Tutorial T-3: Greening Cloud Networks

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Tutorial Overview

In this tutorial we will introduce and discuss a number of measures that can be used to reduce the power consumption of cloud networks and will introduce methods for the optimum use of renewable energy in cloud networks to reduce the carbon footprint at a given power consumption level. We will introduce network optimization through the use of mixed integer linear programming (MILP) giving a short tutorial on MILP and build on this and heuristics inspired by it to explore a number of energy and carbon footprint reduction measures including

(i) Optimum use of time varying renewable energy in cloud networks where we show how the network can be optimized to reduce the non-renewable energy used and illustrate the additional energy savings that can be gained through Adaptive Link Rate techniques;

(ii) Physical topology design considering operational and embodied energies: We show the energy saving gains as a result of optimizing the physical topology of IP over WDM networks with the objective of minimizing the network's operational and embodied (embodied energy is the energy used to manufacture components) energies. Furthermore the optimization of the physical topology is investigated in the presence of renewable energy sources in the network;

(iii) Elastic optical networks using mixed line rates and optical OFDM, here we introduce the use of mixed line rates to reduce the power consumption of cloud networks and examine elastic optical networks where resources are allocated adaptively through optical OFDM to save power

(iv) Optimum resource allocation and green network design with data centres: Here firstly, through MILP models we optimize the location of a cloud hosting data center or multiple data centers in core networks so as to minimize the network power consumption. Secondly, we consider the optimum replication of content of different popularity so as to minimize the network power consumption. Thirdly, we answer the question (from energy minimization point of view) of whether to locate data centres / clouds next to renewable energy or to transmit renewable energy to data centers / clouds;

(v) Dynamic energy-efficient content caching: By 2015 over 91% of the global IP traffic is projected to be a form of video, hosted in clouds, with an annual growth of 33%. We will show the power savings that can be introduced by caching content near the end users in networks and the impact of optimizing the cache sizes at the different network nodes at different times of the day considering different content popularity distributions including Zipf, Pareto and Bimodal content popularity distributions to exemplify different types of video libraries (eg. YouTube), video streaming and IPTV (eg. broadcast TV) services respectively hosted in the cloud;

(vi) Energy efficiency through data compression: We show that the optimum energy efficient deployment of data compression should achieve a trade-off between the additional energy consumption of computational resources in clouds and memory required to compress and decompress data and the network energy savings;

(vii) Energy-efficient peer-to-peer content distribution: BitTorrent traffic accounts for 17% to 50% of the total Internet upload traffic in some segments. We will show how MILP models and heuristics can be used to minimize the power consumption of BitTorrent over IP over WDM networks while maintaining its performance and the energy efficiency gains over traditional cloud networks;

(viii) Energy-efficient distributed clouds: We consider centralization versus distribution of clouds and the impact of demand, content popularity and access frequency on the clouds placement, and cloud capability factors including the number of servers, switches and routers and amount of storage required in each cloud

(ix) Energy-efficient network virtualisation: We introduce an energy efficient virtual network embedding (EE-VNE) methodology, optimized using a mixed integer linear program (MILP) model, as a means of resource consolidation to bring about energy savings in cloud networks.

Presenter Biography

Prof. Jaafar Elmirghani is a Fellow of the IET, Fellow of the Institute of Physics, Senior Member of the IEEE and is the Director of the Institute of Integrated Information Systems and Professor of Communication Networks and Systems within the School of Electronic and Electrical Engineering, University of Leeds, UK. He joined Leeds in 2007 having been professor in optical communications at the University of Wales Swansea 2000-2007. He was Chairman of the IEEE UK and RI Communications Chapter and was Chairman of IEEE Comsoc Transmission Access and Optical Systems Committee and Chairman of IEEE Comsoc Signal Processing and Communication Electronics (SPCE) Committee. He is an editor of IEEE Communications Surveys and Tutorials, was a member of IEEE ComSoc Technical Activities Council' (TAC), was an editor of IEEE Communications Magazine and is and has been on the technical program committee of 33 IEEE ICC/GLOBECOM conferences between 1995 and 2014 including 14 times as Symposium Chair / Track Chair. He was founding Chair of the Advanced Signal Processing for Communication Symposium which started at IEEE GLOBECOM'99 and has continued since at every ICC and GLOBECOM. Prof. Elmirghani was also founding Chair of the first IEEE ICC/GLOBECOM optical symposium at GLOBECOM'00, the Future Photonic Network Technologies, Architectures and Protocols Symposium. He chaired this Symposium, which continues to date. He is Co-Chair of the IEEE Green ICT committee within the IEEE Technical Activities Board (TAB) Future Directions Committee (FDC), a pan IEEE Societies committee responsible for Green ICT activities in IEEE, 2012-2015. He is founding Chairman of GLOBECOM'11 Selected Areas in Communications, Green Communication Systems and Networks (GCSN) track. The track took / is taking place at GLOBECOM'12, ICC'13, ICC'14 and ICC'15. He received the IEEE Communications Society 2005 Hal Sobol award for exemplary service to meetings and conferences, the IEEE Communications Society 2005 Chapter Achievement award, the University of Wales Swansea inaugural 'Outstanding Research Achievement Award', 2006, the IEEE Communications Society Signal Processing and Communication Electronics outstanding service award, 2009, and IEEE ICC'13 best paper award. He is currently an editor of IET Optoelectronics, editor of Journal of Optical Communications, Co-Chair of the GreenTouch® Wired Core and Access Networks Working Group, an adviser to the Commonwealth Scholarship Commission, member of the Royal Society International Joint Projects Panel and member of the Engineering and Physical Sciences Research Council (EPSRC)

College. He has been awarded in excess of £22 million in grants to date from EPSRC, the EU and industry and has held prestigious fellowships funded by the Royal Society and by BT. He has published over 400 technical papers, co-edited “Photonic Switching Technology- Systems and Networks”, IEEE Press 1998, leads a number of research projects and has research interests in energy efficiency, communication networks and optical communication systems; see http://www.engineering.leeds.ac.uk/people/electronic/staff/j.m.h.elmirghani for more details. He is an IEEE Comsoc Distinguished Lecturer, 2013-2014.