Global Journal of Information Technology: Emerging Technologies

Volume 7, Issue 3, (2017) 116-127

www.gjit.eu

Investigation of challenges and opportunities for the adoption of cloud-based Internet of things (IoT) in Australian agricultural SMEs

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Suggested Citation:

Sandu, N. & Gide, E. (2017). Investigation of challenges and opportunities for the adoption of cloud-based Internet of things (IoT) in Australian agricultural SMEs. *Global Journal of Information Technology: Emerging Technologies*. *7*(3), 116-127.

Received July 12, 2017; revised October 01, 2017; accepted November 19, 2017.

Selection and peer review under responsibility of Prof. Dr. Dogan Ibrahim, Near East University, North Cyprus.

Abstract

Increasing adoption of the Internet of things (IoT) is bringing revolutionary changes in the agricultural, manufacturing, retailing and finance industries, as they improve the existing business processes and reduce cost. IoT is seen as a powerful tool for agricultural SMEs in Australia, with the potential to transform farming and food production into a smart web of interconnected objects and, thus, improve the general productivity and sustainability of the food chain. However, as some of the innovative solutions may need to store the data locally on the device, and mostly on the cloud, it raises serious privacy and regulatory concerns. This paper used a pilot online survey to investigate the challenges and opportunities for adoption of IoT for Australian SMEs in agriculture and it is expected that it will help application and solution providers to address any issues that may arise in the Australian scenario.

Keywords: Internet of things, cloud systems, small-to-medium enterprises, adoption issue, agriculture, Australia.

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1. Introduction

The Internet of things (IoT) is primarily a wirelessly connected network of various devices and objects that enable computers, infrastructures, machines and people to transfer data among each other, without having to interact. It, therefore, enables a new way of communication between objects and humans (Xia, Yang, Wang & Vinel, 2012). With advancements in technology, the IoT promises a major technological development in various industries as regards enhancing innovation and business opportunities. Through the adoption of IoT, Australia has been able to witness a significant and transformational economic growth through the use of smarter infrastructures that enhance efficiency and more sustainable business growth (IoT Alliance Australia, 2016-2017). This is primarily because the information that is gathered through the use of IoT provides a better decision-making process for the objects that are being monitored. The global demand for high-quality food products, especially in the Asian market, will generate significant growth opportunities for the Australian agribusiness in the future. According to the Rural Industries Research and Development Corporation (RIRDCsmart agriculture and big data analytics are new trends in the agricultural industry. Furthermore, Meola (2016) mentions that an average farm will generate 4.1 million data points by 2050, even though this was only 190,000 in 2014. As a result, firms and organisations that adopt this kind of a structure will witness improved efficiencies and performance accuracy, which will eventually provide economic benefits for the whole country (Liu & Tao, 2016).

In the country's agricultural sector, small-to-medium enterprises (SMEs) are seen to be the major drivers of increased economic growth with more than 2 million SMEs employing more than 70% of the entire population (ABS, 2014). Therefore, SMEs are seen to be the major drivers of innovation in the economy in several sectors of the country. This means that, with the adoption of IoT among the SME firms in the country, there is a high probability that there would be increased productivity in the country's agricultural sector. Cloud-based services are important for solving issues faced by SMEs, which can be in terms of security, cost-effectiveness and availability of ICT resources such as software and hardware (Sandu, 2017). However, the advent of the use of IoT has various challenges and opportunities to these firms. For this reason, this paper focuses on the challenges and opportunities for the adoption of cloud-based IoT in Australian agricultural SMEs.

2. Literature Review

2.1. Opportunities for the Implementation of IoT in Australian Agricultural SMEs

Innovation is the key driver towards increased farm-level productivity, given that farmers are able to maximise on their profits while lowering their production costs (Gray *et al.*, 2015). In the 1990s, adoption of the global positioning system (GPS) to provide guidance for the grain industries was one of the greatest steps towards the adoption of IoT. This was soon enhanced with mapping systems and auto steer technologies linked to various office-based computers (Friess, 2016). Therefore, farmers were able to integrate the agricultural machinery with the technology to enhance efficiencies in farming. Today, agricultural machinery has greatly advanced along with technology to include various ways of planting and spraying and, thus, enabling growers to increase their yield while reducing the overall level of the use of crop inputs. In the cutting edge society, the consistent increment of innovation has brought about the improvement of modern programming, multiplying applications and cloud information stockpiling choices for various firms and individuals. With this kind of development, IoT has provided agricultural firms with access to integrated and comprehensive decision support tools that guide them in farm management decisions (Friess, 2016).

Applications of IoT have increased in most countries, including in Australia, USA and the European Union. In general, there has been more development in the cropping sector with the application of IoT in monitoring and managing cropping programmes among the agricultural SMEs in Australia (Gray *et al.*, 2015).

Cloud computing is primarily required in agricultural SMEs, given that it provides these firms with numerous data and services that improve crop production based on various factors such as climate conditions and land (Biduaa & Patela, 2015). In this sense, the use of IoT can offer data as a service, which costs less compared to the fixed services that charge on a certain fixed basis without the consideration of the utilisation of services. Besides, IoT provides sharing of resources at much cheaper costs, given that it offers various services such as infrastructure as a service, platform as a service, and software as a service (Biduaa & Patela, 2015). According to statistics on food production, it was seen that automation and mechatronics, coupled by the use of IoT, enhanced efficiency, sustainability and quality improvements in crop production (Vermesan & Friess, 2016). For example, the use of these systems resulted in a 77% increase in the world's crop production yields between 1961 and 2007 (Poppe, Wolfert, Verdouw & Verwaart, 2013).

Agricultural SMEs in Australia have a duty to adopt advanced mechanisms to feed the ever-growing population through the use of environment-friendly techniques. Besides, these firms have the responsibility of dealing with climatic changes, improving livestock conditions, become more resource efficient, reduce waste and guarantee food safety. However, this is possible through the use of IoT, which is quite promising for the achievement of new levels of control concerning the various factors that the agricultural SMEs are facing (Sami, 2016). Besides, IoT offers better sensing and monitoring of all production processes, including crop development resource utilisation and food processing, among others (Sami, 2016). IoT also enhances improved food quality through tracing and monitoring of locations and conditions of the crop production process remotely. This is possible given the fact that IoT is able to provide these firms with an understanding of the specific farming conditions such as the environmental and weather conditions, weeds and diseases, the emergence of pests, and the formation of the necessary knowledge to manage it. This has resulted in what is termed as 'smart farming', which increases productivity and efficiency in crop and livestock production (Khattab, Abdelgawad & Yelmarthi, 2016).

2.2. Challenges for the Implementation of IoT in Australian Agricultural SMEs

From the above discussion, it is seen that the adoption of IoT has rapidly transformed farming and the food industry. This is because IoT can bring in huge benefits that result in sustainable agriculture, while at the same time lowering the environmental impact. However, there are several problems associated with the use of IoT in agricultural SMEs. The main challenges of adopting IoT in Australian agricultural SMEs primarily include the quality and support in regard to the use of these devices (Hori, Kawashima & Yamazaki, 2010). There was a lack of successful businesses reporting positive returns on investment as a result of the adoption of IoT until 2016, in Australia (Liu & Tao, 2016). However, it is believed that there would be increased incorporation in the future agriculture among the SME firms in Australia. Some of the challenges associated with the use of IoT in the agricultural sector are discussed below.

2.2.1. The Outer Model (Measurement Model) of the Success Criteria

Most of the IoT hardware devices are developed in the USA, and this might present compatibility issues with some of the Australian equipment. Also, while the cost of adopting technology into the devices may be marginal, the cost of utilising the process for business gains could be considerable. As a result, IoT devices should be cost-effective, reliable and robust to enhance increased returns on investment (Gubbi, Buyya, Marusic & Palaniswami, 2013).

2.2.2. Internet Access

IoT devices require a reliable and fast Internet connection. However, access to the Internet in the rural parts of Australia can be a major impediment. The IoT wave is expected to be more than 5G by

2020, which means that the SMEs would have to look for higher Internet access in the country (Vermesan & Friess, 2016).

2.2.3. Perceived Value of Data

There is a great challenge among agricultural SMEs to demonstrate to farmers the importance of collecting data on a wider and more local firm scale. This is because farm-based data are crucial for enhancing better on-farm decision-making processes, while the regional data can be used to access the firm's performance through the benchmarking process (Poppe, Wolfert, Verdouw & Verwaart, 2013). These data are also important for biosecurity management, natural resource management, research and policy formulation.

2.2.4. Data Quality and Access

IoT is only good when it has good data to process, and thus data quality is required with regard to the scale, quantity, accuracy and resolution. As a result, the use of IoT requires that there be access to data of several years, to enhance efficient agricultural operations and also be able to make effective decisions. Besides, the data ought to be scalable and interoperable so as to build on wide data streams and networks to enable efficient analysis. Different IoT devices have different measures, and thus it requires the management to have different approaches concerning the use of data (Vermesan & Friess, 2016).

3. Statement of the Problem

According to the Food and Agricultural Organisation (FAO), the global population is expected to reach over 9 billion by 2050 (Biduaa & Patela, 2015). This means that there is a need to increase agricultural food production by more than 70% by around 2050, to meet the needs of people worldwide. Australia is a huge agricultural country, and its agricultural production has a great impact on the national food security. Just like the USA, Australia has a huge population that is dependent on the country's food production (Gray, Oss-Emer & Sheng, 2014). According to a 2015 IDC research in Australia, it was seen that IoT has been quite transformational in the country's agricultural sector. This can be seen in Figure 1.

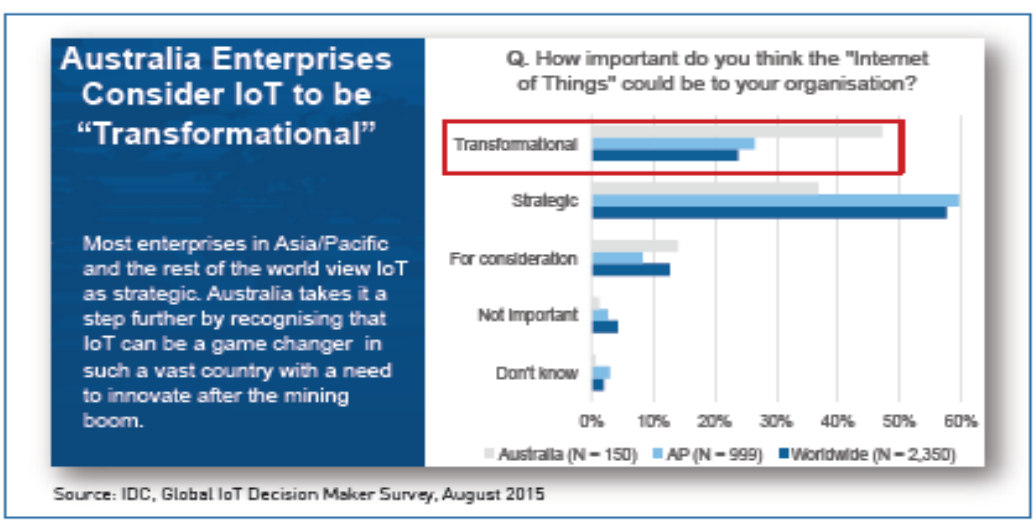

Figure 1. The use of IoT in Australian SMEs (Source IDC, 2015)

As a result, Australia's agricultural base is primarily dependent on the use of innovative systems to enhance a high level of farm productivity. According to ABS [16], the gross value of Australian agriculture had increased to $56 billion during 2015–2016. Thus, it is a very important industry for Australian GDP, and application of innovative technology such as IoT can improve the output of the industry.

3.1. Purpose of the Study

From the survey presented by FAO, it is predicted that increase in the population would result in increased demand and prices for food products if proper measures are not taken ((Biduaa & Patela, 2015). As a result, organisations are constantly using technologies to improve food production in various regions. The adoption of IoT is one of the measures to improve crop production, based on irrigation facilities, crop, land, finance availability and climate conditions (Gill, Chana & Buyya, 2017). The use of IoT can be a powerful tool for connecting the world's objects in both an intelligent and sensory manner and thus helping farmers in sharing resources at cheaper costs (Li, Gu & Yuan, 2016 Farmers are adopting these new efficient technologies that maximise the production output while minimising the production costs (Deshpande, Patil, Tonape, Kadam & Bhandari, 2017). However, there are varied outcomes involving the use of cloud-based IoT systems used by both public and private organisations. Hence, there is a need to find how the use of the cloud-based IoT is going to enhance the country's agricultural sector and the various challenges that come with the adoption process.

3.2. Research Objectives

Over the previous years, there has been incredible enthusiasm on the use of cloud computing, given that there have been various benefits perceived from adopting this kind of a system (Gide & Sandu, 2015). However, most firms have remained conservative despite the perceived benefits of the adoption of IoT (Levenburg, Schwarz & Motwani, 2005). From various studies, it is seen that there are various factors that influence the decisions of SMEs for adoption of the cloud-based IoT. Therefore, the following research questions would provide some of the reasons that SMEs adopt or fail to adopt the use of IoT in their operations:

- What are the opportunities for the use of cloud-based IoT for agricultural SME firms?
- What are the challenges in the use of cloud-based IoT for agricultural SME firms?

3.3. Overview of Australia's Agricultural Sector

Australia's agricultural industry consists of a wide range of industries. Besides, the country has a comparative advantage over its broad agriculture, given that it has a broad abundance of land (Gray, Oss-Emer & Sheng, 2014). Given that most of the country's land is arid and semi-arid, it is most suitable for native vegetation and livestock. However, through its broad acre firms, it is seen that the farms contribute to about 54% of the gross value of its agricultural production, making up to about 53% of the country's agricultural businesses (Gray, Oss-Emer & Sheng, 2014).The horticultural industry in the country also contributes to about 16% of the country's gross value of its agricultural production. This can be seen in Figure 2.

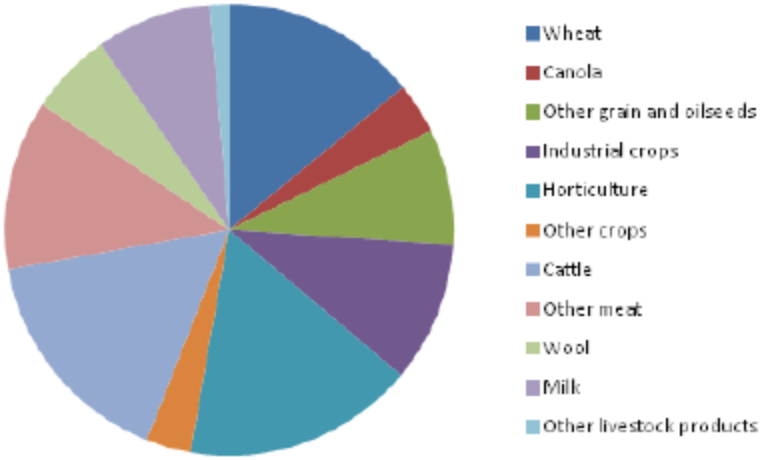

Figure 2. Share of gross value of Australia's agricultural production, by industry (2012–2013) (ABARES, 2012)

Over the past ten years, Australia has developed in importance as a growing hub of agricultural production, with the Asian markets accounting for about 60% of all the agricultural exports between 2011 and 2012 (ABARES, 2012). With the increased competition in the world market in agricultural production, there is a great need for the Australian market to increase its production through adoption of advanced agricultural systems such as IoT. Australia's agricultural industries majorly depend on irrigation to sustain its agricultural production. In the year 2011–2012, the country irrigated less than 1% of its agricultural land, but the sector managed to realise a 30% gross value of its agricultural production. This means that with the adoption of IoT systems, the country is likely to have increased agricultural productions. Besides, drought has been seen to have adverse impacts on the country's agricultural sector, which raises the need for the country to use other advanced systems to increase its production. Figure 3 shows the impact of drought on the country's agricultural production.

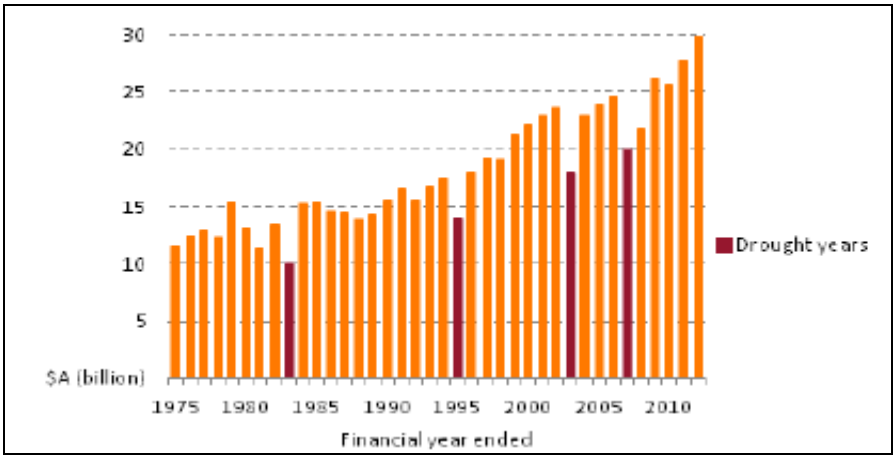

Figure 3. The impact of drought on the gross value of agricultural production [22]

Today, it is seen that most farmers have begun adopting the use of high-tech farming technologies and techniques to improve the efficiency of their agricultural operations. Farmers can now use smartphones to remotely monitor all the agricultural operations and at the same time obtain statistics on their crop and livestock production. According to the BI Intelligence survey, the use of IoT devices in agriculture is likely to rise by up to 70 million in 2020, with a compounded annual growth rate of 20% (Attaran, 2017).

4. Statement of the Problem

4.1. Research Design

This study achieved results by deploying the real cloud-based pilot system that is useful for collecting feedback from the SME employees selected in the study. The use of the pilot system is important to understand the implementation and performance issues with regard to the use of the cloud-based IoT, particularly in agricultural SMEs in Australia. The cloud-based pilot system is also important in allowing the quantitative benchmarking in the SMEs of some of the performance metrics that include computational and access latencies (Gide & Sandu, 2015a). However, as that the cloud-based pilot system may not capture all the necessary information regarding the use of IoT in SMEs, a survey was conducted to provide direct feedback from both the employees and managers of SMEs. In this way, the advantages and challenges concerning the use of IoT would be achieved.

4.2. Population of Study

The target population in this study was agricultural SME firms in Australia that have adopted or considering adopting the use of the cloud-based IoT systems. The employees of the firms were researched in regard to the implementation of the IoT systems and the level of satisfaction that they obtained through the use of these IT systems. Managers/CEOs and owners of the SMEs were evaluated through the use of the survey study. Besides, these individuals provided responses concerning the use of the IoT systems in addressing key decision-making processes in the agricultural sector.

4.3. Data Collection

The primary data that were collected through the use of survey questionnaires was distributed among the SMEs' employees using Survey Monkey. Survey questions were sent to 300 Agricultural SMEs with a usable return of 42 responses to be analysed. Through the survey study, the questionnaires did provide data that included both the opportunities and challenges to the use of the IoT systems.

4.4. Data Analysis

The survey results show that 67% firms admitted that they fully understood the relevance of IoT in their agricultural applications. Besides, about 21% of the firms indicated that they understood how the IoT functions as opposed to 5% which said that they had no idea of how this computing platform works. This can be seen in Table 1.

Table 1. Level of understanding of IoT among agricultural SMEs

		Frequency	Percent	Valid percent	Cumulative percent
Valid	I fully understand the term and relevance to my industry	28	66.7	66.7	66.7
	I fully understand the term and think it is just hype	3	7.1	7.1	73.8
	I have no idea how it works	2	4.8	4.8	78.6
	I have some idea about how it works	9	21.4	21.4	100.0
	Total	42	100.0	100.0	

On the other hand, the survey also sought to investigate whether these firms had the required skills for developing IoT in the agricultural sector. From this study, it was seen that about 86% of the SME firms admitted to having the right skills as opposed to 14% who said that they lacked such skills. This can be seen in Table 2.

Table 2. Statistics on the required skills for the adoption of IoT services

	Frequency	Percent	Valid percent	Cumulative percent
No	6	14.3	14.3	14.3
Yes	36	85.7	85.7	100.0
Total	42	100.0	100.0	

The participants in the survey were also asked about their plan for the IoT solution in their organisations. From the respondents, it was seen that 45% of the firms indicated that they were going to develop and deploy IoT applications immediately as opposed to 5% who indicated that they were not going to deploy IoT in their firms at all. However, others indicated that they were going to adopt the IoT in a period of about 6–12 months. This can be seen in Table 3.

Table 3. The plan for the SMEs to adopt IoT in their firms

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Planning to develop and deploy IoT in the next 12 months	6	14.3	14.3	14.3
	Planning to develop and deploy IoT in the next 6 months	7	16.7	16.7	31.0
	Planning to develop and deploy IoT now	19	45.2	45.2	76.2
	We are already using IoT in our field	8	19.0	19.0	95.2
	We are not planning to deploy IoT in our field	2	4.8	4.8	100.0
	Total	42	100.0	100.0	

When the SME firms were also asked about their strategic reason for adopting IoT in their agricultural sector, 31% indicated that they needed to analyse agricultural product performance and for monitoring the functioning and maintenance of the agricultural machines/devices. Besides, 19% indicated that they wanted to adopt IoT for reducing the agricultural costs. However, 5% of the firms indicated that they wanted it for increasing the revenue opportunities, while 7% indicated that they needed it for improving competitiveness and reducing the break cycle. This can be seen in Table 4.

Table 4. Strategic adoption of IoT among SMEs

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Improved competitiveness	3	7.1	7.1	7.1
	Increased revenue opportunities	2	4.8	4.8	11.9
	Reduced cost	8	19.0	19.0	31.0
	To analyse agricultural product performance	13	31.0	31.0	61.9
	To better monitor performance of agriculture machines/devices for better service/maintenance	13	31.0	31.0	92.9
	To reduce break cycle	3	7.1	7.1	100.0
	Total	42	100.0	100.0	

For the firms that had implemented the use of IoT in their organisations, they were asked to indicate the percentage of the growth rate that they had experienced due to the use of IoT. From the respondents, it was seen that approximately 57% of the SMEs had witnessed a growth rate of between 50% and 70%, as opposed to 5% who had witnessed a growth rate of below 25%. This means that the adoption of IoT was quite essential for these firms, given that they were able to enhance their production. This can be seen in Table 5.

Table 5. Impact of IoT on the agriculture among the SMEs

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Growth rate over 25–50%	12	28.6	28.6	28.6
	Growth rate over 50–75%	24	57.1	57.1	85.7
	Growth rate over 75–100%	4	9.5	9.5	95.2
	Growth rate under 25%	2	4.8	4.8	100.0
	Total	42	100.0	100.0	

Apart from the impact of IoT on the SMEs, the participants were also asked about the types of IoT applications that these organisations had implemented in their agricultural operations. From the study, it was evidenced that 33% of the SMEs used it for monitoring their livestock from birth to the sale of their livestock as opposed to 14% who used it for water management activities. In other statistics, about 26% of the firms used the IoT applications for monitoring horticulture and ensuring security in their firms. This can be seen in Table 6.

Table 6. Types of IoT applications used in the SMEs

	Percent	Cumulative percent
Horticulture—using wireless sensors to monitor soil temperature and moisture, greenhouse temperature and humidity, leaf wetness levels, solar radiation and rain levels.	26.2	26.2
Livestock—the monitoring of livestock via a GPS connected to a local wireless network and with RFID technology counting and tracking the animals' individual statistics from birth to sale	33.3	59.5
Security—adding GPS tracking devices to expensive machinery; intrusion-monitoring sensors to sheds, gates, pump boxes and greenhouses	26.2	85.7
Water management—monitoring water use and wastage across all storage tanks, flow sensors and river water movement	14.3	100.0
Total	100.0	

When the SMEs were asked what kind of cloud-based services they would use, about 36% of the firms confirmed they would use Amazon web services compared to only 7% who would consider the use of other kinds of platforms. However, a high number of the respondents (29%) preferred to use the private cloud services for their operations. This can be seen in Table 7.

Table 7. Types of cloud-based services that the SMEs would use

		Frequency	Percent	Valid percent	Cumulative percent
Valid		1	2.4	2.4	2.4
	Amazon web services (AWS)	15	35.7	35.7	38.1
	Google cloud platform	6	14.3	14.3	52.4
	Microsoft azure	5	11.9	11.9	64.3
	Others	3	7.1	7.1	71.4
	Private cloud services	12	28.6	28.6	100.0
	Total	42	100.0	100.0	

In another response from the SMEs, about 52% of the firms felt that they expected the IoT to have similar security issues compared to other applications and systems. Besides, when asked on what they thought about the greatest threat of IoT in the near future, about 43% and 41% indicated that they were afraid of malware infection and hacking of their devices, respectively. This can be seen in Table 8.

Table 8. Greatest threat to IoT among the SMEs

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Accidental exposure of DATA	1	2.4	2.4	2.4
	Deliberate sabotage of system	4	9.5	9.5	11.9
	Denial of service attack (DOS)	2	4.8	4.8	16.7
	Hacking devices	17	40.5	40.5	57.1
	Malware infection	18	42.9	42.9	100.0
	Total	42	100.0	100.0	

Finally, when asked about the particular government policy for the organisations to accelerate the benefits of IoT, about 69% indicated that they would like the National Broadband Plan policy to be implemented. In other words, approximately 21% of the respondents indicated that they wanted the data privacy policy to be implemented. This can be seen in Table 9.

Table 9. Government policies that should be implemented for the SMEs to benefit from IoT

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Data privacy policy	9	21.4	21.4	21.4
	Do not know	2	4.8	4.8	26.2
	National broadband plan (NBN) related	29	69.0	69.0	95.2
	Open standards and interoperability	2	4.8	4.8	100.0
	Total	42	100.0	100.0	

4.5. Research Limitation

This research is focused on Australian Agricultural SMEs only, so the research results cannot be generalised for other developed and developing countries. Also, the research could not be applied to large agricultural-based businesses as well. For future research, qualitative data would be collected by using interview techniques from the decision makers to get more detailed information in regard to the challenges and opportunities to adopt cloud-based IoT by Australian SMEs.

5. Conclusion

From the above contentions, it is seen that the utilisation of IoT has resulted in various opportunities for the agricultural SMEs in the country. The information that is gathered through the use of IoT is seen to enhance better decision-making processes with regard to the elements that are being monitored and thus resulting in improved efficiencies. Besides, the use of IoT has been seen to enable farmers to effectively scan the process of their crop production process and thus achieve high levels of precisions in the decision-making process.

Finally, the use of IoT requires that there is high-supportive Internet access in order to provide quality experience for the cloud-based services being used. This means that agricultural SMEs need to pay close attention to their existing network infrastructure to ensure their reliability and available capacity for obtaining data in their farms. Besides, these firms need to increase awareness among the farmers for the need to collect data with regard to their farms to enhance efficient decision-making processes.

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