Institution: University of Aberdeen

Unit of Assessment: 15 (General Engineering)

Title of case study: Internet transport protocols and satellite broadband

1. Summary of the impact

While basic communications protocols for the Internet were developed decades ago, new requirements such as bandwidth-hungry multimedia and the need for the Internet to reach the "final third" of the population create constant demand for improvements. Research at the University of Aberdeen has greatly contributed to meeting this demand by influencing the standardization and implementation of the Internet Protocol (IP) stack in commercial networks. New standards for Internet Transport Protocols and Satellite IP Transmission resulting from the research have been implemented in industrial products in Europe and the US, benefitting industry and millions of end users.

2. Underpinning research

In recent years, ever-growing Internet multimedia content has presented major challenges for network operators, creating constant demand for improvement. It is essential that network traffic coexists with other traffic and that it receives acceptable service quality, without contributing to network congestion. Led by Gorry Fairhurst (Professor in Communications Engineering since 2008), the University of Aberdeen's School of Engineering has completed important research in internet engineering, including research in Internet Transport Protocols (the layer that defines how the network is shared among applications) and network engineering to enable broadband satellite internet access.

Research in Internet Transport Protocols [1-3] on new protocol mechanisms for congestion control, focussed on support for networks that include wireless/satellite links. Using a blend of simulation and practical investigation, research between 2006 and 2009 comprised performance analysis, evaluation and optimisation for: TCP (Transmission Control Protocol); TFRC (TCP-Friendly Rate Control); DCCP (Datagram Congestion Control Protocol). It also included examination of transport techniques, mechanisms for scalable multicast delivery, explicit congestion notification, and new cross-layer radio/transport methods to optimise multimedia performance. Funding was provided by research grants and industry contracts.

Fairhurst's research group has over 25 years' experience in Satellite Networking, and since 2004, has been a member of SatNEx, a European Network of Excellence (see Section 5, [6] bringing together 21 leading research establishments in the field. Research in this area at Aberdeen [4-6] between 2008 and 2011 proposed and analysed new bandwidth-on-demand techniques and studied their interactions with higher layer protocols. This has resulted in extensive simulation using an advanced satellite model, developed from industry-funded research by Astrium UK, and Thales France, and was made available in 2011 by Aberdeen University as an open source contribution to the Network Simulator project ns2, used by researchers worldwide.

As a part of the research, between 2007-2012 Fairhurst and his group in Aberdeen designed techniques for efficient delivery of IP-based TV and radio over the Internet [4], with particular attention to high scalability (ability to handle a growing volume of traffic) including development of protocol mechanisms for satellite multicast, quality of service, and cross-layer mechanisms for

resource management [5-6]. EPSRC and funding from Thales (France), Astrium (UK) [D], and the European Space Agency enabled the research to underpin development of a standardized framework for next generation broadband satellite equipment [6].

A priority across all the areas has been to ensure robust Internet access over a wide range of network link characteristics. The new techniques developed through the research provide the adaptation needed for users with limited access, especially relevant for locations at the edge of reach for wired broadband coverage or where wireless/satellite Internet access is used.

Applied research on Next Generation Access services (2009 – 2014) explores the challenges faced in deploying next generation satellite broadband technology and developing new services for the "final third" of the UK population. [6]

3. References to the research

1. Sathiaseelan, A., **Fairhurst**,G. "*TCP Friendly Rate Control (TFRC) for Bursty Media Flows.*" Computer Communications, SN 0140-3664, 2011.
   Investigates a set of new mechanisms for multimedia transport over UDP, reporting results and making recommendations on the methods finally published as a part of RFC 5348.

2. Biswas,I., Sathiaseelan, A., **Fairhurst**, G. "*Analysing TCP for Bursty Traffic.*" International Journal of Communications, Network and System Sciences, 2010.
   Identified core issues with bursty applications using TCP, and proposed new techniques to improve network congestion performance.

3. **Fairhurst**, G., Eggert, L., "UDP Usage Guidelines for Application Designers." Internet Society, RFC 5596, 2010.
   Defines techniques that applications should use for UDP - one of the core Internet protocols.

4. Cantillo, J., Collini-Nocker, B., De Bie, U. Del Rio, O., **Fairhurst**, G. Jahn, A. Rinaldo, R., "*GSE: A Flexible, yet Efficient Encapsulation for IP over DVB-S2 Continuous Generic Streams*". Int. Journal of Satellite Communications, 0737-2884 26 231, DOI: 10.1002/sat.915, 2008.
   Describes the design and performance of a new broadcast link design, finally published as ETSI TS 102 606.

5. **Fairhurst**, G., Secchi, R., Yun, A., *"Design of the DVB-RCS2 Higher Layer Satellite Architecture"*, Int. J. Satell. Commun. Network. (2013), DOI: 10.1002/sat.1037.
   Paper describing work contributed to the DVB-RCS2 HLS Architecture, published as ETSI TS 101 545-3.

6. **Fairhurst**, G., Yun, A., "*A flexible QoS architecture for DVB-RCS2",* Int. J. Satell. Commun. Network. (2013), DOI: 10.1002/sat.1026.
   Paper describing the work contributed on QoS functions for the DVB-RC2 LL and HLS, included as a part of ETSI TS 101 545-2 and ETSI TS 101 545-3.

Grants:

1. SATSIX, 1/01/06 → 31/05/08, £210,540, NoE, European Commission.
2. DVB Activity, 1/07/11 → 31/08/11, £161,822, Astrium Ltd.
3. Rural Digital Economy Research Hub, 1/10/09 → 30/09/14, RCUK, Share of £11.8m, EPSRC.
4. Study of Generic Stream Encapsulation, 1/05/09 → 30/04/10, £43,623, ESA ARTES.
5. Efficient Networking and MAC Techniques, 4/04/11 → 3/04/12, £74,820, ESA ARTES.
6. Reducing Internet Transport Latency (RITE), 1/11/12 → 31/10/15, £371,270, EC FP7.

4. Details of the impact

(numbering refers to Section 5 unless specified)

Research by Fairhurst and his group has directly benefitted industry, who have taken up and used the new standards created from it. Although the commercial gain yielded by open standards is not measurable, these standards are hotly contested in competitive markets and achieve very wide reach – as in the case of mobile phone or TV standards, which ultimately affect millions of users. Other beneficiaries of the research have been the principal Internet standards authority, as well as end users of web and mobile technology.

Internet Engineering Task Force

Throughout the impact assessment period, as a direct result of his research expertise, Fairhurst has been an active member of the Internet Engineering Task Force (IETF) [1, 2], the principal Internet standards organisation. This specifies protocols and current best practice for Internet operators in the Request for Comments (RFC) series. These standards ensure the inter-working of hardware and software produced by different manufacturers. Throughout the impact assessment period, Fairhurst served as Chair of the IP over Digital Video Broadcast (IPDVB), Datagram Congestion Control (DCCP) and Transport and Services (TSVWG) working groups. He became a member of the Transport directorate, which advises the IETF on transport standards, in 2009 [3].

Internet Transport Protocols

Since 2008, Fairhurst co-authored a series of ten published IETF standards documents [1], cited by 29 other standards documents [1-3]. This work directly benefited industry: UDP-Lite, RFC5097, co-authored by Fairhurst, is used in third-generation mobile phone (3GPP UMTS) equipment enabling operators such as Ericsson AB [2] to transition to an internet-based voice service. This has been implemented in the Linux operating system since release 2.6.20. Work has also made significant contributions to UDP (e.g. Section 3 [1, 3]), TCP (e.g., Section 3 [2]) and the development of DCCP (2, 3)).

Satellite IP Networking

Research by Fairhurst and his group directly benefitted the satellite terminal industry. Techniques for IP transmission [Section 3 [4]] were applied by leading European space companies Astrium, Portsmouth (for a mesh satellite network [4] and Thales (cross-layer transport optimisation).

Fairhurst was an invited technical expert to the European Telecommunications Standards Institute (ETSI) between 2001-2009, where he contributed to the BSM series of satellite system specifications [e]. Building on this, Fairhurst et al [Section 3 [4]] designed the Generic Stream Encapsulation (GSE) for efficient transport of network packets over second generation Digital Video Broadcast (DVB) standards [6, 7]. This was standardized [8], with work continuing by the Universities of Aberdeen and Salzburg to specify Extension Formats (RFC 5163, 2008) and Implementation Guidelines (TS 102 771, 2009). GSE has been implemented in commercial broadcast products in Europe [9] and America since 2009, (Newtec's EL470, EL970; Work Microwave's SK-IP; GCS's ODG200 and BSR200; Advantec Wireless's AMT75e; Comtech CDM-840; KS Transpleneta dpi4502; and Computer Module's DVB Rocket). GSE has reduced operational cost for companies delivering satellite IP services [e, f]. Current work within DVB is adapting GSE to become a standard for all second generation transmission technologies [9].

In 2009, again on the basis of his research, Fairhurst was co-opted onto the TM-RCS standards group on behalf of ESA, the largest standardization initiative for open satellite communications. He provided expertise on protocol design and contributed to defining the QoS [Section 3 [6]] and network-layer architectures [Section 3 [5]] for the Higher Layers, published in the DVB Return

Channel via Satellite (DVB-RCS2) specification in 2011 [5, 6]. DVB-RCS2 was successfully demonstrated by STM, one of the largest privately-held satellite engineering companies, in their SatLink platform in June 2011. It has since been implemented by iDirect, Virginia, USA. Thales-Alenia Space is currently developing commercial DVB-RCS2 gateway products [6].

Next Generation Access

Fairhurst and his group contributed to design of the Digital Advanced Rural Testbed (DART, 2012) and the evaluation of user-experience (2013). This pre-commercial platform allowed SMEs to explore technology and economic impacts (ranging from on-demand TV to wireless access for government services) with results disseminated to stakeholders and network operators (e.g. Avanti, BT). Avanti PLC is using the technology enablers developed in DART to build new user services for commercial launch in 2013 [7].

Public engagement

Fairhurst and his team have increased awareness and understanding of satellite broadband research through public engagement activities [7[. These included presentations at the major annual science and technology festival in Aberdeen "TechFest" (2011) on the evolution of satellite broadband, "Satellites in Space", attracting an audience of 150. Presentations to business and government representatives at Technology Strategy Board events, including Innovate (2011, 2013), and the International Telecommunication Union Geneva Conference (2011) presenting DART to network operators and government policy makers. Public awareness was also promoted through schools visits in 2012 and 2013, and through national radio (e.g., interviews with Townsend, Research Fellow working with Fairhurst, on BBC Radio Scotland's Out of Doors, 2011).

5. Sources to corroborate the impact

1. http://www.arkko.com/tools/allstats/godredfairhurst.html
   This source corroborates contributions to IETF.
2. The Transport Area Director, IETF corroborates contributions to IETF.
3. The Chair of Internet Research Task Force, IRTF will corroborate contributions to IETF.
4. A member of EADS Astrium can corroborate contributions to Satellite Networking.
5. The Chairman at TM-RCS can corroborate contributions to ETSI-BSM and DVB-RCS2.
6. The Editor HLS, as part of the TM-RCS Working Group, will corroborate contributions to DVB-RCS2.
7. A member of staff at Avanti Communications PLC can corroborate contributions to Broadband Satellite.
8. *ETSI TS 102 606, "Generic Stream Encapsulation (GSE) Protocol",* 2007.
9. DVB GSE Status: http://www.dvb.org/resources/public/factsheets/DVB-GSE_Factsheet.pdf
10. ETSI TS 101 545-3, "DVB Interactive Satellite System (DVB-RCS2); Part 3: Higher Layers Satellite Specification", 2013.