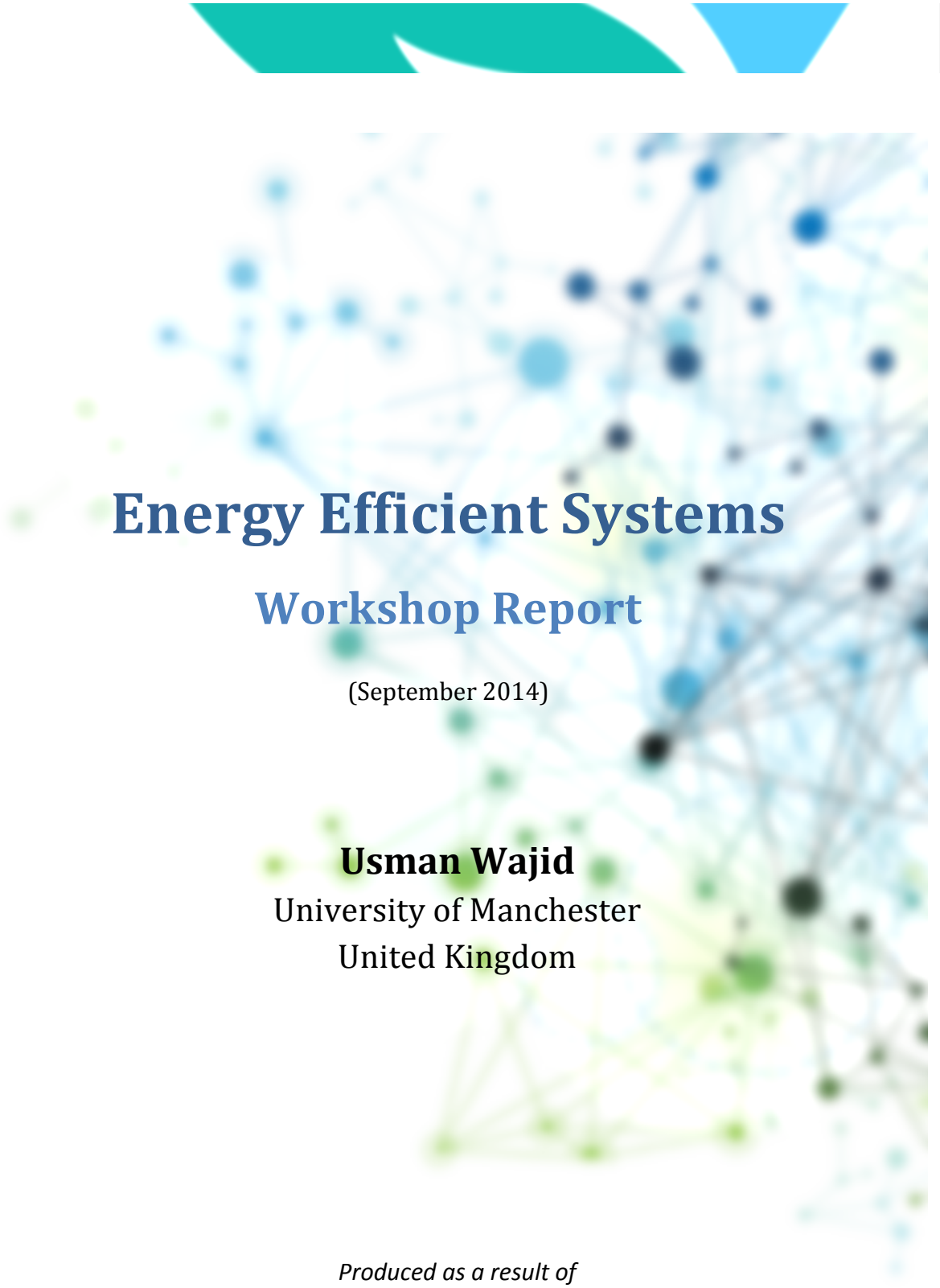

Energy Efficient Systems

Workshop Report

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Introduction

With the rapid technological advancements in ICT there is an increasing concern about the rising cost of energy and the impact of the ICT industry as a contributor to global CO_2 emissions. It is estimated that ICT consumes 7.8% of all energy produced in EU, which is expected to grow to 10.5% by 2020[1]. This is a financial, political, regulatory and ethical issue, which also raises significant questions about the overall environmental sustainability of ICT as its uptake increases. In this respect, there is an ever increasing need for innovative solutions to address the issues concerning energy consumption and resulting CO_2 emissions at different levels of ICT e.g. from application design and execution to the modelling and management of underlying ICT infrastructure.

Among recent developments in ICT, cloud computing offers a new and different approach from Software-as-a-Service and other utility based models when it comes to managing workloads in cost effective and highly scalable manner. Nonetheless, with compound annual growth rate of 28.8% projected up to 2015[2], cloud computing is not only raising its stakes in global ICT infrastructure but also attracting concerns about its long term environmental or ecological consequence.

With its focus on cloud computing the Workshop on *Energy Efficient Systems* at International Conference on ICT for Sustainability (ICT4S) (Stockholm, August 2014)provided participants from academia and industry an opportunity to present and discuss current initiatives targeting energy efficiency in the cloud as well as in the wider ICT domain. The workshop was organised by the the European Commission (EC) funded ECO_2Clouds[3]: *Experimental Awareness of CO_2 in Federated Cloud Sourcing* project. ECO_2Clouds aims to develop a CO_2 aware solution for the deployment and management of workloads on cloud infrastructure that can ensure best energy-performance ratios. The project particularly focuses on federated cloud infrastructure where applications may span over different cloud sites making it relatively difficult to track their energy consumption and CO_2 footprint as compared to when they are deployed at one cloud site.

This workshop report presents the overview of 5 research papers presented in the workshop on *Energy Efficient Systems* along with the summary of discussions that took place during the session.

Overview of Papers

The papers presented in the workshop on *Energy Efficient Systems* addressed energy efficiency and CO_2 issues in different areas of ICT with particular focus on cloud computing.

The paper *Eco-efficient Cloud Resource Monitoring and Analysis* presented *an approach for saving energy and reducing the Carbon footprint of cloud infrastructure*. The resource monitoring and analysis approach, implemented in the ECO_2Clouds project, enables specification and collection of specific metrics at physical infrastructure (testbed and hosts) and virtualization (VM) levels. The metrics currently implemented in ECO_2Clouds enable quantification of energy consumption and Carbon footprint at the above mentioned two levels. The data collected by the monitoring approach

[1] Communication from the Commission: http://ec.europa.eu/information_society/activities/sustainable_growth/docs/com_2009_111/com2009-111-en.pdf

[2] Cloud Computing Energy Efficiency: http://www.navigantresearch.com/research/cloud-computing-energy-efficiency

[3] ECO_2Clouds (Oct. 2012 – Sept. 2014) is funded by European Commission under 7th Framework Programme

is stored in a database for later use. The paper also provides an overview of a Data Mining service that uses the stored data to perform analytical operations that may help in the application deployment or resource utilization decision making.

The paper *Eco-reports in Clouds* provides an overview of a reporting mechanism for cloud computing. The reporting mechanism enables presenting to the user the information about the environmental impact of their cloud applications. The reporting mechanism also supports the goal of informing users about different operations that may have been performed during the execution of their cloud application to satisfy their non-functional requirements and to optimize their energy consumption and Carbon footprint.

The paper *Load Balancing to Save Energy in Cloud Computing* introduces two algorithms for efficient resource utilization in cloud computing. The algorithms aim to minimize the wastage of cloud resources as a result of under-utilization of some resources, and minimize lengthy response times as a result of over utilization, where both cases contribute towards excess energy consumption by the underlying resources. The experimental evaluation of the two algorithms reveals their strengths and weaknesses as one might be performing better than the other in any given context.

The paper *Energy Efficiency Embedded Service Lifecycle: Towards an Energy Efficient Cloud Computing Architecture* argues the need to provide novel methods and tools to support software developers aiming to optimise energy efficiency and minimise the carbon footprint resulting from designing, developing, deploying and running software in clouds. Based on the ongoing work in the EC funded ASCETiC (Adapting Service lifecycle towards Efficient Clouds) project, the paper provides an overview of a cloud architecture that can support energy efficiency at service construction, deployment and operations. The cloud architecture enables adequate support for energy efficiency at different layers such as IaaS, PaaS and SaaS.

The paper *A Look at Energy Efficient System Opportunities with Community Network Clouds* describes community networking as an emerging model of shared communication infrastructure that can support interconnection and interoperation of shared resources within different communities. The introduction of cloud computing in community networks is the focus of Clommunity project, described in the paper. In this respect, community clouds can be seen as a set of federated micro-clouds that can range from desktops to small data canters interlinked within a specific (community) cloud framework. The heterogeneity of resources in community cloud can enable allocation of suitable (energy efficient) resources for user application based on an energy model for available resources. In this respect, he paper discusses different options to enable energy efficiency in community clouds in order to realise support for energy efficient systems in community clouds and to seek collaboration with other related initiatives.

Discussions

The discussions that took place during the workshop on *Energy Efficient Systems* centred around the following four main topics:

Energy efficient systems – target domains and potential impact: The workshop participants had diverse opinion about the target domains and the scope of potential energy efficient systems. Target areas for achieving energy efficiency were narrowed down to buildings and cloud computing

infrastructure. Due to the growing number of data centres maximizing green energy utilization in this area can make a substantial impact both financially and in terms of environmental implications. Also the location and design of building can impact on the energy consumption of a data centre e.g. reduced cooling overhead of physical servers. Another aspect discussed was the consumer behaviour concerning the use of different devises for performing ICT operations e.g. from desktops, laptops to tablets and smartphones. Rapid technological advances mean the lifespan of these devices is getting smaller; however their CO_2 footprint in terms of R&D, manufacturing, logistics and recycling operations stays the same. Hence somehow increasing the lifespan of these devices can also contribute towards lowering the CO_2 footprint in the ICT domain. Furthermore, the potential impact of energy efficiency efforts in the above areas can result not only in financial gains but also open the way for technological innovations e.g. sensors for energy and CO_2 measurements at micro level and new ways for machines to community within buildings. Lastly, monitoring of energy consumption and environmental impact is quite important since the development of effective monitoring techniques and mechanisms can have second order effect on the any other system.

Energy efficiency motives – cost, environment and/or efficiency: The motives for energy efficiency can be different at developer (of technological solutions) level and at organization level. The discussions in the workshop unanimously concluded that at organization level cost is the most important factor or motive for achieving energy efficiency and environmental concerns can follow from that. On the other hand, for technology developers efficiency is the top priority and as a consequence it can translate to energy saving and other benefits. However, some participants placed less emphasis on efficiency and linked it to the second order effect of quality assurance. Environmental aspects are currently only reserved to a limited section of society and therefore depended on individual commitments or enforcement by regulatory authorities.

State of art – what's new, What's missing: Here the workshop participants had a lot to say about what's currently missing e.g. the discussions revealed that based on the low levels of awareness about environmental implications, lack of standardisation and best practices the commercial drive for eco-friendliness is currently not there to realise full commercialisation potential of energy efficiency systems at large. In this respect, establishment of new regulatory and standardization measures and code of conduct can be an important step. In terms of new developments, distributed resource utilization and ease of access enabled by cloud computing is a step forward from traditional networking topologies and grid. This new connectivity and access model allow investigation of new ideas and techniques for service delivery while considering different aspects like energy efficiency, efficiency, cost savings and other aspects.

ECO_2Clouds Usefulness – new or innovative ideas, future potential: Finally, this topic was focused on gathering general opinion about the ECO_2Clouds project based on the three paper presentations highlighting various aspects of the project earlier in the workshop. The participants discussed the different features of ECO_2Clouds project particularly the CO_2 measurements at different levels of cloud infrastructure. For participants new ideas developed in ECO_2Clouds also included the awareness of energy mix and its utilization in the decision making model and control mechanisms. In terms of future potential of ECO_2Clouds ideas, the discussions raised the various issues that can hold back any technological advancements in the area of energy efficiency these included varying level of support and regulatory measures concerning CO_2 emissions e.g. dynamic energy mix information is not available in Germany and in France the regulations are in place for CO_2 audit of

companies but there are no penalties yet. However, the advancements made in the project were deemed a step in the right direction.

Further, the workshop participants noticed that the research in the area of energy efficiency was making its way towards mainstream technologies and influencing different sects of industrial solutions e.g. some cloud service providers are pitching the use of green energy sources as their main marketing messages. However, further research, standardisation and clarity of existing regulatory measures can help boost the awareness about energy efficient solutions and ensure transparency across different levels of the market.

Summary

With increasing popularity of cloud computing the topic of energy efficiency has been getting profound attention owing firstly to the growing financial pressure on infrastructure providers to reduce energy related costs and secondly due to the environmental policies and 'green' measures from governments and other regulatory authorities (such as European Commission) that impose levies on CO_2 emissions from corporate infrastructures. With this upbeat of environmental concerns at different levels; for data centre and cloud infrastructure providers addressing energy efficiency and CO_2 footprint concerns will become as bigger challenge as maintaining quality-of-service. Furthermore, in such competitive and volatile market consumer awareness also plays a key role in shifting market orientation. Thus environmental awareness and pressure by regulatory authorities (such as EC) can influence consumers' selection criteria for ICT services, adding more pressures for datacentres and cloud service providers to do more!

About the author: *Dr Usman Wajid is a researcher at University of Manchester (UK) where he conducts research and development in the areas of service systems and future Internet. His research addresses problems in enabling automated interactions and multi-criteria optimization. Usman is currently the science and technology leader of EC funded ECO₂Clouds project (2012-2014) that aims to raise CO_2 awareness in cloud sourcing using energy aware application deployment and adaptation techniques.*

(The papers presented in the Workshop on Energy Efficient Systems will be published in the proceedings of ICT4S workshops)