensive insights into the internal workings of any system, the interactions between its components, and the anticipated behavior of its physical counterpart. These insights are actionable for users and stakeholders [13]. The virtual twin environment is generated with the help of data captured from IoT sensors and device metadata [14]. In Figure 5, the relationship between IoT and virtual twin environment is shown.

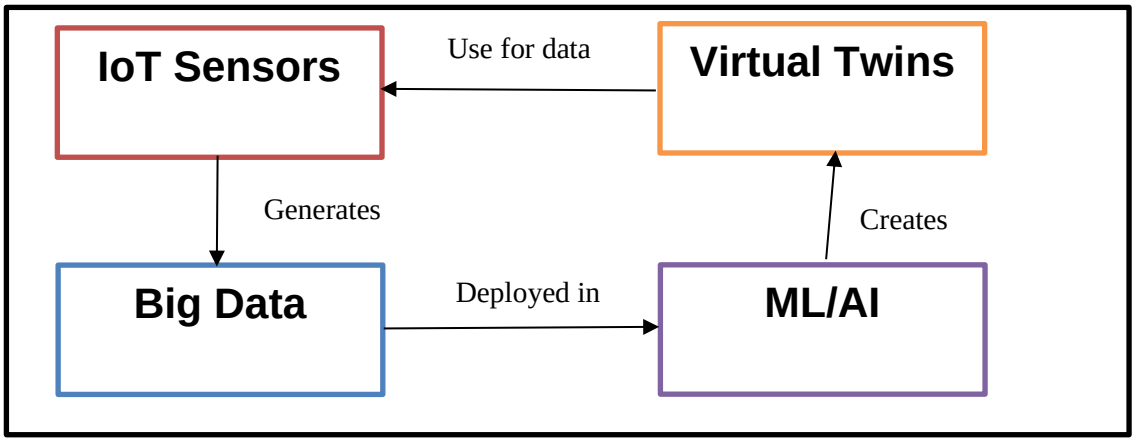

Figure 5: Relationship between IoT and Virtual Twins

Next is the Operations Centre. The Operations Centre serves as a centralized nerve center for delivering real-time support decisions for all manufacturing processes. Utilizing data obtained from IoT sensors, analysis and visualization, potentially through the use of the virtual twin environment, production trends and performance can be closely monitored and managed in case a problem occurs.

After Operations Centre is Robotics and Automation. With robotics and automation, especially using Autonomous Mobile Robots (AMR) as shown in the video in ST Engineering page, processes can be more efficient. Similar to the mobile shuttle in Star Living's IoT-driven warehouse, these AMRs can be used to lift materials around the manufacturing grounds, capable of carrying more objects compared to a normal person, and enables other workers to focus on other sectors of the manufacturing process. These AMRs can be instructed to travel to a certain region of the warehouse and carry the targeted objects to another region. Using sensors such as infrared sensors, sonar or radar, these AMRs can avoid dangerous situations such as hitting a wall or hitting a person while travelling in the manufacturing grounds.

Last but not least, the final usage of IIoT is through Integrated Supply Chain Management. By utilizing RFID technology and RFID tags, the manufacturing status of a large number of materials and products can be edited at the same time as shown in Figure 6, reducing time wasted labelling these materials or products. Furthermore, as shown in Figure 7 these statuses can be delivered to the process managers in the Operations Center such that they can make quick decisions on the next step of the process or solutions to potential issues.

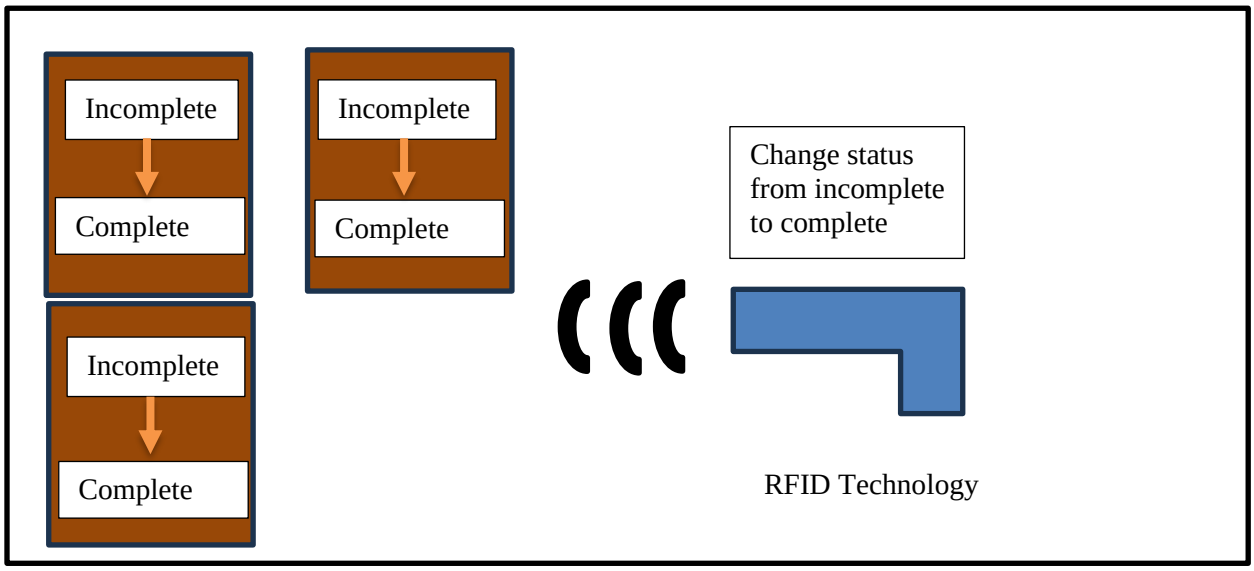

Figure 6: RFID Technology enabling multiple status updates at the same time

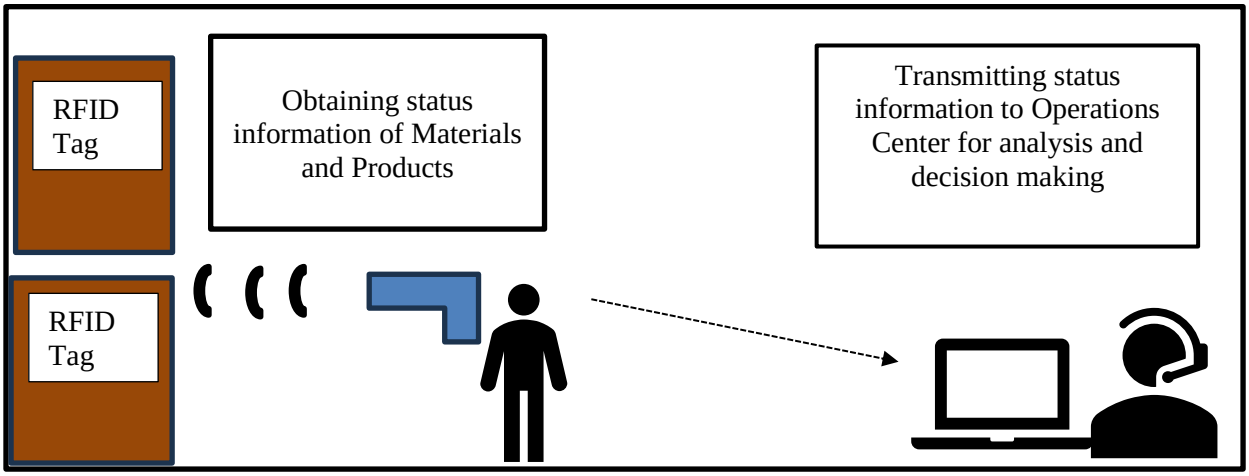

Figure 7: Transmission of material and products status information

During distribution of products and materials, ST Engineering can also utilize location sensors to keep track of the vehicle carrying their products or materials, and also the condition of the

products and materials during delivery.

In conclusion, utilization of IoT in smart factories enables higher output of products, higher efficiency of processes and better relocation of tasks between workers in the factory. IoT sensors enable workers to obtain big data which could be used for analysis and improvement of the factory's processes.

2.3 Urban Farming

Urban farming involves the cultivation of crops, livestock, or various plants within urban settings [15]. Given the challenge of land scarcity in Singapore, urban farming emerges as a viable solution to establish a sustainable local food source. This is utilized as a measure for Singapore's 30 by 30 initiative, aiming to boost local food productivity to 30% by 2030 [16]. This initiative exists due to Singapore's large reliance on exports from other countries for fresh produce and other foods, which takes up to 90% of Singapore's food supply, shown by Figure 8 and Figure 9 [17].

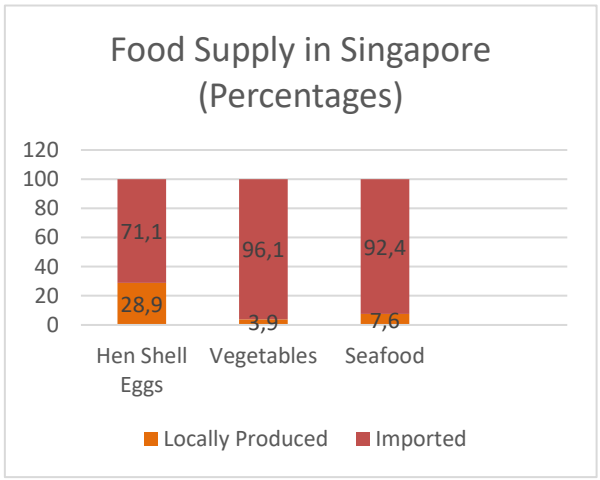

Figure 8: Statistics on Singapore's food supply (Left)

Figure 9: Statistics on Singapore's produce of hen shell eggs, vegetables and seafood (Right)

In Singapore, IoT plays a crucial role in revolutionizing urban farming practices, addressing the challenge of limited land availability. One prominent example is Sky Greens, acknowledged as

the world's first hydraulic-driven vertical farm. Sky Greens integrates IoT systems to monitor various environmental factors essential for crop growth, including pH control, electricity conductivity, light detection, nitrogen and oxygen levels, and temperature control [18]. By leveraging real-time data from these sensors, Sky Greens optimizes growing conditions shown in Figure 10, ensuring maximum crop yield despite the small plot of land allocated for farming. In addition to environmental monitoring, IoT is utilized in urban farming through automated irrigation systems. These systems are equipped with IoT sensors that regulate water usage based on real-time data on soil moisture levels and temperature [19]. By continuously monitoring these factors, the system ensures that water is delivered to the soil only when necessary, thereby minimizing water wastage and optimizing plant growth. This approach contrasts with traditional methods of periodic watering, offering more efficient resource utilization in urban farming.

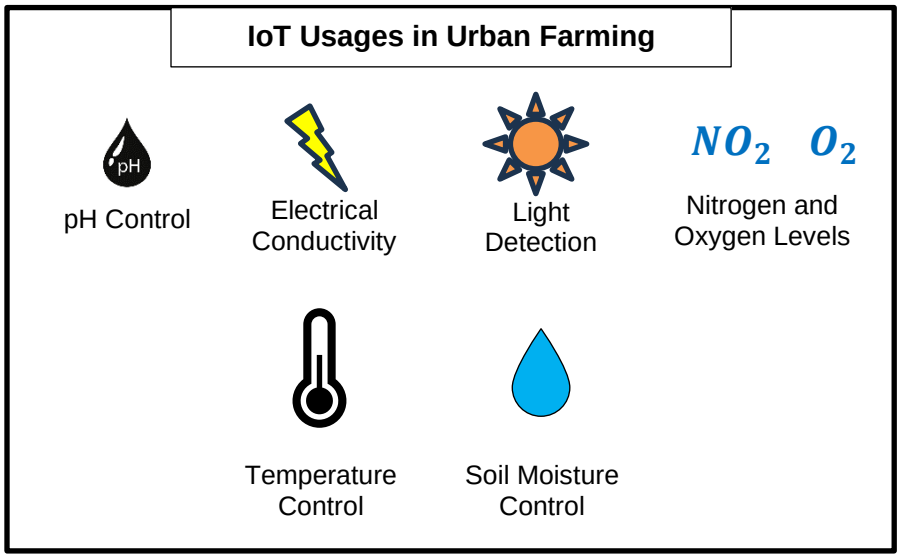

Figure 10: Different environmental settings monitored through IoT

Sky Greens' vertical farm, shown in Figure 11, demonstrates the effectiveness of IoT integration by producing an impressive 500 kg of fresh crops daily, including mini cai xin, jie lan, and Chinese cabbage. This remarkable output underscores the potential of IoT-driven urban farming to enhance food security and sustainability in Singapore, potentially enabling

Singapore to procure their own sustainable source of fresh produce without the need to greatly rely on other countries for their food source.

Figure 11: Sky Greens Vertical Farm [20]

In conclusion, the integration of IoT technologies into urban farming represents a great shift in Singapore's agricultural landscape. By utilizing real-time data analytics, precision farming techniques, and remote monitoring capabilities, urban farmers are not only maximizing crop yields and resource efficiency but also driving sustainability and resilience in food production. As Singapore continues to embrace innovation and technology-driven solutions to address the challenges of urbanization and climate change, urban farming supported by IoT will become an essential component for self-sustainability for future generation.

2.4 Smart Textile

Smart textile are wearable materials with electronic components or sensors embedded in it which enables them to respond to external stimuli or interact with their environment. There are multiple uses of smart textile, which includes healthcare, sports and fitness, and environmental monitoring. In recent years, there has been many projects regarding creating new smart textile for consumption. For example, scientists from National University of Singapore (NUS) recently have created the Spiders-Inspired Soft Fibers. These soft fibers were created by using the method in which spiders weave webs using their silk. These fibers were proven to be more

efficient compared to the traditional method of forming smart fabric and can be woven to create a strong and durable fiber under room temperature and pressure [21]. These fibers can be used for creating strain-sensing gloves for gaming purposes or as a smart face mask capable of monitoring breathing status for health conditions such as obstructive sleep apnea.

One noteworthy development in the realm of smart textiles is the creation of chainmail fabric, a collaborative effort between scientists from Nanyang Technological University (NTU) and the California Institute of Technology (Caltech) [22]. This innovative fabric, constructed from nylon plastic polymers and comprised of hollow octahedrons densely packed together, demonstrates remarkable versatility. When encased in a plastic covering and vacuum-sealed, the fabric undergoes a remarkable transformation, becoming up to 25 times more rigid and capable of supporting weights up to 50 times its own. This technology holds significant potential for various applications in Singapore's context.

For instance, by integrating sensors for monitoring vital signs such as heart rate, respiration, and movement, the chainmail fabric can be utilized in the development of advanced protective gear. Such gear could prove invaluable for athletes engaged in high-impact sports or elderly individuals at risk of falls or accidents. Beyond providing physical protection, these smart textiles have the capability to continuously monitor the wearer's health status and detect any irregularities in real-time. Figure 12 shows the different methods of implementing Smart

Textiles.

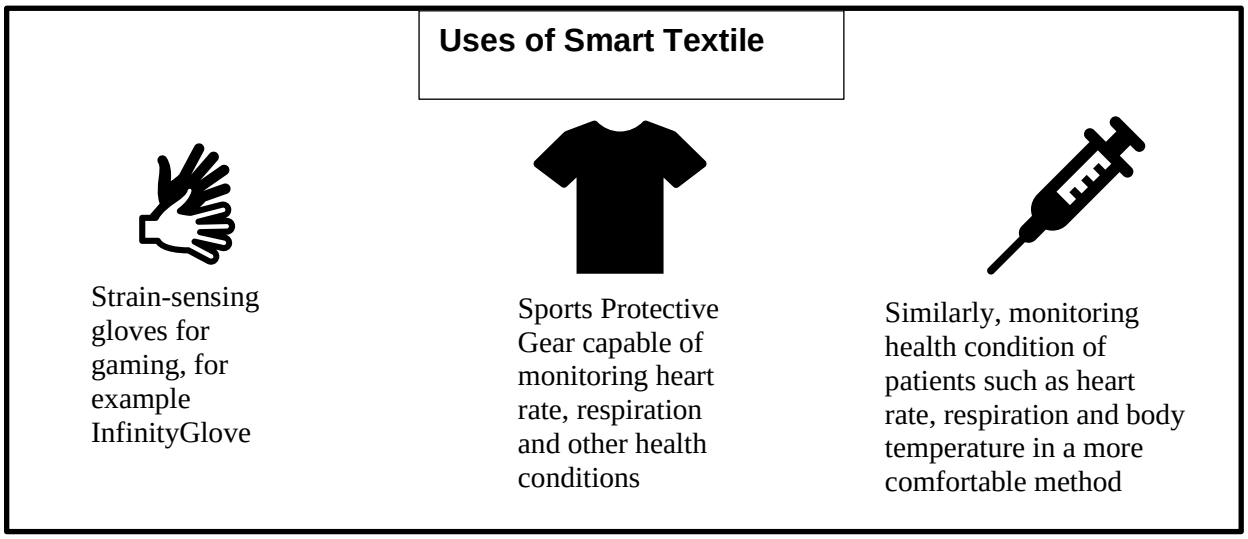

Figure 12: Different implementations of Smart Textiles

In the context of Singapore's initiatives towards becoming a Smart Nation, the adoption of such technologies holds promise for enhancing healthcare outcomes and promoting active aging among its population. Collaborations between local research institutions like NTU and global partners such as Caltech underscore Singapore's commitment to innovation and technological advancement. Furthermore, initiatives aimed at integrating smart textiles into existing healthcare and sports development programs align with Singapore's vision of leveraging IoT and technology to improve the quality of life for its citizens.

3. Conclusion

In conclusion, the applications of IoT in Singapore which we have discussed in this paper are transportation systems, smart factory, urban farming and smart textile. IoT has great potential to revolutionize different fields as shown in this term paper.

As Singapore continues with the Smart Nation Initiative, IoT will have greater impact on the future of Singapore. With its strong infrastructure, supportive government policies, and tech-savvy population, Singapore is well-positioned to lead the way in IoT adoption and innovation. However, to ensure that IoT implementation is successful in Singapore, a few concerns such as data privacy, security and interoperability needs to be addressed. It is important for stakeholders to ensure that IoT is used responsibly and ethically.

In summary, the introduction of IoT to Singapore has made Singapore more advanced as a country. If Singapore continues to use IoT responsibly, Singapore will be able to continue as a Smart Nation.

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Declaration of GAI Tools

- Use of GAI for key ideas of writing the fourth paragraph of Urban Farming.
- Use of GAI for getting urban farming example Sky Greens.
- Use of GAI for key ideas of writing concluding paragraph of Urban Farming.
- Use of GAI for key idea of writing the conclusion of the term paper.
- Use of GAI to refine syntax and grammar for correct language submission.