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| **Institution:** University of Northumbria at Newcastle | | |
| **Unit of Assessment:** 11 (Computer Science and Informatics) | | |
| **Title of case study:** Improved Interoperability and Data Sharing on the Internet of Things | | |
| **Period when the underpinning research was undertaken:** 2014 - 2019 | | |
| **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:** |
| Nanlin Jin | Senior Lecturer | 01/02/2013 – present |
| Gerhard Fehringer | Principal Lecturer | 01/06/2002 – present |
| Tom Fleming | KTP Associate | 05/06/2017 – 27/04/2018 |
| Ranti Endeley | KTP Associate | 02/07/2018 – 28/02/2019 |
| **Period when the claimed impact occurred:** 2018 - 2020 | | |
| **Is this case study continued from a case study submitted in 2014?** N | | |

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

The Internet of Things (IoT) is growing extremely rapidly, however, its widespread adoption in industrial and commercial settings is hampered by the lack of interoperability between various communication protocols. Northumbria's research into data analytics and the integration of multi-protocol IoT solutions has contributed to the core functionality of ADLINK EDGE, a flagship product launched in 2018 that enables communication between two leading industrial machine-to-machine communication protocols (OPC UA and DDS). Since its launch, ADLINK EDGE has become the single most important software solution offered by ADLINK and has enabled the company to gain valuable new business [text removed for publication]. Benefits of ADLINK EDGE reported by customers include improved infrastructure interoperability and savings resulting from the prevention of costly equipment breakdowns [text removed for publication]. Northumbria's research has contributed, via ADLINK EDGE, to the creation of highly efficient manufacturing environments, that meet the demanding requirements of smart factories of the future.

**2. Underpinning research** (indicative maximum 500 words)

Research into the Internet of Things (IoT), a network of so-called 'smart' devices that are wired with sensors and are connected to the internet, is a core focus of the Cyber Security and Network Systems (CyberNets) research group at Northumbria University. Industrial IoT applications can potentially increase efficiency in factories and other industrial settings through the remote monitoring and control of machines enabled through IoT. However, there is a common misconception that IoT offers an easy "plug and play" functionality. In reality, using IoT in industrial applications can be challenging and costly (in terms of effort, time, money, and specialist skills) because the machines often use different communication protocols ('languages' machines are 'programmed' with) that are not always compatible with each other or with the network they are part of, i.e., they have poor interoperability.

In 2015, the CyberNets (known as NetSyS until October 2020) research group was approached by ADLINK - a global software and hardware manufacturer with GBP300,000,000 annual turnover - to aid creation of a novel solution for data transfer and sharing of large volumes of data in IoT systems. Specifically, ADLINK wanted to address the fundamental problem of interoperability between different communication protocols. In response to this request, researchers from Northumbria (Nanlin Jin and Gerhard Fehringer) used their expertise in data sharing, analysis, and management of IoT systems with diverse sensors, networking protocols, and hardware to develop a successful Knowledge Transfer Partnership (KTP) proposal with ADLINK (KTP number: 10596). Between December 2016 – March 2019, the KTP consortium investigated issues of interoperability between two leading competitor communication protocols for industrial IoT applications: the OPC Foundation's Unified Architecture (OPC UA), adopted by the German Industry 4.0 initiative, and the Object Management Group's Data Distribution Service (DDS) standard, supported by the Industrial Internet Consortium. This built on Northumbria's earlier research into data mining, subgrouping, and clustering [**R1**, **R2**].

One important aspect of IoT is real-time video sharing (for example, when cameras are used to monitor production lines). Research from Northumbria explored how low power platforms commonly used to implement IoT devices may facilitate live video sharing. Through experiments using ADLINK's Vortex line of DDS middleware (software that acts as a bridge between an operating system/database and applications on a network), Northumbria researchers demonstrated that DDS middleware running on low power hardware with native code can provide sufficient performance, while being efficient enough to consistently handle high bandwidth live video [**R3**]. These research findings allowed the adoption of low power devices for sharing live video in IoT over DDS. Subsequent research focused on the development of a novel middleware solution that enabled effective communication between OPC UA and DDS, and the evaluation of the middleware's performance by measuring response times and reliability [**R4**].

Northumbria researchers worked with ADLINK to develop multi-protocol functionality for an IoT data-sharing platform. In April 2018, this was launched as the flagship ADLINK EDGE product (initially called Vortex Data River). At the heart of ADLINK EDGE is a data model with a hierarchy of 'things' that describes the whole system, from a single sensor to a complex multi-machine system. The middleware connects hardware (e.g., factory equipment and data sent through sensors) and software solutions. Within this complex system, there exists a significant amount of data, and it is important that communication channels are not overloaded, as this could impede system efficiency.

ADLINK EDGE, therefore, synthesises a number of related research strands into a single product; accurate clustering of data [based on fundamental principles established in **R1** and **R2**] means that only significant information is communicated to the end user (e.g., when there are disruptions in the system and equipment is about to shut down), and performance and interoperability issues are evaluated and addressed through two novel developmental case studies [**R3**, **R4**]. ADLINK EDGE seamlessly communicates messages associated with relevant categories of data (e.g., temperature and humidity levels of equipment), allowing the end user to easily gain an overall picture of system performance.

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

**R1. Nanlin Jin**, Flach*, P., Wilcox*, T., Sellman*, R., Thumim*, J., and Knobbe*, A. (**2014**). 'Subgroup discovery in smart electricity meter data' *IEEE Transactions on Industrial Informatics* **10**(2): 1327-1336 https://doi.org/10.1109/TII.2014.2311968

**R2.** Al-Otaibi*, R., **Nanlin Jin**, Wilcox*, T., and Flach*, P. (**2016**). 'Feature construction and calibration for clustering daily load curves from smart-meter data' *IEEE Transactions on Industrial Informatics* ***12****(2):* 645-654 http://doi.org/10.1109/TII.2016.2528819

**R3.** Bagley, A., **Gerhard Fehringer**, **Nanlin Jin**, and Cammish**, S. (**2017**). Conference paper 'Live video transmission over data distribution service with existing low-power platforms' *Proceedings of the Second International Conference on Internet of Things, Data and Cloud Computing*: 1-5 https://doi.org/10.1145/3018896.3025129

**R4. Ranty Endeley**, **Tom Fleming**, **Nanlin Jin**, **Gerhard Fehringer**, and Cammish**, S. (**2019**). Conference paper 'A smart gateway enabling OPC UA and DDS interoperability' *2019 IEEE SmartWorld*: 88-93 http://doi.org/10.1109/SmartWorld-UIC-ATC-SCALCOM-IOP-SCI.2019.00058

* **External university co-authors:** T. Wilcox, R. Sellman, and J. Thumim from Centre for Sustainable Energy, Bristol; A. Knobbe from the Leiden Institute of Advanced Computer Science (The Netherlands); P. Flach and R. Al-Otaibi from the Department of Computer Science, University of Bristol
** **Industrial collaborator:** S. Cammish from ADLINK

**Research funding:** Innovate UK Knowledge Transfer Partnership (KTP) number KTP010596, December 2016 – March 2019, Grant value GBP51,431

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

### 4.1 Launch of the flagship ADLINK EDGE product

The lack of interoperability between various communication protocols presented a significant barrier to widespread integration of the IoT. In 2018, ADLINK launched their flagship product ADLINK EDGE [**E1**, p7 shows that the project resulted in 'new products for new markets'] utilising research from Northumbria's CyberNets group.

ADLINK EDGE is a simple-to-implement solution that translates communication protocols between devices and applications, or between devices and peers [**E2**, **E3**]. This interoperability offered by ADLINK EDGE allows IoT architects to implement best-in-class technologies in a seamless system [**E3**, see *Figure 1*]. As a peer-to-peer system with no centralised broker, ADLINK EDGE avoids a single point of failure. Auto-discovery means that, in the event of an unforeseen outage of part of the system, it is not necessary to reset the whole system to re-establish communication links, as the system is self-healing [**E2**]. Moreover, multiple data readers can simultaneously consume data, with no impact on performance. ADLINK EDGE thus offers *'secure, scalable and fault-tolerant data connectivity'* [**E2**]. Highlighting the seamless flow afforded by ADLINK EDGE to the entire IoT ecosystem, Rob Boville, Head of Software Engineering at ADLINK, stated:

> *'As a direct result of the KTP with Northumbria University, ADLINK developed a new product, which we called ADLINK EDGE (previously called Vortex Data River) … A central function of this product is to facilitate bridging between machines and translate their contents. [This protocol] embodied in our ADLINK EDGE product <u>became the single most important software solution</u> offered by ADLINK'* [**E4**].

[text removed for publication]

### 4.2 Commercial impact on ADLINK

ADLINK EDGE has enabled ADLINK to access new Industrial IoT and Smart Factory (or Factories of the Future) opportunities that were previously not open to the company [**E1**, p2]. The Smart Factory market size is expected to reach USD75,000,000,000 by 2022, and the launch of the flagship ADLINK EDGE product enabled ADLINK to win new contracts in this rapidly growing Smart Factories market. Boville stated that:

> 'text removed for publication] *This novel product secured our reputation as leaders in IoT software solutions in the field, and has, to date, generated a total revenue* [text removed for publication] *for ADLINK. Importantly, it has opened new markets and opportunities'* [**E4**].

New business, secured exclusively through ADLINK EDGE, includes such clients as: [text removed for publication] [**E4**, **E5** provides examples of how companies use ADLINK EDGE]. To sustain innovation within the company, ADLINK hired 3 software engineers: KTP Associate Ranti Endeley and 2 additional members of staff (headcount: 6) [**E1**, p9; **E4**].

### 4.3 Increased interoperability of IoT, savings and fault prevention for ADLINK's customers

ADLINK EDGE has been integrated into in-house systems by a number of companies, increasing the interoperability of their IoT systems and improving performance. Completed projects to date include one run by [text removed for publication], where ADLINK EDGE was used to extract efficiency data, enabling the smooth running of their [text removed for publication]. Prior to their integration of ADLINK EDGE, the company frequently suffered from

costly breakdowns of the [text removed for publication]. ADLINK EDGE enabled [text removed for publication] to monitor the running of their equipment in real time, and to prevent breakdowns through efficient data extraction and predictions about potential equipment failure. As a result of this,

> *'*[text removed for publication] *provided positive feedback and informed us [ADLINK] that they obtained a return on their investment in ADLINK EDGE even before the solution was fully implemented, as equipment failure prior to its integration was costing them up to* [text removed for publication] *per day'* [**E4**].

Efficiencies realised by companies utilising the Smart Factory approach include ADLINK's customers [text removed for publication]. [text removed for publication] used ADLINK EDGE in the manufacture of their [text removed for publication]. This solution allowed factory staff to make real-time decisions, e.g., when a conveyor belt overheated, staff could notice this in real-time and slow down the process to prevent equipment breakdown, saving time and costly repairs. Currently implemented across one factory operation, [text removed for publication] plans to incorporate ADLINK EDGE solutions into other parts of the factory, and potentially across an entire network of their factories [**E4**].

[text removed for publication]

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

| Ref. | Source of corroboration | Link to claimed impact |
|---|---|---|
| E1 | Document - Final KTP report | Corroborates the launch of the new product ADLINK EDGE developed using Northumbria's research and confirms impact on securing new business and consequent employment of KTP Associate |
| E2 | Document - Vortex Data River (previous name of ADLINK EDGE) datasheet | Details the functionality of ADLINK EDGE as a novel IoT solution that improved the interoperability of communication protocols |
| E3 | Document - ADLINK marketing materials 'Smart Manufacturing Solutions' | Details the functionality of ADLINK EDGE as a novel IoT solution, confirms commercial impact on ADLINK, and Northumbria's contribution to Factories of the Future |
| E4 | Testimonial - Rob Boville, Head of Software Engineering at ADLINK | Corroborates Northumbria's role in the development of the new ADLINK EDGE product, new business contracts that had been secured as a result, and economic and reputational impacts |
| E5 | Document - ADLINK OPC UA usage materials | Details how ADLINK's customers are integrating and using ADLINK EDGE |