Institution: Kingston University		
Unit of Assessment: 11 – Computer Science and Informatics		
Title of case study: Industrial innovations through enhanced multimedia quality of experience		
Period when the underpinning research was undertaken: 2008 – 2018		
Details of staff conducting the underpinning research from the submitting unit:		
Names:	**Roles:**	**Periods employed by submitting HEI:**
Maria Martini	Professor; Leader of the Wireless Multimedia and Networking (WMN) Research Group	Aug 2007 – present
Nabajeet Barman	Lecturer; WMN member	2010 - present
Period when the claimed impact occurred: 2015 – 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Martini's research in multimedia quality of service and experience has been adopted by: Entryphone, a UK SME, through the creation of an innovative door intercom system. This led to additional cumulative sales of GBP412,000 between 2018 and 2019, projected to double annually, and a holistic embrace of future-facing development leading to market share protection and expansion.
Deutsche Telekom (DT), a multinational company, through the integration of video streaming quality monitoring into its networks enabling the offer of cloud gaming services - which contributed to an increase in revenue by 0.9%, to €5.7 billion, and gained 1,100,000 customers in Europe and 642,000 customers in Germany alone.

2. Underpinning research

Modern technological advances and the proliferation of fast, cheap, and ubiquitous network access has enabled new services such as video streaming. Streaming may be directed to a range of devices - laptops, phones, door entry systems. However, these services must meet stringent requirements in terms of network performance and capacity for end-users, even when only low bandwidth is available.

To ensure such requirements are met, Martini and her KU team, with long-term contributions from Barman, undertook research on multimedia quality of service and experience (QoE). The research addressed the trade-off between almost lossless compression and low available bandwidth, and assessment of QoE.
Martini's team evaluated the performance of seven video quality metrics for compressed medical ultrasound videos, finding that high efficiency video codecs reliably and suitably maintained visual information fidelity **[R1]**. Directing their focus to gaming video streaming, they met the need for application-specific light-weight models, using machine-learning rather than knowledge of the original video sequence **[R2]**. They presented two no-reference quality estimation models and evaluated their performances, showing improvements over current metrics and comparable accuracy with a full reference metric.
Based on the properties of the human eye, Martini's team have proposed an edge-based reduced reference quality metric **[R3]**, whose results correlate well with both subjective observations and commonly used full-reference metrics. This algorithm maintains fidelity, complexity, and low overheads, outperforming state-of-the-art metrics. Later, they presented a new approach for quality evaluation when the reference video is not available for comparison **[R4]**. This almost-blind quality metric achieved a high correlation with subjective results, and a negligible associated overhead.

Martini has applied the use of these QoE metrics to wireless network, proposing a content-aware packet scheduling approach **[R5]** and presenting an evaluated concept of quality switching for light field video **[R6]**.

This research work was conducted with the support of the EU, i.e. OPTIMIX (FP7, 2008 – 2011), innovative solutions enabling enhanced video streaming for point to multi-point in an IP based wireless heterogeneous system, Qualinet (COST, 2010 – 2014), CONCERTO (FP7, 2011 – 2015, Content and cOntext aware delivery for iNteraCtive multimedia healthcaRe applications), and QoE-NET (Horizon2020, 2015 – 2018, innovative QoE maNagement in Emerging mulTimedia services), EPSRC (Iosire, 2017 – 2020), Innovate UK (Entryphone Ltd., Vocality International Ltd.), other research councils, and industries (e.g., DOCOMO, Siemens).

3. References to the research

R1 – Razaak, M., **Martini, M.G.** and Savino, K. (2014) A study on quality assessment for medical ultrasound video compressed via HEVC. IEEE Journal of Biomedical and Health Informatics, 18(5), pp. 1552 – 1559. ISSN (print) 2168 – 2194
DOI: 10.1109/jbhi.2014.2326891 REF2ID: 11-40-1372

- This is the main reference in the Qualinet* Working Group on medical imaging.

R2 – **Barman, N.**, Jammeh, E., Ghorashi, S.A. and **Martini, M.G.** (2019) No-reference video quality estimation based on machine learning for passive gaming video streaming applications. IEEE Access, 7, pp. 74511 – 74527 DOI: 10.1109/ACCESS.2019.2920477
REF2ID: 11-12-1346

R3 – **Martini, M.G.,** Hewage, C.T.E.R and Villarini, B. (2012) Image quality assessment based on edge preservation. Signal Processing: Image Communication, 27(8), pp. 875 – 882. ISSN (print) 0923 – 5965 DOI: 10.1016/j.image.2012.01.012

R4 – Nasr, K.M. and **Martini, M.G.** (2017) A visual quality evaluation method for telemedicine applications. Signal Processing: Image Communication, 57, pp. 211 – 218. ISSN (print) 0923 – 5965 DOI: 10.1016/j.image.2017.06.003 REF2ID: 11-39-1371

- Obtained excellent feedback when presented at IEEE International Conference on Communications 2017, triggering discussions about collaborations. The Qualinet* chair heighted its potential for industries beyond medical imaging, leading to integration of the results into the newly formed No References Metrics Working Group.

R5 – C. T. E. R. Hewage and M. G. Martini, "Edge-Based Reduced-Reference Quality Metric for 3-D Video Compression and Transmission," in IEEE Journal of Selected Topics in Signal Processing, vol. 6, no. 5, pp. 471-482, Sept. 2012,
DOI: 10.1109/JSTSP.2012.2195155

R6 – Kara, P.A., Cserkaszky, A., **Martini, M.G.**, Barsi, A., Bokor, L. and Balogh, T. (2018) Evaluation of the concept of dynamic adaptive streaming of light field video. IEEE Transactions on Broadcasting, 64(2), pp. 407 – 421. DOI: 10.1109/TBC.2018.2834736
REF2ID: 11-36-1368

* *QUALINET (European Network on Quality of Experience in Multimedia Systems and Services), coordinates European Quality of Experience (QoE) research, with membership across the globe. It aims at extending the notion of network-centric Quality of Service in multimedia systems, by relying on the concept of QoE, (http://www.qualinet.eu).*

4. Details of the impact

Kingston University's (KU) research around live video streaming has led to impact in both a UK SME, Entryphone, and a multinational company, Deutsche Telekom AG (DT).

Entryphone: Developing a New Approach

In 2015 Entryphone, a UK manufacturer of door entry systems, entered into a 30-month Knowledge Transfer Partnership with Kingston to deliver quality video streaming. They saw that for "*long term prosperity it is essential our products [are] updated to be able to exploit the Internet of Things (IoTs) and mobile communication devices*." **[S1]**
Historically, door intercom systems have been analogue, and Entryphone was not taking advantage of solutions from the IoTs revolution, with the market for 'traditional' hard-wired products shrinking. Customers demand new products that allow them to operate their door entry system with a smartphone. This is of particular importance for people with mobility and health issues and who cannot physically access their door entry system. Entryphone reported that the KTP addressed "*The business opportunity in developing new systems that would function exploiting the wireless technologies but also work alongside our existing apparatus*." **[S1]** The KTP led to existing product ranges having increasing compatibility with personal mobile IP devices and to non-distributive upgrade paths, and to enhanced service contracts, thereby protecting and improving market share **[S1]**. Entryphone's Director described the game-changing contribution to Entryphone's evolution saying *'it was Kingston University who introduced us to using WebRTC, otherwise we wouldn't have thought about it … I am happy we were able to move early to WebRTC rather than SIP, which is used by other market players at greater cost*" **[S2]**.

Entryphone: Developing Teledial

Based on research by Martini's team, Entryphone developed a unique hybrid multi-occupant visitor communication door control system combining traditional video door phone services (analogue audio/video) and IP services such as video and voice over IP using the H.264 codec. The hybrid approach introduced an effective interface, incorporated fail-safe characteristics of the analogue system, and was cheaper for customers who do not have to replace their entire legacy analogue system **[S3]**. This has led to the commercialisation of two novel product ranges: Teledial (GSM, audio only) **[S4]** from 2018, and Teledial (video, audio & video) from 2019.

Entryphone: Economic Impact

Financial gains from additional sales were GBP32,000 in 2018 and GBP390,000 in 2019 and (before Covid-19) projected cumulative sales were GBP900,000 by the end of July 2020 (20% year-on-year increase). The offer of new connected services has led customers to take out additional service contracts. The Director said the "*Teledial GSM has been quite successful in terms of industry impact and [Entryphone] remain positive about the business impact it will have*", adding "*the Teledial unit retails for over £800, making a contribution to the company's overall turnover as multiple systems are put into whole blocks of flats. We would not make other sales without this product; and we remain very confident that the initial financial predictions will eventually come to pass*. *Moreover, as digital solutions allow staff to remotely check many system functions, there are fewer visits by field service engineers, increasing both the speed of response to customers and the company's profit margins*" **[S2]**. The impact includes:

- internal development with "*a growth factor in employee numbers, including an associate from the KTP and three out-sourced sub-contractor*" **[S2]**.
- the new mind-set *"to transform the knowledge and culture of the company to prepare, secure, and expand [the] business to thrive in the decade ahead*" **[S1]** has already been enacted. All 24 members of staff had formal training to update their digital skills and knowledge, from detailed sales advice to new set-ups and procedures.
- access to new markets such as schools, universities, hospitals, local authority housing, and larger new-build developments is ensured, whilst protecting Entryphone's position with multiple-occupancy high-rises.

Deutsche Telekom: Developing Metrics and Models

With mobile operators believing that cloud gaming will represent up to 50% of 5G data traffic by 2022, quality cloud gaming operating in a low latency environment is a priority to DT. The need to ensure high quality service management led to a collaboration with Kingston University, as part of the H2020 QoE-Net project, for facilitating smart monitoring of QoE. One in-house researcher on the project commented that "*Kingston University's research was especially valuable in assessing compression-quality trade-offs and the creation of open-source datasets and achieved three ITU recommendations (G.1032, P.809, G.1072)*" **[S5]**. The project leader defined the collaboration as '*very fruitful'* and stated that *"The contributions to standardization will create real value for Deutsche Telekom that will be paying off in the next two years, as well as Cloud Gaming being 'a significant use case for future* projects" **[S6]**.

Deutsche Telekom: Economic Impact

The QoE-NET project achieved the '*development of metrics and models for objective quality assessment' and will help 'maintain DT's competitive edge in the market*' **[S5]**. By 2018, '*some results of QoE-Net [*were*] already effective in service management operation*' **[S6]**. This adoption by DT has enabled it to offer cloud gaming services: in August 2018 DT added 'StreamOn Gaming' (free for 'Young rate plans', €2.95 per month for over 27s) to its existing music and video streaming service **[S7]**. To further support 4G and then 5G mobile multi-player gaming, DT has built four new dedicated edge data centres. In 2018, this contributed to DT seeing its revenue increase by 0.9% to €5.7 billion and gaining 642,000 customers in Germany and 1,100,000 in Europe despite a very competitive telecommunication market. In 2019, a project lead at DT, described the market opportunity of cloud gaming and the need to '*ensure that the game-streaming traffic is delivered efficiently'* and at *'the required gaming quality*' **[S8]**. Thus, the research still contributes to DT, providing an edge in innovation, despite competition from Microsoft and Google.

Technological Impact

While the early adopters of technology may suffer from the absence of technical standards, Martini's contribution to international standards—ITU standard contributor **[S9]**, P3333 group on Standard for the Quality Assessment of 3D Displays, 3D Contents, and 3D Devices based on Human Factors (key contributor of IEEE Standard P3333.1.2 **[S10]** and chair of IEEE Standard P3333.1.4—will enhance the longevity of the implemented video streaming technologies.

5. Sources to corroborate the impact

S1 – Entryphone KTP report, 2019
S2 – Testimonial by the Director of The Entryphone Co. Ltd.
S3 – Adeyemi-Ejeye, A.O., Mehdi, M., Martini, M.G., Philip, N. and Orwell, J. (2017) Design of a hybrid multi-occupant visitor communication and door control system. IEEE 7th International Conference on Consumer Electronics - Berlin, pp. 246 – 247. ISSN (online) 2166 – 6822 DOI: 10.1109/ICCE-Berlin.2017.8210639
S4 – TeleDial GSM Product Sheet
S5 – Testimonial by a former Deutsche Telekom researcher
S6 – Testimonial by the former project leader at DT Laboratories
S7 – StreamOn Gaming: Telekom announces flat rate for online gamers, Spiegel Online, 2018
S8 – Industry Reflection from Gazetta Byte, 24 October 2019
S9 – ITU-T Contributions: https://www.itu.int/md/T17-SG12-C-0096/en and https://www.itu.int/md/T17-SG12-C-0200/en
S10 – IEEE Standard contribution: IEEE Standard for the Perceptual Quality Assessment of Three-Dimensional (3D) and Ultra-High-Definition (UHD) Contents