Impact case study (REF3)

Institution: University of Derby

Unit of Assessment: 11

Title of case study: Edge computing

Period when the underpinning research was undertaken: 2015–2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Nick Antonopoulos	Professor, PVC Research & Innovation, Dean of College of Engineering & Technology, Head of School of Computing & Mathematics	March 2009–January 2019
Fatih Kurugollu	Professor of Information Security, Lead Information Security research theme	October 2016–present
Bo Yuan	Lecturer in Data Science	April 2019–present
Byungseok Kang	Lecturer in Internet of Things	January 2019–present

Period when the claimed impact occurred: 01 January 2015–31 December 2020

Is this case study continued from a case study submitted in 2014? No

1. Summary of the impact (indicative maximum 100 words)

Edge computing, as opposed to centralised data processing using a warehouse, aims at capturing, storing and processing data at source, i.e., near the client. It is a distributed computing paradigm. As with any computing configuration, it has its own challenges that include performance, security and organisation. The Edge Computing team at the University of Derby has used deep learning techniques to support intelligent decision-making in a fully decentralised edge environment. The research designed a novel and efficient network configuration to allow effective resources discovery and query resolving performance. The evidence of the impact of this research is demonstrated in its use in the development of a real-life solution in the form of an edge data management system by the RDS company in collaboration with the Derby research team. The solution was adopted by many organisations and allowed them to operate in the challenging COVID-19 environment.

2. Underpinning research (indicative maximum 500 words)

Edge computing is a distributed computing paradigm attempting to reduce latency by bringing computation and data storage closer to the location where it is needed. Over the last five years, the University of Derby has invested heavily and engaged in state of the art research and development in Edge Computing that resulted in internationally recognised publications and the development of innovative solutions with strong theoretical foundations [3.6]. These innovative solutions were used to solve real-life problems faced by some industries. In particular, the research team worked closely with RDS-Global, an IT services company on their trademark RDS Black Box. RDS Black Box solution provides customers with a 'One Stop' solution allowing for all network and system connectivity to run through a cohesive support infrastructure system.

To enable decision-making at the edge devices, deep learning techniques were investigated [3.5]. To the best of our knowledge, this is the first work that incorporates deep learning techniques in a fully decentralised edge environment to support intelligent decision-making on the edge. The potential contribution to the research field is significant as this research designed a novel and efficient network representation model that enables deep learning algorithms to be trained and tested in the resource-constrained edge devices. Experiments conducted on real-world datasets demonstrated the superiority of the proposed model over the state of the art in terms of decision making at the edge for resource discovery and the query resolving performance. The research work can potentially be deployed to millions of industrial Internet of Things (IoT) devices to support timely AI on the edge without dedicated high performance servers.

The increasing deployments of edge devices are expected to bring more processing power and storage supplements to IoT and mobile devices. It is foreseeable that thousands of devices will be connected to RDS cloud servers and it is extremely likely that these devices will receive compute supplements from Clouds and upload data to the backend data centres for execution. An Intelligent framework based on state of art data analytics and Artificial Intelligence (AI) techniques, aimed at predicting the anticipated level of resource requests over a period of time into the future is developed [3.1]. The proposed prediction framework exploits an improved Gated Recurrent Unit (GRU) neural network integrated with a resource straggler detection module to classify tasks based on their resource intensity and further predicts the expected level of resource requests. Applications on the efficient use of drones in the distribution of products and services is a natural extension of this work [3.3]. Another issue faced by the connected devices and particularly mobile sensor networks is that of area coverage. A location-aware fast PMIPv6 (LA-FPMIPv6) protocol [3.2] enables efficient routing and data transmission in a mobile sensor network environment composed of mobile sensors with continuous mobility and was developed by the Derby team. The results of the performance evaluation show that LA-FPMIPv6 effectively reduces the handover latency, signalling cost and buffering cost compared to the conventional method.

One of the success factors of the Black Box Solution is the number of its customers for it to be economically viable and socially acceptable. For this purpose, socially aware business decisions such as precision marketing and service recommendations for the edge users of RDS is of paramount importance. A model is developed for efficient evolutionary user interest community discovery which employs a nature-inspired genetic algorithm to improve the quality of community discovery [3.4]. Specifically, a pre-processing method based on hypertext induced topic search improves the quality of initial users and posts, and a label propagation method is used to restrict the conditions of the mutation process to further improve the efficiency and effectiveness of user interest community detection.

3. References to the research (indicative maximum of six references)

Researchers employed by the University of Derby on the publication date are indicated by black, underlined text:

[3.1] Y. Lu, L. Liu, J. Panneerselvam, B. Yuan, J. Gu and N. Antonopoulos, 'A GRU-Based Prediction Framework for Intelligent Resource Management at Cloud Data Centres in the Age of 5G,' in *IEEE Transactions on Cognitive Communications and Networking*, 6(2):486-498, June 2020. DOI: 10.1109/TCCN.2019.2954388

[3.2] B. Kang, C. Park and H. Choo, 'A Location Aware Fast PMIPv6 for Low Latency Wireless Sensor Networks,' in *IEEE Sensors Journal*, 19(20):9456-9467, October 2019. DOI: 10.1109/JSEN.2019.2925637

[3.3] B. Kang, H. Ahn and H. Choo, 'A Software Platform for Noise Reduction in Sound Sensor Equipped Drones,' in *IEEE Sensors Journal*, 19(21):10121-10130, November 2019. DOI: 10.1109/JSEN.2019.2927370

[3.4] L. Jiang, L. Shi, L. Liu, J. Yao, <u>B. Yuan</u> and Y. Zheng, 'An Efficient Evolutionary User Interest Community Discovery Model in Dynamic Social Networks for Internet of People,' in *IEEE Internet of Things Journal*, 6(6): 9226-9236, December 2019. DOI: 10.1109/JIOT.2019.2893625

[3.5] <u>B. Yuan</u>, J. Panneerselvam, L. Liu, N. Antonopoulos and Y. Lu, 'An Inductive Content-Augmented Network Embedding Model for Edge Artificial Intelligence,' in *IEEE Transactions on Industrial Informatics*,15(7): 4295-4305, July 2019. DOI: 10.1109/TII.2019.2902877

[3.6] M. Ahmed, L. Liu, J. Hardy, <u>B. Yuan</u> and <u>N. Antonopoulos</u>, 'An efficient algorithm for partially matched services in internet of services', *Personal and Ubiquitous Computing*, 20: 283–293, 2016. DOI:10.1007/s00779-016-0917-9

All these papers were published in highly ranked peer reviewed journals.

Funding

4. Details of the impact (indicative maximum 750 words)

The partnership between the University of Derby and RDS Global (RDS from hereon) started in 2015 when RDS sought funding from the University of Derby's Invest to Grow programme, a multimillion-pound Regional Growth Fund (RGF) project that provides grants and loans to support private-sector businesses across the East Midlands to innovate, grow and create jobs [5.1]. In 2015, GBP74,400 was awarded to RDS to enable the development of an integrated fleet management system. The funding was primarily used by RDS to purchase new premises to facilitate the system's development, leading to an initial six jobs being created. In 2017, a further funding of GBP58,875 was awarded towards the development of a cyber-audit portal which enabled clients to self-assess compliance with the government's Cyber Essentials Certification and the General Data Protection Regulation (GDPR). This second investment, lead to the recruitment of a further five new members of staff, creating a full in-house development team. This has led to positive economic impacts for the business, with the RDS CEO commenting: *"This project launched the growth of the business, which went from GBP2.8m before development of the cyber portal to close to GBP4m at the end of 2019"* [5.2].

In 2019, a research collaboration was launched between the Edge Computing research team at the University of Derby and RDS that led to the development of the Black Box solution. This research collaboration was funded by an Innovate UK Knowledge Transfer Partnership [G3.1]. The RDS CEO stated in his testimonial that: *"The Black Box solution has had a hugely positive impact on our organisation"* [5.3]. A number of third-party organisations have purchased and adopted the solution.

The development of the Black Box solution has allowed RDS to evolve from an IT support provider into a software solution provider that can assist its customers. The company has particularly benefited from the expertise in the fields of Data Science, Edge Computing and Security from the research developed by the Derby research team to provide solutions and expertise using these cutting-edge computing solutions. In particular, it provided solutions to capture data, process it and make decisions in real-time. This was of paramount importance for many organisations during the COVID-19 pandemic.

From a financial perspective, the RDS CEO confirmed that: *"The Black Box solution has produced a new revenue and profit stream to the business"* [5.3]. The Black Box solution has increased the income of RDS. Furthermore, this solution allowed the business to streamline its costs by adopting themselves the developed solution. It was reported by the company that during 2020, they have

produced an additional income of £160,000 and a reduction of their systems cost by £16,000 [5.3]. This was right in the middle of the pandemic when many organisations have reported losses.

The RDS CEO has stated that the: *"Black Box solution has played an important role in providing COVID-19 workplace solutions"* [5.3]. Sited at venue entrances, Black Box stations can provide hand sanitiser, temperature monitoring, ID card or facial recognition, access control, and collection of track-and-trace data. For employees, visitors and customers, the system provides reassurance that robust safety measures are in place. For businesses, it delivers real-time information – via online reports and dashboards – so that alerts can be raised, PPE usage can be monitored and sanitiser re-fills can be ordered.

As an example, the Head of Visitor Experience at Derby Museums Trust indicated that the use of the Black Box solution, *"helped grow confidence amongst its staff and public users"* [5.4]. She added: *"We reopened our museum at the beginning of July when most other cultural organisations were still in lockdown. Staff, especially front of house staff were extremely anxious. Having this solution offered reassurance to them and it also enabled the organisation to check staff coming into work each day"* [5.4]. Although the number of visitors to the museum remained low during the COVID-19 pandemic: *"People that did visit though were pleased to see the Black Box at the entrance as this gave them the reassurance that we were doing everything possible to keep the site safe for visitors so were keen to return for a second visit"* [5.4].

Increase in sales and boost in revenue at RDS, *"allowed the business to contract new sectors"* and extend its market to sectors that included logistics, sports, education, retail, marketing, health, and construction [5.3]. Such expansion had a positive impact on job creation for RDS, as it resulted in a new marketing team dedicated to Black Box sales by sector as well as the recruitment of three full-time roles within the development team in 2020 [5.3].

We continue collecting impact evidence and testimonials from third party organisations that have adopted the Black Box solution particularly during the COVID-19 pandemic period.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[5.1] Invest to Grow Funding For Your Business, University of Derby, https://www.derby.ac.uk/business-services/funding-services-and-support/access-to-funding/ (Accessed: 14 December 2020).

[5.2] RDS Global Case Study, University of Derby, https://www.derby.ac.uk/business-services/funding-services-and-support/access-to-funding/case-studies/rds-global-ltd/ (Accessed: 14 December 2020).

[5.3] Testimonial from CEO, RDS Tailored Solutions (28 January 2021).

[5.4] Testimonial from Head of Visitor Experience, Derby Museums Trust (21 January 2021).