Mobile Cloud Computing In The Technology Era: An Overview Of The Factors Influencing The Adoption Process

Dr. Mahmoud Odeh

Abstract: Mobile cloud computing considered as a hot topic in the information systems field. However, despite the advanced technology adopted in mobile devices, they are still a limitation in several aspects such as processing power, storage capacity, scalability, battery life, security and privacy, and cost. Fortunately, cloud computing provides several solutions for mobile limitations through the integration of cloud technology and mobile devices. This integration provides the ability to use the advance application through mobile devices for users. However, the process of adopting mobile cloud computing in developing countries still need more research and investigations. This paper presents the main benefits and challenges of using mobile cloud computing and suggests a new theoretical framework for such usage. A triangulation methodology has been employed in this study for the data collection process. Accordingly, data were collected from twenty-two interviews, two focus groups, direct observation, and 223 qualitative surveys. Nvivo software and other tools were applied for the data analysis process.

Index Terms: Mobile Cloud Computing, Information Systems, security, privacy, Nvivo.

1. INTRODUCTION

Cloud computing could is a web-based technology, which provides the ability to store, processing, and presenting data through servers hosted on the internet instead of using local resources [1]. Cloud technology provides almost unlimited processing and storing power based on user requirements through virtual resources [2]. Therefore, these resources can be simply added or removed without expensive costs [3]. Such resources can be scaled up or down and uses will pay per use when using them [4]. Accordingly, single users or companies could avoid the expensive costs of start-up projects for advance infrastructure by using cloud computing technology [5]. Cloud technology provides the ability to simulate any in-house technology such as servers, virtual desktop, software applications, and storage data. Accordingly, cloud resources can be connected directly to the internet and start a virtual company with almost zero upfront costs [6]. In the 2000s, Apple company introduced a new technology that changed the music industry. Apple's first experience with cloud computing was the iTunes music store [7]. Such a store offers millions of online songs, videos, and pictures. The data resources are mainly stored on Apple servers and can be the stream, upload, or download on Apple devices such as iPods, iPads, and iPhones. End users will only pay-per-use and the cost dramatically dropped down. On the other hand, Apple makes a large profit from such industry [8].

- *Mahmoud Odeh is currently assistant professor in management information system department in Zarqa University-Jordan. E-mail: Modeh@zu.edu.jo*

However, Apple's iCloud was an extension for iTunes as it provides the ability to extend the storage area for apple devices as well as provides a full backup and restore solutions. Such cloud-based storage providing almost unlimited storage space based on payment plan for storing music, videos, books, pictures, and any documents and application. User data will be saved in centralized storage hosted on virtual servers provided by Apple [9]. In addition, iCloud users can rapidly customize their storage plan by adding or remove any resource to back-up as well as creates an incremental process for restore. Accordingly, Apple users will not be prisoner in specific hardware as the user has the ability to restore all data through any other compatible Apple device.

1.1 Mobile Cloud Computing

The integration of mobile and cloud computing provides a great window for almost unlimited resources [10]. However, despite the fact that security and privacy still a big concern in cloud technology, enterprise companies such as Apple, Samsung, and Huawei argued that cloud technology will make their devices a secure place. For instance, Apple users could track their devices in case of losing or stealing. In addition, such devices will be useless without the iCloud user name and password. Furthermore, Samsung and Huawei provide the ability to block any mobile online through cloud computing technology. Several authors argued that internet applications such as blogs, Wiki, Twitter, Facebook, and YouTube are mainly cloud-based technology [11]. Therefore, well-known applications mainly stand on cloud computing technology. These applications can be run over mobile devices and stored on servers hosted on the internet. According to [12], on YouTube there are one billion videos plays daily by millions of users. Furthermore, billions of Gigabytes are streaming and storing on Facebook. These applications are mainly accessed through mobile devices.

1.2 Cloud computing models

Cloud service provides offers a wide range of cloud technology solutions based on cloud users' requirements. Several researchers classified cloud computing into the deployment model and service model. The cloud deployment model

consists of four models: private cloud, public cloud, hybrid cloud, and community cloud [13]. In private cloud the resources are owned by a specific user [14]. However, it is the most expensive and secure option. As this solution is mainly used by a specific company, it is greatly expensive comparing with other cloud deployment models [15]. On the opposite, public cloud model provides a shared pool of applications for a large number of cloud users. However, the public cloud could be the least expensive solution and the less secure one comparing with private cloud model. The integration between private model and public model generates the hybrid cloud model. Such model may consist of several public, private, and community cloud models [2]. A hybrid model is in the middle between the public and private cloud models, as it considers as more expensive solution comparing with public cloud. However, hybrid cloud takes advantage of private cloud technology [16]. The community cloud model is the model shared by several organizations that have the same concerns such as universities, libraries, and manufactories. Community cloud costs can be shared by this community, which provides less cost for each user. The community cloud model, furthermore, provides the customization ability for shared applications based on cloud users' requirements [15]. A cloud service model consists of three main models: Infrastructure as a service (IaaS), Platform as a service (PaaS), and application as a service (AaaS) [17].

2 RESEARCH METHODOLOGY

The research methodology in this paper aims to provide a clear design, tools for data collections and analysis process [18]. Accordingly, a triangulation methodology applied in this study by conducting twenty-two semi-structured interviews, tow focus groups, 223 surveys, and secondary data analysis. Nvivo, Microsoft Visio, and excel are used as data analysis tools. The data was collected from private companies in the kingdom of Jordan. Data were collected and analyzed in sequence levels following the methodological approach suggested by [19]. Started with the research mental model, defending the main concepts of study, the study ideas in the field of mobile cloud computing, the theories that may use in the literature review and collected data, applied the suitable methodology with methods, and finally present the study findings [20]. In addition, qualitative data analysis was created through three main steps suggested by Miles and Huberman [21]: data condensation, data display and drawing/verifying conclusions.

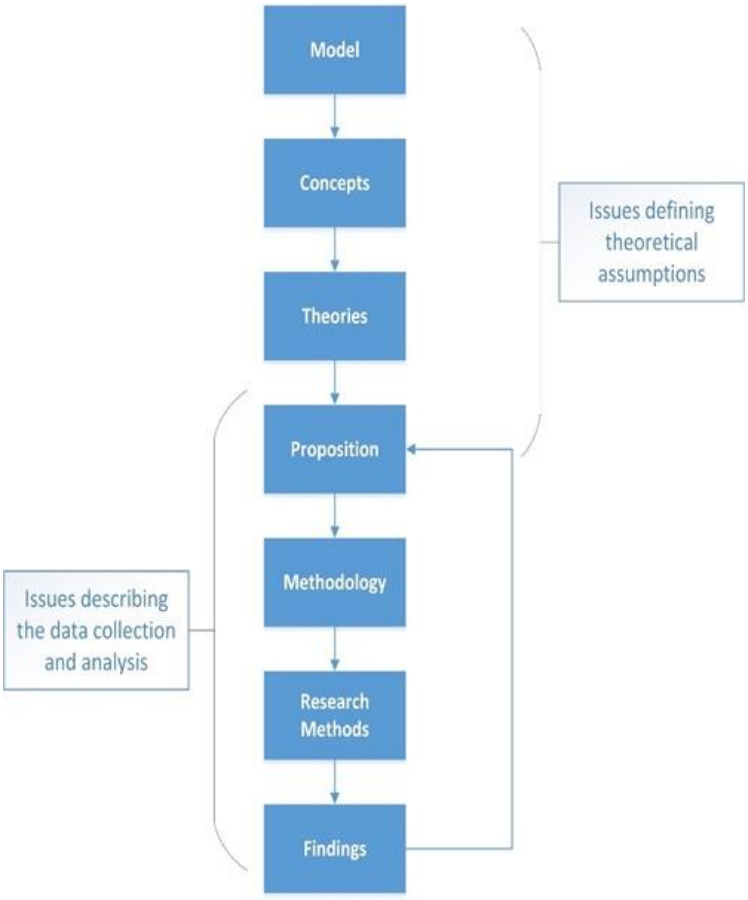

Figure 1: *Sequence levels of methodological approach adopted in this study [19].*

2.1 Conducting the pilot study

A pilot study could be defined as a small study, which aims to test a questionnaire, interview, and direct observation schedule as well as to avoid any problems in actual data collection processes such as recording problem. In addition, pilot study provides the chance to test the validity and reliability of the data that will be collected [22]. Therefore, a pilot study was conducted to improve the validity and reliability of the actual data collected as well as to avoid any possible weakness in the research; and in addition to providing better planning of the schedule of data collection from potential research sites. The researcher conducted three informal interviews and in addition revised the questions for the interviews, focus groups, and the survey with a professor in management information systems. In addition, the researcher asked five participants to answer the questionnaire. The pilot study indicated some errors in the interview and survey questions, and accordingly, some questions were modified before the actual data collection took place. The researcher gave each interview code started from Pn1 to Pn22, which related to participant 1 to participant 22. Such codes aim to provide a reference code for the arguments collected from interviewees during data analysis process. As was previously mentioned in this paper, three focus groups have been conducted in order to provide better understanding of this study's factors and its effect over the usage of mobile cloud computing.

3 MAIN RESULTS

As demonstrated in this document, the numbering for sections upper case Arabic numerals, then upper case Arabic numerals, separated by periods. Initial paragraphs after the section title are not indented. Only the initial, introductory paragraph has a drop cap.

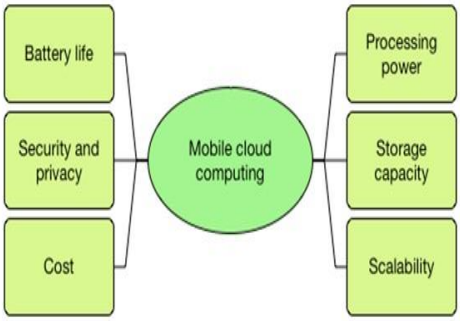

Figure 2: *Main factors influencing mobile cloud computing adoption for Nvivo Mind-Map analysis.*

3.1 Mobile processing power

The results from the qualitative analysis show that one of the main weaknesses of mobile devices is processing limitations. It is obvious that mobile processing capabilities still limited comparing with servers, edge computing, workgroups, and super-computers. An expert in mobile technology who works as associate professor in information technology department argued that: The mobile devices are very limited in processing despite that mobile providers confirm that these devices are very smart with high processing power. For simple applications, smartphones will be fine. However, advance applications such as 3D rendering or engineering applications like MATLAB will definitely not effective at all. (Pn3) As can be seen from figure (3) findings show that 11% of participants believed that the current processing power of mobile smartphones is fair enough for processing requirements. However, 77% of participants in this study believed the opposite and 12% have no idea. Cloud computing technology, therefore, may provide almost unlimited processing power to mobile devices by sending the input for processing through cloud servers hosted on the internet and finally receiving the outputs or results. Such process would help smartphones to overrun the limited power of internal process to hundreds of thousands of processers available in cloud computing technology.

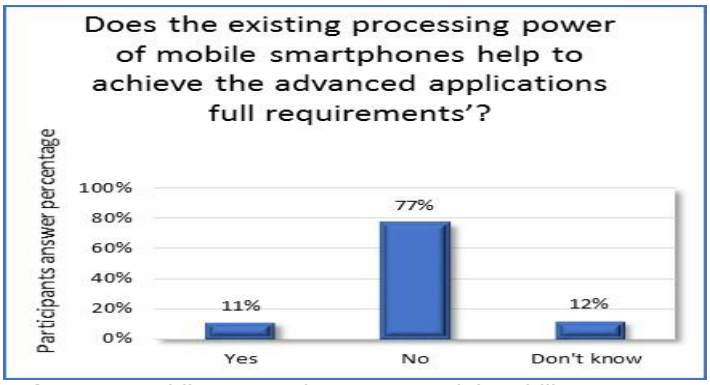

Figure 3: *Mobile processing power and the ability to support the advanced applications.*

3.2 Mobile storage capacity

Another limitation found in this study is the limited storage of smart-phones. One of the main benefits and simple service provided by cloud computing is the online cloud storage. Several cloud technology service providers such as Apple and Microsoft provide free and limited storage to their users in order to overcome this limitation [23]. However, mobile cloud technology provides a big amount of storage through pay-per-use or monthly and yearly payments. Several participants in this study stressed that cloud storage servers are definitely cheaper than buying this storage in physical devices. Another feature that the user can access the stored data from any place at any time using any device [24]. A computer engineer from the engineering school said: It is very clear that new mobile devices have enough space for normal usage such as camera photos and social media as well as video recording even at a high-quality level, which could be around 1080 p. However, when we talking about advance applications that need terabytes or even more storage areas, these devices still useless. (Focus group) However, it is interesting to mention that the majority of participants believed that nowadays smartphones storage is not helping to achieve even the normal application requirements. As can be seen from the data in figure (4) 89% of participants believed that the adoption of mobile cloud computing would improve the storage capacity. Furthermore, one of the interviewees said: Smartphones have limited storage capacity. However, if you buy a high capacity device such as 512 GB it will be very expensive. However, this storage still less than terabyte, which will not be suitable for one-hour 3D render
ing. (Pn20)

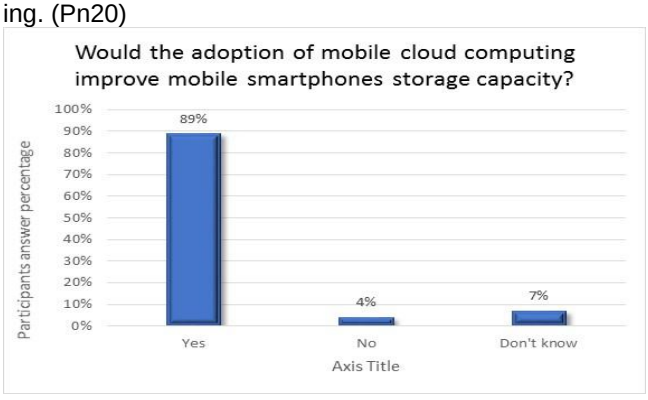

Figure 4: *The benefit of extending storage by adopting mobile cloud computing.*

3.3 Scalability

In cloud computing technology, scalability is the ability to increase or decrease the usage of data storage or processing based on uses usage. This feature integrated with mobile smartphones, which creates a fantastic pricing system for mobile cloud users. Cloud computing business models based on pay-per-use provide the ability to increase or decrease the cost of using cloud technology. Mobile cloud computing technology enables end-users to add or remove virtual nodes, servers, and resources automatically based on customer usage. Scalability, therefore, is one of the best features offered by cloud computing, which crossed with cost benefits. Pn22 stressed that: Scalability in mobile cloud computing would definitely save time and cost of adopting additional physical resources, it also enables mobile cloud users to maximize the number of CPUs, RAMs, Graphic cards with additional cost as well as back to the original level in case of resources downgrade required. According to the findings of this study, it could be argued that scalability in mobile cloud computing is one of the most important enablers for the process of adopting mobile cloud technology. Several benefits can be gained through scalability such as the ability to increase or decrease the resource directly with the need for removing or adding physical machines. Moreover, the cost benefits of scalability feature should be taken into consideration, especially that the mobile cloud users cannot easily predict their requirements.

3.4 Mobile battery life

Extending battery life is one of the most essential challenges for smartphone devices. Considerable solutions have been introduced to improve the performance as well as to extend the battery life. However, a long applications execution time may increase the smartphones battery consumption up to 45%. Therefore, it could be argued that mobile cloud technology is almost the only solution that may help such devices to execute applications outside the mobile devices in order to save the limited capability of mobile devices battery. Remote applications would save the limited energy by remote processing by using mobile cloud computing. For instant 3D image rendering could reduce around 41% of mobile energy consumption within less than 30 minutes. What is interesting in the findings from this study is that 46% of participants believed that they need their battery life for smart devices to stay working for more than 72 hours to be satisfied. However, nowadays for smartphones, the maximum battery life with normal usage may not exceed more than 48 hours in the best-case scenario.

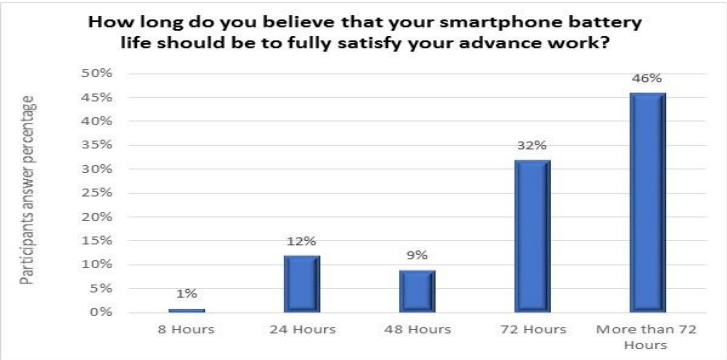

Figure 5: *participants point of view about the smartphone ideal battery life.*

3.5 Security and privacy

Security refers to the ability of protecting data from unauthorized access, whereas privacy is focus on permissions and policies, which decide who could access the data, why, and how. All the findings from this study, which collected from interviews, focus groups, and survey argued that data security and privacy are the main concern in mobile cloud computing technology. It is interesting to note that participants in this study who working as decision-makers in their companies argued that cloud computing in general and mobile cloud computing in particular might rejected if the security and privacy are not fully guaranteed form cloud technology service provides. As one of the decision-makers Pn9 explained: Privacy is the main concern of using mobile cloud computing in our company. It is not a joke we may lose everything in case of data hacking. The issue is that our data is not storing in the company servers. Therefore, we need a clear answer in cloud service level agreement about the privacy of data as well as who can access them and why. I think that security would be fine as I believe that private cloud servers will be secure. Findings from the survey in this study argued that the majority of participants believed that security and privacy is the main concern in mobile cloud computing. As can be seen from the results in Figure (6) 69% of participants in this study believed that security and privacy are the main concern of the adoption of mobile cloud computing technology, whereas 14% of participates mentioned cost concerns, 6% believed that processing power is the concern, 5% storage and capacity, 4% battery, and 2% scalability.

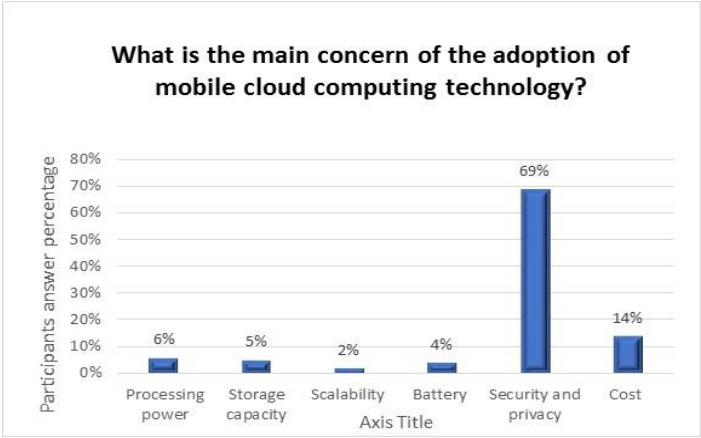

Figure 6: *main concerns of the adoption of mobile cloud computing technology.*

3.6 Mobile cloud computing cost

The results from participants' in this study argued that one of the most important features of cloud computing is the cost-benefit, which can be used in mobile cloud technology as a power point when using advance processing requirements. Almost all interviewees focused on the cost benefits of cloud computing by using pay-per-use business model. Such feature could be one of the most important enablers of mobile cloud computing adoption technology. However, it is suggested by several experts in cloud computing to study the return on investment when using cloud technology. As one of the experts in cloud computing technology said: It is essential point to study the return on investment when using mobile cloud computing specially the storage and processing cost during the long term. As you may know, cloud computing

startup cost is almost zero, while running cost cloud be expensive comparing with own the storage device rather than rent it by iCloud for example. (Pn13)

Another participant argued that:
The integration of cloud technology and cloud computing could be a great idea for saving cost when using a huge amount of capacity such as terabytes. However, for normal use this could not be a good investment. The use of mobile smartphone for a big data usage would makes them as a window for accessing data. (Pn18) Figure (7) presents the results from the survey about the participant point of view. 74% of participants believed that mobile cloud computing could improve the overall cost, while 17% believed that it is not worth to use mobile cloud technology for saving costs, and 9% have no answer or maybe don not know.

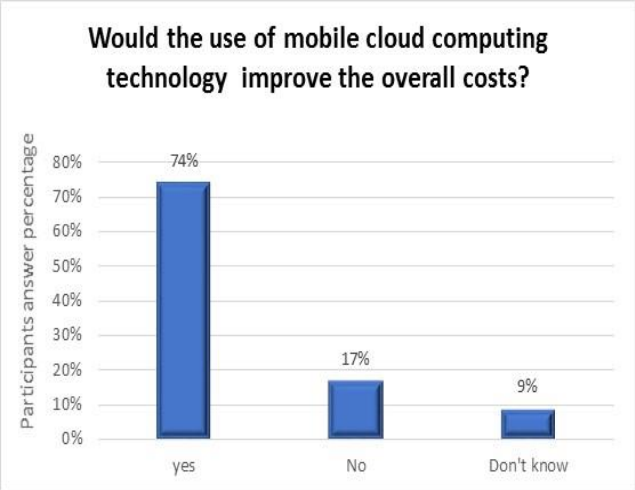

***Figure 7**: Cost benefits of mobile cloud computing*

To conclude, the feedback from participants shows that the cost-benefit of mobile cloud computing could be taken in to consideration in case of advance usage by using the smartphone as a connector with cloud servers.

4 A PROPOSED FRAMEWORK FOR THE FACTORS AFFECTING THE ADOPTION OF MOBILE CLOUD COMPUTING

As can be seen from the figure (8), the author suggests a proposed framework for the adoption of mobile cloud computing based on the findings from this study. In addition, a sequence diagram has been integrated from the right-hand side describe how mobile cloud technology could be adopted in sequence steps. The adoption process started with the awareness of the meaning of mobile cloud computing and its benefits and limitations. Such awareness could be achieved by reviewing the factors from this study and its effect over the adoption of mobile cloud technology as well as the initial requirement of adoption process. The second step focuses on the initial decision of the adoption process of mobile cloud applications, which normally started with trial version of advance application to make the first decision. The initial decision could be positive rejection, negative rejection, or acceptance. In positive rejection there is a chance to repeat the process after creating a report that justifies the reason for rejection, while in negative rejection the process of mobile cloud adoption will be rejected without any justifications. In case of acceptance, initial mobile cloud applications will be adopted and the initial confirmation phase will take place. Finally, the usage of mobile cloud computing will be run for long-term usage with update process, application maintenance, and software upgrade.

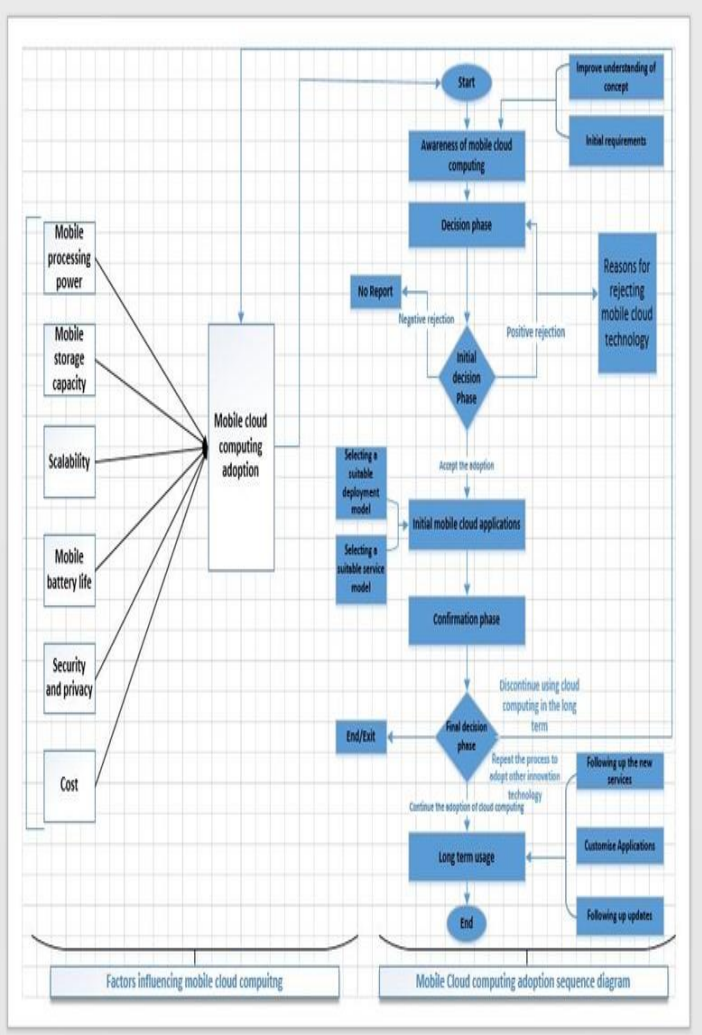

***Figure 8:** A proposed framework for mobile cloud computing adoption*

After developing the proposed framework for mobile cloud computing adoption based on the factors form this study. The framework has been tested and validated by three companies with participants who did not participate in this study from the first stage to check out the ability to apply such framework in the real-life.

5 CONCLUSION

This study presents the main factors for adopting mobile cloud computing. The data were collected from interviews, focus groups, surveys, and direct observation. Several factors found in this study, which have a direct influence on mobile cloud computing. Such factors are the limitation of mobile processing power, the limitation of mobile storage capacity, the scalability feature of cloud computing, battery life limitations in smartphones, security and privacy of using mobile cloud computing, and cost benefits. The results in this study show

that the benefits of using mobile cloud technology are much higher comparing with drawbacks. However, end-users may gain the maximum benefits of using mobile cloud technology for advance applications only. As the usage of mobile cloud technology for limited basic applications seems to be not worth using.

ACKNOWLEDGMENT

This research is funded by the Deanship of Research in Zarqa University / Jordan.

[1] REFERENCES

[2] M. M. Odeh, "A proposed theoretical solution for transferring from physical to virtual machines based on cloud computing," in 2019 5th International Conference on Information Management (ICIM), 2019, pp. 221-226.
[3] K. T. McDonald, Above the Clouds: Managing Risk in the World of Cloud Computing. IT Governance Ltd, 2010.
[4] D. G. Chandra and M. D. Borah, "Cost benefit analysis of cloud computing in education," in Computing, Communication and Applications (ICCCA), 2012 International Conference On, 2012, pp. 1-6.
[5] A. Bento, Cloud Computing Service and Deployment Models: Layers and Management: Layers and Management. IGI Global, 2012.
[6] V. Chang and G. Wills, "A University of Greenwich Case Study of Cloud Computing," E-Logistics and E-Supply Chain Management: Applications for Evolving Business, vol. 232, 2013.
[7] H. Hassan, M. H. M. Nasir and N. Khairudin, "Cloud computing adoption in organisations: Review of empirical literature," in SHS Web of Conferences, 2017.
[8] H. Arif, H. Hajjdiab, F. Al Harbi and M. Ghazal, "A comparison between google cloud service and iCloud," in 2019 IEEE 4th International Conference on Computer and Communication Systems (ICCCS), 2019, pp. 337-340.
[9] V. L. Vaccaro and D. Y. Cohn, "The evolution of business models and marketing strategies in the music industry," International Journal on Media Management, vol. 6, (1-2), pp. 46-58, 2004.
[10] S. Bhattacharyya, "Research on Edge Computing: A Detailed Study," International Journal of Information Technology (IJIT), vol. 2, (6), 2016.
[11] D. Tayade, "Mobile cloud computing: Issues, security, advantages, trends," International Journal of Computer Science and Information Technologies, vol. 5, (5), pp. 6635-6639, 2014.
[12] M. Attaran and J. Woods, "Cloud computing technology: improving small business performance using the Internet," Journal of Small Business & Entrepreneurship, vol. 31, (6), pp. 495-519, 2019.
[13] J. Davidson, B. Liebald, J. Liu, P. Nandy, T. Van Vleet, U. Gargi, S. Gupta, Y. He, M. Lambert and B. Livingston, "The YouTube video recommendation system," in Proceedings of the Fourth ACM Conference on Recommender Systems, 2010, pp. 293-296.
[14] T. V. N. Rao, K. Naveena and R. David, "A New Computing Envornment Using Hybrid Cloud," Journal of Information Sciences and Computing Technologies, vol. 3, (1), pp. 180-185, 2015.
[15] R. Masadeh, M. Al-Lozi and S. R. Darawsheh, "A Theoretical Study on Cloud Computing Adoption in Jordanian Universities," vol. 2, (5), pp. 75-89, 2015.
[16] S. Yangui, P. Ravindran, O. Bibani, R. H. Glitho, N. B. Hadj-Alouane, M. J. Morrow and P. A. Polakos, "A platform as-a-service for hybrid cloud/fog environments," in Local and Metropolitan Area Networks (LANMAN), 2016 IEEE International Symposium On, 2016, pp. 1-7.
[17] M. Armbrust, A. Fox, R. Griffith, A. D. Joseph, R. Katz, A. Konwinski, G. Lee, D. Patterson, A. Rabkin and I. Stoica, "A view of cloud computing," Commun ACM, vol. 53, (4), pp. 50-58, 2010.
[18] S. Murugesan and I. Bojanova, Encyclopedia of Cloud Computing. John Wiley & Sons, 2016.
[19] R. Stockdale and C. Standing, "An interpretive approach to evaluating information systems: A content, context, process framework," Eur. J. Oper. Res., vol. 173, (3), pp. 1090-1102, 2006.
[20] D. Silverman, Doing Qualitative Research: A Practical Handbook. SAGE Publications Limited, 2013.
[21] S. Wolf, "A companion to qualitative research," in, B. Jenner, U. Flick, E. von Kardoff and I. Steinke, Eds. Sage, 2004, pp. 284.
[22] M. Miles, A. Huberman and J. Saldaña, "Qualitative Data Analysis. A Methods Sourcebook." 2014.
[23] M. Saunders, P. Lewis and A. Thornhill, "Research Methods for Business Students (4: e uppl.) Harlow: Pearson Education," 2007.
[24] G. Schulz, Cloud and Virtual Data Storage Networking. CRC Press, 2011.
[25] E. Park and K. J. Kim, "An integrated adoption model of mobile cloud services: exploration of key determinants and extension of technology acceptance model," Telematics Inf., vol. 31, (3), pp. 376-385, 2014.