Bull, DR. (2007). Communicating pictures: the test of future wireless networks. In *International Symposium on Signal Processing and Its Applications, Sharjah* (pp. 1 - 4). Institute of Electrical and Electronics Engineers (IEEE). <https://doi.org/10.1109/ISSPA.2007.4555633>

Peer reviewed version

Link to published version (if available):
[10.1109/ISSPA.2007.4555633](https://doi.org/10.1109/ISSPA.2007.4555633)

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COMMUNICATING PICTURES: THE TEST OF FUTURE WIRELESS NETWORKS

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ABSTRACT

Before wireless multimedia applications can be truly successful, a number of technologically demanding problems must still be resolved. For example, future services will need to be delivered at a range of bit rates, dependent on network and channel characteristics, platform type, application and material content. End to end provision of multimedia information across network components of varying capability and performance will therefore impose the need for coding regimes which are inherently robust to different forms of loss and error.

This paper addresses one of the most challenging coding problems- associated with the delivery of real time video over wireless communication networks. Specific examples will be based on H.264 transport over the 802.11 family of wireless LAN standards. The lecture will also describe how aspects of wireless video research in the University of Bristol have been successfully extracted from the laboratory and commercially exploited through a spin-out company, ProVision Communications.

1. INTRODUCTION

Personal and business multimedia communications is a major growth area today. The convergence of telecommunications, information processing and multimedia is of strategic importance worldwide and will enable both businesses and citizens to have access to extensive on-line communication and entertainment services. However, before multimedia applications can be truly successful, a number of technologically demanding problems must still be resolved. For example, future services will need to be delivered at a range of bit rates, dependent on network and channel characteristics, platform type, application and material content. End to end provision of multimedia information across network components of varying capability and performance will therefore impose the need for coding regimes and transport mechanisms which are inherently robust to different forms of loss and error.

This paper focuses on one of the most challenging coding problems- associated with the delivery of real time video over wireless networks. Specific examples will be based on H.264 transport over the 802.11 family of wireless LAN standards. It also describes how

research in this field can be commercially exploited. A key hurdle in this respect is the exploitation gap between the research laboratory and the commercial world.

A University of Bristol spin-out Company, *ProVision Communications*, is used here to provide an insight into the problems associated with progressing technological developments while growing the business structures needed to fill the exploitation gap.

2. MAKING VIDEO WIRELESS

This section focuses on the challenges of achieving reliable video transmission over wireless networks. Examples are taken from ongoing exploitable research at the University of Bristol.

2.1 Propagation Modelling and Planning

Network planning tools are used to deploy wireless networks in complex environments. Examples include cellular networks, radio hotspots for public access, coverage of specialist events or mobile TV. In all cases, access points and basestations must be correctly positioned to ensure reliable reception at all times.

Propagation models are employed to take into account the exact position, orientation and electrical properties of individual buildings and foliage. Modelling large areas of detailed urban environment is extremely challenging. Ray-tracing techniques, based on the computation of direct, reflected and diffracted waves, have emerged as the dominant method to predict propagation in such environments. An example output of the latest ray-tracing model is shown in figure 1.

Tools developed at the University of Bristol [1] offer high levels of spatial and temporal coverage and have been rigorously validated using narrow and wide-band measurements. They support the accurate modelling of antennas (including spatial pattern and polarisation) and hence allow advanced wireless video solutions (eg MIMO) to be fully evaluated before moving to prototype.

The cost and complexity of a network is closely related to the number of base-stations (BSs) required. The location of BSs is not straightforward and numerous factors must be considered. A highly optimized combinatorial algorithm (CAT) has been developed at Bristol [2] which efficiently searches through all viable network combinations to find the optimal client solution.

Figure 1. Predicted RF coverage using Prophecy.

2.2 Error Concealment

Error resilience has been a key factor in enabling real time video transport over wireless communication networks. When transmitted over a mobile channel, video can be affected by a number of loss mechanisms, such as multipath fading, shadowing and co-channel interference. The effects of such errors are magnified because of the need to compress the video to meet stringent bandwidth constraints. Predictive coding and variable length coding lead to severe spatial and temporal error propagation and can cause significant degradation.

Several techniques exist for mitigating the effects of errors on a video stream (see [3,4]). One key method is error concealment. An enhanced spatiotemporal concealment method (EECMS) that offers significant gains (up to 9 dB) over the concealment approach of the H.264 JM decoder has been proposed [5]. The method combines both spatial and temporal concealment through a mode selection algorithm. A spatial error concealment

Fig. 2. Mode selection results for 'Table Tennis'. TL - error free, TR - corrupted, BL - TEC, TR - Proposed.

(SEC) module switches interpolation methods based on the directional entropy. This has been combined with an optimised temporal concealment algorithm (TEC). A mode selection algorithm examines the suitability of each method for concealing the missing macroblock by evaluating the levels of motion compensated activity in its neighbourhood. The proposed algorithm outperforms other mode selection methods consistently across a range of sequences with little additional complexity (figure 2).

2.3 Cross Layer Optimisation – Link Adaptation

Wireless Local Area Networks such as IEEE 802.11a/g utilise numerous transmission modes, each providing different throughputs and reliability levels. Many Link Adaptation algorithms proposed in the literature either maximise error-free data throughput based on channel conditions or on the number of failed transmissions. However, these do not take into account the content of the data stream and strongly rely on the use of ARQs, thus introducing variable delay. For video transmission, low latency is a key requirement. Moreover, completely error-free communication is not essential, especially if robust video compression techniques are applied.

A link adaptation scheme is proposed in [6] that improves the Quality of Service (QoS) for video transmission based on the overall received video quality and minimum latency, rather than by maximising error-free throughput. The PER thresholds used for switching modes are much lower than those currently used by throughput based schemes. Results for H.264 compression over IEEE 802.11a are shown in figure 3.

Figure 3. Link Adaptation Comparison

2.4 Cross Layer Optimisation – MIMO video

It is clear that new coding and delivery methods are required to fulfill the bandwidth demands of HD content and the growing quality expectations of users. Solutions are required that provide enhanced compression performance and the ability to trade error resilience and range against throughput. Two important developments in this area are multiple-description coding (MDC) [7] and multiple-input-multiple-output (MIMO) systems [8].

To meet the growing demands for higher throughput and enhanced quality of service (QoS), an approach using multiple antennas has emerged and is now being standardised via IEEE 802.11n and 802.16. MIMO systems offer an excellent means of trading error resilience against throughput even in highly challenging environments.

A new and efficient approach to the efficient and robust transmission of video over wireless channels, through a combination of MIMO and MDC technology was proposed in [8]. MDC exploits the interactions between descriptions when losses occur in multiple

channel wireless communications to reliably recover the video. Mapping of video content for spatial multiplexing MIMO systems was achieved using SVD. Results indicate improvements in average PSNR of decoded test-sequences of up to 7dB compared to standard video transmission. This is also supported by significant subjective quality enhancements (see fig 4).

Figure 4. Subjective results for “Paris” $E_b/N_0=28\text{dB}$.

3. COMMERCIALISATION OF RESEARCH

3.1. Motivation

UK Government policy and university strategy in the UK is geared towards generating new income streams. This not only creates disposable capital but also frees up research funds. The UK White Paper “Future of Higher Education” (2003) emphasised the need to strengthen the research base for economic growth, and to facilitate wealth creation through knowledge transfer.

UK universities are the recipients of over £3Bn of public research funding per annum. The UK produces about 8% of the World's scientific papers and wins around 10% of the internationally recognised scientific prizes. Its universities are clearly bursting with ideas yet exploitation of these ideas is often slow or non-existent.

3.2 Universities – A platform for innovation

Several examples of successful research exploitation can be cited for UK Universities. An excellent example is that of the stored programme computer: In 1948 The Manchester Baby operated for first time at Manchester University. In 1949 the Manchester Mk1 was completed - acknowledged to be the first stored programme computer. Two years later in 1951 the Ferranti Mk 1 was launched.

Enterprise is becoming an essential part of the portfolio for the modern academic. For example it is now not uncommon for academics to have research links with world-class companies, to engage in consultancy or to be a company director. This enterprise culture often includes training programmes in areas such as project management, IP and finance as well as providing IP management and business advice.

Importantly, direct funding for business ideas at the pre-start up stage is available and incubator programmes provide space for early stage businesses. Examples of support available to the University of Bristol include: Sulis (provides support for the early stage commercialisation of research and is backed by £9M of capital from the Wellcome Trust and the OST); IP2IPO (generates commercial value from IP created by its

university partners by building long-term partnerships and providing strategic and financial support in return for equity); and SET SQUARED (the largest government-funded, privately-backed support programme of its kind in the UK. It has supported more than 100 ventures)

3.3 The Challenges of a Start Up

3.3.1 License or Spin-Out

The first decision to be made is often whether to start a business at all. Alternatives such as licensing may be more appropriate in some cases. For example there may be significant barriers to a new company entering the market or if the technology is based on a single patent or perhaps is near enough to market to sell without further development. In other cases, their may already be a sponsoring company linked with the research.

In some situations a spin-out company may be more appropriate. For example, where entry to the market by a new company is relatively easy with few significant barriers, or where the marketplace is fragmented with a lot of small companies. In such cases, the technology would typically have many applications and there may be a portfolio of IP. Most importantly the inventors need to be motivated to start the company and there should be a clear financial exit route for investors and the University.

3.3.2 Building the business

Many factors favour the survivability and growth of the university spin-out. For example, the experienced academic should already have a strong network of trusting and often major industry partners. Ongoing links with the university may also provide visibility of ongoing research output and potential access to IP. Financial benefits arise as access to government funding can sometimes be easier and investors like university spin-outs as they have technical credibility.

Several sources of competitive research funding are available to spin-outs. While these only part-fund R&D or development work, they often favour SMEs. Examples include: *EU Framework FP6* (17.5Bn Euro 2002-6) and *FP7* (2007-2013, providing 73.2Bn Euro); *University Innovation Centres* (funded by the UK government in 2001. In Bristol: 3CRL forms a unique collaboration between communications, computing and multi media content with DTI funding of £7.62M); and *DTI Technology Programmes* (which provide sustained links with a university and access to a network of larger (potentially client) organisations).

3.3.3 What do investors look for in a spin-out?

Investors will normally look for businesses which possess a few key characteristics: a strong management team; a scalable business model with international potential; strong IPR and a defensible technological advantage. Market-driven rather than technology-led development is required with the potential to exit within 4-6 years.

While seedcorn funds such as from SULIS can be readily available, subsequent early stage funding can be

difficult, often relying on business angels or small funds. If the spin-out is successfully grown to a scale suitable for sale or acquisition, how is this best achieved? A listing on AIM (Alternative Investment Market) in the UK can be good for raising capital. A trade sale is often a better exit for high technology companies (80% exit this way) as investors more rapidly benefit from the business growth.

4. PROVISION COMMUNICATIONS

4.1 History

ProVision Communications is an example of a University of Bristol high technology spin-out. Founded in 2001, by the author and a colleague, Prof Andrew Nix, *ProVision Communications* was established to exploit research in three key and interrelated areas: *robust video codecs; advanced wireless OFDM technology and propagation modeling and planning.*

ProVision is uniquely positioned for a small company, having technology covering wireless, video and network deployment. It has provided highly robust digital transmission solutions for a large number of clients including international media organisations (BSkyB), telecoms providers (BT, Toshiba and TTPComm), consumer electronics companies (Imagination Technologies, Mitsubishi) and businesses with specialist telemetry requirements (British American Racing).

ProVision was a founder member of the University Innovation Centre, 3CR Ltd, and has also benefited from participation in EU projects ROMANTIK, WCAM and ASTRALS.

A time line for the company's history is given below:

- 1996: Research collaboration between Bull and Nix,
- 2000: Company formation supported by UoB,
- 2001: Business plan prepared and seedcorn capital, Spun out with part-time CEO and 2 employees. 1st contracts with Toshiba and BAR. High levels of investor interest,
- 2002: New CEO and NED appointed. Technology market slump and investor interest 'dips'. Adopts contract R&D business model,
- 2003: MIMO video demonstration at Telecom World,
- 2004: 10 people. Investment in product R&D,
- 2005: Corporate partnership agreed for products,
- 2006: Demonstration of ProVu-Sport at World Rally. *Prophecy* plans first London WiMax network. DTI funds wireless MIMO video system,
- 2007: 20 people including a Business Manager. Further investment sought to support product launch.

ProVision has thrived through difficult times because the breadth of its portfolio and expertise allow it to rapidly shift business model, undertaking contract R&D and strategic co-development with blue chip partners.

4.2 Market strategy

ProVision's strategy to take it from a consultancy base into supplying technology and products into consumer markets now has three distinct strands:

1. System solutions for location-based AV services,
2. Sales of OEM wireless-video boards, and IP license,
3. Consultancy services (eg RF planning).

The *ProVu* concept builds on IP and research which originated in the University of Bristol. It combines robust video acquisition with low cost IP distribution using off the shelf terminals and standardised WiFi and WiMax technology. Rapid system deployment and planning is achieved using *Prophecy*.

5. CONCLUSIONS

This paper has described how wireless video research has been successfully taken from the research laboratory into a spin-out Company. It is clear that enterprise in a world-class research-intensive university is highly dependent on its research base. It is only by ensuring that the University undertakes high quality research that it can hope to achieve a similar position in enterprise. For universities to be successful, we need to preserve the balance between fundamental research and exploitation as a joint effort between government, academia and business. Universities must continue to develop and sustain a culture that is supportive of enterprise. Success breeds success.

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