Tutorial T-5: Greening Big Data 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 big data networks and will introduce methods for the optimum use of renewable energy in these 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 big data 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 big data 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 big data 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 2020 over 91% of the global IP traffic is projected to be a form of video, hosted in data centres, 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 data centres for hosting big data:** We consider centralization versus distribution of data centres and the impact of demand, content popularity and access frequency on the data centres placement, and capability factors including the number of servers, switches and routers and amount of storage required in each data centre

(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 big data networks.

Presenter Biography

Prof. Jaafar M. H. Elmirghani is the Director of the Institute of Integrated Information Systems within the School of Electronic and Electrical Engineering, University of Leeds, UK. He joined Leeds in 2007 and prior to that (2000–2007) as chair in optical communications at the University of Wales Swansea he founded, developed and directed the Institute of Advanced Telecommunications and the Technium Digital (TD), a technology incubator/spin-off hub. He has provided outstanding leadership in a number of large research projects at the IAT and TD.

He received the BSc in Electrical Engineering, First Class Honours from the University of Khartoum in 1989 and was awarded all 4 prizes in the department for academic distinction. He received the PhD in the synchronization of optical systems and optical receiver design from the University of Huddersfield UK in 1994 and the DSc in Communication Systems and Networks from University of Leeds, UK, in 2014. He has co-authored Photonic switching Technology: Systems and Networks, (Wiley) and has published over 400 papers. He has research interests in optical systems and networks.

Prof. Elmirghani is Fellow of the IET, Chartered Engineer, Fellow of the Institute of Physics and Senior Member of IEEE. He was Chairman of IEEE Comsoc Transmission Access and Optical Systems technical committee and was Chairman of IEEE Comsoc Signal Processing and Communications

Electronics technical committee, and an editor of IEEE Communications Magazine. 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 under different names. He was the founding chair of the first Green Track at ICC/GLOBECOM at GLOBECOM 2011, and is 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 across IEEE, 2012-present. He is and has been on the technical program committee of 34 IEEE ICC/GLOBECOM conferences between 1995 and 2015 including 15 times as Symposium Chair. He has given over 40 invited and keynote talks over the past 8 years.

He received the IEEE Communications Society Hal Sobol award, the IEEE Comsoc Chapter Achievement award for excellence in chapter activities (both in international competition in 2005), the University of Wales Swansea Outstanding Research Achievement Award, 2006; and received in international competition: the IEEE Communications Society Signal Processing and Communication Electronics outstanding service award, 2009, a best paper award at IEEE ICC'2013, **the IEEE Comsoc Transmission Access and Optical Systems outstanding Service award 2015 in recognition of "Leadership and Contributions to the Area of Green Communications" and received the GreenTouch 1000x award in 2015 for "pioneering research contributions to the field of energy efficiency in telecommunications"**.

He is currently an editor of: IET Optoelectronics, Journal of Optical Communications, IEEE Communications Surveys and Tutorials and IEEE Journal on Selected Areas in Communications series on Green Communications and Networking. He is 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 is an IEEE Comsoc Distinguished Lecturer 2013-2016.