Institution: Bournemouth University

Unit of Assessment: 11

Title of case study: Creating internationally-recognised standards for crowdsourced systems

Period when the underpinning research was undertaken: 2016 – 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:
Dr Marios Angelopoulos	Principal Academic, Computing and Informatics	2016 – current
Professor Raian Ali	Professor in Computing	2012 – current
Professor Keith Phalp	Professor of Software Engineering	1997 – current
Dr Jacqui Taylor	Associate Professor in Psychology Education	2009 – current

Period when the claimed impact occurred: 2019 – 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)

Crowdsourced systems – which tap into the power of the crowd for data collection and problem-solving – have grown in use and prominence over recent years. However, no standardised definitions or reference architecture existed for building such systems.

BU research identified and developed formal definitions of crowdsourced systems and the associated reference architecture, which have been accepted by the International Telecommunications Union (ITU-T) as the formal definitions for crowdsourced systems, under ITU-T Recommendation Y.4205.

This provides an internationally-recognised standard and common point of reference globally for industry, policy makers and local stakeholders when developing systems employing crowdsourcing practices. This formal, standardised framework helps to address issues around transparency and privacy, and increase common understanding.

2. Underpinning research (indicative maximum 500 words)

Crowdsourcing can be defined as the practice of soliciting input from the general public. Crowdsourced systems incorporate devices provided by the public to opportunistically supplement their infrastructure. Key technological enablers of such systems are personal smart devices (such as smartphones) and single board computers (such as Arduino and Raspberry Pi). Both device types have been widely adopted by the public over the past decade and demonstrate significant computing and communication capabilities.

In crowdsourced systems, members of the general public permit the system to access and use the resources of their devices in return for an incentive; this can either be intrinsic (e.g. for social good) or extrinsic (e.g. receiving a service, a micropayment, etc). The digital contact tracing

apps rolled out to help identify Covid-19 transmission chains are just some of the most recent and high-profile examples of this type of system.

However, the highly personal nature of devices like smartphones poses significant trust and privacy issues. Since crowdsourced systems are characterised by the network effect (their efficacy increases as the number of their users increases), such issues can hinder their adoption and development. In addition, the community lacked a common understanding of which systems can be classified as crowdsourced systems and how such systems can be built following a trustworthy and transparent method.

BU researchers conducted a systematic survey of crowdsourcing research to extract and describe the taxonomy of features which characterise crowdsourcing. The analysis considered 652 papers by employing rigorous, scientifically replicable methods, and 113 papers (72 academic papers and 41 from industry) were identified that provided definitions on crowdsourcing [R1]. The paper detailed the methodology that was assumed in order to elicit the key features of the concept of crowdsourcing and the corresponding definition, which was adopted in the ITU-T standard.

Furthermore, the reference model defined by BU identifies the four fundamental constituents of crowdsourcing: the crowd, the crowdsourcer, the crowdsourced task, and the crowdsourcing platform [R2]. This model formed the basis for the reference architecture for crowdsourced systems specified in the ITU-T standard.

BU and European collaborators also assessed how crowdsourcing methods and tools can be used in designing systems (particularly in requirements engineering) and how these can be applied in industrial contexts [R3]. These findings informed the discussion within the ITU-T Study Group 20 regarding the importance and relevance of crowdsourcing and crowdsourced systems to the industry and policy-making.

Discussions within ITU-T Study Group 20 around implementation aspects of crowdsourced systems and corresponding use cases were underpinned by Angelopoulos' research [R4-R6], which eventually helped shape the final text of the standard. These included architectural approaches for crowdsourced systems in a variety of applications, such as localised distributed computer infrastructure [R4], crowd-enabled IoT systems [R5] and crowdsourced systems as enablers for citizen science [R6].

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

R1-6 have all been subject to rigorous peer review.

R1: Hosseini, M., Shahri, A., Phalp, K., Taylor, J. and Ali, R. (2015), "Crowdsourcing: A taxonomy and systematic mapping study," *Computer Science Review*, vol. 17, pp. 43-69. https://doi.org/10.1016/j.cosrev.2015.05.001

R2: Hosseini, M., Phalp, K., Taylor, J. and Ali, R. (2014), "The four pillars of crowdsourcing: A reference model," IEEE Eighth International Conference on Research Challenges in Information Science (RCIS) 2014: pp. 1-12. https://www.researchgate.net/publication/269293142_The_four_pillars_of_crowdsourcing_A_reference_model

R3: Groen, E. C., Seyff, N., Ali, R., Dalpiaz, F., Dörr, J., Guzman, E., Hosseini, M., Marco, J., Oriol, M., Perini, A. and Stade, M. (2017), "The Crowd in Requirements Engineering: The Landscape and Challenges. IEEE Software," 34(2): pp. 44-52. http://eprints.bournemouth.ac.uk/28519/

R4: Hosseini, M., Angelopoulos, C. M., Chai, W.K. and Kundig, S. (2018), "Crowdcloud: a crowdsourced system for cloud infrastructure," *Cluster Computing*, vol. 22 pp. 455–470. https://doi.org/10.1007/s10586-018-2843-2

R5: Angelopoulos, C. M., Ziouvelou, X., Alexandrou, P., Evangelatos, O., Fernandes, J., Loumis, N., McGroarty, F., Nikoletseas, S. and Rankov, A. (2017), "*Crowd-Driven IoT/IoE Ecosystems: A Multidimensional Approach*," In: Battala, J. M., Mastorakis, G., Mavromoustakis, C. and Pallis, E., eds. *Beyond the Internet of Things: Everything Interconnected.* Springer, pp. 341-375. https://doi.org/10.1007/978-3-319-50758-3_14 (PDF of chapter available on request.)

R6: Alexandrou, P. Angelopoulos, C. M. et al. (2016), "A Service Based Architecture for Multidisciplinary IoT Experiments with Crowdsourced Resources," pp.187-201. http://dx.doi.org/10.1007/978-3-319-40509-4_13 (PDF of chapter available on request.)

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

The International Telecommunications Union (ITU) is the United Nations' special agency for information and communication technologies, with global membership including 193 member states, as well as some 900 companies, universities, international and regional organisations, and 20,000 industry professionals (https://www.itu.int/en).

Its recommendations act as an international standard and common point of reference globally to enable members to develop policies at a local or national level. As such, it is 'one of the most prominent and influential standards developing organisations (SDO) in the international ICT standardisation landscape that greatly affects policy-making across the world.' [E1]

The ITU accepted the definitions and reference architecture developed through BU research as the formal definitions for crowdsourced systems, as outlined in ITU-T Recommendation Y.4205 [E2, E3]. Angelopoulos was an associate rapporteur, leading the BU delegation, for the recommendation throughout its lifetime [E4], as part of ITU-T Study Group 20 (SG20), which develops recommendations in the field of Internet of Things (IoT) and smart cities and communities (www.itu.int/en/ITU-T/about/sg20).

The level of adoption is key to crowdsourced systems, as the more people use them, the more accurate conclusions one can draw from the data (the so-called 'network effect'). Defining processes and attributes, and producing a standardised framework for the ways in which such systems are developed, helps to increase their transparency and provides a guarantee with regards to privacy and cybersecurity issues. This, in turn, helps increase public trust towards crowdsourced systems and, consequently, promotes their use.

Y.4205 provides definitions of crowdsourcing, crowdsourced systems and other closely related concepts – based on the definitions outlined in [R4] - as well as the reference model of IoT-related crowdsourced systems for the support of IoT applications and services [E3]. The terms defined were accepted by the Standardisation Committee for the Vocabulary and form part of official ITU terminology, which acts as a reference point for the international community. The recommendation was formally ratified by the ITU on 13 February 2019 during the SG20 meeting held in Wuxi, China [E2, E5]. Following publication, the recommendation was disseminated among ITU members and can be found in the public repository of ITU [E5].

By helping to provide this formal, standardised framework - accepted by the global community through the ITU – BU has delivered a foundation of common understanding that will facilitate the growth and further adoption of crowdsourced systems and reference architecture, as well as identifying and addressing relevant security, privacy and trust issues.

Experts from national delegations and sector members on the ITU group developing Y.4205 drew on BU's research outputs and the ITU commended the university delegation as 'one of the most active contributors', acknowledging its significance in getting it formally accepted: 'The

peer-reviewed academic publications by BU provided the needed rigour and have been pivotal in helping State and Sector Members to achieve consent and the Recommendation to be formally adopted and published' [E6].

'In an era when the use of personal smart devices by citizens is prevalent globally, ITU-T Recommendation Y.4205 acts as a reference point for the industry, policy makers and local stakeholders when developing systems employing crowdsourcing practices. We regard the contribution of BU research to ITU-T Recommendation Y.4205 as a fine example of how academia can impact and drive the development of international standards at the highest international level.' [E6]

BU's contribution was further recognised by StandICT.EU, a European Commission-funded initiative which aims to support the participation of European experts in international ICT standardisation, strengthen the digital single market and boost Europe's competitiveness. It stated that Angelopoulos, as 'lead editor', and 'the corresponding [BU] research played a key role', and 'directly impacted the development of [the] ITU Recommendation' [E1].

StandICT.eu adds that the recommendation provides a 'needed reference framework for facilitating the development and promotion of such systems by the industry globally', commenting that it is also well-aligned with the European Commission's *Digitising European Industry* initiative, as well as the pillars of 'a thriving IoT ecosystem' and 'a human-centred IoT approach' [E1], helping to boost digital innovation, investment and industry.

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

E1: StandICT.eu. (2020). Testimonial letter, 11 December.

E2: ITU. (2019). *ITU-T Recommendation database*. [online] Available at: https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=13859&lang=en [Accessed 4 February 2021].

E3: ITU-T. (2019). *Requirements and reference model of IoT-related crowdsourced systems*. Series Y: Global information infrastructure, internet protocol aspects, next-generation networks, internet of things and smart cities. ITU.

E4: ITU. (2017). *List of Questions and Rapporteurs*. [online] Available at: https://www.itu.int/net4/ITU-T/lists/loqr.aspx?Group=20&Period=16 [Accessed 27 January 2021].

E5: ITU. (2019). *ITU-T AAP text details*. [online] Available at: https://www.itu.int/itu-t/aap/AAPRecDetails.aspx?AAPSeqNo=8378 [Accessed 4 February 2021].

E6: ITU. (2020). Testimonial letter, 18 September.