

A Conceptual Framework for BYOD to Support Green Computing in Public Sector

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Abstract : The paper aims to understand and develop a conceptual framework of Bring Your Own Device (BYOD) to support green computing in public sector. The research focuses on literature in green computing, BYOD model, BYOD process, BYOD component and end-user segmentation to identify BYOD components for end-user profiling in public sector and green computing approaches. The results of the research suggest a conceptual framework to map the concept of BYOD as an approach to support green computing with six components of BYOD which are device choice, affordable, technical component, content, liability and sustainability. This framework considers that end-user profiling for public sector, BYOD process and green computing approaches are the main key for public sector to support green computing. This conceptual framework is an initial research for researchers and practitioners to further examine BYOD practices in public sector. The framework can be implemented based on different BYOD practices for public sector, to identify the suitable end-user profiling and the component of BYOD that support green computing.

Keywords : Bring Your Own Device (BYOD), Component of BYOD, Green Computing, Public Sector.

1. INTRODUCTION

Green computing in organizations has become the trends in usage of information technology (IT). Reduce the carbon emission, electricity consumption and waste in lifecycle of IT device should be existing within the business processes as a core value [1]. There are several practices in the implementation of green approach in organizations such as green data center, software and deployment optimization, power management and materials recycling. It provides benefit to the organization in terms of electricity savings, reduction in environmental pollution and savings in purchasing new hardware. Green computing captured the attention of Malaysian government and has introduced National Green Technology Policy (NGTP) by Ministry Energy, Green Technology and Water (KeTTHA) to promote and support the use of green ICT [2].

BYOD define as the practices of bringing personally owned device to the workplace, connecting them to the corporate network and using them for business purposes [3]. BYOD is a new approach to optimize the use of IT devices through the use of the same device for both personal and office work in various forms such as laptops or smartphones[4]. The implementation of BYOD practices support green initiative by reducing the IT hardware in a working environment that will help to reduce carbon emission. IT hardware is the major contribution to the disposal and IT usage that give negative impact to the environment [5].

End-users play an important role in green attitudes and behavior of the organization's workforce towards environment[6]. However, the different end-user need different IT hardware based on usage pattern, location requirement that including job specification, time, value derived from mobility, data access and system access [7]. It is still not clear what the main components of BYOD that must be considered to support green computing. In Malaysia public sector, there is an on-going promotion of green initiative but there is still lack of BYOD procedure about what BYOD component and green computing approach involves.

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2. LITERATURE REVIEW

A. Green Computing

The term green computing is also known as green IT or ICT sustainability in IT domains which aims to reduce the environmental impact of IT operations [5]. Some of the major benefits of green computing are reduce energy consumption [8], reduce carbon footprint [13] reduce total cost of ownership [11] and *e-Waste* [8]. Each of these benefits plays a role in how green IT is measured to ensure that the impact on the environment is minimized. In green computing literature, the following are considered as main approaches of green computing in the context of their benefit: telecommuting, voice over Internet protocol (VoIP), power management, algorithmic efficiency, virtualization, material recycling and procurement [12]-[13]. Approaches identified in previous studies that have key elements from benefit of the use of BYOD to support green computing.

- 1. Telecommuting :** Telecommuting is about flexible work location in which employees perform tasks at home or remote offices that is facilitated by electronic media such as virtual private network, video conferencing and VoIP with others from the organization [14]. Telecommuting allows employees to communicate over a different distance that can be efficient for both organization and employees. Hence, it saving amounts of the travel time and cost that can reduce greenhouse gas emissions that can support green computing [15].
- 2. Algorithmic Efficiency :** Efficiency of algorithms has an impact on the amount of computer resources requires for any computing function and there are many efficiency trade-offs in writing programs [15]. The use of algorithms is an important approach in supporting green computing as new technic for reuse or use self modifies code for innovation to programs needs. As the result, the benefits of algorithms in supporting green computing is achieved through minimizing the cost and time for developing new programs or new applications.
- 3. Power Management :** The use of IT device in the organization directly or indirectly influences carbon emission and electricity consumption in the environment. IT device has power management tool to directly control the power saving for each of the hardware. Carbon emission and electricity can be reduced through auto shutdowns and hibernation modes that controlling the power usage that can support green computing [16].
- 4. VoiP :** VoIP is a transmission technology for delivery of voice communications over the Internet. VoIP reduces the wiring infrastructure by sharing the existing Ethernet copper, thus reduce the use of metallic waste. During a VoIP call, laptop can reduce energy consumed with components of the hardware [17].
- 5. Virtualization :** Virtualization is increasingly being used for storage and server environment. It involves transformation of a physical hardware into virtual entity that reduced the quantity of physical hardware. With virtualization, multiple virtual servers with more powerful are using less electricity as well as reduces data center space that makes better use of computing power, and reduces the data center's energy demands [18].
- 6. Material Recycling :** Recycling old computers keeps away the harmful material such as cadmium, arsenic, lead and chromium from entering the landfills. Refurbishing and reusing existing old computers keeps defunct systems and reduced e-waste, energy and emissions. Besides that, IT vendors play a major role on taking responsibility for the full lifecycle of products that they produce [19].
- 7. Green Procurement :** It refers to the process of supplies, services and works by the government that takes into account environmental criteria to conserve and minimize the impact on the environment [13]. The practices aims for choosing product that have the least possible impact on the environment throughout their whole life cycle. The criteria for choosing product must be reducing energy, carbon emission and waste.

B. BYOD Model

Currently, there are three type of BYOD model that consist of deployment model [20], BYOD framework [21] and Hybrid BYOD model [22]. Each of the models has different approach to implement BYOD. However, each of the model only concern about deployment, selection of device, policy and security. There is no work process that can support green computing related to end-user.

- 1. BYOD Deployment Model :** It is consists of two different types of BYOD programs model; “coffee shop” and 1:1 programs [20]. The coffee shop model of BYOD is basically based on the BYOD implementation for school using public Wi-Fi. Students can bring devices since they are provided with Internet access. However, it has some restrictions which student can use their devices for their homework only. The BYOD for 1:1 programs is meant for each student with a device that typically seen as a way for school to ask parents for financial support. Students who can afford to provide their own device can join the programs and those who cannot will use devices provided by the school [20]. However, this study only proposed the model that based on affordable and device choice with objective of the study is to provide the best BYOD model for student. It is not concerned about type of device and the impact of using device for environmental issues such as electricity consumption and carbon emission.
- 2. BYOD Framework Model :** This model is significant solution in IT organization to promote service-oriented models. They proposed three BYOD model based on computing device ownership, infrastructure set-up and support policies. Selection out of these delivery models depends on employees’ needs in terms of security, access to applications, device preferences and need for mobility [21]. First, the personal devices issued model concerns about the use of both devices from company and their personal device. The infrastructure and applications provided are partially virtualized which is all IT sources not involving employee. At the same time, IT support and corporate service also will be provided for employee. Second, catalog of managed BYOD devices model is about providing workstation sourced from organization to employee. All the employee can choose their own device and access all the services and applications from organization resources. The employees also are supported by IT helpdesk. The third is full BYOD model. End-user is fully utilize their own source and personal device. The organization may offer allowances to purchase the own device. However, IT support for the hardware is the employee’s responsibility. All BYOD models mentioned about the saving capital expenditure of hardware and software, and related IT operational expenses but cost benefit often get eroded by further investments such as virtualization or security reinforcement to support the BYOD model. However, it need a work process through implementation of virtualization concept for long-term development since it can support green computing in term of reducing carbon emission, electricity and *e-waste* [19].
- 3. Hybrid BYOD Model :** This model integrates the aspect of specific functionality model and integrated model of BYOD [22]. The hybrid model consists of BYOD component that apply selected device choice on the adoption of BYOD concept. The model takes into consideration the standardized and flexible aspects in order to be integrated between the users and the organizations. The standardized components include technical (hardware), content, liability and sustainability aspects. The flexible components allow the user to choose devices to use, based on the affordability, privacy and level of training on the use of device functionalities. This model proposes general processes for BYOD policy development. However, the model still lacks work process that details component that can support green computing.

C. BYOD Process

BYOD consist of three general work processes which are bring own device, using organization resources and multiple use of device to perform work task [23]–[25]. However, end-user are embracing their own

device which demands access to organizational resources to perform their work tasks [25]. Some aspects of the devices will be managed by organization and need to be aligned with organizational infrastructure. Bringing own device is the process of bringing end-user device that consist of selection of device of choice and affordability [20], [22]. End-user can bring their own device based on their choice and affordable to perform their jobs but they need to remain compliant with organization policies that follow existing rules and regulations. Using organization resources is a process require end-user device to connect and access the organization network to perform work tasks [23]–[25]. It consists of technical component, content, liability and sustainable component to support existing organization infrastructure such as server, storage and network [22]. Each of the devices that has access to organization network and using resources such as apps and data from premises or remotely over the Internet will be managed by IT department. Multiple use of device to perform work task is a process that end-user connect their multiple devices to the organization’s infrastructure [23]–[25]. It allows end-user to bring different device for work and personal use. This process increases the number of devices that must be connected to organization network that require liability and sustainable component to adopt BYOD [26].

D. BYOD Component

There are various components that need to be considered by organizations while adopting the BYOD such as device choice, technical aspect, user privacy, sustainability, affordability, training, liability and content which are the main component to setup BYOD policy [20]–[22]. Table 1 summarizes the component of BYOD based on existing BYOD model.

Table 1
Literature Based on Component of BYOD

<i>Component</i>	<i>BYOD programs model; “coffee shop” and 1:1 [20]</i>	<i>BYOD model based on computing device ownership, infrastructure set-up and support policies. [21]</i>	<i>The Hybrid BYOD [22]</i>
Device Choice	x	x	x
Affordable	x		x
Technical Component	x	x	x
Content		x	x
Liability		x	x
Sustainable			x
User privacy		x	x
Training			x

The device choice aspect is comprised of various elements such as analyzing employee preference and understanding which devices they have already bought. BYOD is also about end-user choice [20]. It is important to highlight that device choice is an important component to support green computing through a selection of green device that can reduce power consumption and carbon emission[31]. It also can reduce IT support and device maintenance [28] since the ownership of device will take full responsible for their device [21].

In terms of affordability, aspects that are considered include the shifting of the cost of device hardware to the user [20], [22]. All the latest devices is affordable to all the users with consist of latest operating system, support virtualization, more thin, less power consumption and less hazardous material [29]. Using latest device that comply green standard can reduce energy consumption and e-waste. Besides that, the old device can be transform into thin client technology by using virtualization through accessing virtual server to reduce power consumption and minimize e-waste [30].

The component of liability captures the definition of the elements of baseline protection for enterprise data on BYOD devices; assessing liability for system and application usage; assessing liability for usage onsite and offsite; and inside work hours and outside work hours [22]. Liability component also plays an important role to reduce IT overhead and device procurement cost [31].

The technical consideration aspect may be considered with reference to the capacity and structure of the existing infrastructure and wireless networks to accommodate this influx of devices, including the BYOD devices that will be accessing to the organization network [20]–[22]. Using organization resources require the technical component through virtualization to support green computing. The current physical server and storage that is obsolete or old will be replaced by virtual server and virtual storage to reduce power consumption and cost [15]. The devices that have access to organization network will be standardized to support existing system and application that will reduce procurement cost in terms of license purchasing [32].

In terms of content, this may be integrated through the identification of various basic sets of applications such as productivity suite and e-mail client among others which may be resident on the devices to reduce time installation that can reduce power consumption [21], [22], [33]. The content may also include the options for licensing agreements for software by using virtual storage that all the licensing will be stored centralize to reduce cost [32].

The sustainability of BYOD addresses the areas of securing corporate data; minimizing cost of implementation and enforcement; maintain a positive user experience that can reduce IT support and installation time [34]; and staying up-to-date with user preferences [22] to ensure that the BYOD concept is effectively integrated with the organization's infrastructure.

The component of the user privacy focuses on various issues regarding the safety of information that may be contained in the employees' devices or the organizations and restrictions for sustainability [22].

3. THE CONCEPTUAL FRAMEWORK

The purpose of this framework is to link the concept of BYOD as the approach to support green computing and the different end-user profile in public sector. The main point of this framework is not only on selected component of BYOD but also align with end-user profile that available in public sector so that proper process can be use to support green computing. Fig. 1 shows the proposed conceptual framework that integrates the BYOD component and green computing based on end-user. There are three general processes for BYOD consisting of bring own device, using organization resources and multiple use of device. Green computing approaches include telecommuting, algorithm efficiency, power management, VoIP, virtualization, materials recycling and green procurement.

This research will be detailing out each of the work process based on BYOD component and end-user profile. This research highlights the six major that related to BYOD process which are device choice, affordable, technical component, content, liability and sustainable because they are commonly used in BYOD work process and bring benefits that can provide advantages to support green computing. However, this study not requires user privacy as the component since it only focuses on various issues regarding the safety of information. Training component also not included since the use of device functionalities already support by the level of understanding related to their own device.

Bringing own device is the process of bringing end-user device that consist of selection of device choice and affordability [24],[25]. Using organization resources is a process require end-user device to connect and access the organization network to perform work task [23]–[25]. It consists of technical component, content, liability and sustainable component to support existing organization infrastructure such as server, storage and network [22]. Multiple use of device to perform work task is a process that end-user would like to connect multiple devices to the organization's infrastructure [23]–[25]. This process will increase the number of devices that must be connected to organization network that require the liability and sustainable component to adopt BYOD [26].

Process of bringing own device by end-user save the operation cost, reduce power consumption and carbon emission by selection device choice and based on affordable. Device choice selected by end-user has green computing contribution where it highlights the selection of green device, reduction of IT support and reduce the maintenance [28]. The selection of device also based on affordability that highlights the latest device which consist less energy consumption and carbon emission [29]. It can also recycle old device or refurbish that can be used as a device to reduce cost and waste [30]. Bringing own device's attributes matches the telecommuting, power management, VoIP, virtualization, material recycling and procurement attribute. Therefore, those attributes will facilitate green computing effectively.

Using organization resources processes enable the end-user to connect their device to organization network in providing IT support in terms of technology alignment between the devices brought by the employees with the organization infrastructure [15], [31], [35]. The BYOD model must provide technical support in terms of infrastructure, content, liability and sustainable to connect any devices to access organization's data or system. Using organization resources have shown contribution benefits to green computing by promote standardization of device using algorithm efficiency and virtualization[32]; using virtual storage by reducing power consumption and carbon footprint [15]; type of accessing data and system using virtualization [32]; reduce installation time; reduce IT support by apply power management to support energy efficiency and minimize the cost [34].

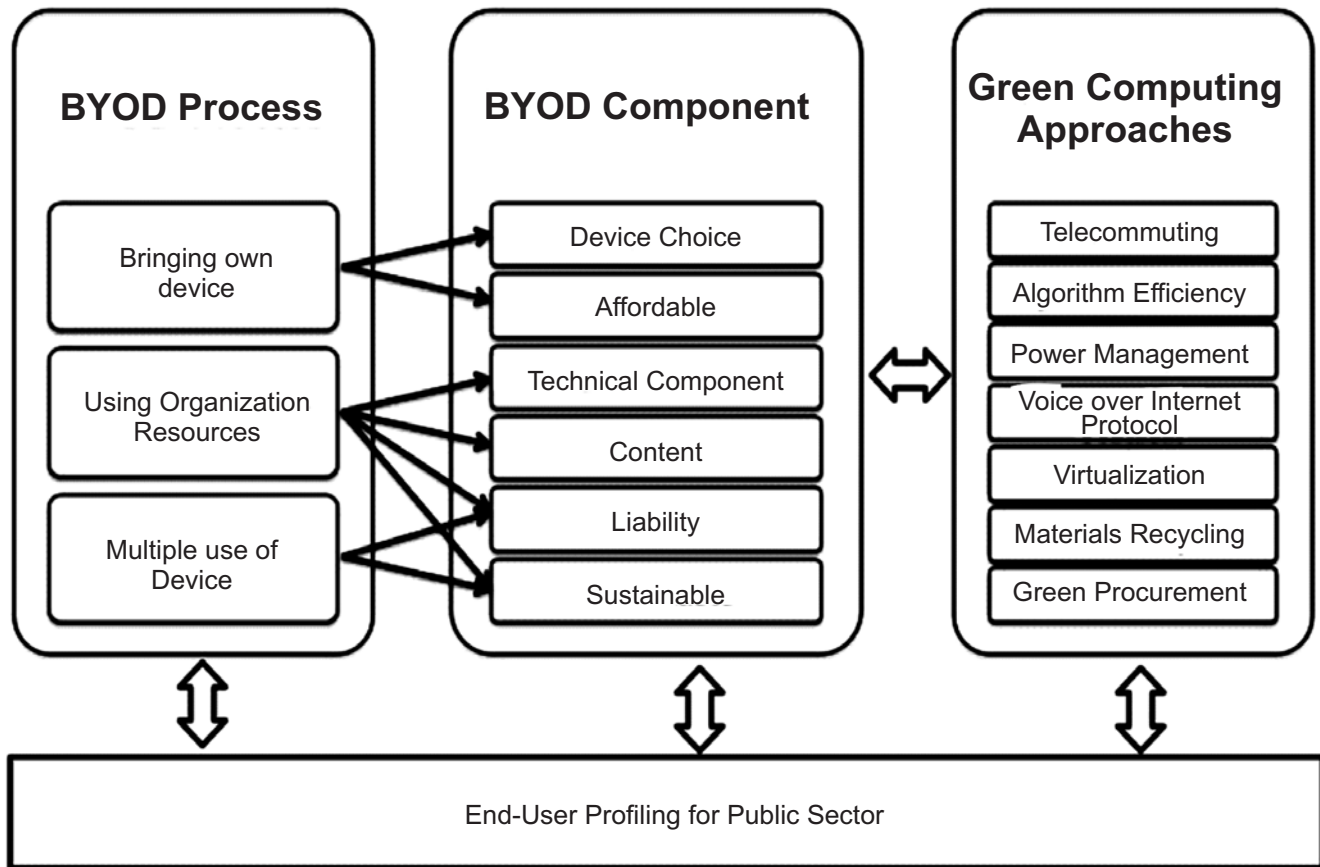


Figure 1: BYOD to Support Green Computing in Public Sector Conceptual Framework

End-user computing can be defined as the use of computing technology or software applications, together with the enhancement and development of information systems by end users [36]. End-user is a major part of BYOD implementation. Selection of BYOD device depends on end-user needs in terms of security, access to applications, device preferences and need for mobility [21]. The existing types of BYOD model has different approach to implement BYOD, based on end-user device ownership, affordability and device choice [20]. The implementation of BYOD still relies with Internet network.

4. CONCLUSION

Malaysia is moving towards advanced nation by 2020 which different dimension and multiple focuses such as economy and technological progress. At the same time, public sector is expected to highlight awareness and implementation of green practices to reduce environmental impact. The framework is constructed with component and benefit of green computing that is mapped from a review of the literature on green computing, BYOD model, and BYOD component. The conceptual framework has potential for guiding researchers to enhance knowledge for BYOD that can support green computing. The framework helps clarifies the contributing components of BYOD and its impact to green computing approach.

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6. REFERENCES

1. A. Molla, 'Organizational Motivations for Green IT : Exploring Green IT Matrix and Motivation Models', in PACIS 2009 Proceedings, 2009, pp. 1–14.
2. '(2011) KeTTHA Website', Kementerian Tenaga, Teknologi Hijau dan Air. [Online]. Available: <http://www.kettha.gov.my/portal/index.php>.
3. M. Loose, H. Gewalt, and A. Weeger, 'Determinants of Bring-Your-Own-Device (BYOD) Adoption from the Perspective of future Employees', HNU Work. Pap., no. 25, pp. 1–122, 2013.
4. Y. Song, "'Bring Your Own Device (BYOD)" for seamless science inquiry in a primary school', *Comput. Educ.*, vol. 74, pp. 50–60, 2014.
5. B. Saha, 'Green computing', *Int. J. Comput. Trends Technol.*, vol. 14, no. 2, pp. 46–50, 2014.
6. G. Philipson, 'A Comprehensive and Practical Green ICT Framework', in *Handbook of Research on Green ICT: Technology, Business and Social Perspectives*, 2010, pp. 131–145.
7. A. Cavoukian, 'BYOD : (Bring Your Own Device) Is Your Organization Ready ? BYOD : (Bring Your Own Device) Is Your Organization Ready ?', 2013.
8. O. U. Franklin and M. I. Zainul Abeeden, 'The Impact of Green Computing in Higher Institutions', *Int. J. Inf. Syst. Eng.*, vol. 2, no. 1, pp. 199–210, 2014.
9. N. Tiwari, 'Green Computing', *Int. J. Innov. Comput. Sci. Eng.*, vol. 2, no. 1, pp. 1094–1100, 2014.
10. A. Shukla, 'Green IT: A Strong Business Case', *The Chief Technology Officer Forum*, no. 2, pp. 36–37, 2012.
11. S. Brooks, X. Wang, and S. Sarker, 'Unpacking Green IT : A Review of the Existing Unpacking Green IT : A Review of the Existing Literature', *Am. Conf. Inf. Syst.* 2010, no. JANUARY, 2010.
12. H. Haron, Y. Y. A. Ibraheem, S. A. Aljunid, and M. Bakri, 'Software Reusability in Green Computing', *Adv. Sci. Lett.*, vol. 21, no. 10, pp. 3283–3287, 2015.
13. K. N. Adham and C. Siwar, 'Empirical investigation of green government procurement (GGP) practices in Malaysia', *OIDA Int. J.*, vol. 4, no. 4, pp. 77–88, 2012.
14. R. S. Gajendran and D. A. Harrison, 'The Good, the Bad, and the Unknown About Telecommuting: MetaAnalysis of Psychological Mediators and Individual Consequences', *J. Appl. Psychol.*, vol. 92, no. 6, pp. 1524–1541, 2007.
15. S. Choudhary, 'A Survey on Green Computing Techniques', *Int. J. Comput. Sci. Inf. Technol.*, vol. 5, no. 5, pp. 6248–6252, 2014.
16. K. Kawamoto, Y. Shimoda, and M. Mizuno, 'Energy saving potential of office equipment power management', *Energy Build.*, vol. 36, no. 9, pp. 915–923, 2004.
17. P. Somavat and V. Namboodiri, 'Energy consumption of personal computing including portable communication devices', *J. Green Eng.*, vol. 1, no. 4, pp. 447–475, 2011.
18. S. Murugesan, 'Harnessing Green It: Principles and Practices', *IT Prof.*, vol. 10, no. 1, pp. 24–33, 2008.
19. P. Pazowski, 'Green Computing : Latest Practices And Technologies For Ict Sustainability Computing Approaches', *Manag. Intellect. Cap. Innov. Sustain. Incl. Society*, pp. 1853–1860, 2015.

20. B. Moore, 'BYOD Considerations for K12 Schools', 2014.
21. B. Alleau and J. Desemery, 'Bring Your Own Device, It's all about Employee Satisfaction and Productivity, not Costs!', 2013.
22. H. K. Mwenemeru and V. O. Omwenga, 'Towards the adoption of bring_your_own_device concept in an organization', *Int. J. Soc. Sci. Entrep.*, vol. 1, no. 11, pp. 1–12, 2014.
23. I. Forrester Research, 'Key Strategies To Capture And Measure The Value Of Consumerization Of IT Enterprises Achieve A Wide Range Of Benefits By Deploying Bring-Your-Own-Device Programs', 2012.
24. M. Loose, A. Weeger, and H. Gewalt, 'BYOD–The Next Big Thing in Recruiting? Examining the Determinants of BYOD Service Adoption Behavior from the Perspective of Future Employees', *Proc. Ninet. Am. Conf. Inf. Syst.*, pp. 1–12, 2013.
25. B. Niehaves, S. Köffer, and K. Ortbach, 'The Effect of Private IT Use on Work Performance - Towards an IT Consumerization Theory', *11th Int. Conf. Wirtschaftsinformatik*, no. March, pp. 39–53, 2013.
26. EY, 'Security and risk considerations for your mobile device program', *Insights on governance, risk and compliance*, no. September, pp. 1–16, 2013.
27. A. Garcia-saavedra, P. Serrano, A. Banchs, G. Bianchi, and V. Politecnico, 'Energy Consumption Anatomy of 802.11 Devices and its Implication on Modeling and Design', *Co-NEXT'12*, pp. 169–180, 2012.
28. Citrix System Inc, 'The complete solution for enabling BYO', Citrix System, p. 11, 2010.
29. Masood Anwar, Syed Furqan Qadri, and Ahsan Raza Sattar, 'Green Computing and Energy Consumption Issues in the Modern Age', *IOSR J. Comput. Eng.*, vol. 12, no. 6, pp. 91–98, 2013.
30. D. R. Herrick and M. R. Ritschard, 'Greening your computing technology, the near and far perspectives', *Proc. ACM SIGUCCS fall Conf. User Serv. Conf. - SIGUCCS '09*, pp. 297–304, 2009.
31. A. S. Reddy, J. Wallace, T. Rose, and A. Sengupta, 'Making BYOD Work for Your Organization', Cognizant, pp. 1–17, 2012.
32. F. Mirza, C. Weiss, and R. Jekel, "'Bring Your Own Device" Shakes IT Departments Up.', A.T. Kearney, pp. 1–7, 2012.
33. Converge, 'Readying Your Campus for Mobile Learning and BYOD: A Guide to Strategy and Planning', *Converge Magazine*, pp. 1–28, 2012.
34. Mobile Iron, 'The Ultimate Guide to BYOD', MobileIron, pp. 1–21, 2014.
35. Aruba Networks, 'Conquering Today 's Bring Your Own Device Challenges', Aruba White Pap., pp. 1–14, 2012.
36. S. Barker, 'End User Computing and End User Development: Definitions for the 21st Century', *2007 Inf. Resour. Manag. Assoc. Int. Conf.*, no. 1983, pp. 249–253, 2007.