INTERNATIONAL JOURNAL OF NETWORK MANAGEMENT
Int. J. Network Mgmt
Published online in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/nem.1930

Recent advances delivered by Mobile Cloud Computing and Internet of Things for Big Data applications: a survey

Christos Stergiou and Kostas E. Psannis*†

Department of Applied Informatics, School of Information Sciences, University of Macedonia, Thessaloniki, Greece

SUMMARY

The Internet of Things (IoT) is a new technology that is growing rapidly in the field of telecommunications and especially in the modern field of wireless telecommunications. The main goal of the interaction and cooperation between things and objects sent through the wireless networks is to fulfill the objective set to them as a combined entity. In addition, based on the technology of wireless networks, both the technologies of Mobile Cloud Computing (MCC) and IoT develop rapidly. In this paper, we combine the two aforementioned technologies (i.e., MCC and IoT) with the technology of the Big Data in order to examine the common features and to discover which of the MCC and IoT benefits improve the use of the Big Data applications. Finally, we present the contribution of MCC and IoT individually to the technology of Big Data.

Received 23 November 2015; Revised 14 February 2016; Accepted 11 March 2016

1. INTRODUCTION

In the field of modern wireless telecommunications, there is a novel paradigm that is rapidly gaining ground. This is the technology of the Internet of Things (IoT). The basic idea of the IoT is the pervasive presence of a variety of things or objects used by people such as radio-frequency identification tags, sensors, actuators, and mobile phones. Through unique addressing schemes, these things interact with each other and cooperate with other things near them in order to reach the common goals [1].

In addition, the main strength of the IoT idea is the high impact that it will have on several aspects of the everyday life and behavior of potential users. The most obvious effects of the IoT, as a private user could observe, would be visible in both domestic and working fields. In the first case, some examples of the possible application scenarios in which the new paradigm, that is, the IoT, will play a leading role in the near future are domotics, e-health, assisted living, and enhanced learning [2]. In the second case, business users could observe the similar consequences that are traceable in some fields such as logistics, intelligent transportation of people and goods, automation and industrial manufacturing, and business/process management.

The IoT is composed of three main parts:

1. the ‘things’ (objects);
2. the communication networks that connect them;
3. the computer systems using data streaming from and to objects.

For example, home security systems already allow you to check remotely the locks on your doors and thermostats in the house. But what if it was possible to act proactively on your behalf? Imagine

*Correspondence to: Kostas E. Psannis, Department of Applied Informatics, School of Information Sciences, University of Macedonia, Thessaloniki, Greece.
†E-mail: kpsannis@uom.edu.gr

you opened the windows to ventilate your house before arriving, based on your personal preferences, weather conditions, and the distance from your house.

To summarize, the IoT is a type of network of some physical objects or things that, embedded with software, electronics, sensors, and connectivity that enables them, achieves greater value and service by exchanging data with manufacturers, operators, and some other connected devices [3]. Thus, the intensive computations and the mass storage, which are supported by clouds, are often inefficient. Some examples include the limitations of storage, communication capabilities, energy, and processing. Such inefficiencies motivate us to combine the technology of Mobile Cloud Computing and the IoT. As an emerging technology, Mobile Cloud Computing integrates multiple technologies for maximizing capacity and performance of the existing infrastructure [4].

The third technology that is vital for our research is that of Big Data. This is a new popular term, used to describe the surprisingly rapid increase in volume of data in structured and unstructured form. Big Data is a broad term for datasets so large or complex that traditional data processing applications are inadequate. Big Data often refers to the use of predictive analytics or certain advanced methods to extract value from data. Rarely, it also refers to a particular size of dataset. Accuracy in Big Data may lead to more confident decision making, and better decisions can result in greater operational efficiency, cost reduction, and reduced risk [5]. From this scope, we realize that the Big Data is now equally important for both business and internet. This happens because more information leads to more accurate analyses.

The real problem is not that you have acquired large amounts of data, but whether it has any value or not. Hopefully, by envisaging that the organizations would be able to obtain information from any source, harness the relevant data, and analyze it in order to obtain quick answers, we will achieve the following: (1) to reduce costs; (2) to reduce time; (3) to develop new products and to optimize their offerings; and (4) to make more intelligent decisions. For example, some of the possible results could be as follows:

- Determine the root causes of failures, problems, and defects in near real time, saving millions.
- Optimize routes for thousands of package delivery vehicles, while on the road.
- Analyze million storage units (StockKeeping Units), to set prices that maximize profit.
- Create coupons at retail points of sale, based on current and past purchases of the customer.
- Send personalized offers to mobile devices while your customers are in the appropriate area to benefit from them.
- Recalculate entire risk portfolios in just minutes.
- Locate sooner your most important customers.
- Use clickstream analysis and data mining to detect fraud.

Moreover, a new generation of services, based on the concept of the ‘cloud computing’, has made its appearance in the last few years with the purpose of providing access to the information and the data from any place at any time, thus restricting or eliminating the need for hardware equipment. The term ‘cloud computation’ is defined as the use of computing logistical resources, as well as the software level, through the use of services transported over the Internet. Nowadays, cloud computing services constitute one of the world’s largest areas of competition between giant companies in the IT sector and software, such as Google, Amazon, and Microsoft, which are struggling to take an advantageous position, to this rapidly growing industry [6]. More specifically, Mobile Cloud Computing is defined as an integration of cloud computing technology with mobile devices so as to make the mobile devices resourceful in terms of computational power, memory, storage, energy, and context awareness. Mobile Cloud Computing is the outcome of interdisciplinary approaches, combining mobile computing and cloud computing. Therefore, this transdisciplinary domain is also referred as mobicloud computing [7]. The term mobile cloud is generally referred to in two perspectives: (a) infrastructure-based and (b) *ad hoc* mobile cloud. In infrastructure-based mobile cloud, the hardware infrastructure remains static and provides services to the mobile users. Although cloud is useful for computing and storage [8,9], the traditional computation offloading techniques cannot be used for the smartphones directly because these techniques are generally energy unaware and bandwidth hungry.

This paper is organized into five sections. In Section 2, there are reviews of the related research and the theoretical references to the three technologies we deal with in this paper (IoT, Mobile Cloud

DOI: 10.1002/nem

Computing, and Big Data). Sections 3 and 4 show the contribution of the IoT and Mobile Cloud, respectively, in Big Data applications. Finally, Section 5 elaborates on the conclusions of our study.

2. RELATED WORK

In recent years, they have made a couple of researches in order to improve the field of telecommunications. In this field, there are some technologies that we study and analyze in this paper. As regards the Mobile Cloud Computing, a presentation of what it offers about abundant computing power that can be tapped easily have been studied and, also, what systematically explore of the fundamental research questions when mobile and cloud computing combining [10,11]. Additionally, a study of these fundamental new capabilities will enable mobile users to seamlessly utilize the cloud to obtain the resource benefits without incurring delays and jitter and without worrying about energy [10]. Moreover, the cloud computing technology is now used in the emerging IT platforms, used as a market-oriented resource allocation by leveraging technologies such as virtual machines and the insights on market-based resource management strategies that encompass both customer-driven service management and computational risk management to sustain service level agreement-oriented resource allocation. [12]. Therefore, the Mobile Cloud Computing technology starts to work with J2ME applications [13]. Thus, as long as the research continues, the architecture of Mobile Cloud Computing evolves, and now, the interactions between mobile applications and cloud services will be decoupled, and a depiction of the uncoupling of service access and delivery to mobile applications was provided [14]. The Cloud Computing technology in nowadays affects the remote resources on the quality and reliability of augmentation processes and discusses the challenges and opportunities of employing varied cloud-based resources in augmenting mobile devices and in a taxonomy of Comparing Modeling Approaches (CMA) approaches [15]. Finally, to conclude with the technology of the Mobile Cloud Computing, we realized that with the evolution of this technology, now, we can run runtime application partitioning on Surface-Mount Device (SMD) by analyzing additional resources utilization on SMD in the mechanism of runtime application profiling and partitioning [16].

Subsequently, as regards the technology of Big Data, we have study the aspects of scheduling and storage, which are the foundations of modern Big Data analytics systems and their key principles, and how these principles are realized in widely deployed systems [17]. Moreover, as the field of mobile telecommunications evolves, new technologies have been explored and some of them based on the combination of current technologies. Big Data and the technology of IoT have been combined to work together, and they create a Cognitive Oriented IoT Big Data framework along with implementation architecture, IoT Big Data layering architecture, and data organization and knowledge exploration subsystem for effective data management and knowledge discovery that is well suited with the large-scale industrial automation applications [18]. Also, these two technologies ease the reuse of algorithms and support scientific discussions by providing a comparison schema and the use of cases from different industries [19]. In addition, we have study the six phases of location information flow in the IoT and the three areas of privacy controls that may be considered in order to manage those flows and so to be helpful to practitioners and researchers when evaluating the issues involved as the technology advances [20]. Finally, we have study and analyze an integrated Big Data analytical framework for IoT and Smart City application, which contributes three things: (1) we provide an overview of Big Data and IoT technologies including a summary of their relationships; (2) we present a case study in the smart grid domain that illustrates the high-level requirements towards such an analytical Big Data framework; and (3) we present an initial version of such a framework mainly addressing the volume and velocity challenge. Finally, they present the findings of extended results from the European Union (EU)-funded project BIG and the German-funded project PEC [21]. As a conclusion, we have study the combination of the technologies of Mobile Cloud Computing, Big Data, and IoT, and we have study some analysation of existing components and methods of securely integrating Big Data processing with cloud machine-to-machine systems based on remote telemetry units [22].

By studying the technologies of Mobile Cloud Computing and IoT, we realize that they have some features that will be able to assist in improving the functionality of Big Data applications. As a result, these three technologies can be clearly improved in if we combine their use.

DOI: 10.1002/nem

2.1. *Internet of Things*

Internet of Things is a new technology in telecommunication fields. The IoT is the network of physical objects, devices, vehicles, buildings, and other items that are embedded with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data [23].

The IoT is a network of devices that transmit, share, and use data from the physical environment to provide services to individuals, corporations, and society. The objects–things function either individually or in connection with other objects or individuals and have unique IDs (identifiers). Also, the IoT has different applications in health, transport, environment, energy, or types of devices: sensors and devices worn/carried (wearable), for example, watch, glasses, and home automation (domotics) [24].

The IoT is the next big step in the field of new technology, but the big difference is found in the way businesses operate. Overall, over the next few years, a flare in the number of connected devices, the sites are located, and of course, the functions they will perform are expected. We can mention future hospitals as an example: in addition to standalone devices connected, there will be numerous devices that will be connected to patient, monitoring stations of the nursing staff.

2.1.1. *Ten facts and predictions about the Internet of Things*

There are many items that are connected through the Internet and many economic benefits that can be generated from the analysis of the data flows. Consider the following:

- The total added value of the IoT in all sectors will reach $1.9 trillion by 2020 worldwide, according to Gartner.
- Fifty-billion devices will be connected to the Internet by 2020, down by Cisco.
- The market of equipment for remote patient monitoring was doubled from 2007 to 2011 and is expected to double again in 2016.
- Smart grids in the energy sector are expected to double the market information systems of customers from $2.5 billion in 2013 to $5.5 billion in 2020, according to a study by Navigant Research.
- The widespread use of IoT technologies in the auto industry could save $100 billion a year by reducing accidents, according to McKinsey.
- Industry Internet could add 10–15 trillion in world gross domestic product, doubling the US economy, says General Electric (GE).
- Seventy-five per cent of leaders of the global business world explore the economic potential of the IoT, according to a report by The Economist magazine.
- The UK Government has recently approved £45 million in research funding for the technologies of the IoT.
- The cities were to spend $41 trillion over the next 20 years on the upgrading of the IoT infrastructure, according to Intel.
- The number of manufacturers involved in activities related to IoT will reach the number of 1.7 million worldwide by the end of 2014, according to ABI Research.

2.1.2. *Internet of Things: take advantage of the data*

What does it mean when the devices and sensors are networked together and communicate with each other? How can the IoT affect our daily life? GPS systems, alarm systems, and thermostats all send and receive constant feeds to monitor and automate activities in our daily lives [19]. And the not so obvious, Mosaic, cups, clothes, and other everyday objects, can also join network to send and receive data over the Internet.

Opportunities where the streaming data will create new markets in order to inspire positive change or to enhance existing services are examined by businesses [25]. In the succeeding texts, there are some examples of sectors that are at the heart of these developments:

- Smart solutions in the bucket of transport achieve a reduction of traffic on the roads, reduce fuel consumption, set priorities in vehicle repair programs, and save lives.
- Smart power grids incorporating more renewables improve system reliability and reduce the charges consumers, thus providing cheaper electricity.

DOI: 10.1002/nem

- Remote monitoring of patients provides easy access to health care, improving the quality of services, increasing the number of people served, and saving money.
- Sensors in homes and airports, or even in your shoes or doors, improve safety by sending signals when left unused for a certain period of time or when used in the wrong time.
- Engine monitoring sensors detect and predict maintenance issues and inventory replenishment and even define priorities in scheduling maintenance work, repairs, and regional operations.

2.2. *Mobile Cloud Computing*

Cloud computing provides computing, storage, services, and applications over the Internet. In general, to render smartphones energy efficient and computationally capable, major changes to the hardware and software level are required. This entails the cooperation of developers and manufacturers. [7]. Mobile Cloud Computing is defined as an integration of cloud computing technology with mobile devices in order to make the mobile devices resourceful in terms of computational power, memory, storage, energy, and context awareness. The technology of Mobile Cloud Computing is the outcome of interdisciplinary approaches combining mobile computing with cloud computing. Thus, this transdisciplinary domain is also referred as Mobile Cloud Computing [7].

There are two perspectives in which the term Mobile Cloud refers to: (a) infrastructure-based and (b) *ad hoc* mobile cloud. In the infrastructure-based mobile cloud, the hardware infrastructure remains static and also provides services to the mobile users. Nevertheless, there are several applications that utilize cloud resources, but the usage is limited to only storage-specific and application-specific services such as Apple's Siri (voice-based personal assistant) and iCloud storage service (Figure 1).

2.2.1. *Mobile Cloud Computing trade-offs*

Mobile Cloud Computing has some disadvantages and limitations that should be eliminated over the years in order to achieve a better and more ideal use. Some businesses, especially the smaller ones, need to be aware of these limitations before going in for this technology.

A. *Security*

A major issue of the Mobile Cloud Computing is security issue. Before someone adopts this technology, they should know that all the company's sensitive information would be released to a third-party cloud service provider. This could potentially put the company to great risk. Hence,

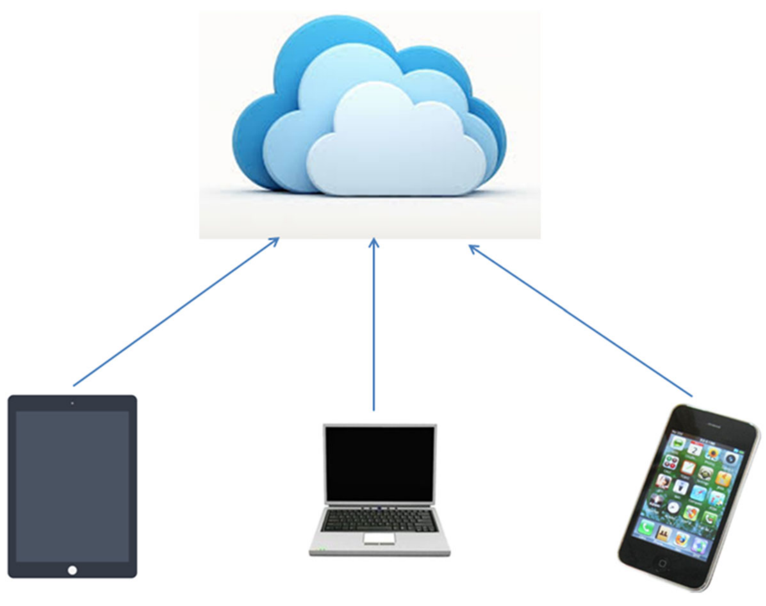

Figure 1. Mobile Cloud Computing technology

DOI: 10.1002/nem

someone must be absolutely sure that they would choose the most reliable service provider, who will keep the given information completely safe [26].

B. *Connectivity*

Internet connection is critical to Mobile Cloud Computing. Thus, the user should be certain that there is a good result before opting for these services. Because owing a mobile device that is connected to the internet has become the norm in the wireless world of today, Mobile Cloud Computing has a very large potential user base [27].

C. *Performance*

Another major concern of the Mobile Cloud Computing relates to its performance. Some users feel performance is not as good as with native applications. Thus, checking with one service provider and understanding their track record are advisable [28].

D. *Latency (Delay)*

In Mobile Cloud Computing, latency is defined as the time involved in offloading the computation and obtaining back the results from the nearby infrastructure or cloud (sometimes referred as turnaround time). The latency depends on multiple factors such as offloaded code size, data input size, location of the required data, offloading scheme and granularity, network bandwidth, execution delay, and resultant data size.

Privacy

Data privacy is important and is one of the main bottlenecks that restrict consumers from adopting Mobile Cloud Computing. The users' data stored in the cloud may include emails, tax reports, personal images, salary, and health reports and may contain sensitive information. Therefore, the consumers cannot afford any privacy leakage as it may lead to financial loss and legal issues [29]. The EU has passed some laws [30] for the handling of data, according to which the data storage servers must reside in the countries in order to provide sufficient protection. Moreover, in some cases, the data storage location must be known. However, this is not always possible in a cloud environment because of the absence of standards, data privacy, and cloud security [31]. Therefore, to gain consumers' trust in the mobile cloud, the application models must support application development with privacy protection and implicit authentication mechanisms [32].

2.3. *Big Data applications*

More than $15 billion on software firms that specialize in data management and analytics have been spend by AG, Oracle Corporation, IBM, Microsoft, SAP, EMC, HP, and Dell. These companies increased their demand for information management specialists on the provided software. In the year 2010, these industries were worth more than $100 billion and were growing at almost 10% in a year, which is about twice as fast as the software businesses as a whole [33].

The use of data-intensive technologies by the developed economies has increased. Nowadays, there are up to 4 billion mobile phone subscriptions around the world and approximately 2 billion people have access to the Internet [33]. From 1990 to 2005, up to 1 billion people worldwide joined the middle class, and as a consequence, more people are characterized as literate, which in turn leads to information development. The predictions of the world's effective capacity to exchange information through telecommunication networks put the amount of internet traffic at 667 EB annually by 2014 [33,34].

There is a large number of examples for the use of Big Data technology in the public service such as follows:

1. The joining-up data, which is a local authority blended data about services, such as road gritting rotas, with services for people at risk, such as 'meals on wheels'. The connection of data allowed the local authority to avoid any weather-related delay.
2. The data on prescription drugs. By connecting the origin, the location, and the time of each prescription, a research unit was able to exemplify the considerable delay between the releases

DOI: 10.1002/nem

of any given drug. A specific example is the UK-wide adaptation of the National Institute for Health and Care Excellence guidelines.

2.3.1. Predictable and efficient

Big Data applications significantly increase the amount of real-time and workload-intensive transactions through the massive amounts of diverse data transferred. The supporting network that connects the hyperscale server architectures, consisting of thousands of nodes that in turn contain several processors, must be robust enough to ensure these data could move quickly and efficiently.

The appropriate line rate of performance furthers the network efficiently. One of the essential tasks needed to achieve network efficiency is to rightsize switch capacity. The typical network configurations for the Big Data are likely to require 1-GB access layer switch capacity in the current environment. For the upcoming 12 to 18 months, 10-GbE server connectivity would become more common, as the cost–performance ratio becomes more efficient, and it might need to upgrade aggregation switch capacity to 40 or even 100 GbE by some organizations [35–37].

2.3.2. Holistic network

When it comes to the optimized network performance, it is necessary that it takes place within the Big Data domain as well as in the connection with the more traditional undertaking infrastructure [35–37].

The benefits to a holistic network approach include the following:

- ability to minimize duplicative costs whereby one network can support all workloads;
- multitenancy to consolidate and centralize Big Data projects;
- Ease of network provisioning where sophisticated intelligence is used to manage workloads based on business priorities;
- ability to leverage network staffing expertise across the entire datacenter.

2.3.3. Network partitioning

The separation, without adding cost and complexity, was enabled by logical partitioning. In addition, with the use of hard partitioning on the Ethernet switch, various tasks might also need to be isolated. This means that the tasks are completely separated at the data plane level. As an example, the data plane separation would be necessary to comply with regulations and privacy requirements, associated with healthcare applications that might contain sensitive data [35–37].

2.3.4. Scale out

The ability of 'Junior Science projects' (Big Data projects that might start small) to 'scale out' would ensure a seamless transition as projects increase in size and number. Additionally, an equally important issue is that network performance and ease of management remain constant as the cluster scales. The oversubscription should be minimized within the Big Data cluster network because of the demands of machine-to-machine traffic flows [35–37].

2.3.5. Unified Ethernet fabrics

Through leveraging multiple paths through the network and continuously determining the most efficient route, unified Ethernet fabrics enable full link utilization. The unified Ethernet fabrics offer an excellent scalability because the virtual chassis architectures provide access to multiple switches and, at the same time, manage them as a single device. This creates a pool of virtual switching resources and eliminates the need for manual configuration. Also, predictable any-to-any latency and bandwidth for traffic between servers within the Big Data cluster are provided by this design. Finally, a distributed approach to networking, which is much more resilient to failures, was brought by the unified Ethernet fabrics [35–37].

DOI: 10.1002/nem

3. CONTRIBUTION OF INTERNET OF THINGS IN BIG DATA APPLICATIONS

Table 1 lists the features of the Internet of Things, with regard to the convenience it offers. It also presents some of the most powerful features of Big Data technology that relate to the Big Data applications. The purpose of Table 1 is to show which of the particular features of the IoT technology pertain to, and improve the specific features of the Big Data applications. As we can observe, unified Ethernet fabrics and network partitioning are the Big Data application features that are affected more by the features of the IoT technology. In contrast, the holistic network and the scale out are the two features influenced less by the features of IoT technology.

3.1. Smart solution in the bucket of transport

Smart solutions in the bucket of transport achieve a reduction of traffic on the roads, reduce fuel consumption, set priorities in vehicle repair programs, and save lives [7,25–28].

3.2. Smart power grids incorporating more renewable

Smart power grids incorporating more renewables improve system reliability and reduce the charges consumers, thus providing cheaper electricity [7,25–28].

3.3. Remote monitoring of patients

Remote monitoring of patients provides easy access to health care, improves the quality of services, increases the number of people served, and saves money [7,25–28].

3.4. Sensors in homes and airports

Sensors in homes and airports, or even in your shoes or doors, improve safety by sending signals when left unused for a certain period of time or when used in a wrong time [7,25–28].

3.5. Engine monitoring sensors that detect and predict maintenance issues

Engine monitoring sensors detect and predict maintenance issues and inventory replenishment and even define priorities in scheduling maintenance work, repairs, and regional operations [7,25–28].

Table 1. Contributions of Internet of Things in Big Data applications

Internet of Things	Predictable and efficient [2.3.1]	Holistic network [2.3.2]	Network partitioning [2.3.3]	Scale out [2.3.4]	Unified Ethernet fabrics [2.3.5]
Smart solution in the bucket of transport [3.1]	X		X	X	
Smart power grids incorporating more renewable [3.2]	X	X			X
Remote monitoring of patients [3.3]		X	X		X
Sensors in homes and airports [3.4]			X	X	X
Engine monitoring sensors that detect and predict maintenance issues [3.5]	X		X		X

DOI: 10.1002/nem

4. CONTRIBUTION OF MOBILE CLOUD COMPUTING IN BIG DATA APPLICATIONS

Table 2, like Table 1, lists the features of the Mobile Cloud Computing technology, regarding the convenience this technology offers. It also enumerates some of the powerful features of Big Data technology that pertain to the same Big Data applications studied in Table 1. The purpose of Table 2 is to show which of the specific features of the Mobile Cloud Computing technology relate to, and improve the characteristics of Big Data applications that we singled out. As we can observe from Table 2, network partitioning, holistic network, and network partitioning are the Big Data application features that are influenced more by the features of Mobile Cloud Computing technology. In contrast, scale out is the feature affected less by the features of Mobile Cloud Computing technology.

4.1. Storage over Internet

Storage over Internet can be defined as a technology framework that uses Transmission Control Protocol/Internet Protocol networks to link servers and storage devices and to facilitate storage solution deployment. The Storage over Internet technology is also known as Storage over Internet Protocol technology. With the combination of the best storage and networking industry approaches, Storage over Internet Protocol provides high-performance and scalable Internet Protocol storage solutions [36,37].

4.2. Service over Internet

The main objective of the Service over Internet is to be committed to help customers all over the world in order to transform aspirations into achievements by harnessing the Internet's efficiency, speed, and ubiquity [36,37].

4.3. Applications over internet

The programs that can be written to do the job of a current manual task, or virtually anything, and that perform their job on the server (cloud server) via an internet connection rather than the traditional model of a program that has to be installed and run on a local computer are the cloud applications, or as a scientific definition Applications over Internet. Some examples of powerful programs that run in the cloud and perform incredible feats of computing for the oblivious user who only needs an internet connection and a browser are Google applications, Internet banking, and Facebook [35–37].

4.4. Energy efficiency

As a definition, energy efficiency is a way of managing and restraining the growth in energy consumption. Delivering more services for the same energy input or for the same services for less energy input may be something more energy efficient. As an example, when a compact florescent

Table 2. Contributions of Mobile Cloud Computing in Big Data applications

Mobile Cloud Computing	Predictable and efficient [2.3.1]	Holistic network [2.3.2]	Network partitioning [2.3.3]	Scale out [2.3.4]	Unified Ethernet fabrics [2.3.5]
Storage over Internet [4.1]		X	X		X
Service over Internet [4.2]	X	X	X		
Applications over Internet [4.3]	X		X	X	
Energy efficiency [4.4]	X	X	X		
Computationally capable [4.5]	X	X			X

DOI: 10.1002/nem

lightbulb uses less energy (33% to 20%) than an incandescent bulb to produce the same amount of lights, the compact florescent lightbulb is considered to be more energy efficient [35–37].

4.5. Computationally capable

The services of computational clouds are leveraging the computationally intensive and ubiquitous mobile applications that have been enabled by the technology of Mobile Cloud Computing. Thus, a system is considered as computationally capable when it meets the requirements to provide us the results we want, by making the right calculations [36,37].

5. CONCLUSION

Considering that the Big Data is a new technology that develops rapidly in the field of telecommunications and especially the modern field of wireless telecommunications, we have tried to combine this technology with the technologies of Mobile Cloud Computing and IoT. Additionally, the technologies of Mobile Cloud Computing and IoT begin to develop rapidly within the technology of wireless networks. We combined the Mobile Cloud Computing and the IoT with the technology of the Big Data, so we can check the common features and discover the benefits of these two technologies regarding their use with the Big Data applications.

In this paper, we present a survey of IoT Technology, with an explanation of its operation and use. Moreover, we present the main features of the Mobile Cloud Computing and its trade-offs. Also, we have a presentation of the Big Data applications and some of its basic features. Finally, we present the contribution of the IoT technology and the Mobile Cloud technology to Big Data applications.

The exploration of the contribution provided by IoT features and by Mobile Cloud Computing features in dealing with the basic characteristics of the Big Data applications is shown in Tables 1 and 2, respectively. However, based on these two tables, we can observe that the IoT mostly contributes to the field of network partitioning and unified Ethernet fabrics of Big Data applications. The Mobile Cloud Computing technology mostly contributes to the field of Predictable and efficient, holistic network, and network partitioning of BIG DATA applications.

In conclusion, we can infer from the information, which can be observed in Tables 1 and 2, that the technologies of IoT and Mobile Cloud Computing possess features that could be beneficial for the use of Big Data applications. As for future research, we suggest that the use of the Big Data applications is combined with the technologies of IoT and Mobile Cloud Computing in order to achieve better results. Also, as a continuation of this research, we will further examine the features of Big Data applications, which could be improved from the contribution of the technologies of Mobile Cloud Computing and IoT.

ACKNOWLEDGEMENTS

The authors would like to thank the anonymous reviewers for their valuable comments and feedback that was extremely helpful in improving the quality of the paper.

REFERENCES

1. Giusto D, Iera A, Morabito G, Atzori L (eds.). *The Internet of Things*. Springer: London, 2010. ISBN:978-1-4419-1673-0.
2. Swan M. Sensor mania! The Internet of Things, wearable computing, objective metrics, and the quantified self 2.0. *Journal of Sensor and Actuator Networks* 2012; **1**(3): 217–253. DOI:10.3390/jsan1030217.
3. Mongay Batalla J, Krawiec P. Conception of ID layer performance at the network level for Internet of Things. *Journal Personal and Ubiquitous Computing (Springer)* 2014; **18**(2): 465–480.
4. Y Kryftis, G Mastorakis, C Mavromoustakis, J Mongay Batalla, E Pallis and G Kormentzas. Efficient entertainment services provision over a novel network architecture. To be published in IEEE Wireless Communications Magazine, 2016.
5. Hilbert M, López P. The world’s technological capacity to store, communicate, and compute information. *Science* 2011; **332**(6025): 60–65. DOI:10.1126/science.1200970.
6. The NIST definition of cloud computing, National Institute of Standards and Technology, Retrieved 24 July 2015.

7. Huang D. Mobile Cloud Computing. *IEEE COMSOC Multimedia Communications Technical Committee (MMTC) E-Letter* 2011; **6**(10): 27–31.
8. Cloud data storage services. *IEEE Network* 2010; **24**(4): 19–24.
9. Sakr S, Liu A, Batista DM, Alomari M. A survey of large scale data management approaches in cloud environments. *IEEE Communications Surveys & Tutorials* 2011; **13**(3): 311–336.
10. Bahl P, Han YR, Erran LL, Satyanarayanan M, Advancing the state of Mobile Cloud Computing, ResearchGate, January 2012, Microsoft Research, University of Colorado at Boulder, Bell Labs, CMU, USA.
11. Bahl P, Han YR, Li LE, Satyanarayanan M, Advancing the state of Mobile Cloud Computing, MCS'12, 25-06-2012, Low Wood Bay, Lake District, UK, Microsoft Research, University of Colorado at Boulder, Bell Labs, CMU, USA.
12. Buyya R, Shin Yeo C, Venugopal S, Broberg J, Brandic I. Cloud computing and emerging IT platforms: vision, hype, and reality for delivering computing as the 5th utility, Future Generation Computer Systems, 25, 2009, p.599-616, Grid Computing and Distributed Systems (GRIDS) Laboratory, Department of Computer Science and Software Engineering, The University of Melbourne, Manjrasoft Pty Ltd, Melbourne, Australia, Institute of Information Systems, Vienna University of Technology, Argentinierstraÿe 8, 1040 Vienna, Austria.
13. Prajapat B, Shrivastava M. Mobile Cloud Computing through J2ME application: cloud enabled web services, International Journal of Advanced Computer Research Volume-2 Number-4 Issue-6 December-2012, Department of Information Technology, Laxmi Narain College of Technology, Bhopal, India.
14. D Sohini, D Suddhasil. Uncoupling in Services of Mobile Cloud Computing using tuple space model: design and formal specifications, MobileCloud'13, 29-07-2013, Department of Computer Applications, Siliguri Institute of Technology, West Begnal, Department of Computer Science and Engg., Indian Institute of Technology Guwahati, Assam, India.
15. Abolfazli S, Sanaei Z, Ahmed E, Gani A, Buyya R. Cloud-based augmentation for mobile devices: motivation, taxonomies, and open challenges, IEEE COMMUNICATIONS SURVEYS &AMP TUTORIALS, June 2013, University of Malaya.
16. Shiraz M, Ahmed E,Gani A, Han Q. Investigation on runtime partitioning of elastic mobile applications for Mobile Cloud Computing, J. Supercomput, 2014, 67, p.84-103, Mobile Cloud Computing Research Lab, Faculty of Computer Science and Information Technology, University of Malaya, Kuala Lumpur, Malaysia.
17. Ananthanarayanan G, Menache I. *Big Data Analytics Systems*. Microsoft Research: Redmond WA, USA.
18. Mishra N, Lin C-C, Chang H-T. A cognitive adopted framework for IoT Big-data management and knowledge discovery prospective, Department of Computer Science and Information Engineering, Chang Gung University, 259Wen-Hwa 1st Road, Kwei-Shan, Tao-Yuan 333, Taiwan, 2014.
19. Niggemann O, Kinnebrew JS, Khorasgani H, Volgmann S, Bunte A, Biswas G. Data-driven monitoring of cyber–physical systems leveraging on Big Data and the Internet-of-Things for diagnosis and control, Vanderbilt University and Institute for Software Integrated Systems, Nashville, TN, USA, Fraunhofer Application Center Industrial Automation, Institute Industrial IT, Lemgo, Germany, 2015.
20. Minch RP. Location privacy in the Era of the Internet of Things and Big Data analytics, 48th Hawaii International Conference on System Sciences, 2015, Boise State University.
21. Strohbach M, Ziekow H, Gazis V, Akiva N. *Towards a Big Data Analytics Framework for IoT and Smart City Applications*. AGT International: Darmstadt, Germany, 2015.
22. Suciu G, Suciu V, Martian A, Craciunescu R, Vulpe A, Marcu I, Halunga S, Fratu O. Big Data, Internet of Things and Cloud convergence – an architecture for secure e-health applications, Patient Facing Systems, 2015, DOI 10.107, Journal of Medical Systems 39:141, Polytechnic University of Bucharest.
23. Internet of Things global standards initiative. *ITU*. Retrieved 26 June 2015.
24. Höller J, Tsiatsis V, Mulligan C, Karnouskos S, Avesand S, Boyle D. *From Machine-to-machine to the Internet of Things: Introduction to a New Age of Intelligence*. Elsevier: Oxford, 2014. ISBN:978-0-12-407684-6.
25. Mongay Batalla J. Advanced multimedia service provisioning based on efficient interoperability of adaptive streaming protocol and high efficient video coding. *Journal of Real-Time Image Processing-Springer* 2015. DOI:10.1007/s11554-015-0496-4link.
26. P Viswanathan. Mobile devices expert, cloud computing – Is it really all that beneficial?, Advantages and Disadvantages of cloud computing, [Online], retrieved: 24/01/2015, Available: http://mobiledevices.about.com/od/additionalresources/a/Cloud-Computing-Is-It-Really-All-That-Beneficial.htm
27. E Almort & S Andersson. A study of the advantages & disadvantages of Mobile Cloud Computing versus native environment, School of Computing, Blekinge Institute of Technology, Sweden, May 2013.
28. Blog: follow what's happening at Get Cloud Services, Mobile Cloud Computing – Pros and Cons, [Online], Posted: 23/12/2014, retrieved: 24/01/2015, Available: https://www.getcloudservices.com/blog/mobile-cloud-computing-pros-and-cons
29. P Murray. Enterprise grade cloud computing, in Proc. Third Workshop on Dependable Distributed Data Management. ACM, 2009, pp. 1–1.
30. Council of July 2002: Directive 2002/58/ec concerning the processing of personal data and the protection of privacy in the electronic communications sector. European Parliament. Accessed November 20th, 2011. [Online]. Available: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32002L0058:EN:NOT
31. L Youseff, M Butrico, and D Da Silva. Toward a unified ontology of cloud computing, in Grid Computing Environments Workshop, 2008. GCE'08. IEEE, 2008, pp. 1–10.
32. E Shi, Y Niu, M Jakobsson, and R Chow, Implicit authentication through learning user behavior, in Information Security. Springer, 2011, pp. 99–113.
33. Data, data everywhere. The Economist. 25 February 2010. Retrieved 26 September 2015.

34. Hilbert M, López P. The World's technological capacity to store, communicate, and compute information. *Science* 2011; **332**(6025): 60–65. DOI:10.1126/science.1200970.PMID21310967.
35. L Borovick & RL Villars. The critical role of the network in Big Data applications IDC Analyze th Future, pp. 1-12, 1 4 2012.
36. Haque MN, Chowdhury MRK, Gani A, Whaiduzzaman M. A study on strategic provision of cloud computing services. *The Scientific World Journal* 2014; **15**(6): 1–8.
37. Garg SK, Versteeg S, Buyya R. A framework for ranking of cloud computing services. *Future Generation Computer Systems* 2013; **29**(4): 1012–1023.

AUTHORS' BIOGRAPHIES

Christos Stergiou was born in Thessaloniki, Greece. Currently, he is an undergraduate student in the Department of Applied Informatics, School of Information Sciences, University of Macedonia, Greece. Christos received a degree in Informatics and Computer Engineering from Technological Educational Institute of Western Macedonia, Annex of Kastoria (Greece); an MSc degree in Wireless Communication Systems from the Department of Technician of Wired and Wireless Networks of Brunel University (UK); and a Certificate of Proficiency for Teachers of Technological Education from Higher School of Pedagogical Technical Education, Annex of Thessaloniki (Greece). He worked as a professor of Computer Science in Vocational Training Institutes of Euosmos, Thessaloniki (Greece), for the academic years 2010–2011. He also worked for 2 years as a computer engineer and Ebay department manager in Alfanet SA (Greece). Since October 2015, he was working as a professor of Computer Science in Xinis Vocational Training Institutes (Greece). His research interests are IoT, Cloud Computing, Big Data, and Evolution of WiMAX technology.

Kostas E. Psannis was born in Thessaloniki, Greece. Kostas received a degree in Physics from Aristotle University of Thessaloniki (Greece), and a PhD degree from the Department of Electronic and Computer Engineering of Brunel University (UK). From 2001 to 2002, he was awarded the British Chevening scholarship sponsored by the Foreign and Commonwealth Office (FCO), British Government. He was awarded, in the year 2006, a research grant by IISF (grant no. 2006.1.3.916). Since 2004, he has been a (visiting) assistant professor in the Department of Applied Informatics, University of Macedonia, Greece, where, currently, he is an assistant professor (and Departmental LLP/Erasmus-Exchange Students Coordinator and Higher Education Mentor) in the Department of Applied Informatics, School of Information Sciences. He is also a joint researcher in the Department of Scientific and Engineering Simulation, Graduate School of Engineering, Nagoya Institute of Technology, Japan. He has extensive research, development, and consulting experience in the area of telecommunications technologies. Since 1999, he has participated in several R&D funded projects in the area of ICT (EU and JAPAN). Kostas Psanis was invited to speak on the EU-Japan Co-ordinated Call Preparatory meeting, Green and Content Centric Networking (CCN), organized by European Commission (EC) and National Institute of Information and Communications Technology (NICT)/Ministry of Internal Affairs and Communications (MIC), Japan (in the context of the upcoming ICT Work Programme 2013), and International Telecommunication Union (ITU) SG13 meeting on DAN/CCN, July 2012, amongst other invited speakers. He has several publications in international conferences, books, chapters, and peer reviewed journals. His professional interests are multimodal data communications systems, haptic communication between humans and robots, cloud transmission/streaming/synchronization, Future Media Internet, experiments on international connections (E-ICONS) over TEIN3 (Pan-Asian), Science Information Network (SINET, Japan), GRNET (Greece)-Okeanos Cloud, and GEANT (European Union) dedicated high-capacity connectivity. He is a member of IEEE. He is also a member of the European Commission EURAXESS Links Japan and a member of the EU-JAPAN Centre for Industrial Cooperation.