Analysis Review On The Factors Influencing Fog Computing Adoption For Organization

Nur Hamezah Abdul Malic, Tengku Adil Tengku Izhar, Mohd Razilan Abdul Kadir

Abstract: Cloud computing has rapidly improved on the technology innovations however, there is still another aspect of improvement should be looking into at in a way to improve the service connectivity. It has found that cloud computing unable to provide delay-sensitive services longer time to process the data at certain location due to no data centre and the compromised service that has caused from the added mobility dimension. Other than that, cloud computing is storage to manage and process a large number of data. Therefore, fog computing is another computing paradigm known as an extension of cloud computing that helps to reduce the challenges cloud computing facing. The aim of this paper is to identify the gaps to adopt fog computing in organization by reviewing past literature on fog practices. In conclusion, the contribution of this survey may serve as a first step in understanding the adoption of fog computing in analysing organizational data.

Index Terms: Cloud computing, Fog computing, Data analysis, Organization, Technology Framework Adoption..

1.INTRODUCTION

It is the utmost priority for an organisation to gain maximum profit from their day to day business process operations. Businesses use a variety of tactics to meet the goal. Thus, information technology (IT) has become one of the fundamental instrument for an organisation in improving productivity. The significant effects will only be fully realized when IT is widely spread and used (Oliveira, Martins, & Lisboa, 2011). Provisioning, utilizing, and managing information technology (IT) resources through the use of cloud computing has gained prominence and popularity (Bhattacherjee & Park, 2014). However the constrains in using cloud computing has caused processing delay, incurred a higher cost, low capability and longer task length in evaluating a large volume of data (Aazam, Zeadally, & Harras, 2018a). Therefore, fog computing is another computing paradigm that further extend the cloud services to reduce the challenges cloud computing facing. This computing paradigm that preprocessed data from cloud computing that needed by the end devices. Other than that, fog computing is geographically distributed so that it can help to reduce the time taken for data processing at certain location that largely supporting the artificial intelligence (AI), 5G and Internet of things (IoT) devices could take this as an advantage since it is located at (or near) the edge (Tian et al., 2019). Many research highlighted fog computing as a computing processing critical tasks for data analysis that generated by different devices. As a new computing model, fog computing has the ability to provide networking and local computing resources and storage for end-users (Liu, Qi, Zhou, & Wu, 2018). The adoption of fog computing enables business models and services to generate high revenues by improving QoS and cost-saving (Kumari et al., 2018).

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Despite the existing theoretical foundations, however organisation adoption of fog computing to support their big data analysis is still at its very beginning. For this reason, it is necessary to know the theoretical models for any technology adoption (Abdullah & Seng, 2015). In this case, It would be appropriate if there are many established technology models that would help the organisation to have the right framework for fog computing adoption. Though there are many models of technology that can lead to adoption of fog computing, there is a lack of knowledge regarding the most appropriate model of technology that can be used to adopt fog computing in organisation level (Pauline, 2014). It is important to explore the determinant of fog computing adoption and theoretical models that have arisen addressing the fog computing adoption to meet an organisation's goals (Abdullah & Seng, 2015; Bouzarkouna, Sahnoun, Sghaier, Baudry, & Gout, 2018). The aim of this survey paper is to review a number of fog computing adoption for organizational data analysis. Therefore, a detailed literature review is provided particularly to discuss the gaps in factors that influence an organisation to adopt fog computing. The evaluation of organisational data in relation to the organisational goals through the use of fog computing is important role of the IT experts and professional. Literature search was conducted using research sources scholarly in scientific journals within the scope of fog computing approaches. Based on the business information system subject area, Science Direct (Elsevier), Emerald Fulltext (Emerald) and ProQuest Business are few of the databases were used in developing the literature review. As a result, papers published in journals related to information science, organisational modelling and information system are reviewed the most in this survey paper. The most recent paper reviewed in this survey is published in 2019 and meanwhile, the oldest paper reviewed is 2011. With this in mind, there might be some of the earlier works of literature included in this survey paper have been reviewed and have not been reviewed. The reviewed papers have been categories to fit the structure of fog computing, fog computing adoption and analytic review. During the observation, researcher found from 2011 to 2019 there is a sense of discontinuity of published papers that related with to the literature subject area. In Table 1, studies on the organization goals have been carried out since 2011. However, studies in this research area have been gradually in 2011, only one 2012, five in 2013, four in 2017 but it has been actively studied in 2015 and 2019. As shown in Table 1 below, studies on fog computing are very limited. In this survey, we confine attention to fog computing by reviewing previous studies frameworks and models. However, whether all fog computing approaches are applicable or not are beyond the scope of this paper. This is because other approaches and issues might exist and have not been identified in this survey.

Table 1: *Years of Review on fog implementation*

Years	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
No. of Reviews	*3*	*1*	*5*	*9*	*10*	*6*	*4*	*17*	*3*

The rest of the paper is organized as follows: Section 2, the need for fog adoption. In this section, we discuss the need for the organization to adopt fog computing. Section 3 discusses recent studies on fog computing. We analyze the discussion with an analytical table. Section 4 is the conclusion.

2. THE NEED FOR FOG ADOPTION

Potential prospect looking at fog computing adoption with reservation is certainly because they are comfortable with cloud computing deployment flexibility to meet with business application. At this point in time, organisation sees the cloud computing still have enough processing power is the other push back of why organisation is unlikely to explore the proposition of fog computing adoption (Skarlat, Schulte, Borkowski, & Leitner, 2016). However, cloud computing data centre are deployed in concentrated and far remote areas fail to guarantee the service latency, bandwidth, energy consumption and network cost (Hussain, Alam, & Beg, 2018). Fog computing is an enabler for many different services due to its proximity and geographic coverage, bandwidth required, accessibility and processing data generated from various set of devices (Khan, Parkinson, & Qin, 2017). However, as with all the characteristics, organisation is not yet taking full advantage by the different benefits of fog computing adoption. Research in this domain still in its infancy and lacks in comprehensive understanding on organisation exposure to fog computing adoption (Govender, 2016; Khan et al., 2017). Fog computing brings intelligence to a different range of industry. Few of the popular industry implemented fog computing are healthcare, smart cities, manufacturing and etc. Industry-required data to be processed locally with proper safety or equipment alerts that can be prompt immediately (Brogi, Forti, & Ibrahim, 2017). Hence, fog can be viewed as a delay-sensitive application with the ability to be accessed faster when using the resources (Aazam et al., 2018a). Due to its instant response capability, fog system supports a wide range of industrial applications (Khan et al., 2017). Studies show that in order to achieve a reasonable and efficient resources management, the scenarios in fog computing is extensive at the organizational level (Song et al., 2017; Souza et al., 2018). Placement of fog computing resources and architecture for supporting scenario is highly innovative since it depending on the motivations for organisation environment adopting fog computing as a technology enabler to minimise the overall delay (Nunes et al., 2017; Song et al., 2017). There is a high probability that fog computing architecture can differ on the deployment, since it focuses on the organisation technical and non-technical compliance (Brogi et al., 2017). Limited computing and storage capacity on end-user devices making it to heavily depend on external computing. Fog computing is maximising its capability in providing a better solution for data processing, outsourcing and hosting of computation and storage (Lee, Lee, Hong, & Yoo, 2018). As computation for end-user devices moved to the network, fog system storage resources can be increased on-demand (Khan et al., 2017; Nunes et al., 2017). Fog computing efficiently process and rapid transmit large scale of data generated from a huge amount of fog nodes located in a distributed environment. Data acquired from the environment will further process and analysis by the fog nodes so it can meet the data integrity (Tian et al., 2019). Thus, it is important to position the fog nodes at the right place to handle the demands and requirements on processing a large amount of data with minimum latencies (Firdhous, Ghazali, & Hassan, 2014). Fog computing equipped with high requirements on security to serve large scale of IoT applications (Misra & Sarkar, 2016). Security in fog computing help to manage and update the security credentials and software on fog devices to avoid intolerable disruptions to business operation and also fog technical components (Chiang & Zhang, 2016). The security requirements available in fog computing is made to improve cost-effectiveness, high-performance services, secured interactions and high resiliency against failures (Zhang, Zhou, & Fortino, 2018).

Table 2*: Factors for Fog Adoption*

Factors for Adoption	*Fog*	*Author(s)*
Target user	*Computer resource constrained users*	*(Bellavista et al., 2019; Varghese & Buyya, 2018; Yousefpour et al., 2018)*
Geographical distribution	*Geographically distributed applications allow decentralized*	*(Mutlag, Abd Ghani, Arunkumar, Mohammed, & Mohd, 2019; Naha et al., 2018; Tang et al., 2015)*
Main content generator and consumer	*Wide range of IoT devices*	*(Bouzarkouna et al., 2018; Hussain et al., 2018; Peng, Dhaini, & Ho, 2018)*
Data storage	*Temporary*	*(Aazam et al., 2018a; Khan et al., 2017; Peng et al., 2018; Piao, Shi, Yan, Zhang, & Liu, 2019; Yousefpour et al., 2018)*
Data processing	*Large-Scale Distributed processing*	*(Krishnan, Bhagwat, & Utpat, 2015; Maksimović, 2018; Piao et al., 2019)*
Latency tolerant	*Very Low and Predictable Latency Applications*	*(Cisco, 2015; Lee et al., 2018; Y. Zhang, Cai, Xu, Vasilakos, & Huang, 2018)*
Security	*Can be defined High security*	*(Chiang & Zhang, 2016; Misra & Sarkar, 2016; Stojmenovic & Wen, 2014; P. Zhang et al., 2018) (Fan et al., 2018; Liu, Qi, Zhou, & Wu, 2018; Murguzur et al., 2014; Liu et al., 2018)*
Decision-Making	*Fast responsive*	*(Amron, Ibrahim, & Chuprat, 2017;Peng et al., 2018; Fan et al., 2018)*

Developing countries may find the emerging economies is increasingly challenging the existing task of planning and management of ICT. Eventually, advanced innovative IT ecosystems are also intensively important with other developing countries (Muhamad, 2015). The adoption of fog computing in organization will strengthen lifelong learning for skills enhancement which managing large amount data for critical analysis. Organization data, work performance and efficient service delivery for a more competitive and productive economy can be improved through the use of technology. In industry, using particular knowledge technology in machines with human knowledge shows potential growth in knowledge-based economy. Hence, having an ability to adopt fog computing to analyse data in a timely fashion can ensure businesses have a competitive edge to improve productivity in relation to company goals (Adil & Apduhan, 2016). Handling a huge amount of data by cloud computing make it easier with fog computing that available at the edge of network. Fog computing solution has proved to be the option for handling critical data analysis task. However, despite all the good characteristics of fog computing, it also faces few challenges on its own (Ardagna et al., 2018; Bellavista et al., 2019). Many of the literature highlighted the same issues of fog computing such as the high on heterogeneity, security/privacy, critical data analysis to support business value (Hashem et al., 2015; Strong et al., 1997).

3. LITERATURE REVIEW

3.1. Fog Computing

The advancement of Internet of Things (IoT) has become more increasingly mobile, heterogeneous and intelligent, the connection of devices with the human is expected to increase rapidly. IoT has seen to produce a large scale of data. To facilitate sharing and integration of the IoT devices, an IT infrastructure called cloud computing is capable of reducing costs and improve accessibility (Almutiry, Wills, Alwabel, Crowder, & Walters, 2008). However, a new trend called fog computing developed providing a natural bridge between IoT and cloud (Patil, 2015). In addition, the need for fog computing to filling in the gap of cloud limitation on latency and bandwidth in supporting the IoT devices. Fog computing has proven to become handling local tasks and information via direct interaction with near devices and virtually decrease the distant of data centers (Nunes et al., 2017). In supporting the deployment and recommended practice of fog computing in any organization, Openfog Consortium is a non-profit organization established to provide open and uninterruptable information about fog computing. Their committees mainly focus on technical work, promoting innovation, encourage organization to follow standard development and etc. OpenFog believes with RAS (reliability, availability and serviceability), security, scalability, open, autonomy, agility, hierarchy and programmability are the key pillars of the OpenFog architecture (OpenFog, 2015). A few of well-known organization join together in shaping the standard framework of fog computing such as Princeton University, Cisco, Microsoft, Dell, Intel and many more.

3.1.1. Client Objective

Fog computing landscape implemented to support organization to perform jobs and tasks in productive manner. Thus, employee in an organization tend to perform effectively as according to the organization's goal. This computing paradigm landscape able to give a roadmap for client to conceptualizing, designing, building and deploying fog solution (Upadhyay, 2018). Other than that, client seeing fog computing as a computer paradigm that able to give a promising benefits such as remain competitive with the business environment and maximising return of investment (Alshamaila, Papagiannidis, & Li, 2013). Providing new capabilities and opportunities and supporting day-to-day business practices is expected to influence client approach IT-related service.

3.1.2. End Users

End-users of fog computing realised that they should not be focusing or burdening themselves too much on the details of technical specifications such as the storage resources, network communication cost and computation limitation (Stojmenovic & Wen, 2014). Usually, the end-users of fog computing are not first-time IT users. Their intentions to use IT is consistently affected by the pull factors of relative usefulness and expected omnipresence. In addition, users are in favor to utilize the cloud is usually influenced from the advantages offered by fog computing rather than using the traditional computing. Despite all the good characteristics of fog computing, some users tend to feel dissatisfied with the overall first-hand experience due to IT usage and high-security concerns (Bhattacherjee & Park, 2014).

3.1.3. Quality of Results

Yousefpour et al., (2018) defines Quality of Results (QoR) as "to minimise response time and energy consumption by joining task assignments to all edges with edge nodes' then later it will contribute to the framework's goal". They also added that QoR is not necessarily focused on gaining a perfect result. However, based on Zhang & Li, (2006), QoR processing probabilistic queries is important. User tends to focus more on the QoR compare to probability or decision threshold. But still, in the end, user are left unsatisfied with the query generated. Another challenge of analyzing a high volume of data is due discrepancy of requirements from multiple users.

3.1.4. Review and Analysis

Error! Reference source not found.3 provides a summary of fog computing with respect to client objective, end-users and quality of results. There are limited study on QoR in fog computing platform. In the advancement of fog computing utilization, it is important to address the complication of processing unreliable and invalid data outcome which later it can decrease the overall performance on the organisation decision-making process.

Table 3: *Review of Fog Computing*

Authors	*Client Objective*	*End Users*	*Quality of Results*
Upadhyay, (2018)	/		
Stojmenovic & Wen, (2014)		/	

Authors	*Client Objective*	*End Users*	*Quality of Results*
Bhattacherjee & Park, (2014)		/	
Alshamaila et al., (2013)	/		
Zhang & Li, (2006)			/

3.2. Fog Computing Architecture

The three-tier layers of fog computing network built essentially to be closest to the ground to allow low latency and location awareness. For example, in smart cities several layers of fog computing architecture is potentially able to reduce energy waste, increase computing performance, traffic congestion and intelligence in future devices and applications which for this reason quick response at neighbourhood-wide, community-wide and city-wide levels are supported greatly. Limited semi-permanent storage provided by fog computing devices is for temporarily conducting data analysis which the result is send to devices for generating useful feedback. On the other hand, virtual cluster (VC) located within the specific geographic location of fog instance (FI) included with Internet-connected terminal nodes (such as mobile phones or smart vehicles) enabling self-adaption through the use of GPS for geospatial location and may join and leave or connected and disconnected to any VC and FI (Misra & Sarkar, 2016). Tian et al., (2019) mentioned each mobile sinks control the data integritybefore transmitting the data to fog nodes. Fog nodes act as a local server fordata analysis and processing by detecting any faulty or any incorrectness forensuring future cost-efficient storage in the future. The collected authenticated environmentaldata later will send to public clouds for an advance digital application and longterm storage. User as a data owners needs to verify the data correctness even though this advance computing is capable to the logics on measuring thedata correctness by implementing data auditing which consists of privateauditing and public auditing. Another purpose of data auditing mentioned bythe authors is "to provide more convincing auditing results while markedlyalleviating the computational and communication overhead of user". In a Water Transfer Project Safety, it proposed four layers of the safety system architecture which consist of cloud computing, regional computing, edge computing and infrastructure. There are nearly 5,000 wireless and wired sensors were deployed heterogeneously in different locations to ensure a wide geographical distribution for reducing latency, increases the data reliability detection and reducing the incorrectness of data. Part of the huge amount of data that were generated from the sensors is osmotic pressure, water flow and water level. The computing edge layer containing virtualization (algorithm and transport) and hardware layer responsible for storing, troubleshooting, processing and analysing the data. Data transmitted in a short time from regional computing allow for local data computation and management quick decision making (Fan et al., 2018). Tang et al. (2015) proposed a computing architecturethat consisting 4-layer of fog computing provides an instance supports indetecting and predicting the hazards or uninterruptible computing servicemanagement on smart pipeline monitoring. Fog computing layer 2, 3 and 4 arespecifically consisting numerous high performance of edge devices and sensorsfor city-wide real-time interaction and monitoring of the environment andparameters. Layer 4 consists of nodes that are geospatially distributed, each ofwhich is to process huge amount of sensing data at a time. At Layer 3, intermediate computing nodescontains numerous edge devices forimmediate response to threats or anomaly detected on the parameters. To furtherdetection of hazardous events, the edge devices on layer 2 are purposelyconnected with layer 3 edge devices. The connection between these layers is torecognise event pattern and enable a physical machine to response upon previousdata sequences (Tang et al., 2015). The term offloading is widely being used in IoTand computing paradigm solution for assisting the user's devices in performingtasks intended to achieve the final goal of the application. Some of the famousscenarios that this technique can incorporate on different elements of fog orfog-cloud call are on data filtration, data distribution, security and privacy,data analysis etc. Algorithm of offloading mostly depending on the location,services and the user's devices. The demand for IoT devices is for the fog toprovide security and limited latency during the data transmission offloading.Communication between IoT and fog increase the threats in data security andprivacy own by the users. However, with proper measurement of data securitysuch challenges can be avoided. In the case of criteria used in offloading, it supports tasks that required latency and security-sensitive, accessibility, minimalmaintenance of servers and data management (Aazam, Zeadally, & Harras, 2018b). **Error! Reference source not found.**4 shows the gaps from the previous studies. In this table, most of the previous study on fog computing architecture focus on cloud computing. Cloud computing stated in the infrastructure diagram is referring to the overall cloud computing component such as the data centers, cloud storage and cloud gateway. The reason why a fog computing infrastructure is still depending to cloud computing in providing permanent data storage. On the other hand, fog server and security are mentioned the least in the infrastructure diagram.

Table 4: *Review of Fog Computing Architecture*

Author	*IoT Devices*	*Fog Nodes*	*Fog Server*	*Fog storage*	*Gateway*	*Cloud Computing*	*Edge Computing*	*Security and Privacy*
(Misra & Sarkar, 2016)	/			/	/	/		
(Tian et al., 2019)	/	/				/		

Author	IoT Devices	Fog Nodes	Fog Server	Fog storage	Gateway	Cloud Computing	Edge Computing	Security and Privacy
(Fan et al., 2018)		/	/			/	/	
(Tang et al., 2015)	/	/				/	/	
(Aazam et al., 2018b)	/			/	/	/		/

3.3. Theoretical Framework

Cohen, Mou, & Trope, (2014) proposed a research model that can beused for studying the cloud computing adoption behaviour influenced by theabsorptive capacity, top management support, normative and mimeticinstitutional pressures. Authors stated the pressure for the organisation to complyand changes are influenced by behavioural and structural. The mimetic pressuresuses to measure the extent and perceived success of competitor adopters andnormative pressures measure the extent of adoption among suppliers, extent ofadoption among customers and participation in professional, trade and businessbodies. Meanwhile, the organisation is driven by the top management support andabsorptive capacity are organisation capability to utilise knowledge foradvantages and organisational changes. Big size organisation is likely to facethe challenges in cloud computing adoption considering the number of employeesand compatibility of multiple business process requirements to meet productspecification.

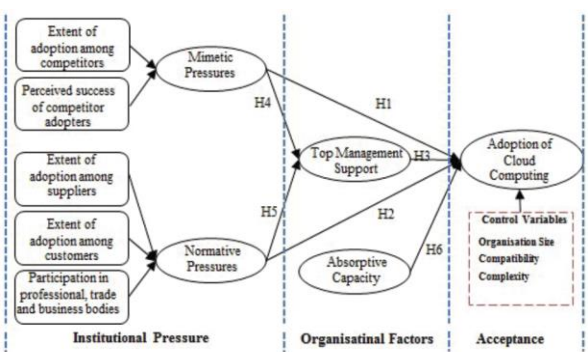

***Fig. 1**. Cloud computing adoption research model (Cohen et al., 2014)*

TAM (Technology AcceptanceModel) is widely used in investigating factors that influence users to accepttechnologies organisation in term of knowledge and readiness (Abdullah & Seng, 2015; Wang, Jeng, & Huang, 2017). As shown in **Error! Reference source not found.**1, TAM conceptual framework in the article titled "Acceptanceof Cloud Computing in Klang Valley's Health Care Industry, Malaysia" has beenextended to make it more related to the study. It consists of perceived risk,attitude toward use, institutional trust, perceived ease of use and perceivedusefulness are five important elements to measure health care professionals' acceptanceto use cloud computing. Compare to a locally hosted computing environment, cloudcomputing intended to serve on-demand access to resources while lowering theoverall IT investment and to make available in term of business applicationsdeliverable to the end-users (Abdullah & Seng, 2015).

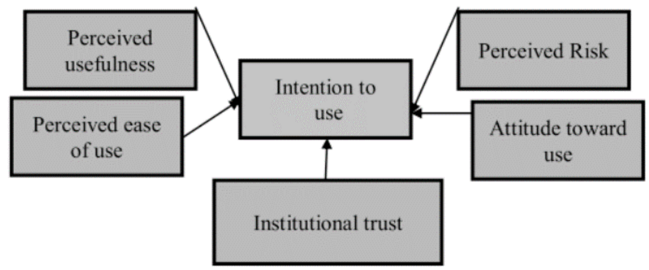

***Fig. 2**. Conceptual model of users' acceptance of cloud computing solutions (Abdullah & Seng, 2015)*

Sabi, Uzoka, Langmia, & Njeh, in 2016 conducted the study in sub-Sahara African region to study the usage and adoption of cloud computing at educational level. This study has proposed a model that involves the factors of usability, innovations, organisational, contextual, technological and economic to measure and validate the usage and intention to adopt cloud computing. The data collection were conducted in several universities in sub-Sahara African region. Based on the pilot study's result among the respondents and academic experts, it has found that the developed instrument and model is ready to serve the target population.

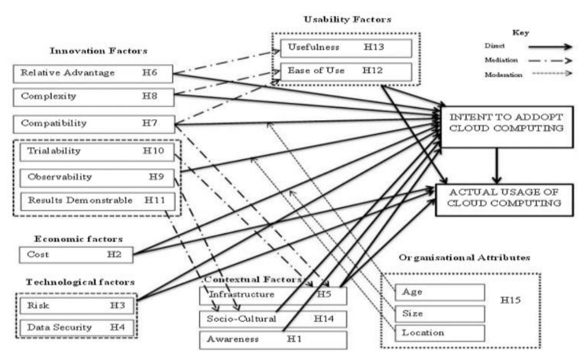

***Fig. 3**. Cloud computing adoption model (Sabi et al., 2016)*

There was a study conducted on the factors that affect Malaysia SMEs (small to medium-sized enterprise) service sector decision to adopt cloud computing. Author proposed researchmodel are factors are employee knowledge, IT resources and top management support.As a result, it shows that only IT resources have significant relationship withcloud computing adoption. On the contrary, top management support and employeeknowledge have a less significant impact. This is due to the fact that top managementin SMEs organisation have a minimal concern on cost of employee training and purchasingof new technology since they are using the free based cloud services (Hassan, 2017).

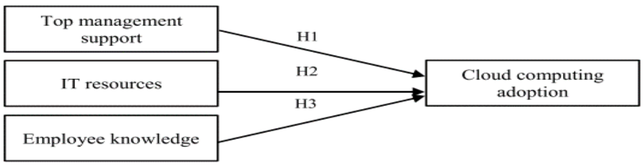

***Fig. 4**. Cloud computing adoption research model (Hassan, 2017)*

Low et al., conducted a study among the IT staff or managers of 111 high-tech firms in Taiwan that aims toinvestigate the factors that affect the adoption of cloud computing by firmsbelonging to the 111 firms belonging to high-tech industry in Taiwan. Respondentsinvolved in the subject field by responded to questionnaire email to them. Theeight factors examined in this study adapted from TOE framework are relativeadvantage, compatibility, complexity, firm size, top management support,technology readiness, trading partnerpressure and competitive pressure. The result of the studies showed several factors that are a significant effect on the adoption of cloud computing arerelative advantage, top management support, firm size, competitive pressure andtrading partner pressure.

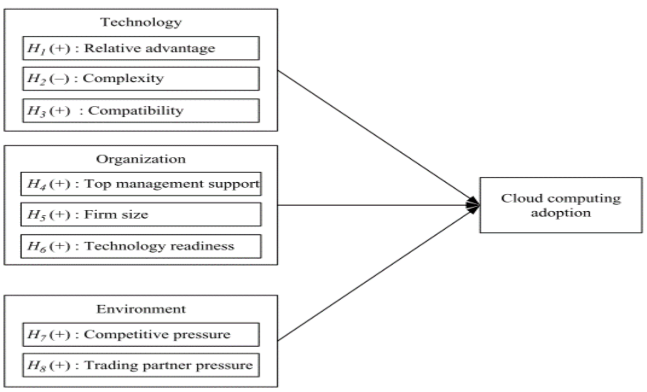

***Fig. 5**. Conceptual model for the adoption of cloud computing (Low et al., 2011)*

A study on cloud computing in small to medium-sized enterprise (SME) adoption process conducted by Alshamaila et al., (2013). Data were gathers among the 15 selected SMEs in North-east of England. Among the individual involved in the survey are the service providers, SMEs' adopters, prospectors and individual who do not have any concern to adopt cloud computing services. Based on the result, the researcher found out the main factors that have a significant relationship on the adoption are: top management support, relative advantage, uncertainty, geo-restriction, compatibility, trialability, size, prior experience, innovativeness, industry, market scope, supplier efforts and external computing support.

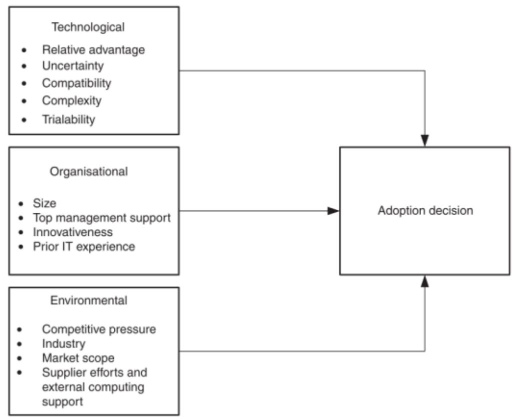

***Fig. 6**. Proposed framework for SME adoption of on-demand computing services (Alshamaila, 2013)*

Table 5 below highlighting the gaps on adoption from the previous studies. Most of the studies focus on the top management support. The role of top management support has been proven important in most of the existing studies on cloud computing adoption (Alshamaila et al., 2013; Cohen et al., 2014; Hassan, 2017; Li, Gan, Li, & Gu, 2015; Low et al., 2011; Sabi et al., 2016). In contrary, there are few gaps shown in computing adoption factors such as the trialability, observability, results demonstratable, cost, risk, data security, infrastructure, socio-cultural awareness

***Table 5:** Factors in Adoption*

Authors	*Top Management Support*	*Absorptive capacity*	*Perceived usefulness*	*Perceived ease of use*	*Perceived risk*	*Institutional trust*	*Attitude toward use*	*Relative advantage*	*Complexity*	*Compatibility*	*Trialability*	*Observability*	*Results demonstratable*	*Economic Factors*	*Contextual Factors*	*Usefulness*	*Ease of use*	*Employee Knowledge*	*IT Resources*	*Technology readiness*	*Environmental*	*Trading partner pressure*	*Technological*	*Organisational*
Cohen et al., (2014)	/	/																						
Abdullah & Seng, (2015)			/	/	/	/	/																	

Sabi et al., (2016)								/	/	/	/	/	/	/	/	/	/						/	
Hassan, (2017)	/																	/	/					
Low et al., (2011)	/							/	/	/										/	/	/		
Alshamaila (2013)	/							/	/	/	/										/		/	/

3.4. Heterogeneous Data Analysis in Fog Computing

The emerging of fog computing brings muchchallenges and opportunities towards the data environment. The demand for real-time access to data keeps increasing every day which has caused the growth ofheterogeneous data. Fast interactions and transmitting of data have led to thehigh data rates that originate

from a different kind of source. Real-time datais required for end-user devices to operate, thus heterogeneous data analysisis required for prediction of forecasting, failure and power consumption.

3.4.1. Data Analysis

Structured and unstructured data can be transformed into an analysis workflow. Structured data need to pre-process and then retrieve meanwhile unstructured undergoing storage and process (Hashem et al., 2015). Data analysis requires high computational resources for processing data-intensive operations (Ardagna et al., 2018). Distributed and scalable of data are the challenges posed by fog computing. Thereby, to achieve decision making intelligent data analysis are need to perform in a timely manner (Tang et al., 2015). Furthermore, Kumari et al., (2018) also mentioned data security and integrity, standardization of communication protocol and system integrity are also contributed to the challenges of conducting data analysis.

3.4.2. Data Quality

Strong, Lee, & Wang, (1997) defined data quality as “data that is fit for use by data consumers”. They also added data quality for consumer use is important for decision making and control over the computing environment. Increasing data collected from different sources are not verifiable and well-known (Hashem et al., 2015). However, the performance andreliability of fog computing can be affected by the useless and faulty datacollected are not filtered during the initial steps. Data analytics need to beperformed in real-time which part of the initial steps are data filtering, datanormalization, data aggregation and etc (Bellavista et al., 2019). Furthermore, data quality able to enhance data analysis by using thereliability analytics results which depend on the reliability of the analysedinformation (Ardagna et al., 2018).

3.4.3. Internal Data analysis

Paper or electronic that contains information gathered within an organization’s environment is known as internal data (Fawi, 2014). Examples of internal data are companies everyday employee personal information, tender documents, clients’ prospect and etc. It holds a proprietary value which makes them restricted to access by the unauthorised people. It is not a common practice for an organization to share information especially on the closely guarded information (Dholakia & Dholakia, 2013). However, analysis on internal data is important in order for organization to obtain a competitive edge. Additional challenges face by organization is the volume and velocity of internal data (Dholakia & Dholakia, 2013).

3.4.4. External Data analysis

Redman (1996) explained the known external valuesof data is consider as accurate. Some organization tends to gain profit fromexternal data such as customer’s purchase behaviours, lifestyle data, by sellingit to the public. For instance, customer address recorded by online shoppingwebsite could be validated and access through the shipping address matches theactual location of where the customer stay (Hazen, Boone, Ezell, & Jones-Farmer, 2014).

3.4.5. Review and Analysis

Table 6 shows the gaps from the previous studies. In this table, most of the previous study focused on data analysis. Competitive advantage can be achieved from capitalising the data analysis. Meanwhile, data quality equipped with dimensions concerning data accuracy, consistency, completeness and timeliness (Almutiry et al., 2008). In contrast to the previousstudy, this research is to identify the gaps to heterogeneous data analysiswithin internal and external sources from fog computing. For instance, ascenario from water conservatory industrial uses sensors to collect water qualityand water level reading. The reading signalling warning on early warningmechanism and emergency program. Therefore, data collected from the distributedsensors will be analysed on the correlation and trends, which to detect anyabnormal and incorrectness of data (Fan et al., 2018).

Table 6. *Review of Data Analysis in Fog Computing*

Authors	*Data Analysis*	*Data Quality*	*Internal data analysis*	*External data analysis*
Tang et al., (2015)	/			
Kumari et al., (2018)	/			
Hashem et al. (2015)	/			
Bellavista et al., (2019)		/		
Ardagna et al., (2018)		/		
Dholakia & Dholakia, (2013)			/	
Hazen, et al., (2014)				/

3.5. Implementation of Fog Computing

Common industry that uses fog computing are from manufacturing, construction, transportation, energy, oil and gas, telecommunication, finance, retail, smart cities, healthcare and agriculture. The network capability for deployment of IoT applications and services make possible with the cloud computing extension to fog computing (Froiz-Míguez, Fernández-Caramés, Fraga-Lamas, & Castedo, 2018). Fog computing is more comprehensive and flexible compared to other similar computing paradigm proposed by research community such as Cloudlets, cloud of things, mist computing and edge computing (Yousefpour et al., 2018). Before making any decision, the future user of fog computing should consider identifying the current problem with cloud computing (Fan et al., 2018) then they can proceed with exploring the implementation solution and effective design in order for them to get a clear view of suitable approaches for their environment (Peng et al., 2018). To achieve a successful implementation of fog computing, it is important for the business prospect to strengthen knowledge and readiness (Amron, Ibrahim, & Chuprat, 2017). In this section, we will briefly explain a few of the tasks and activities in the implementation of fog computing.

3.5.1. Management

Outsourcing implementation of fog computing to cloud providers may help management in performing decision making such as on deciding the cloud service models, types of deployment, payment scheme and etc. Payment scheme proposed to management usually covers operational cost or capital cost which most cloud providers offer pay-as-you-go cost model (Patil, 2015). Many believe fog computing will leave an impact on the organization and high potential strive further on the strategic operation throughout the organization. Managers need to exploit the IT advances opportunities by providing a proper assurance on associated levels (project team). However, there are few common challenges identified during implementation of fog computing which would be caused by multiple service providers (Varghese & Buyya, 2018) and lack of documentation on standard and guidelines on the implemented infrastructure. Therefore, organization must be competent enough to be able to take actions and undergo decision making based on market change (S. Liu et al., 2018).

3.5.2. Design and Planning

Setting up a fog computing deployment is always be crucial part due to scale and variation of the infrastructure. As a result, deployment of a single node is not easy due to limited resources feature in fog nodes (Brogi et al., 2017). The demand of resource capacity and atomic service should be covered correctly during the preliminary step of service deployment. In addition, infrastructure design is part of the design and planning phase where the activities includes is deciding the fog software, fog network and fog nodes. Example of fog nodes connect to an end device or smart object. Each of the cluster containing fog nodes capable to provide data processing to IoT devices such as edge routers, gateways, smartphones, portable devices, set-top wearable devices and etc (Hu, Dhelim, Ning, & Qiu, 2017). Basically, among this hardware platform there are activities involving sharing of data, collaboration of task and communication (Froiz-Míguez et al., 2018).

3.5.3. Strategy

Distributed execution and overall executionperformance are affected by the service atomization. Thus, to ensure a smoothexecution performance complex IoT services should be carefully divided intosmaller atomic service (Souza et al., 2018). They also added innondependent data portions, splitting large unprocessed data able to ease theparallel processing. Fog computing needs to have a medium for controlling andmonitoring the performance and network in a way to minimise data centers' carbonfootprint. Network should able to handle a large amount of data, thus a frameworkproposed for the fog computing to control and monitor the resources andrequirements of the network such as the utilization of SDN from IoT network.Additional utilization of SDN controllers in fog computing able to balance thenetwork performance if there is any occurrence on controller overheat or fail (Yousefpour et al., 2018).

3.5.4. Analysis

In a fog computing environment, testbed is a a popular term used for testing on machinery which in this case is to experimentally verify the ideas and concepts of fog computing with IoT devices. For example, many studies in their small scale experiment use a resource limited devices such as Rasberry Pi (RPi) for testing on the proposed architecture with the criteria raised (Yousefpour et al., 2018). As for much bigger placement of fog computing in industry, Openfog introduced a controlled experimentation of testbeds that able to validate the requirement of fog computing adopted. Depending on the industry, the selection of testbeds may be different from the needs from different industry. PoTT (Proof of Theory (Technology) Testbeds), OPT (OpenFog Regional Testbeds) and IOM (Interoperability Operational Models) are few of the testbeds proposed by OpenFog. Before using the said testbeds, specific criteria should be considered such as the nature of their business, organization type (university/profit/non-profit organization), approval from top management/BoD, source of data (test data, production data or end-user data) and etc (Huang et al., 2018).

3.5.5. Results

Placement of fog computing has succesfully compliment cloud computing in term of reduces service latency, decrease the demand from remote cloud resources benefited from proximal resources, reduce Service Response Time and etc (Souza et al., 2018). However, limited processing capacity, service quality delivery, limited battery lifetime/energy consumption and distributed management are few of the open issues in fog computing yet unsolved. With this in mind, industry that uses fog computing has seen new infrastructure approach makes IT applications easier to be adopted which help them to easily scale their IT services according to the market flow (S. Liu et al., 2018).

3.5.6. Review and Analysis

Table 7 below highlighting the gaps in fog computing implementation from the previous studies. Most of the previous study focused on management implementation of fog computing. Management has seen to be the factors and impacts that affect the adoption of fog computing. It is advisable for them to approach service providers that are less risky for the development and also to make ease of knowledge transfer to another different providers (Gangwar, Date, & Ramaswamy, 2015). Other than that, design & planning, strategy, analysis and results come in the same way.

Table 7. *Review of Fog Computing Implementation*

Authors	*Management*	*Design & Planning*	*Strategy*	*Analysis*	*Results*
Brogi, Forti, & Ibrahim, (2017)		/			
Souza et al., (2018)			/		/
Liu et al., (2018)	/				/
Yousefpour et al., (2018).			/	/	
Huang et al., (2018)				/	
Hu et al., (2017)		/			
Patil, (2015)	/				
Varghese & Buyya, (2018)	/				
Froiz-Míguez et al., (2018)	/				

4.CONCLUSION

In conclusion, heterogeneous data analysisconsidered to be measured by Quality of Result. In this research, we identifiedfew factors that can be used to measure the QoR of data analysis which arequality indicators, quality control, validity outcome and reliability outcome. This assessment is able to improve and control the errors of data streaming inthe from the devices to the storage. Data quality, internal data analysis andexternal data analysis are the aspects identified in analysing the large scaleof data. Based on the previous papers, it has seen that data analysis isimportant for fog computing high performance and reliability by avoidingprocessing faulty and useless data (Bellavista et al., 2019). In addition, we addressed the brief activities and task of fog computingdeployment which suitable for the company what looking for outsourcing the tasks toexternal service providers.

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