Institution: University of Essex

Unit of Assessment: 11 – Computer Science and Informatics

Title of case study: Optical Switching for High Performance Networks

1. Summary of the impact

Essex research has investigated a range of switching techniques to enable efficient routing in optical networks. This research informed the development of the *iVX8000* system, the world's first 'carrier class' converged switch and transport solution, launched in May 2011 by the network equipment manufacturer Intune Networks Ltd. The development, launch and field implementation of the *iVX8000* system have underpinned a period of sustained growth and success for Intune. The company has enhanced its position within the photonics transmission sector and attracted €15M of venture capital and collaborative research funding since 2011.

2. Underpinning research

Telecommunications networks, such as those supporting high-speed internet and provision of HD television, face ever-growing demands, and this has led to the increased integration of optical elements. Use of optical technology offers potential benefit, both in practical terms (through reduced costs, greater flexibility and smaller dimensions) and in technical terms (through lower signal degradation, higher bandwidth, higher carrying capacity and suitability for digital signals). However, the associated increase of optical/electronic (o/e) interfaces within networks, for example between optical links and electronic routers, can cause problems. Rising demands on data volume can introduce latency and o/e interfaces at routers can significantly deteriorate server performance and waste processor power. Scaling network nodes in this way is costly, cumbersome and power hungry.

The routing, or switching, of network traffic *directly in the optical domain* would subvert the monotonously increasing power consumption associated with network scaling in the electronic domain, as power consumption in optical routing is no longer proportional to data throughput. The issues of latency, as well as size and cost of equipment, could also be effectively addressed. Motivated to realise these benefits, over the past twenty years the High Performance Networks (HPN) group at Essex has pioneered a range of switching technologies to implement effective optical routing. During this time key research staff have included: Professor Dimitra Simeonidou (1998-2012), Dr Reza Nejabati (2002-2012) and Professor Mike O'Mahony, who joined Essex in 1991 and has held the position of Emeritus Professor since 2007.

This research at Essex began in 1992 with participation in the *Multi-Wavelength Transport Networks* (*MWTN*) project, which explored the potential for optical networking in a managed network environment. It was the first project to propose and demonstrate, in real networks, the concept of optical wavelength switching. The positioning of optical cross-connects (OXCs), or 'optical routers', at network junctions was used to switch individual wavelengths onto separate paths, allowing for the specific routing of information. Following this, beginning in 1997, Essex participated in the *WASPNET* project, which examined optical packet switching as an alternative routing implementation (O'Mahony et al., 2001). This involves breaking up messages into 'packets' for transmission. By only switching-on a circuit route for an individual packet, network bandwidth can be utilised more efficiently. Additionally, individual packets also contain a destination address, meaning that packets don't necessarily have to travel the same network route. As network demands vary, this characteristic can be particularly helpful as it enables dynamic re-routing via different paths. This research was later complemented by the *DAVID* (2000), *OPSNet* (2001) and *OPORON* (2002) projects, which led to two further notable publications (Klonidis et al., 2005; Nejabati et al., 2007).

Whereas packet switching involves the use of a network route only when it is needed, optical *circuit* switching involves the establishment of a dedicated, end-to-end connection which remains open, even when only in intermittent use. In cases where bandwidth is at less of a premium this can offer the benefit of increased reliability, as the route is not subject to the demands of other users of the network. The *PROTAGON* project (2003) featured the concept of circuit switching and

involved the development of a cost-effective network for transporting data-centric traffic across circuit-switched optical networks (Zervas et al., 2009).

Finally, the Essex HPN group have also investigated the concept of Optical Burst Switching (OBS), which represents a compromise and embodies aspects of both circuit and packet switching, offering granularities in between the two regimes. OBS aims to improve the efficiency of use of network resources when compared with circuit switching, but compromises on the principles of packet switching; packets having the same destination address are aggregated at an egress node and then conveyed together as a 'burst'. This concept was drawn upon heavily in the *MAINS* project, which investigated the development of a scalable, sustainable and cost-efficient metro-regional network architecture, to cope with ever-increasing network traffic demands.

In summary, the HPN group have built knowledge and capacity across a range of optical switching schemes. Technology developments and implementations enable networks that are scalable, versatile and which make efficient use of network resources. It is now possible to access virtually unlimited amounts of bandwidth at very low cost. High-speed switching and low latency also enable dynamic networking and superior user experience. Optical switching remains an important area of research, evidenced by the continuation of a number of high value projects including *STRONGEST* (2009) and *Transforming the Internet Infrastructure: The Photonic HyperHighway* (2010).

3. References to the research

O'Mahony, M., D. Simeonidou, D.K. Hunter and A. Tzanakaki (2001) The application of optical packet switching in future communication networks, *IEEE Communications Magazine*, 39(3), 128-135. (417 citations – November 2013) DOI:10.1109/35.910600

Klonidis, D., T. Politi, R. Nejabati, M. O'Mahony and D. Simeonidou (2005) OPSnet: Design and demonstration of an asynchronous high speed optical packet switch, *IEEE Journal of Lightwave Technology (JLT)*, 23(10), 2914-2925. (47 citations – November 2013) DOI:10.1109/JLT.2005.856167

Nejabati, R., G. Zervas, D. Simeonidou, M. O'Mahony and D. Klonidis (2007) The "OPORON" Project: Demonstration of a Fully Functional End-To-End Asynchronous Optical Packet Switched Network, *IEEE Journal of Lightwave Technology (JLT)*, 25(11), 3495-3510. (12 citations – November 2013) DOI:10.1109/JLT.2007.906799

Nejabati, R., G. Zervas, G. Zarris, Y. Qin, E. Escalona, M. O'Mahony and D. Simeonidou (2008) Multigranular Optical Router for Future Networks, [Invited], *OSA Journal of Optical Networking*, 7(11), 914-927. (9 citations – November 2013) DOI:10.1364/JON.7.000914

Zervas, G.S., M.D. Leenheer, L. Sadeghioon, D. Klonidis, Y. Qin, R. Nejabati, D. Simeonidou, C. Develder, B. Dhoert and P. Demeester (2009) Multi Granular Optical Cross-Connect: Design, Analysis and Demonstration, *IEEE Journal of Optical Communications and Networking*, 1(1), 69-84. (47 citations – November 2013) DOI:10.1364/JOCN.1.000069

Zarris, G., E. Hugues-Salas, N.A. Gonzalez, R. Weerasuriya, F. Parmigiani, D Hillerkuss, P. Vorreau, M. Spyropoulou, S.K. Ibrahim, A.D. Ellis, R. Morais, P. Monteiro, P. Petropoulos, D.J. Richardson, I. Tomkos, J. Leuthold and D. Simeonidou (2010) Field Experiments with a Grooming Switch for OTDM Meshed Networking, *OSA/IEEE Journal of Lightwave Technology*, 28(4), 316-327. (12 citations – November 2013) DOI:10.1109/JLT.2009.2034121

Research funding: All projects were collaborative, the majority involving multiple academic and industrial partners. Amounts refer to Essex-held awards, rather than total project values.

O'Mahony, *MWTN – Multi-wavelength transport networks*, European Union, Jan '92 – Dec '94, £293,160

O'Mahony, *WASPNET – Wavelength switched packet network*, EPSRC, Jul '97 – Jun '00, £218,132

O'Mahony, Simeonidou, *DAVID – Data and voice integration over DWDM*, European Union, Aug '00 – Jul '03, £198,634

O'Mahony, Simeonidou, *OPSNet – Optical packet switching network*, EPSRC, Oct '01 – Sep '04, £219,276

Simeonidou, Reed, O'Mahony, *OPORON – Optical packet switching over wavelength routed optical networks*, EPSRC, Sep '02 – Nov '05, £283,322

O'Mahony, Simeonidou, *PROTAGON – Protocol agnostic optical networks*, Department of Trade and Industry, Oct '03 – Sep '06, £101,084
Simeonidou, *MAINS – Metro architectures enabling sub-wavelengths*, European Union, Nov '09 – Apr '12, £326,368
Simeonidou, Walker, *STRONGEST – Scalable, tunable and resilient optical networks, guaranteeing extremely high speed transport*, European Union, Dec '09 – Nov '12, £412,761
Henning, *Transforming the internet infrastructure: The Photonic HyperHighway*, EPSRC, Dec '10 – Oct '16, £205,246

4. Details of the impact

Over a twenty-year period the Essex High Performance Networks (HPN) group has developed concepts and implementations across a broad range of optical switching regimes. Principles of optical packet, optical circuit and optical burst switching exhibit broad applicability to a wide range of real-world challenges. This offers benefit to network providers, operators and users seeking to exploit the opportunities associated with increased integration of optical elements in networks.

The HPN group recognised that involving users in projects would offer an excellent means by which research could be targeted towards major industry challenges, and insight could be efficiently channelled into practical application. A notable example is the EU-funded *MAINS* project, which sought direct technical and practical impact upon mainstream network services amongst its primary outcomes. During the project Essex partnered with a number of collaborators including Dublin-based network equipment manufacturer Intune Networks Ltd. This interaction proved to be highly productive, and provided an ideal way for the know-how and research insight of the Essex group to be applied in a commercial context. In particular, Essex research was used to inform development and validation of the *iVX8000* system, Intune's first commercial product. In a letter of support [see corroborating source 1], Intune's Director of Research notes:

> "Through product development and validation, Intune benefitted from the opportunity to draw upon the know-how and research insight of the HPN group. Principles and concepts of optical packet switching, pioneered at the University of Essex and developed through our discussions and collaborative work, were particularly useful in engineering the iVX8000 product."
>
> *Director of Research, Intune Networks*

The *iVX8000* system was launched in May 2011, to lead the *Verisma* product family. It represented the world's first carrier-class converged switch and transport solution, capable of routing optical data traffic in an efficient way and at far greater speeds than existing broadband.

The platform was designed to address the global challenge presented by massive increases in on-demand data traffic and offers enhanced network efficiency, operational simplicity and service delivery agility. It relies upon optical burst technology and features a highly distributed optical packet switching fabric, enabling the performance of both switching and transport functions simultaneously, where fast tuneable lasers are used to transmit packets. The *iVX8000* allows users to overcome a number of key technical challenges, and features a range of particularly important characteristics, as detailed in Intune's May 2011 press release to accompany the product's commercial launch [2]. Prominent amongst these characteristics is the capability to provide 'liquid bandwidth', which permits operators to deliver packets of high bandwidth on demand, allowing the full potential of network assets to be realised. This versatility has particular significance for operators supporting cloud services and also for other high-bandwidth users. Critically the platform also enables networks to be easily scaled – a significant issue faced by network providers and operators. Following a period of on-going development, in January 2013 Intune announced that a new optical switching architecture had been developed to allow interconnection of multiple data centres, enabling the *iVX8000* to virtualise functions across several locations that can span hundreds of kilometres [3].

Both before and after the commercial launch of the *iVX8000* system, Intune's implementations underwent significant technical validation. Notably, in 2010, the technology behind the Verisma platform was selected to form the foundation of the Irish 'Exemplar' network test-bed. An example of an Irish 'Future Internet' project, Exemplar was designed to provide a high-speed

communications network, initially based in Dublin, but later to expand to become a nationwide infrastructure. The network initiative makes use of Intune's platform to provide the flexible network architecture and simplified software operations and control interfaces which will be required by the next generation of carrier services [2]. Exemplar has attracted significant commercial interest from companies keen to make use of the network for technical product development [4] [5] and was, in 2012, recognised by Ireland's Taoiseach (Head of Government) Enda Kenny TD, as a "key component" of the aim to position Ireland as a knowledge economy [6]. Following commercial launch of the technology in the form of the *iVX8000* system, validation also included a comprehensive suite of tests undertaken by Spanish broadband and telecommunications provider Telefónica. In September 2012, the Head of Core Network Evolution at Telefónica I+D (Telefónica's wholly-owned innovation company) reported that under operational conditions in field trials, "the system behaved exactly as predicted" [7].

Throughout its development, launch and field implementation, the *iVX8000* system has underpinned a period of sustained growth and success for Intune. The company's work to commercialise optical packet switch and transport technology led to the award of *The Irish Times* 'Innovation of the Year' in 2011 [8] [9] and the *iVX8000* later became the first distributed switch to be NEBS certified, enabling the potential for use in US carrier networks [10]. The company has enhanced its position within the photonics transmission sector and has attracted a further €15M of venture capital and collaborative research funding since 2011; Essex's contribution towards these successes is acknowledged in the Intune letter of support [1]. With an unprecedented and ever-growing global demand for high-speed broadband access, for applications such as video streaming, data sharing and social networking, the market for Intune's novel implementation is also set to increase, thereby extending further the impact of this research.

5. Sources to corroborate the impact [All sources saved on file with HEI, available on request]

[1] Director of Research, Intune Networks
[2] Intune Networks, 2011. *Intune Networks announces the commercial release of the Verisma product line* [online] Available at: http://www.intunenetworks.com/home/news/latest_pr/product_launch/ [Accessed 18 June 2013]
[3] Intune Networks, 2013. *Intune Networks Announces World's Largest Distributed Data Centre Architecture at 128Tbps* [online] Available at: http://www.intunenetworks.com/home/news/latest_pr/bigswitch/ [Accessed 27 June 2013]
[4] Silicon Republic, 2010. *Ireland's next big thing – Govt commits extra €5m to Exemplar Network* [online] Available at: http://www.siliconrepublic.com/innovation/item/16994-irelands-next-big-thing [Accessed 31 July 2013]
[5] Intune Networks, 2010. *Irish Government Launches Exemplar Network* [online] Available at: http://www.intunenetworks.com/home/news/latest_pr/2010_pr/exemplar_launch/ [Accessed 31 July 2013]
[6] Silicon Republic, 2012. *Boston University and Intune Networks to create BURST network* [online] Available at: http://www.siliconrepublic.com/innovation/item/25875-boston-university-and/ [Accessed 13 August 2013]
[7] Intune Networks, 2012. *Telefonica IDGlobal CTO Unit completes testing of Intune Networks subwavelength switching system* [online] Available at: http://www.intunenetworks.com/home/news/latest_pr/telefonicasuccessful_testing/ [Accessed 31 July 2013]
[8] Intune Networks, 2011. *Intune Networks wins innovation award for optical packet switch design* [online] Available at: http://www.intunenetworks.com/home/news/latest_pr/itaward/ [Accessed 31 July 2013]
[9] Finfacts: Ireland's Business & Finance Portal, 2011. *Intune Networks is the winner of the overall all-Ireland 'Innovation of the Year' 2011 award* [online] Available at: http://www.finfacts.ie/irishfinancenews/Irish_innovation/article_1021772_printer.shtml [Accessed 31 July 2013]
[10] Intune Networks, 2013. *Intune Networks delivers world's first NEBS certified distributed switch* [online] Available at: http://www.intunenetworks.com/home/news/latest_pr/nebs/ [Accessed 31 July 2013]