COVID-19 Can Create Opportunity for IoT in the Caribbean: A Necessary Digital Transformation

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ABSTRACT

Connected devices provide an avenue for directed information to create awareness and enable individuals to make intelligent decisions. These IoT and IIoT devices can create business opportunities by engaging directly in real-time with consumers to provide alert notifications about products, services and processes during the changing parameters of COVID-19.

There is a lack of focused research and reports of Caribbean IoT usage within the health context of the COVID-19 pandemic. Preliminary discussions with regional technology specialists supported this deficiency and noted that the primary goal is the digital transformation process. The net effect of the pandemic was disruptive to the status quo and sensitized the need for faster and wider digitalization through accelerated process changes in both the business and government sector.

This research is a Caribbean focused survey that explored the potential of smart devices (which encompass IoT) during this pandemic. The first section explored IoT use in health through a literature review. The second section summarized the methodology used to generate the primary and secondary data. The Caribbean Perspectives section analyzed the responses from the survey to identify and evaluate investment opportunities of connected technologies (and systems). This was developed into a conceptual IoT Caribbean Solution in the fourth section with a focus on Benefits to the Caribbean in the fifth. The Opportunities for IoT Deployment section developed the IoT Iteration Cycle that can be adopted to increase IoT systems based on new KPIs.

IOT USE IN HEALTH

IoT enables users to "monitor and interact" with the changing physical environment through its virtualization with the use of Cyber-Physical Systems (CPS), that convert physical parameters into data. These devices provide a benefit by "contributing to the solution of specific issues such as public health and well-being"[1] through the autonomous collection and transmission of physical data (light, sound, location, temperature) can directly influence a population's participatory

[1] Tsiatsis, V. *et al.* (2019) *Internet of Things*, *Internet of Things: Technologies and Applications for a New Age of Intelligence*. Elsevier. doi: 10.1016/C2017-0-00369-5.

sensing (a form of social sensing using crowdsourced data[2]). The need to find solutions to enable a safe return to work has increased the focus of using of IoT devices[3].

This concept of using IoT systems in the medical field is not new and was highlighted in the development of "sustainable healthcare"[4], "mobile health applications"[5], "Medical Internet of Things (MIoT)" for use as an "Integrated Clinical Environment (ICE) framework"[6] as well as in the development of a "Smart City Healthcare" system[7]. These systems required the connectivity of various sensors that feed data into the healthcare system[8] and form part of the wider global health agenda set forth in the UN SDG 3 Good heath & Well-being. It had been identified that IoT is a key component to achieving the sustainable development goals[9] [10] [11].

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[2] Xu, Z. *et al.* (2016) 'Participatory sensing-based semantic and spatial analysis of urban emergency events using mobile social media', *Eurasip Journal on Wireless Communications and Networking*. Springer International Publishing, 2016(1), pp. 1–9. doi: 10.1186/s13638-016-0553-0.

[3] Ancipink, P. (2020) *How IoT, Wearables And Existing Tech Will Help Ensure Back-To-Work Safety*, *Forbes*. https://www.forbes.com/sites/ibmsecurity/2020/07/30/how-iot-wearables-and-existing-tech-will-help-ensure-back-to-work-safety/#73c9dea32cb4 (Accessed: 23 September 2020).

[4] Turcu, C. E. and Turcu, C. O. (2013) 'Internet of Things as Key Enabler for Sustainable Healthcare Delivery', *Procedia - Social and Behavioral Sciences*, 73, pp. 251–256. doi: 10.1016/j.sbspro.2013.02.049.

[5] Santos, A. *et al.* (2014) 'Internet of Things and Smart Objects for M-health Monitoring and Control', *Procedia Technology*, 16, pp. 1351–1360. doi: 10.1016/j.protcy.2014.10.152.

[6] Soroush, H., Arney, D. and Goldman, J. (2016) 'Toward a Safe and Secure Medical Internet of Things', *IIC Journal of Innovation*, (June), p. 15. Available at: https://www.iiconsortium.org/news/joi-articles/2016-June-Toward-a-Safe-And-Secure-Medical-IoT.pdf.

[7] Gupta, N. (2017) 'How IoT Can Significantly Improve Healthcare in the Context of Smart City', *IIC Journal of Innovation*, (June). Available at: https://www.iiconsortium.org/pdf/June_2017_JoI_Improving_Smart_City_Healthcare.pdf.

[8] YIN, Y. *et al.* (2016) 'The internet of things in healthcare: An overview', *Journal of Industrial Information Integration*. Elsevier, 1, pp. 3–13. doi: 10.1016/j.jii.2016.03.004.

[9] World Economic Forum (2018) *Internet of Things Guidelines for Sustainability*. Cologny/Geneva. Available at: http://www3.weforum.org/docs/IoTGuidelinesforSustainability.pdf.

[10] Klement, P. *et al.* (2020) *How Digital Transformation and IoT Can Contribute to the UN Sustainable Development Goals*. Needham. Available at: https://www.iiconsortium.org/pdf/IIC_IOTAA_DX_UN_SDG_White_Paper_2020-06-22.pdf.

[11] Salam, A. (2020) *Internet of things for sustainable community development: Introduction and overview*. Edited by G. Fortino and A. Liotta. Cham: Springer International Publishing (Internet of Things). doi: 10.1007/978-3-030-

Demonstrated use of sensors include a color and infra-red camera for "body shape detection for the classification and estimation of health risks"[12], Kinsa's "smart" thermometers which enabled real-time tracking of health data through the connected app[13] and a thermal vision system coupled with Cloud technology that aided in monitoring workers[14].

Personal privacy concerns in "tracking and tracing COVID-19"[15] [16] directly contributed to the slow adoption of contact-tracing mobile apps[17]. Personal information is not needed to enforce social distancing in a work area. A wearable IoT device, issued to each worker in a plant[18], can "precisely sense when other devices breach the universally accepted 2m personal exclusion zone, alerting both wearers with a choice of either visual (LED lights), vibrating, or audio alarm"[19].

In order for the wearable (or portable) device solution to be effective, each individual can be issued one and it must be used (as in the case of Kinsa's thermometers). This involves the cost

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[12] Sooklal, S., Hosein, P. and Teelucksingh, S. (2016) 'A Review of Human Body Shape Detection Techniques and Their Application to the Prediction of Health Risks', in *8th International Conference on e-Health, Madeira, Portugal, July, 2016*, p. 4. Available at: http://hosein.tt/papers/e-health2016.pdf.

[13] Winn, Z. (2020) *Smart thermometers use real-time data to help prevent outbreaks*, *Control Engineering*. Available at: https://www.controleng.com/articles/smart-thermometers-use-real-time-data-to-help-prevent-outbreaks/ (Accessed: 23 September 2020).

[14] Chopra, T. S. (2020) *Factory workers face a major COVID-19 risk. AI can help keep them safe*, *World Economic Forum*. Available at: https://www.weforum.org/agenda/2020/07/factory-workers-face-a-major-COVID-19-risk-here-s-how-ai-can-help-keep-them-safe/ (Accessed: 23 September 2020).

[15] OECD (2020) *Tracking and tracing COVID: Protecting privacy and data while using apps and biometrics*. Paris. Available at: https://read.oecd-ilibrary.org/view/?ref=129_129655-7db0lu7dto&title=Tracking-and-Tracing-COVID-Protecting-privacy-and-data-while-using.

[16] Scroxton, A. (2020c) *NCSC discloses multiple vulnerabilities in contact-tracing app*, *Computer Weekly*. Available at: https://www.computerweekly.com/news/252483418/NCSC-discloses-multiple-vulnerabilities-in-contact-tracing-app (Accessed: 23 May 2020).

[17] Findlay, S., Palma, S. and Milne, R. (2020) *Coronavirus contact-tracing apps struggle to make an impact*, *Financial Times*. Available at: https://www.ft.com/content/21e438a6-32f2-43b9-b843-61b819a427aa (Accessed: 20 May 2020).

[18] Naughton, K. (2020) *Ford Tests Buzzing Wristbands to Create Safe Work Distances*, *Bloomberg*. Available at: https://www.bloomberg.com/news/articles/2020-04-15/ford-tests-buzzing-distancing-wristbands-to-keep-workers-apart (Accessed: 18 April 2020).

[19] Wilson, J. (2020) *'Safe Spacer' wearable could help ensure social-distancing compliance*, *E&T Magazine*. Available at: https://eandt.theiet.org/content/articles/2020/05/safe-spacer-wearable-could-help-ensure-social-distancing-compliance/ (Accessed: 6 June 2020).

and logistics to supply each person (which can become exponential in a consumer-based environment as a retail store) as well as an individual's understanding and compliance to continuously wear the device. Thus, social distancing is only effective if the device is used. An alternative is the use of physically mounted sensors. Al Hossain *et al.* (2020)[20] noted that "FluSense uses a microphone array and a thermal camera along with a neural computing engine to passively and continuously characterize speech and cough sounds along with changes in crowd density on the edge in a real-time manner." The FluSense concept can be applied in commercial business environments to detect specific parameters linked to the virus.

METHODOLOGY

Based on the work by Singh *et al.*, (2020)[21] that highlighted information linking IoT and COVID-19, this focus was to explore the relationship specific to the Caribbean region. Analysis was performed on secondary data using a scoping literature review[22][23] of publicly available documentation (journals, websites, blogs, etc) published from the key date of 19th Jan. 2020.

The search phrase "IoT Caribbean COVID" was performed via Google search on 19th July 2020 and Google Scholar[24] on 26th July 2020. The results were reviewed for IoT based technologies and/or applications used in the Caribbean with either a direct relation to COVID-19 or being developed or implemented during the pandemic period.

Primary data was obtained in three phases. The first two were objective based. Remote One-to-One discussions with specific Caribbean ICT professionals identified their professional and personal perspectives of IoT use during COVID-19 as well as general IoT use in the Caribbean. The second was an anonymous Google Forms online survey to "collect and analyze data"[25]. The third phase was the researcher's personal observations. Although subjective, this reflexive and

[20] Al Hossain, F. *et al.* (2020) 'FluSense', *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, 4(1), pp. 1–28. doi: 10.1145/3381014.

[21] Singh, R. P. *et al.* (2020) 'Internet of things (IoT) applications to fight against COVID-19 pandemic', *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*. Elsevier Ltd, 14(4), pp. 521–524. doi: 10.1016/j.dsx.2020.04.041.

[22] Tricco, A. C. *et al.* (2015) 'A scoping review of rapid review methods', *BMC Medicine*. BioMed Central Ltd., 13(1). doi: 10.1186/s12916-015-0465-6.

[23] Peterson, J. *et al.* (2017) 'Understanding scoping reviews', *Journal of the American Association of Nurse Practitioners*. Blackwell Publishing Ltd, 29(1), pp. 12–16. doi: 10.1002/2327-6924.12380.

[24] Cole, C. *et al.* (2018) 'Google Scholar's Coverage of the Engineering Literature 10 years Later', *The Journal of Academic Librarianship*. JAI, 44(3), pp. 419–425. doi: 10.1016/J.ACALIB.2018.02.013.

[25] Hsu, H.-Y. and Wang, S.-K. (2017) 'Using Google Forms to collect and analyze data', *Science Scope*. Washington: National Science Teachers Association, 40(8), pp. 64–67. Available at: http://search.proquest.com/docview/1884841278/.

autoethnographic approach[26] provided insights from a person living in the Caribbean during the COVID-19 pandemic that continuously questioned the need, benefit and suitability of implementing IoT solutions in common place B2C locations.

Primary data: One-to-One Interviews

Six persons were identified based upon their professional experiences in the ICT sector with a regional focus and experience, such as:

- COO of a software development company that has a strong focus on Cloud usage and product development
- Telecommunications specialist in a Caribbean telecommunications oversight agency that develops policy for the region
- ICT specialist and consultant
- General manager of a telecommunications company
- Sector specialist of an international funding agency for the Caribbean
- Manager of data centers and cloud in a telecommunications company

This research instrument focused on knowledgeable persons in the ICT sectors. An open-ended qualitative question was administered either one-to-one (via a meeting software application) or via email. This determined the scope of knowledge base concerning IoT usage in Caribbean as well as the potential research potential by gaps in available information.

The email was structured to generate interest. The subject line contained the phrase "Insights about IoT use in the Caribbean during the COVID-19 pandemic." The key phrases used in email were "focus on IoT uses in the Caribbean as a result of the COVID-19 pandemic" and "insights from you about practical applications that you know about in the Caribbean".

Primary Data: Survey of Individuals Interacting with IoT Devices

This research instrument focused on personal usage of digital devices. It involved a survey designed to focus on the individual as a key data parameter for the technology. Target audience were persons who have a primary understanding of technology, such as persons who subscribe to or visit technology focused or themed blogs and LinkedIn groups or those who have a background in ICT. This contained both open- and closed-ended questions. The questions developed were based upon the initial IoT design concepts for businesses to interface with consumers (Fig. 12, Fig. 13 and Fig. 14).

[26] Ellis, C. and Adams, T. E. (2014) 'The purposes, practices, and principles of autoethnographic research', in *The Oxford handbook of qualitative research.* New York, NY, US: Oxford University Press (Oxford library of psychology.), pp. 254–276.

The primary purpose determined the IoT devices used (and how) during COVID-19[27], whereas the secondary purpose identified respondents' perspectives on IoT, as its definition, operation and connectivity elements as network, data and personal security.

The raw data from the survey was analyzed and cleaned to provide a meaningful analysis. This involved a review of the data to identify conflicting and/or incoherent answers.

Secondary data: Analysis of Caribbean-Based Technology Blogs

Caribbean technology-based blogs and websites were identified using Google search with the keywords "Caribbean technology blogs" on the 17th August 2020. All 16 pages of search results were evaluated for those active in 2020.

CARIBBEAN PERSPECTIVES

The responses relating to enquiries about IoT in the Caribbean from direct discussion, email correspondences, survey responses, personal experiences and review of technology blogs are summarized (with supporting public information) in their respective categories to provide clarity of the perspectives of the groupings.

Summary of Responses from Interviews

- Focus on increased use of cloud technologies for remote operations, including remote meeting applications as part of growth of digital transformation activities.
- Existing IoT use cases limited to energy and building management systems as data centers and HVACs.
- Telecom operators have plans to leverage existing network infrastructure to provide IoT solutions for key segments of home, industry and health but no COVID-19 foci at present[28] [29] [30].

[27] Xiao, Y. and Fan, Z. (2020) *COVID-19: 10 tech trends getting us through the pandemic*. Available at: https://www.weforum.org/agenda/2020/04/10-technology-trends-coronavirus-COVID-19-pandemic-robotics-telehealth/ (Accessed: 9 May 2020).

[28] Digicel (no date) *Digicel SmartHOME*. Available at: https://www.digicelgroup.com/tt/en/home/SmartHome.html (Accessed: 21 September 2020).

[29] TSTT (no date a) *Amplia Secure*. Available at: https://amplia.co.tt/secure/ (Accessed: 21 September 2020).

[30] TSTT (no date b) *Vigilance – Bmobile*. Available at: https://bmobile.co.tt/vigilance/ (Accessed: 21 September 2020).

- COVID-19 reduced manual operations thus created a necessity for business continuity through cloud services[31], in which increased usage provided a realistic proof of concept for digital transformation of specific Caribbean organizations' business functions[32] [33] [34] [35] [36] [37] [38] [39].

Summary of researcher's personal experiences

- Application of IIoT devices for remote energy metering at an energy company's corporate building, which was initiated before the COVID-19 pandemic.
- A retail pharmacy and commercial bank utilized a "healthgate"[40] which included a mounted temperature sensor, that provided automatic visual feedback (numeric

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[31] ITU News (2020) *How cloud computing has supported the COVID-19 response*. Available at: https://www.itu.int/en/myitu/News/2020/06/01/11/49/Cloud-computing-and-COVID-19-response (Accessed: 22 September 2020).

[32] Bethel, K. (2020) *5 Lessons from Caribbean StartUps & Brands Adapting To COVID-19*, *Silicon Caribe*. Available at: https://www.siliconcaribe.com/2020/03/23/5-lessons-from-caribbean-startups-brands-adapting-to-COVID-19/ (Accessed: 21 September 2020).

[33] Lyndersay, M. (2020a) *C&W and Flow meet COVID19 challenge*, *Trinidad and Tobago Newsday*. Available at: https://newsday.co.tt/2020/06/23/cw-and-flow-meet-COVID19-challenge/ (Accessed: 21 September 2020).

[34] Lyndersay, M. (2020b) *Living Water goes digital to meet demand*, *Tech News TT*. Available at: https://technewstt.com/living-water-digital/ (Accessed: 21 September 2020).

[35] Lyndersay, M. (2020c) *Unqueue: Go online to get out of line*, *Tech News TT*. Available at: https://technewstt.com/unqueue/ (Accessed: 21 September 2020).

[36] TSTT Corporate Communications (2020a) *BATTLE READY BUSINESSES EMERGE FROM COVID -19 BETTER THAN EVER*. Available at: https://www.tstt.co.tt/news/BATTLE-READY-BUSINESSES-EMERGE-FROM-COVID--19-BETTER-THAN-EVER (Accessed: 23 September 2020).

[37] TSTT Corporate Communications (2020b) *Leveraging technology to support the MSME sector through COVID-19 and beyond*. Available at: https://www.tstt.co.tt/news/Leveraging-technology-to-support-the-MSME-sector-through-COVID-19-and-beyond (Accessed: 23 September 2020).

[38] TSTT Corporate Communications (2020c) *Saved by the Cloud*. Available at: https://www.tstt.co.tt/news/SAVED-BY-THE-CLOUD (Accessed: 23 September 2020).

[39] TSTT Corporate Communications (2020d) *TSTT POISED TO LEAD IN POST-COVID RECOVERY*. Available at: https://www.tstt.co.tt/news/TSTT-POISED-TO-LEAD-IN-POST-COVID-RECOVERY (Accessed: 23 September 2020).

[40] Welfor Medical Ltd (no date) *HealthGate*. Available at: https://welformedical.com/product/health-gate/ (Accessed: 26 September 2020).

indicator and colored light) that sometimes incorporated an audio response, which was triggered by proximity sensor. This system was also coupled with a touchless hand sanitizer dispenser.

- Security guards limited the number of persons allowed to pass through the doors of a building (e.g. bank or pharmacy), enforced social distancing guidelines and issued reminders to check temperature and sanitize or wash hands.
- Grocery stores that quickly developed a digital ordering strategy (either via their website or through receipt of WhatsApp messages) experienced transformation and logistics issues as credit cards being charged without the order being processed; varying quality of products selected as the picker's preference was different to the consumer's personal criteria; reduction in the number of available cashiers in order to allocate a lane to processing digital orders. Unfulfilled digital orders were processed as no real-time inventory feedback informed customers about unavailable items. Manual cashing of each item and limited storage of cashed items awaiting pickup (or curbside delivery) caused a bottleneck in the movement of goods and people out of the store.
- Continuity of educational environments by transferring to an online platform created apprehension in using known technology in an unfamiliar purpose. Online presentation in a technical conference, as well as lecturing a class, adhered to social distancing protocols. However, being the first time, it was difficult to observe and "sense" audience's response to modulate the presentation style to maintain engagement.

Summary of survey responses

57 responses were obtained from the Google Forms online survey collected between the 19th August and the 16th September 2020. Cleaned data resulted in 52 Caribbean responses, with a distribution illustrated in Fig. 1. Although the response rate is low, it captured the individual perspectives of a diverse group of Caribbean nationals during the pandemic. Their answers provided insights that aided the development of a focused Caribbean IoT solution, enabled the identification of opportunities for IoT deployment as well as revealed the need for future research in the area of IIoT.

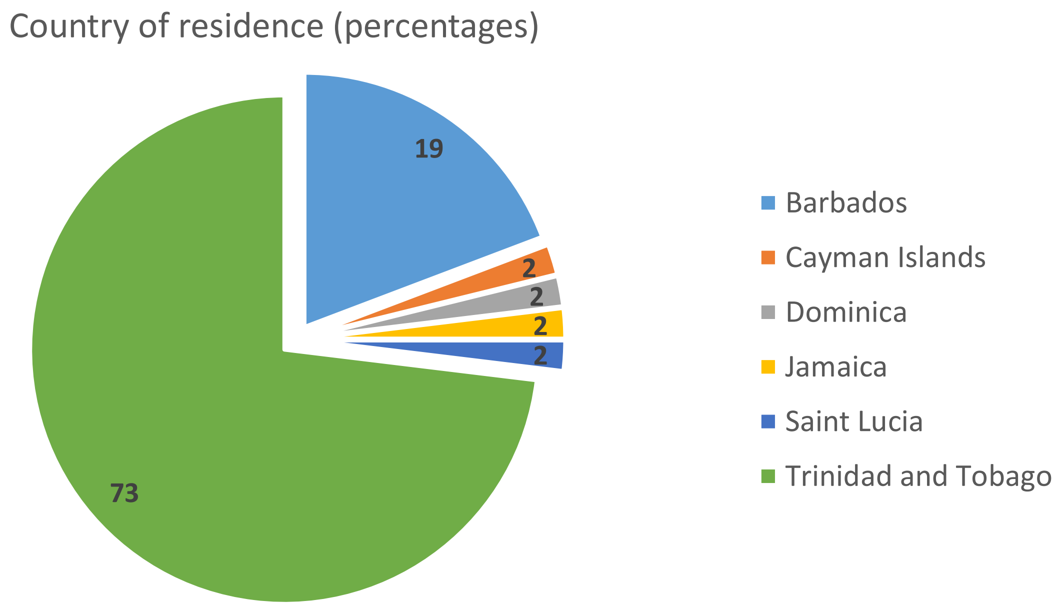

Fig. 1: Distribution of Caribbean respondents (percentages of responses)

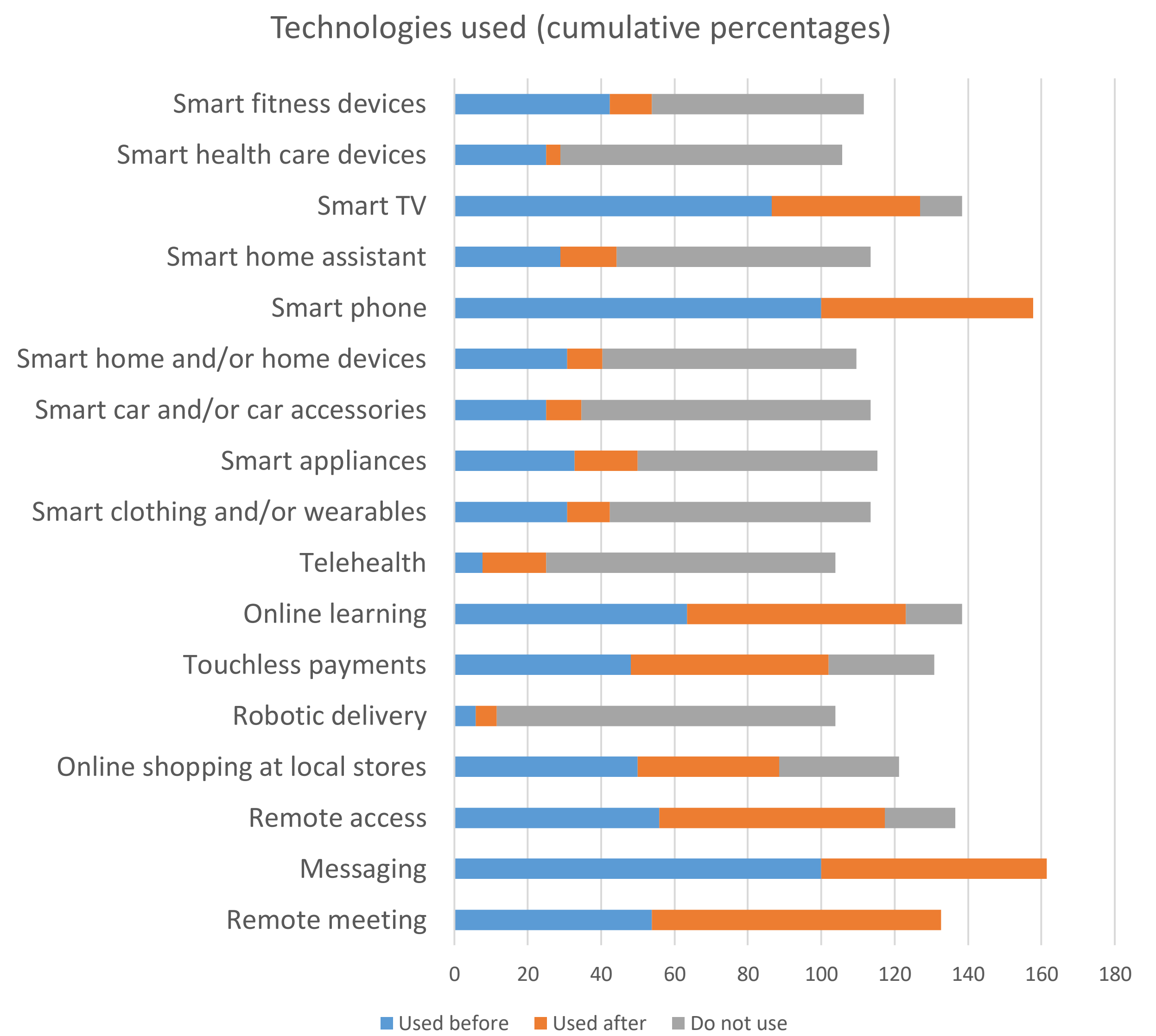

Fig. 2: Summary of technologies used before and after the start of the COVID-19 pandemic (percentages of responses)

Analysis of the responses highlighted a discrepancy in the report of technologies used. Fig. 2 illustrated that usage after was higher than before only in areas as, remote meeting, remote access, touchless payments and telehealth. The restrictions of physical movements would have increased the usage of available digital tools, thereby showing an increase in most of the technologies used.

A potential reason is the misinterpretation of the question that required the respondent to select "all that apply". Although this created an erroneous result, the area identified by "do not use" gave a clear indication of the technologies that were not common during this period. These devices are associated with health (fitness, health care, telehealth), household systems (home assistant, smart home and/or home devices, smart appliances), vehicle systems (smart car and/or car accessories, robotic delivery) and wearables (smart clothing and/or wearables). As a business perspective, these areas show a low demand for investment considerations.

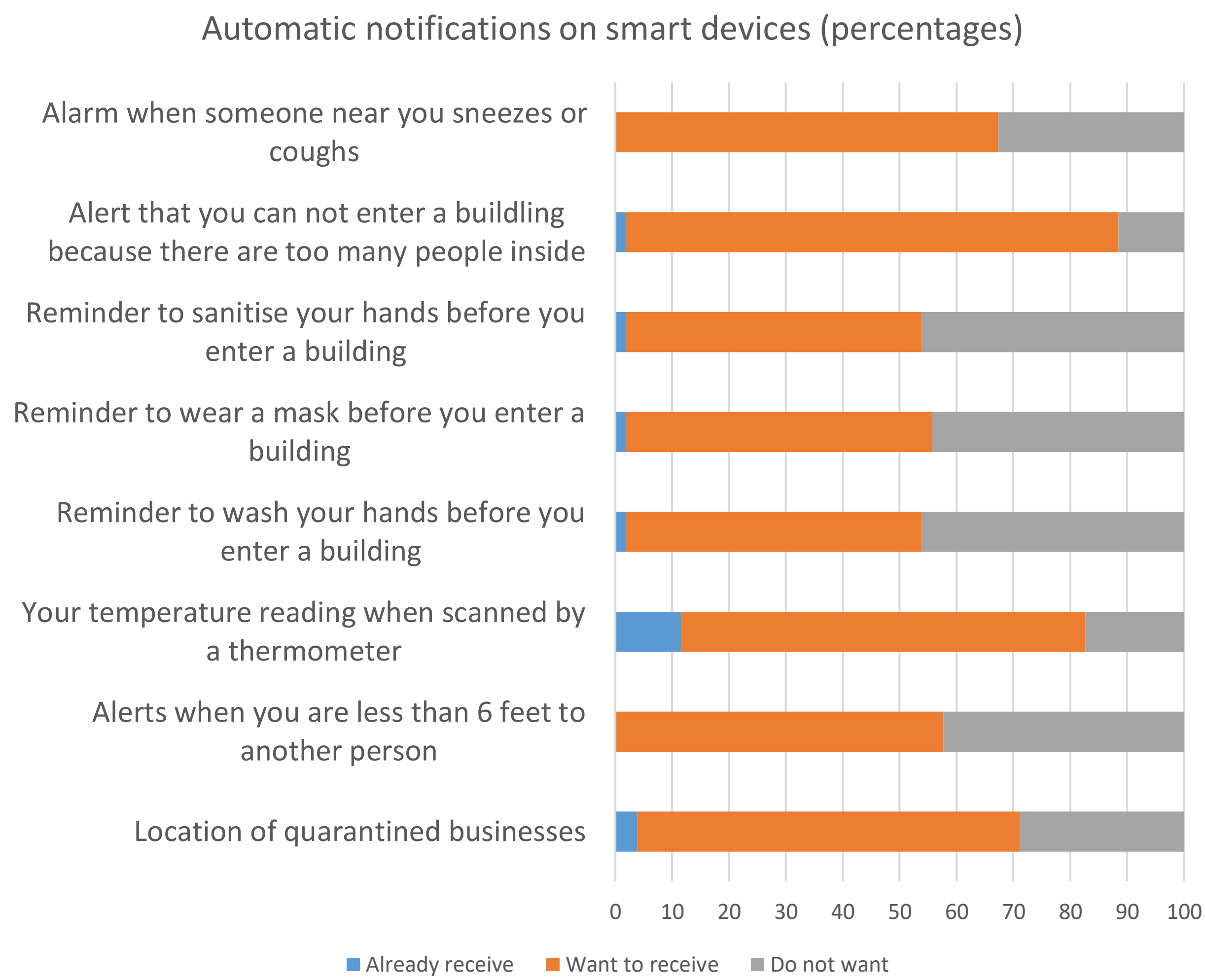

Fig. 3: Summary of automatic notifications on smart devices (percentages of responses)

However, smart phones, messaging and remote meetings are used at some point in time. Therefore, the frequently used smart phone (supported by the 94% response in Fig. 4) should be utilized within the development of any communication strategy. This supported a business focus in developing notifications on smart phones. However, only the alerts for maximum occupancy and temperature reading were identified as clear needs (Fig. 3).

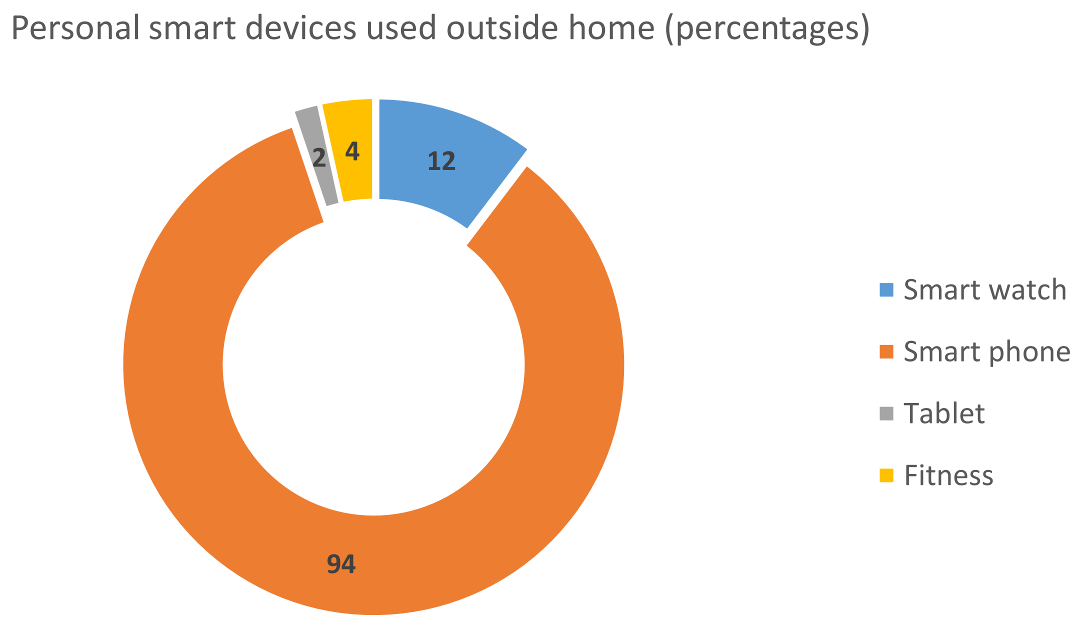

Fig. 4: Distribution of personal smart devices used outside of home (percentages of responses)

The unanimously agreed sensors to be used in a building were touchless systems (water faucets, soap pumps, paper towel dispensers, hand dryers, hand sanitizer pumps, automatic doors) (Fig. 5). However, respondents noted a clear need for cameras to detect adherence to mask protocols, sensors to prevent overcrowding, automatic temperature readings and touchless payments. This supported the key elements in the IoT sensor design for a building (Fig. 12 and Fig. 13).

The reinforced desire was for occupancy detection as well as temperature measurements.

The respondents' unrestricted feedback (via the open-ended question) identified other smart devices to be used in a store. Many answers were repeated devices and/or solutions from previous questions. However, novel suggestions were summarized in Table 1. The thematic areas were touch-free systems (new items being elevator controls, water cooler, aerosol dispenser, bins, robotic arms), reliable in vivo virus detection methods and improved accuracy and sensitivity of increased core temperature.

As a result of the survey being anonymous it was not possible to obtain further clarification on two answers, "holographic technologies" and "wearables for visitors and people in isolation". The former could refer to advanced HMI or augmented reality (identified in another question). The latter had no rationale for omitting residents and no details on data captured.

Design safety was highlighted by a response on potential health risks to electromagnetic radiation due to increased exposure from frequent use.

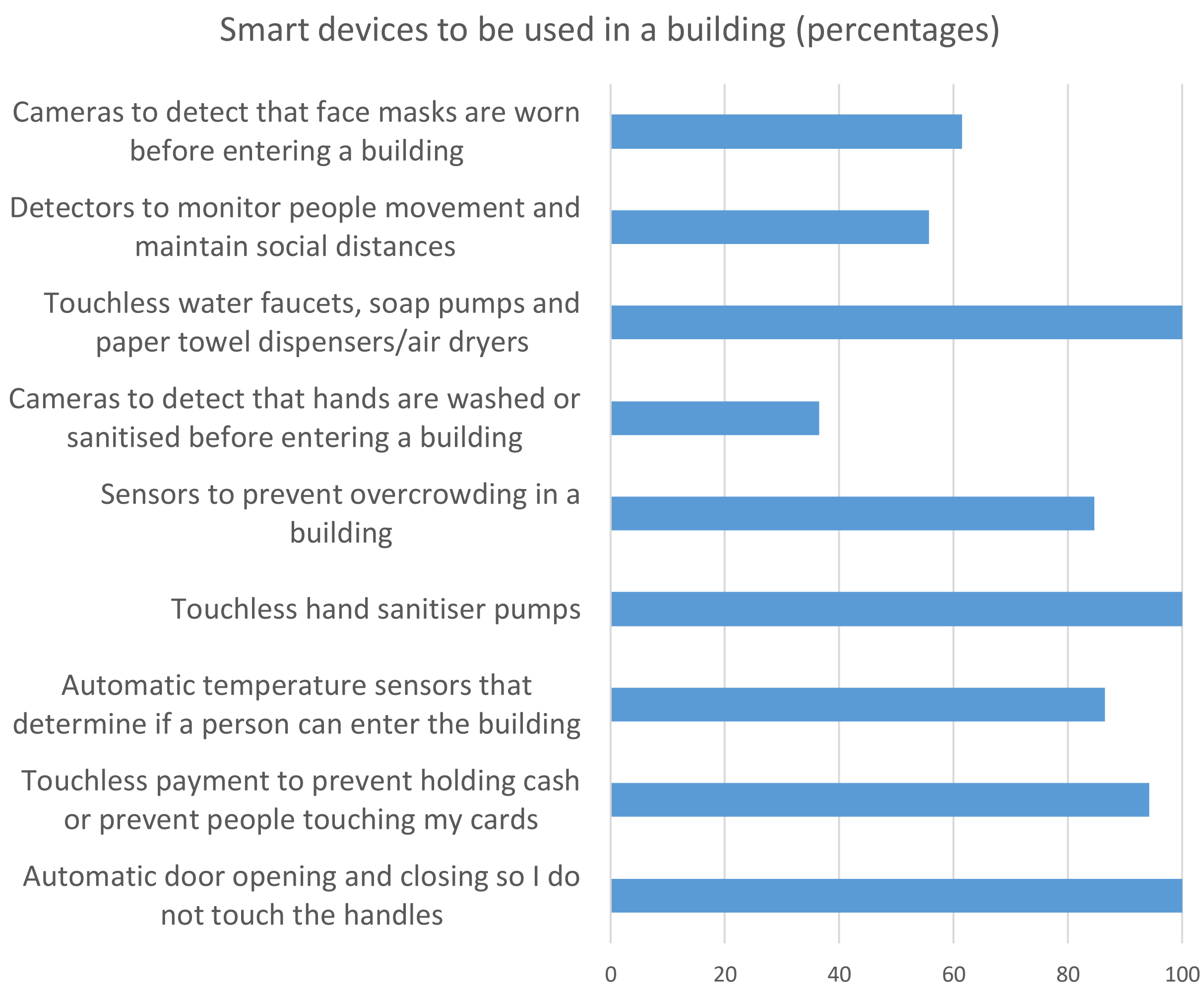

Fig. 5: Summary of smart devices that should be used in a building (percentages of responses)

Autonomous systems (robotic food production, robotic systems in general work environments, automated shopping assistants)
Temperature measurements (sensing on various parts of body, public broadcast readings, continuous measurements during shift)
Smart bins
Internal detectors to identify virus present in saliva or mucus
Smart watch that detects presence of virus in wearer
Wearables for visitors and people in isolation

Touchless controls (elevator buttons and water cooler)
Automatic aerosol dispenser
Holographic technologies
Reduce risk of EM radiation to health from frequent use of devices

Table 1: Summary of open-ended responses to new technologies to be used in a store

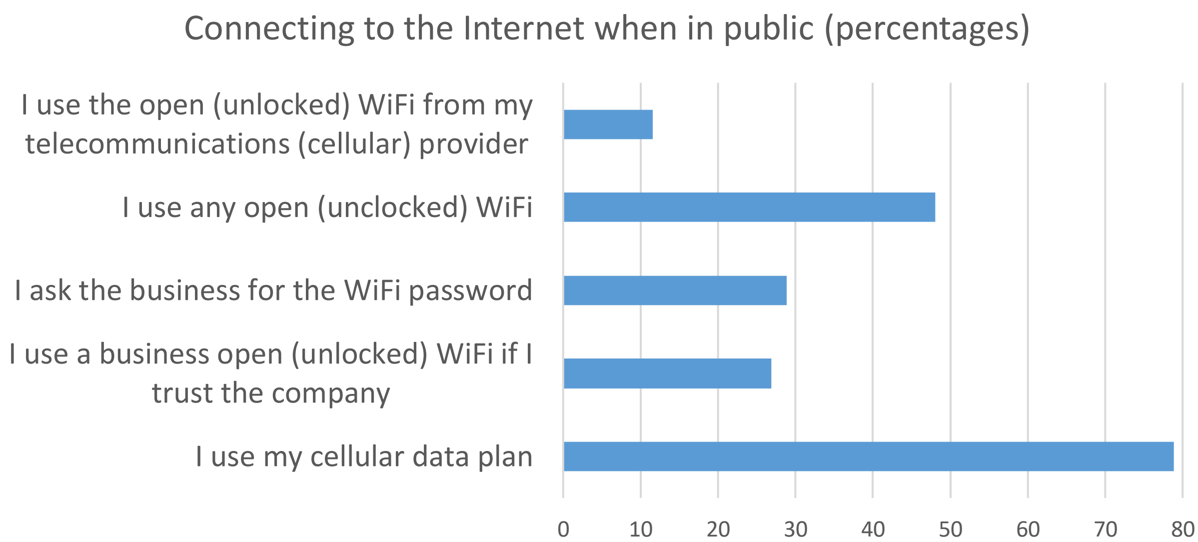

Fig. 6: Summary of methods respondents connect to the Internet when in public (percentages of responses)

Access to the Internet via a cellular data plan (Fig. 6) was the highest choice selected which together with the preference to have businesses communicate via email (Fig. 7) supported using the smart phone for B2C communications.

Fig. 8 revealed that the majority of individuals would only automatically send their health data to medical professionals' dependent on the additional personal information contained in the message. Therefore, anonymization is an important feature of any medical data transmitted. With the concept of enforced personal data privacy (as in "privacy by design and by default"), the results can be reinterpreted to provide an aggregation of the "yes" and "depends" percentages. Therefore, it revealed that 87% wanted to know if they are in close proximity to someone with a disease. Similarly, 71% agreed on the public display of locations of infected persons. However, publicizing a location would facilitate visual confirmation of individuals present, thus negating the benefits of removing personal information from the medical data.

There have been concerns about private information from contact tracing applications[41] [42] [43]. However, the respondents understood its importance to analyse epidemiology.

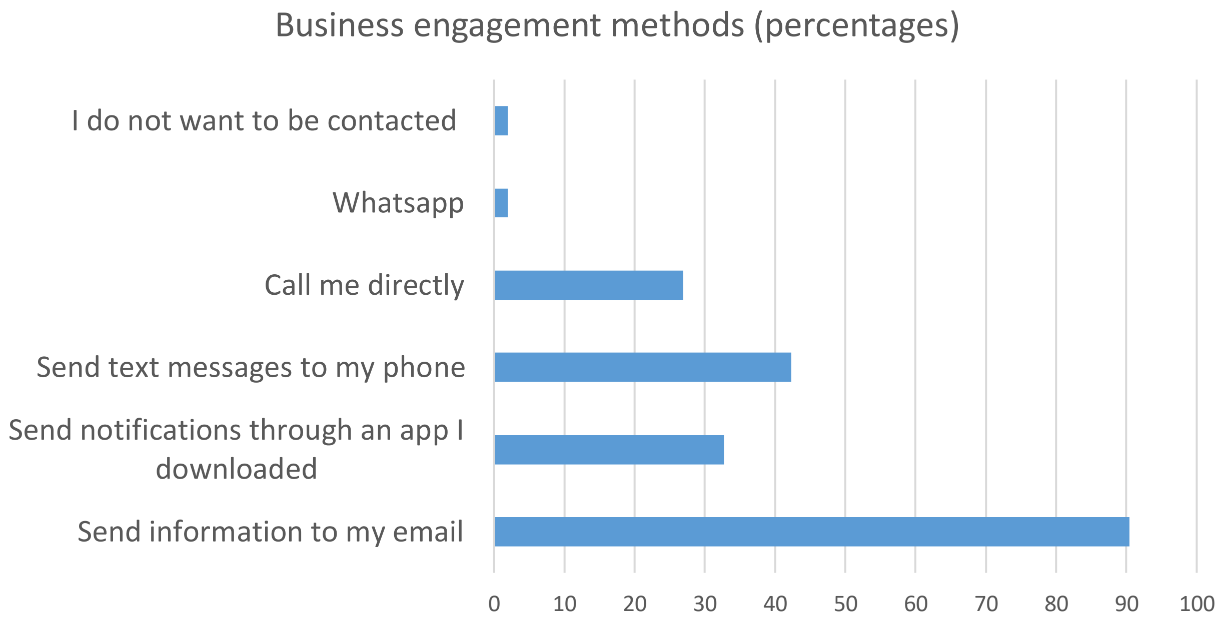

Fig. 7: Summary of business communication methods (percentages of responses)

[41] Busvine, D. (2020) *Rift opens over European coronavirus contact tracing apps*, *Reuters*. Available at: https://www.reuters.com/article/us-health-coronavirus-europe-tech/rift-opens-over-european-coronavirus-contact-tracing-apps-idUSKBN2221U0 (Accessed: 21 April 2020).

[42] Scroxton, A. (2020a) *Contact-tracing app fails to protect privacy and human rights*, *Computer Weekly*. Available at: https://www.computerweekly.com/news/252482805/Contact-tracing-app-fails-to-protect-privacy-and-human-rights (Accessed: 9 May 2020).

[43] Scroxton, A. (2020b) *GDPR wholly inappropriate to govern contact-tracing data*, *Computer Weekly*. Available at: https://www.computerweekly.com/news/252483355/GDPR-wholly-inappropriate-to-govern-contact-tracing-data (Accessed: 20 May 2020).

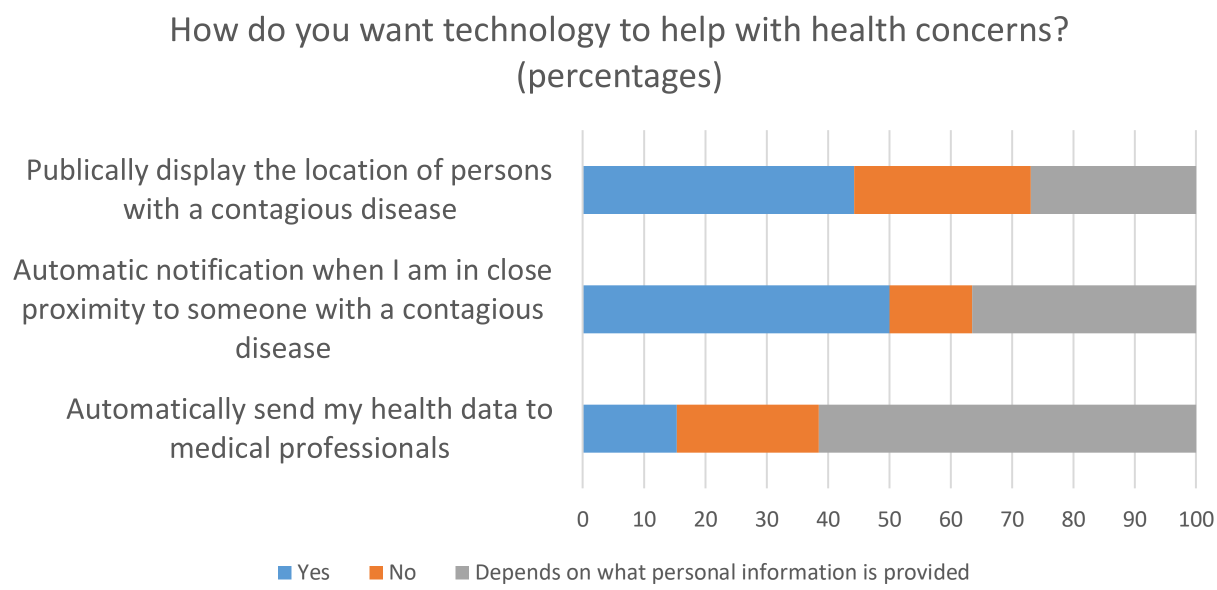

Fig. 8: Summary of technology applications for health concerns (percentages of responses)

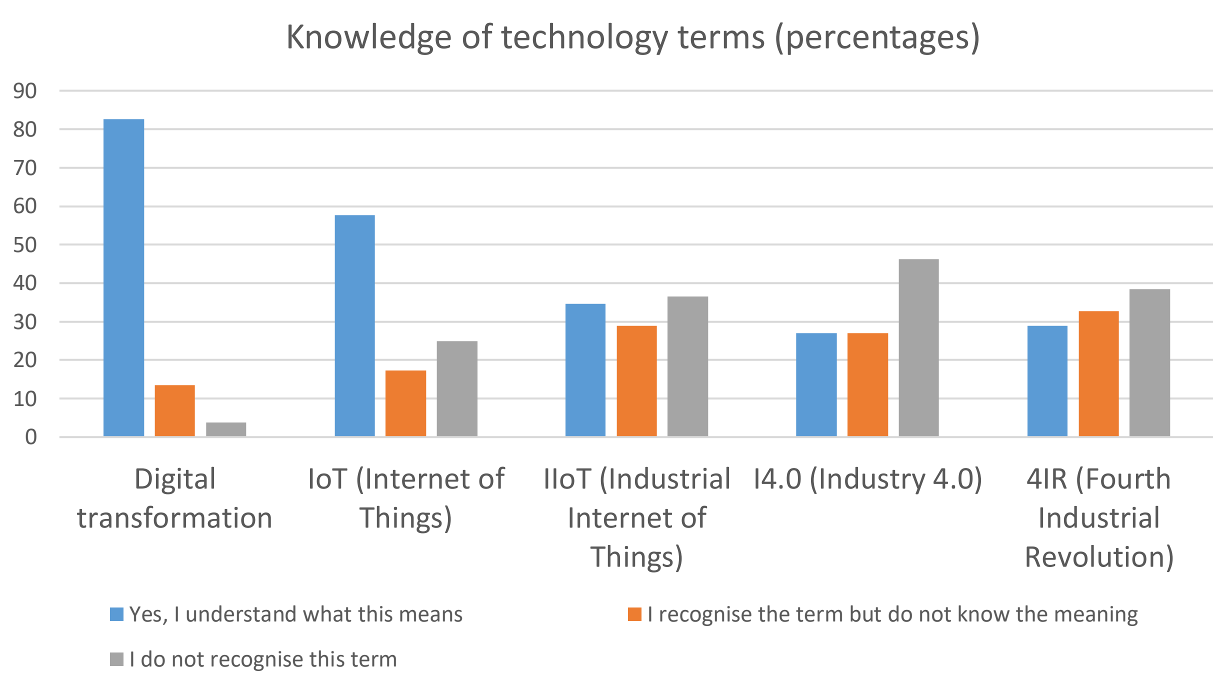

Fig. 9: Illustration of respondents' knowledge of technology terms (percentages of responses)

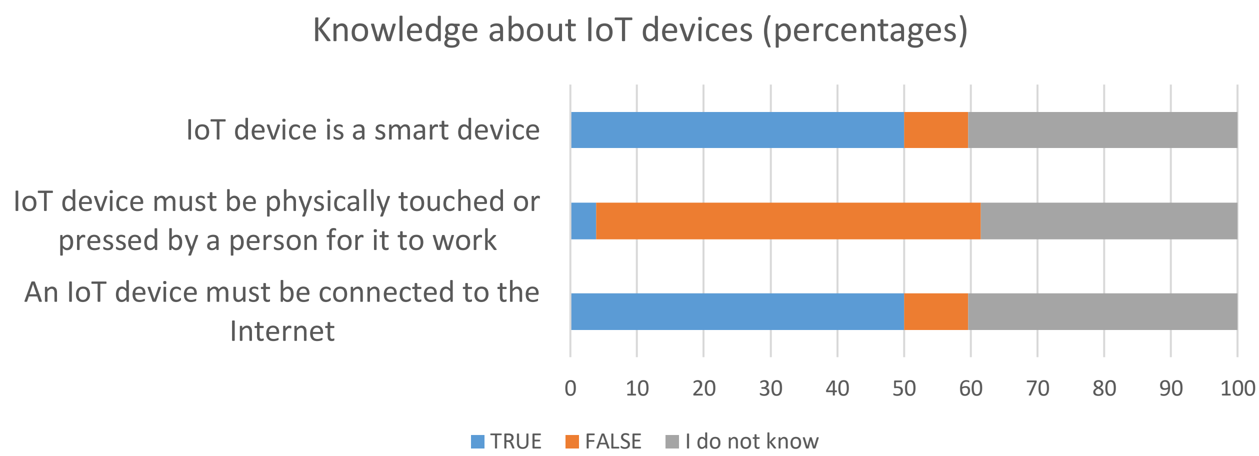

Fig. 10: Illustration of respondents' knowledge about IoT devices (percentages of responses)

Adoption of technology is facilitated by a clear understanding of its purpose and operation[44]. This knowledge is demonstrated in the responses to specific technology terms and IoT concepts (Fig. 9 and Fig. 10). Both digital transformation as well as IoT are recognizable and understandable terms). However, respondents were not as confident about other linked terms as IIoT, I4.0 and 4IR. Additionally, 40% did not know the specific operating requirements of an IoT device.

The majority of respondents agreed that an IoT device is smart, must be connected to the Internet and does not require someone to physically touch it to operate. This assessment together with the awareness of the terms IoT and digital transformation provided support for the future adoption of IoT systems.

A last question determined the full range of technology awareness and implementation. The respondents identified current and future plans of Industry 4.0 enabling technologies[45]. Mobile devices and Cloud computing revealed the highest percentages (Fig. 11).

The review of existing material (technology blogs and scoping literature review) emphasized the importance of a "resilient ICT sector to enable flexible and remote operations" that facilitates

[44] Rameshwar, J. R. and King, G. S. (2019) 'Developmental Requirements Implementing Industry 4.0 in Trinidad and Tobago Companies', *The Journal of the Association of Professional Engineers of Trinidad and Tobago*, 47(2), pp. 11–19.

[45] King, G. S., Rameshwar, J. R. and Syan, C. S. (2020) 'Industry 4.0 in a Small Commodity-Based Economy: A Vehicle for Stimulating Innovation', *Journal of Industrial Integration and Management*. World Scientific Pub Co Pte Lt, 05(03), pp. 365–391. doi: 10.1142/S242486222050013X.

digital transformation. However, both the survey responses and literature identified that privacy of personal health data is an important and often limiting factor to the adoption of a solution.

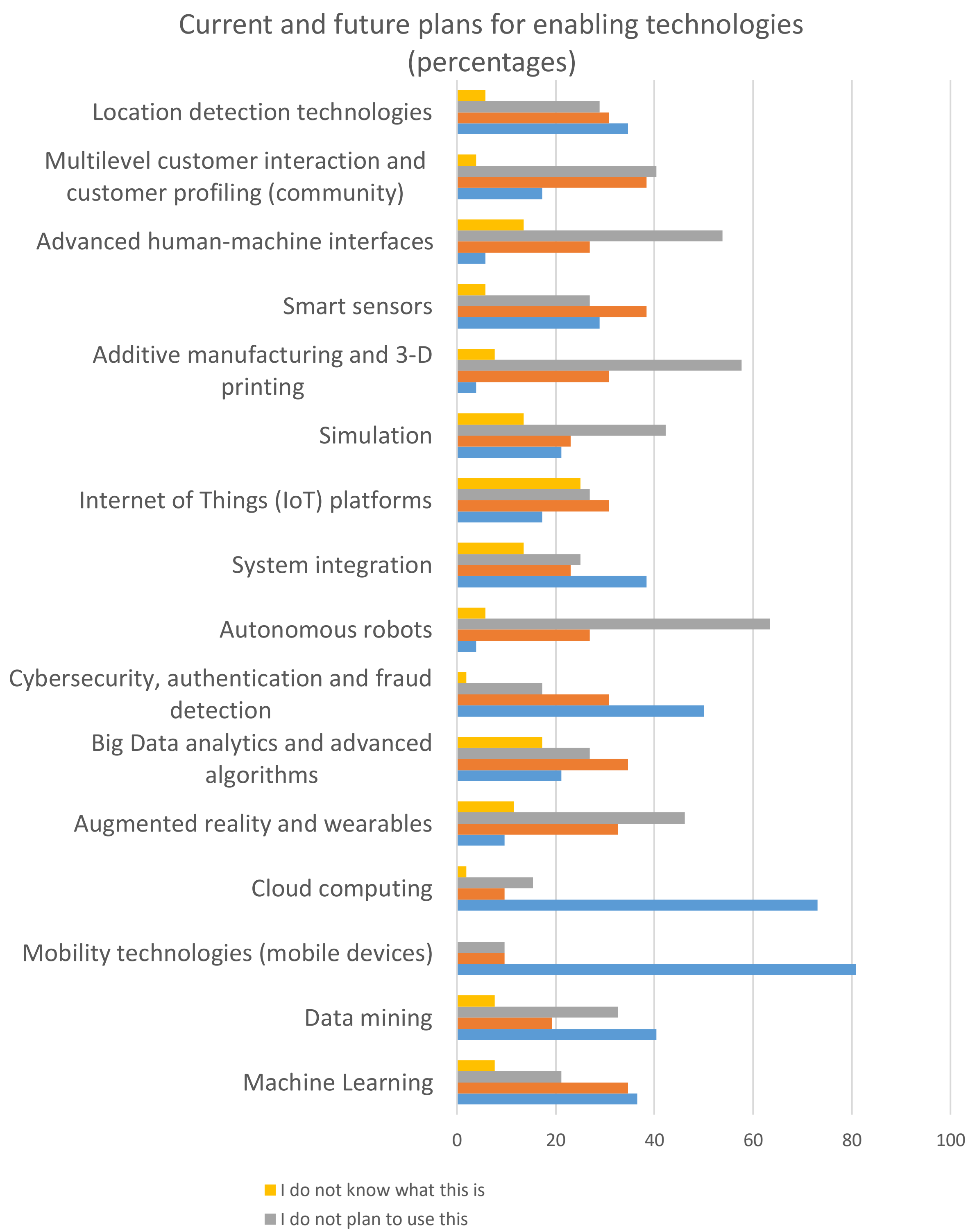

Fig. 11: Identification of respondents' current and future plans for emerging technologies (percentages of responses)

Summary of Caribbean Technology Blogs

Reports from Caribbean based technology blogs[46] [47] [48] demonstrated a specific focus on digital transformation activities.

Scoping Literature Review

In 2017, there was a focused seminar on IoT and the Caribbean[49] that involved policy and regulatory developers, entrepreneurs (users and developers of IoT based solutions) and utility service providers that discussed various elements of IoT SWOT (strength, weakness, opportunities and threats)[50].

Caribbean companies utilized IoT systems to provide solutions as asset tracking and management[51] and drone delivery[52]. However, there was a distinct lack of publicly available information relating to IoT use in the Caribbean for COVID-19.

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[46] *Silicon Caribe - The Future of Digital in Caribbean Business* (no date) *Silicon Caribe*. Available at: https://www.siliconcaribe.com/ (Accessed: 21 September 2020).

[47] *ICT Pulse – The leading technology blog in the Caribbean* (no date) *ICT Pulse*. Available at: https://www.ict-pulse.com/ (Accessed: 21 September 2020).

[48] *Tech News TT - Technology news and reporting from Trinidad and Tobago* (no date) *Tech News TT*. Available at: https://technewstt.com/ (Accessed: 21 September 2020).

[49] Cuffie, M. (2017) 'Feature Address "Internet of Things: Smarter Living in the Caribbean"'. Port-of-Spain: Ministry of Public Administration and Communications, p. 18. Available at: http://mpadt.gov.tt/speeches/Feature%20Address%20by%20The%20Honourable%20Minister%20of%20Public%20Administration%20%26%20Communications%20-%20Internet%20of%20Things%3A%20Smarter%20Living%20in%20the%20Caribbean.

[50] ECLAC (2017) *Forum on Internet of Things (IOT): Smarter Living in the Caribbean*. Available at: https://www.cepal.org/en/events/forum-internet-things-iot-smarter-living-caribbean (Accessed: 22 September 2020).

[51] ACT (no date) *IoT Solutions*. Available at: https://www.actantigua.com/iot-solutions/ (Accessed: 22 September 2020).

[52] News Desk (2019) *AirBox drone delivery tests conducted successfully in Antigua*, *Geospatial World*. Available at: https://www.geospatialworld.net/news/airbox-drone-delivery-tests-conducted-successfully-in-antigua/ (Accessed: 22 September 2020).

COVID-19 related reports focused on the identification, use and limitations of digitalization technologies and the importance for the Caribbean community to have a resilient ICT sector to enable flexible and remote operations[53].

In Jamaica, the Amber Group noted that wearables (based on fleet management technology) would aid in tracking individuals[54]. The company also developed a contact tracing mobile application that "allows citizens to self-report their health status, book an appointment for testing if they are exhibiting symptoms of COVID-19, as well as request emergency services such as the police or ambulance services"[55] .

The "Caribbean Video Assistance Service (CVAS) for the Deaf and Blind"[56] digital platform connects users (via a mobile phone) with an agent (or interpreter) to translate information.

CARIBBEAN IOT SOLUTION DEVELOPMENT

This academic conceptual system was developed based on the literature review and survey responses to illustrate the use of an IoT framework that integrates businesses and consumers.

Fig. 12 demonstrates the basic elements of conceptual vision system for monitoring a hand washing and/or hand sanitizing station with a visible status indicator (physically mounted on the building as well as provided to the user's phone application) that either allows or denies entry based on the completed activity as well as the wearing of a mask. Additionally, the inclusion of a thermal camera and microphone would detect temperature, coughs and/or sneezes.

[53] Morgan, K. (2020) *COVID-19, Technology and the Future of Work*, *CARICOM Today*. Available at: https://today.caricom.org/2020/04/15/COVID-19-technology-and-the-future-of-work/ (Accessed: 19 July 2020).

[54] Hall, A. (2020) *Bracelet tracking coming*, *Jamaica Observer*. Available at: http://www.jamaicaobserver.com/news/bracelet-tracking-coming-amber-group-s-us-400-000-COVID-19-gift-includes-technology-for-tighter-monitoring-of-people-in-home-quarantine_195532 (Accessed: 12 August 2020).

[55] OPM Communications (2020) *JamCOVID App Now Available for Download on Android Devices – Office of the Prime Minister*. Available at: https://opm.gov.jm/news/jamCOVID-app-now-available-for-download-on-android-devices/ (Accessed: 28 September 2020).

[56] Nurse, M. (2020) *CTU Collaborating With Organisations to Assist People With Disabilities During COVID-19 And Beyond*, *CARICOM Today*. Available at: https://today.caricom.org/2020/05/08/ctu-collaborating-with-organisations-to-assist-people-with-disabilities-during-COVID-19-and-beyond/ (Accessed: 19 July 2020).

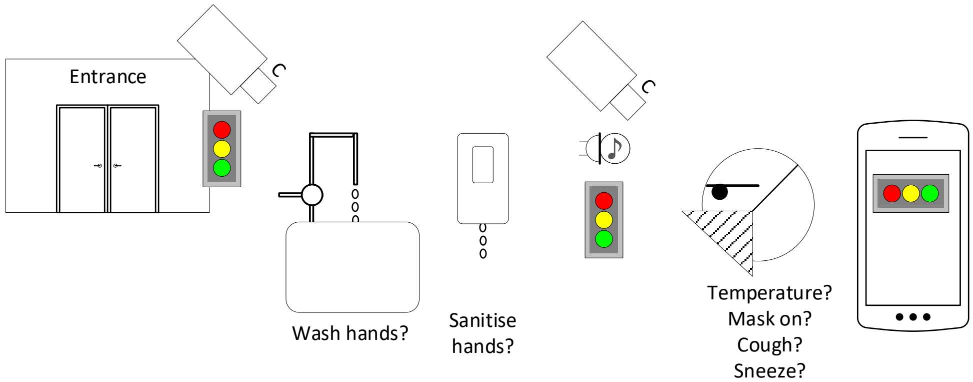

Fig. 12: IoT sensors - External mounted camera, microphone and status indicator

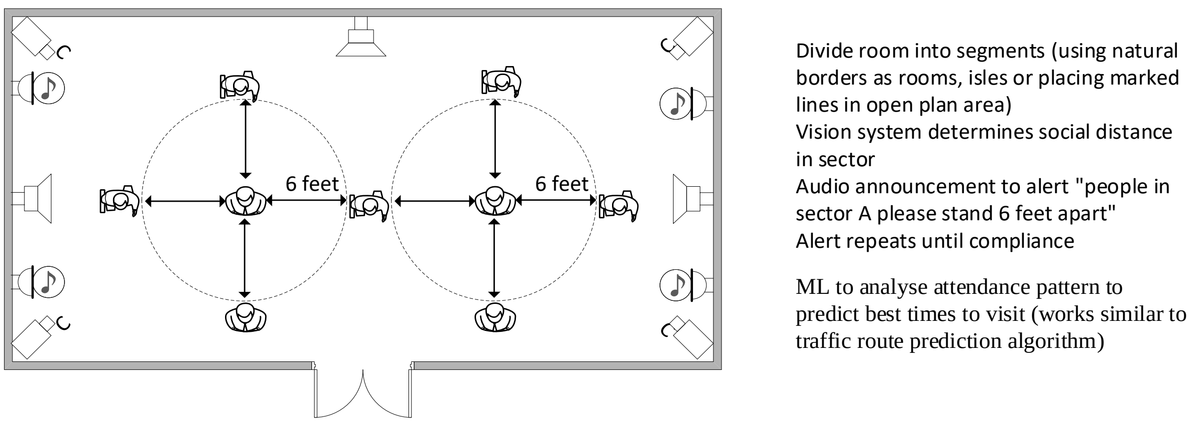

Fig. 13: IoT sensors – Internal mounted camera, microphone and speakers

The design can be applied inside the building (Fig. 13) to maintain social distancing through spatial detection and creating audible alerts that remind persons to stand 6 feet apart. Machine learning (ML) can utilize the information to develop attendance patterns to inform potential consumers of the most suitable times to visit. This type of behavior analysis is commonly used in retail shops using IoT devices to provide an engaged customer experience[57].

Fig. 14 (below) illustrates the conceptual framework in using mounted connected physical sensors that detect and analyze changes in information from light (vision), sound, temperature as well as radio waves. The data generated would be analyzed using Cloud applications, as analytics and machine learning, to develop information specific to individual's behavior as it relates to the spread of COVID-19, such as washing and/or sanitizing hands; whether a mask is

[57] Rohra, G. (2016) 'The Internet of Things in Retail: Redefining Brick and Mortar Stores', *IIC Journal of Innovation*, (June), p. 8. Available at: https://www.iiconsortium.org/news/joi-articles/2016-June-The-Internet-of-Things-in-Retail-Redefining-Brick-and-Mortar-Stores.pdf.

being worn, identification of a viral symptoms as high temperature, coughs and sneezes; adherence to social distancing; as well as the total occupancy within an area. A trigger is generated once a minimum threshold (which is user defined, for example if no mask is detected) is exceeded. A customized alert and notification would be pushed to an individual's mobile phone, either via direct WiFi or SMS or through an application (which would provide additional details as location).

This platform eliminates the reliance of the user's personal devices (wearables and smart phones) to provide all of the data needed for adherence to the COVID-19 protocols. Privacy is another benefit as it reduces the amount of confidential user data accessed. However, the focus on privacy may increase the difficulty in identifying the violating person. A potential solution would involve a real-time response (e.g. an audible descriptor identifying and issuing a warning) aimed at the perpetrator, in which analyzed data determined the individual's relative unique characteristics and location as compared to elements in the immediate vicinity.

WiFi is a cost-effective communication solution[58], which is essential for SMEs during the negative economic phase during the COVID-19 period.

Each of the IoT sensors communicate with the Cloud applications through a wired or wireless Ethernet connection[59], with the latter being a flexible option for physical placement.

Feasibility discussions with Amazon Web Services (AWS) identified the AWS "Connected Home – Telemetry" architecture[60] (Fig. 15) which captured the key project parameters. To be effective, the processing of video data requires real-time analysis of the images. The AWS Kinesis[61] is a potential solution as it "makes it easy to securely stream video from connected devices to AWS for analytics, machine learning (ML), playback, and other processing" together with the AWS Rekognition platform to perform the analytical functions to identify activities (as cleansing and sanitizing hands), facial comparisons (for mask verification), people counting (for social distancing). This modular approach, together with the benefits of the AWS Cloud application

[58] Nikolich, P. (2020) *Wi-Fi for IoT gives organizations low-cost connection option*, *IoT Agenda*. Available at: https://internetofthingsagenda.techtarget.com/feature/Wi-Fi-for-IoT-gives-organizations-low-cost-connection-option (Accessed: 23 September 2020).

[59] D'Ambrosia, J. (2020) *Ethernet in IoT still serves a purpose in the wireless age*, *IoT Agenda*. Available at: https://internetofthingsagenda.techtarget.com/feature/Ethernet-in-IoT-still-serves-a-purpose-in-the-wireless-age (Accessed: 23 September 2020).

[60] Amazon Web Services (no date d) *AWS IoT - Connected Home*. Available at: https://aws.amazon.com/iot/solutions/connected-home/ (Accessed: 23 September 2020).

[61] Amazon Web Services (no date a) *Amazon Kinesis Video Streams*. Available at: https://aws.amazon.com/kinesis/video-streams/ (Accessed: 23 September 2020).

enables the use of a “scalable, deep learning technology that requires no machine learning expertise to use”[62].

Real-time responsiveness is affected by the amount of data being processed as well as the location of the computational systems, thus utilizing “AWS for the Edge” will “move data processing and analysis as close to the end-point as necessary”[63] to facilitate an on-premise scalable platform.

[62] Amazon Web Services (no date b) *Amazon Rekognition*. Available at: https://aws.amazon.com/rekognition/ (Accessed: 23 September 2020).

[63] Amazon Web Services (no date c) *AWS for the Edge - Overview*. Available at: https://aws.amazon.com/edge/ (Accessed: 2 November 2020).

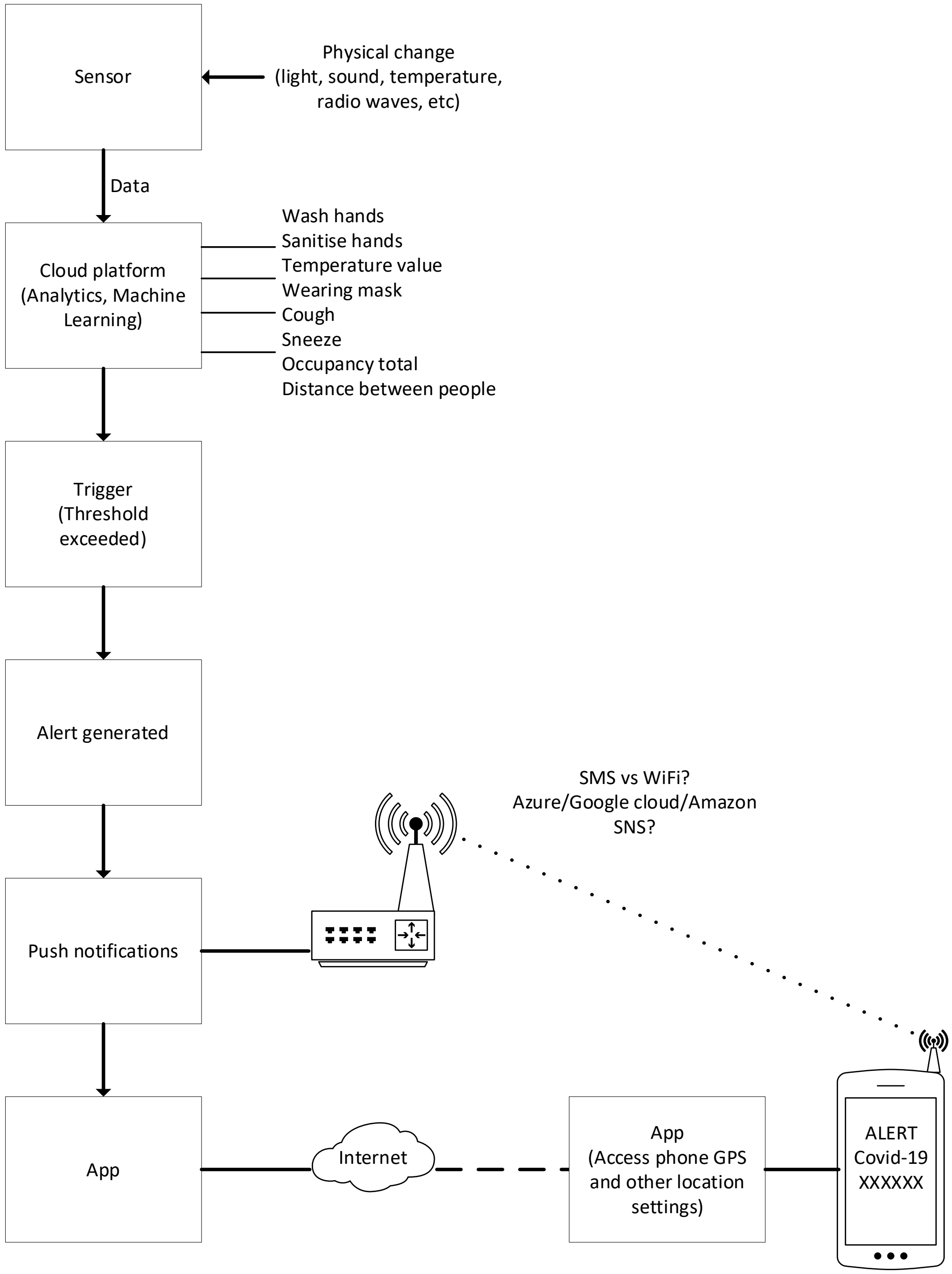

Fig. 14: Conceptual Framework of IoT based Alert System

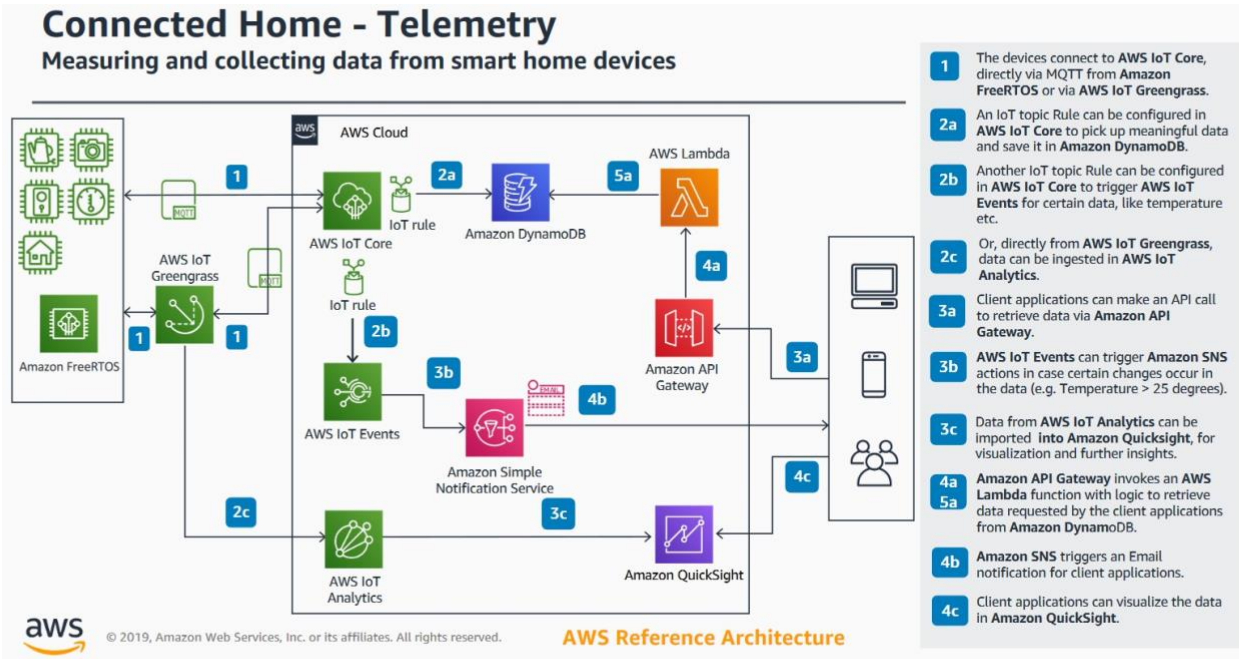

Fig. 15: AWS Telemetry Architecture[64]

Benefits to the Caribbean

Digital transformation and cloud technology usage increased due to COVID-19 and the need for continuity of services (retail and education). This change in normal operating procedures required a learning curve to become competent in using the new environment.

IoT implementation in the Caribbean was for industrial and commercial purposes (as monitoring equipment) but no confirmation was identified on using the technology in the health sector.

In many retail outlets, solutions as a mounted temperature sensor, hands-free sanitizer dispenser and the use of guards to enforce COVID-19 protocols demonstrated that specific aspects of health safety can be achieved with non-IoT systems. However, these systems can become overloaded with an exponential increase in demand, which could cause failures. Therefore, these types of manual operations function only when the users are orderly and controlled. It is not able to adapt to large random disturbances, unlike an IoT platform.

The research revealed specific lessons that can be incorporated into the use of IoT in healthcare

[64] Amazon Web Services (2019) *Connected Home -Telemetry*. Available at: https://d1.awsstatic.com/architecture-diagrams/ArchitectureDiagrams/connected_home_telemetry_ra.pdf.

- B2C Cloud-based email communication strategy accessed by users' smart phones via their mobile data network
- Resilient ICT sector enables flexible and remote operations
- Technology adoption facilitated through a marketing plan using the recognizable and understandable keywords "digital transformation", "IoT" and "smart sensor"
- Important information to be disseminated to individuals in real-time are building occupancy levels (with the allowable maximum value), feedback on individual temperature measurements as well as location and proximity to contagious persons
- Touchless systems (no physical interactions) are a need
- Design safety needed to protect against unintended consequences (as exposure to EM radiation)
- In vivo virus detection can provide real-time information
- Personal data privacy for medical data submitted for analysis must be compliant with the "privacy by design and by default" regulations
- Respondents agreed that an IoT device is smart, must be connected to the Internet and does not require someone to physically touch it to operate.

IoT implementation requires a digital and telecommunications infrastructure to achieve connectivity, scalability, redundancy and to become ubiquitous. As a sensor driven tool, it is used to identify key performance indicators (as energy parameters of a building or an individual's temperature). However, it is a physical device that measures the "analogue" environment and pushes digitalized data to various applications (as analytics and machine learning) to facilitate specific services (as repairs to a HVAC system or creating audible reminders to maintain social distancing).

OPPORTUNITIES FOR IOT DEPLOYMENT

KPIs developed from the first IoT system installed can lead to the identification of other IoT sensors needed to acquire complimentary data of the primary parameter being monitored (as the thermal conditions of the HVAC electrical infrastructure or the acoustic parameters of a person's cough or sneeze). This creates an iterative system which increases the quantity and variety of IoT devices, as illustrated in Fig. 16. In the diagram, the initial IoT system monitors a primary parameter's KPIs and deviations trigger a replacement or repair action. This first iteration is commonplace within the maintenance framework. The data analytics also provides additional insights into the system's behavior that can be developed into new opportunities and KPIs. However, the existing IoT sensors are not designed to detect the new performance indicators thus creating the need for the second iteration. This creates a cyclical pattern driven by KPIs identified through data analysis.

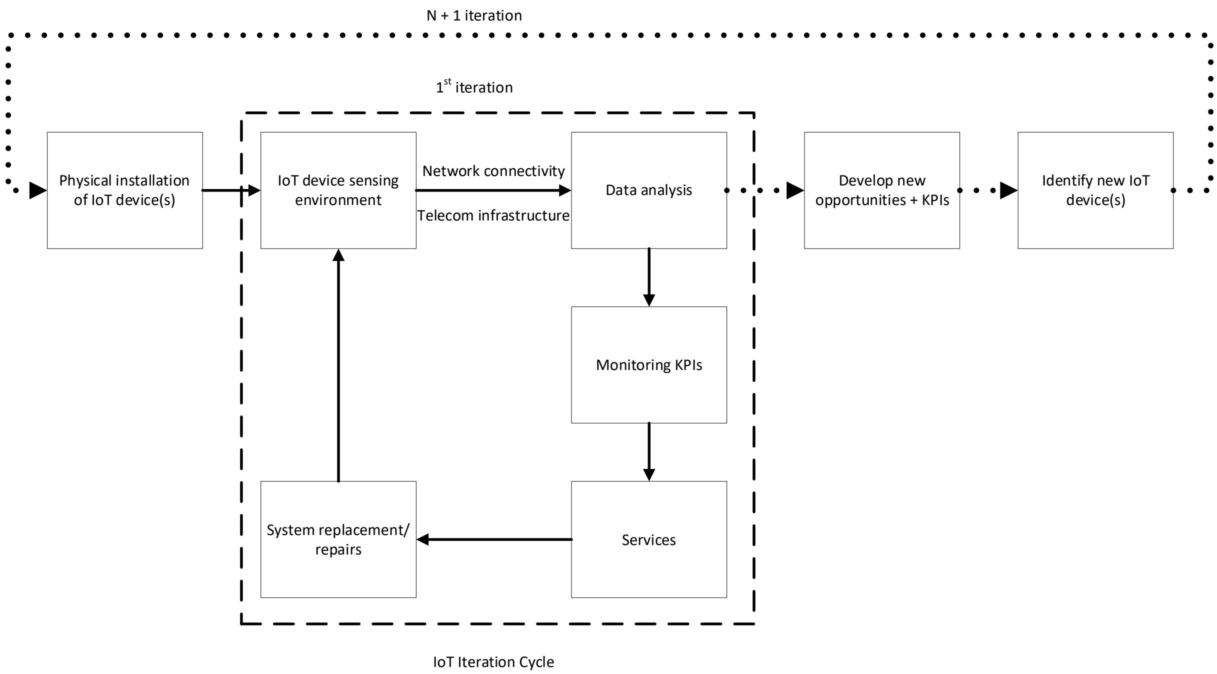

Fig. 16: IoT Iteration Cycle

CONCLUSION

COVID-19 is accelerating digital transformation through Cloud adoption strategies as:

- Business continuity enabled through Cloud services
- Forced migration for new customers as a Proof of Concept that showed benefits

This was the main driver for the research which centered around ICT systems including IoT. This research was initially designed as two sections. The first part to identify consumers' perspectives and then develop a second survey, based on the results, targeted at businesses. Time constraints and delays in feedback and approval, prevented the second business focused research (which would have looked more closely at IIoT).

Although only 55 persons provided data, the research was successful as it provided information about the expectations and habits of Caribbean users of digital technologies, of which IoT is a subset, directly as a result of the COVID-19 pandemic.

The novelty is the shift from using personal devices as contact tracing and data gathering tools as well as applying the concepts in automation (as equipment, product and process tracking) to the health sector.

Business benefits of the IoT strategy would be reduced human interaction; reduced human error; maintenance of required health protocols; ability to change parameters of health protocol triggers via software; increased value to consumers through health focused concerns; and ability to use the platform for focused marketing and logistics planning.

Future work involves focusing on the Caribbean SME sector utilizing the concepts and research data derived from this paper.

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