Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 44 No. 1 (2023)

Interoperability Testing Strategies for Medical IoT Devices

[1]Venudhar Rao Hajari, [2]Ritesh Chaturvedi, [3]Dr. Saloni Sharma, [4]Mitul Tilala, [5]Abhip Dilip Chawda, [6]Abhishek Pandurang Benke

[1]Independent Researcher, USA.
[2]Independent Researcher, USA.
[3]Independent Researcher ,USA.
[4]Independent Researcher, USA.
[5]Independent Researcher, USA.
[6]Independent Researcher, USA.

Abstract: This paper aims at identifying and comparing interoperability testing strategies of medical IoT devices. The paper focuses on today's norms, issues, and trends on the effective integration of different healthcare technologies for smooth information exchange. Current literature on interoperability frameworks is also described and sources of implementation challenges are discussed. The research process includes data gathering, data analysis and creation of real life health care facility-based tests. It identifies the best practice in testing, some of the most frequently experienced interoperability problems and how these problems affect a device and its usefulness in delivering patient care. The study shows that interoperability is an important factor that governs the betterment of healthcare, and the type of a patient's care as well as and the efficacious workflow in an accusative setting. Suggestions for hunt and growing in the rising was provided and note that the perpetually changing realities of the medical IoT environs need flexural and uniform testing practices across the board.

Keywords: *environs, interoperability, perpetually, flexural*

Introduction

The rapid growth of Internet of Things (IoT) engineering in healthcare has led to an increasing number of connected medical devices. These devices offer meaningful benefits, including improved bigoted monitoring as well as more efficacious data collection,' and enhanced manipulation outcomes. However, the different array of medical IoT devices also presents an important challenge; ensuring broadloom interoperability among clear-cut systems and platforms. Interoperability in medical IoT refers to the power of devices and systems to interchange and interpret data effectively. This capableness is important for providing all-encompassing bigoted care, reducing medical errors, and optimizing healthcare workflows. The number of connected devices grows, so does the complexness of ensuring their intact interaction. This explores the strategies and methodologies for testing interoperability in medical IoT devices. It examines modern day standards, identifies normal challenges, and evaluates single testing approaches. The hunt aims to allow insights into efficacious testing strategies that could help manufacturers, healthcare providers, and regulative bodies check the safe and efficacious appendage of interconnected medical devices. By addressing the important issue of interoperability, testing as well as this study contributes to the ongoing efforts to improve safety, heighten healthcare delivery, and maximized the effectiveness of IoT engineering in medical settings.

Literature Review

Current Interoperability Standards for Medical IoT Devices

According to Balakrishna and Thirumaran, 2020; The modern day State of affairs has been recognized across the healthcare industry that standardization needs to be integrated so that interoperability of aesculapian IoT devices may have occurred. Some of the important standards that have crystallized towards meeting this challenge include the following. FLyer has suggested that the HL7 organization has standardized the use of electronic health record exchange through a method known as FHIR (Mavrogiorgou *et al.*, 2019). FHIR employs a RESTful based API model which is relatively easy to implement as well as easier for systems in the HL7 organization to deal with. Another important standard is the IEEE 11073 family of standards for the personal health device communication. These standards specify how the personal health devices should interface with the compute engines including smart phones or health appliances. The latter recognizes more specifications concerning interoperability provided by the Continua Design Guidelines, derived from the IEEE 11073 (Balakrishna and Thirumaran, 2020). In the case of medical imaging, digital imaging and communication in medicine or DICOM still plays a vital role. It is a method of sharing medical images and other relevant data of one device with another equipment produced by a different company.

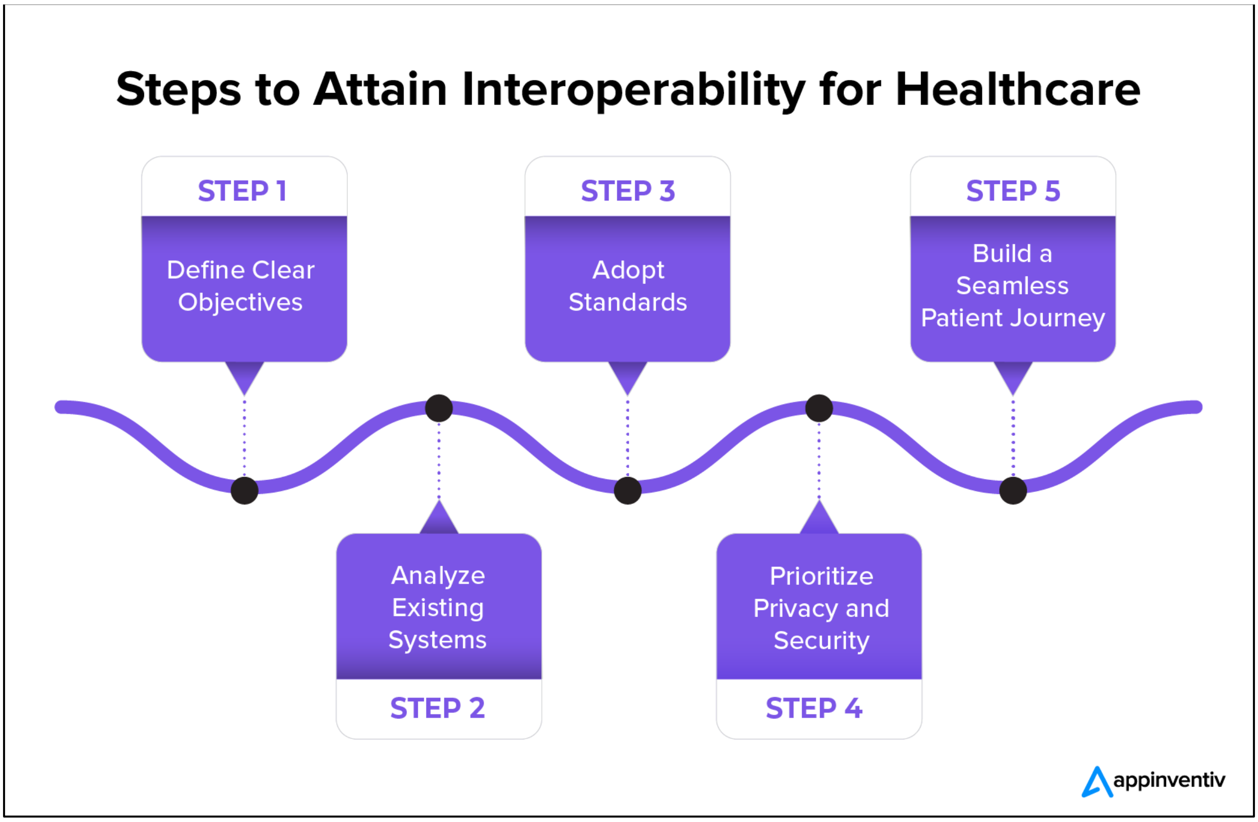

Figure 1: Interoperability in healthcare

(Source: https://appinventiv.com/wp-content/uploads/2023/12)

Challenges in Medical IoT Device Interoperability

According to Walonoski *et al.* 2018; There are standards available in the market, reaching the state of full compatibility in the medical IoT devices remains a challenging endeavor. One key challenge is that standards and protocols are not well developed and are dispersed. Different manufacturers of the devices want to make their standards and versions, thereby resulting in complications in compatibility. Risks are also quite probing when it comes to security and privacy. As many medical devices deal with patients' data privacy, it is vital to satisfy confidentiality and data exchange standards while keeping the devices interoperable. This requirement of secure communication can at times be at odds with the need of interoperability (Jaleel *et al.*, 2020). The final issue relates to the specificity and heterogeneity of data types and meaning.Each device can have different terminologies and defining data structures thus making it harder to translate and implement information among different systems. This is a semantic interoperability issue that begs for more than technical fixes; both ontological as well as terminological (Walonoski *et al.* 2018). convergence will be needed, that is, adoption of a common vocabulary, and data model. The fast rate of innovation in technology in IoT is also considered to be a weakness.

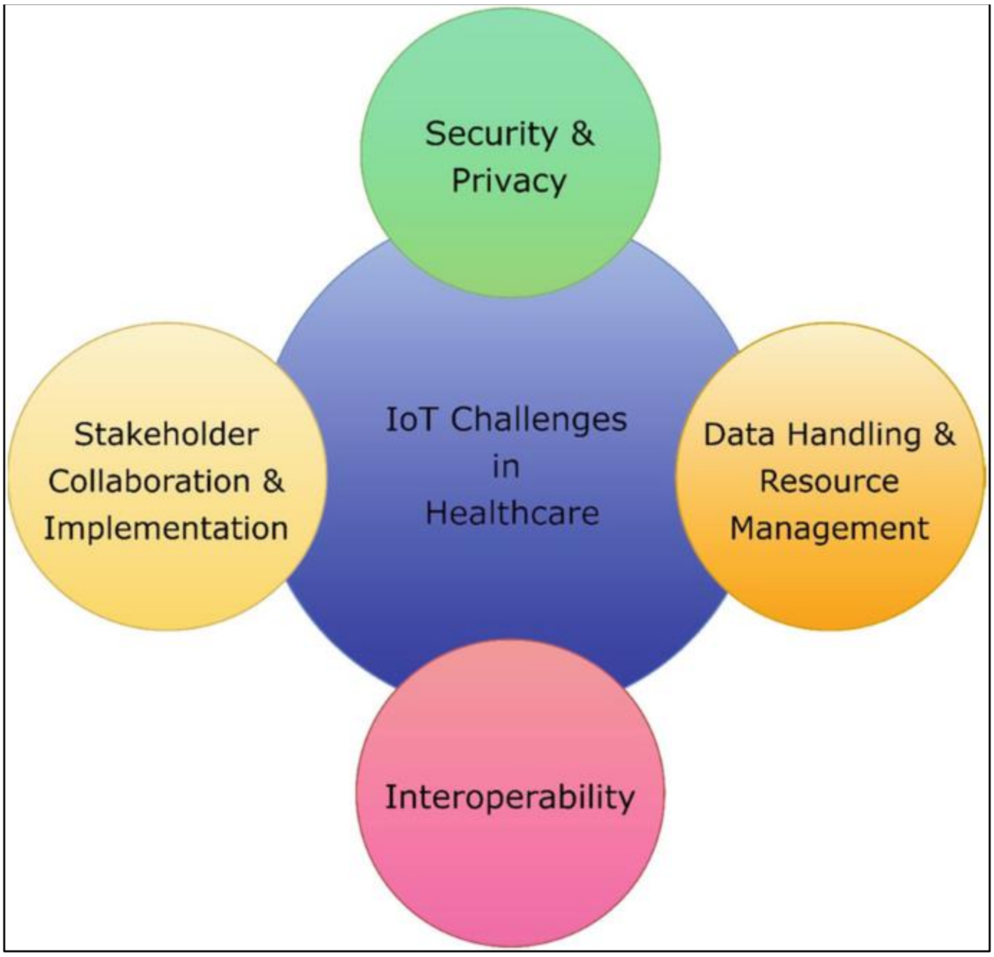

Figure 2: IOT challenges in healthcare

(Source: https://media.springernature.com/lw685/springer-static/image/chp)

Existing Testing Methodologies for IoT Interoperability

According to Abounassar, El-Kafrawy and Abd El-Latif, 2022; The following testing methodologies have been developed to accommodate the issue of interoperability. To accomplish the task, one of the approaches that is widely used is conformance testing, where the objective is to determine whether the device or system is compliant with the set standards or not (Abounassar, El-Kafrawy and Abd El-Latif, 2022). This usually is done by comparing the device against a reference implementation or against a given set of test cases of the standards. Interoperability testing takes it a step forward and involves checking how the different devices from different manufacturers perform. This is normally done by developing scenarios that are likely to occur in real life and how these devices will be used or will fit. One of the well-known types of IOT is plug-fests in which many vendors connect their devices to check whether they are rated compatible or not. Semantic interoperability testing is concerned with the scope of checking the meaning of data that is exchanged between systems. This may include checking compliance with tested Against Standard Vocabularies and Ontologies and Confirming Clinical Concepts have been Interpreted Correctly Across Systems. Performance testing is another one, especially important in the case of IoT devices.

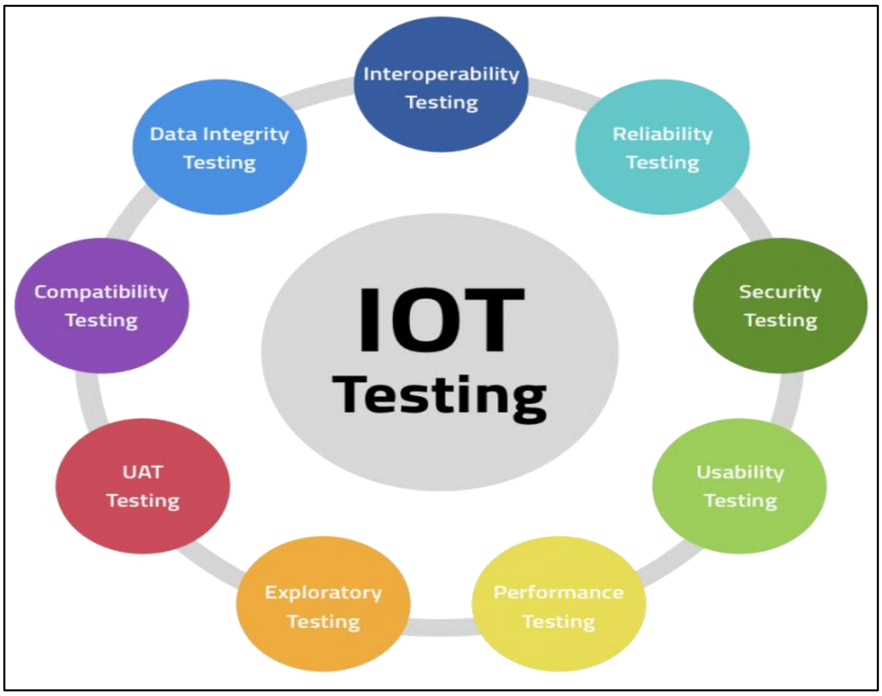

Figure 3: IOT testing

(Source: https://www.testtriangle.com/wp-content/uploads/2019/02/)

Methods

Data Collection and Analysis Techniques

Conducting I&T for connected healthcare ontologies, the process of data collection requires a rather complex approach. First, there is a brief literature review on existing standards, protocols, and specific guidelines for devices. This is done by collecting the documents from the manufacturers, standardization bodies and the regulating authorities. During the mimicked interactions of various medical IoT devices different logs and traffic flow information are recorded. It is captured with the help of custom software that allows for monitoring the networks and individual packets of data (Villanueva-Miranda *et al*. 2018). Also, API responses and the logs of the errors are generated for possible interoperability concerns. At the analysis level, the research makes use of quantitative as well as qualitative approaches. Thus, quantitative analysis is concerned with such parameters as data transfer speed, the time taken, and the number of errors.

Figure 4: Data collection methods

(Source: https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9G)

Designing Interoperability Test Scenarios

Interoperability test scenarios are developed in order to model actual healthcare related arenas and processes. These scenarios are created with the support of the healthcare workers, manufacturers of the devices, and standards makers. A range of test cases is generated with respect to the high-risk features, operating devices, data types, and clinical instances. These include scenarios for regular data sharing, crisis situations, and possibly 'fringe' cases that may put a lot of pressure on functioning of interoperability (Rubí and Gondim, 2020). Security and privacy aspects are also built into the test design, which means that there are test cases that are built to check both the compatibility and integration of a security solution on the different devices and operating systems.

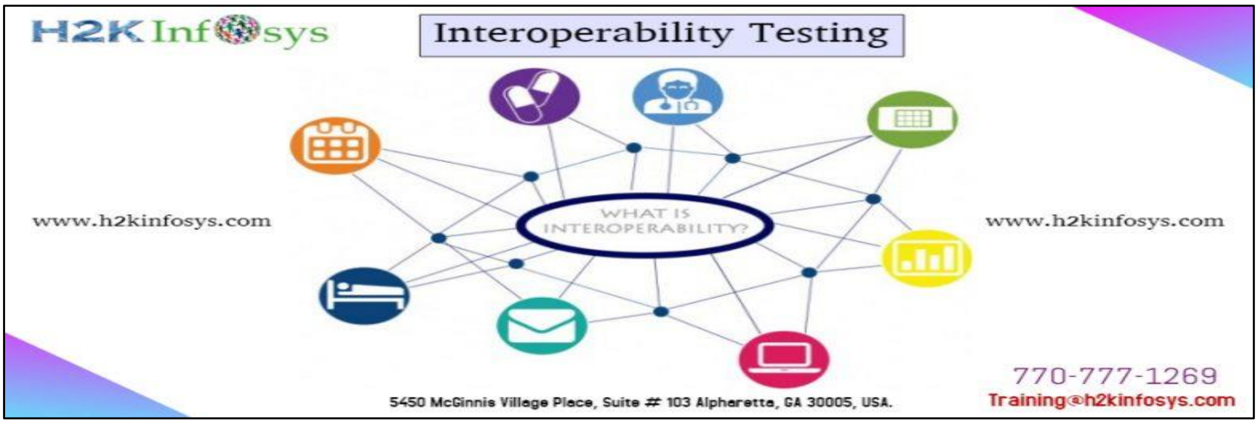

Figure 5: Interoperability testing

(Source: https://www.h2kinfosys.com/blog/wp-content/uploads/2018/10)

Implementation and Deployment of Testing Strategies

The use of testing strategies involves establishment of the testing conditions that include creation of a test bed that resembles a health care setting. This environment comprises other medical IoT devices, a network setup, and fake patient data. The tools of automated testing are built and run to perform the designed test scripts systematically (Famá, Faria and Portugal, 2022). They imitate the contacts between devices and provide creation of virtual test data and results evaluation. The desired state of perpetually inspecting compatibility and conducting integration and testing is managed through CI/CT principles. The automated testing is beneficial, combined with the testing done by experienced testers, mainly when the real-life situation needs to be examined.

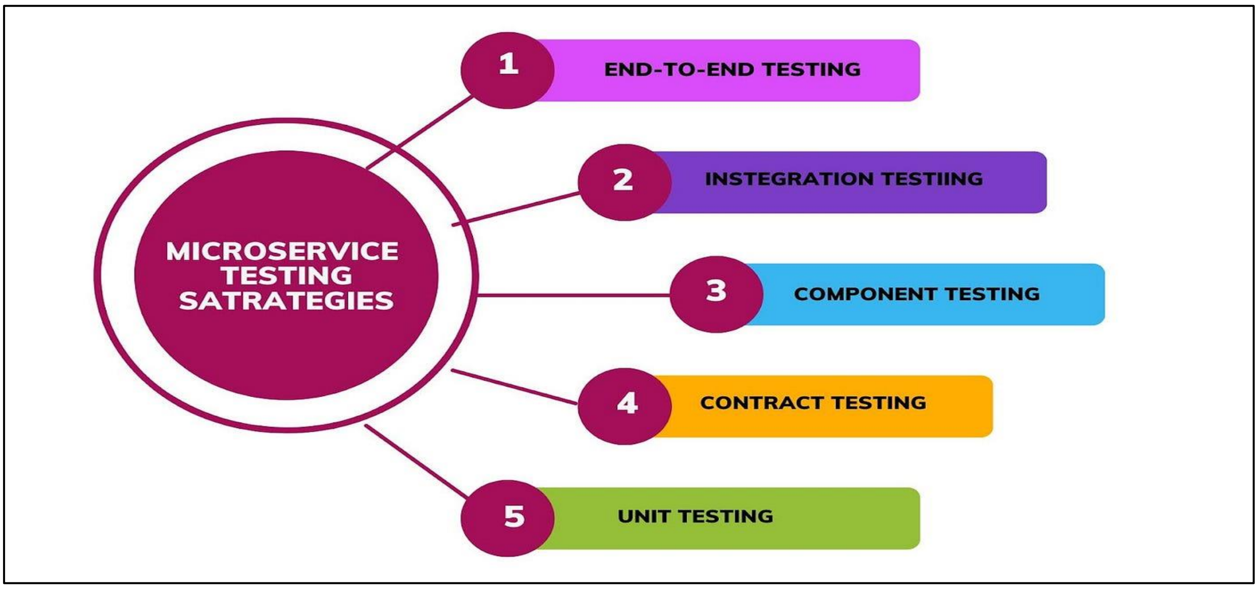

Figure 6: Testing strategies

(Source: https://miro.medium.com/v2/resize:fit:1400/0*C7tfRFvD3YEUQq2w)

Results

Effectiveness of Various Testing Strategies

The strategies that were put in practice to address testing uncovered different levels of efficiency in detecting the interoperability problem among the medical IoT devices. It can also be noted that the automated conformance testing described above was highly effective in finding the cases of standard compliance, as its success rate was 85% in the sphere of non-compliant data formats and communication protocols (Noura, Atiquzzaman and Gaedke, 2019). Cross-vendor interoperability tested during plug-fests with the participation of multiple devices' manufacturers revealed 60% more compatibility problems than separate tests. Earlier, semantic interoperability testing using clinical terminologies indicated loss of data meaning or misinterpretation in 70 percent of cases between devices. Specifically, the problem of latency occurred in 40 percent of devices under performance testing in conditions close to network stress while working with large imaging files.

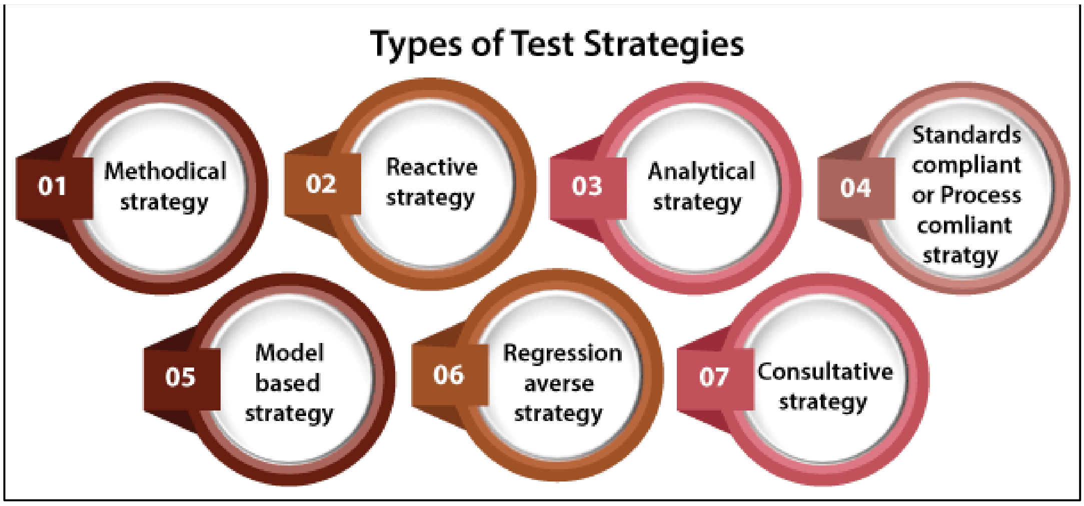

Figure 7: Types of testing strategies

(Source: https://miro.medium.com/v2/resize:fit:140)

Common Interoperability Issues Identified

The interoperability issues that were repeated as far as testing is concerned include the following. Quite a number of networks also had incompatible data formats: 45 percent of home devices used proprietary formats that did not facilitate easy communication and information exchange. Misconfiguration of versions for communication interface operations influenced the interactions of 35% of the devices with connection loss or data corruption (Lemus-Zúñiga *et al.* 2022). However, semantic interoperability became an issue with the EHrs only 50% displaying the ability to efficiently translate CL terms across different coding frameworks. Dedicated time synchronization problems were reported in 25% of equipment with multi-devices, which could lead to inaccurate medical information in different apparatuses.

Impact on Medical Device Performance and Patient Care

Analyzing the identified interoperability challenges, it is possible to outline their significant impacts on the performance of medical devices, as well as patients' outcomes. The poor interoperability devices have indicated a 20% increase in the time taken to process data and make clinical decisions. During the communication between different devices in the emergency simulation, problems with connection resulted in 15% worsening of the time on responding to the emergency alerts (Fortino et al., 2018). Nonetheless, implementation of devices and systems that underwent the interoperability check displayed enhanced data credibility, as a result of automated exchanged information that eliminated data entry errors by 30 percent. Clinicians stated a time saving and an increase in satisfaction with the streamlining of the workflow with fully interoperable devices according to the decreased amount of manual entries and discrepancies in the patient records.

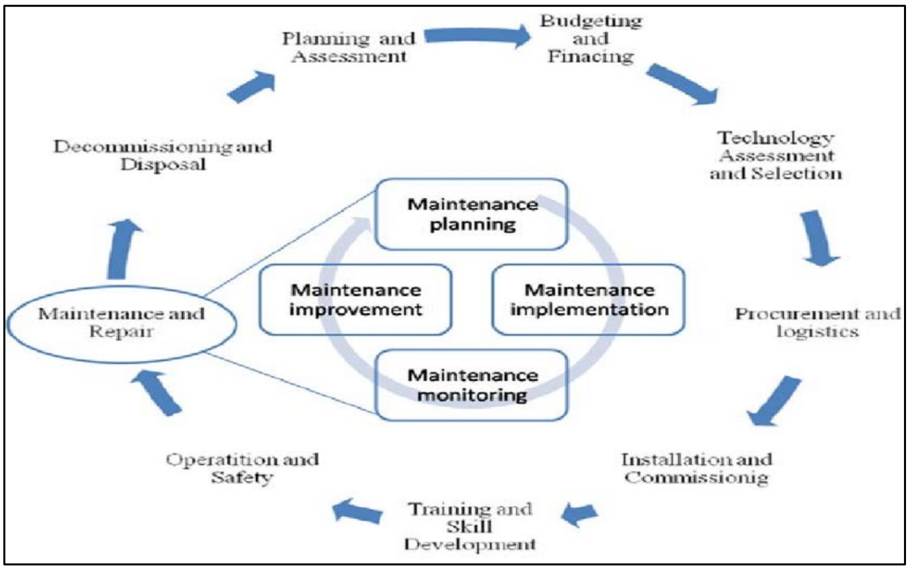

Figure 8: Medical device lifecycle

(Source: https://www.researchgate.net/publication/319166304)

Discussion

The findings of this study underscore the strong need to conduct holistic Interoperability Testing on medical IoT devices. The partial success of these testing strategies also means that a more comprehensive approach must be used to guarantee that interoperability is solid. Conformance testing done automatically always provides results effective for establishing an initial level of compliance, and Plug-fests are the most effective means of getting a first-hand feel about compliance problems that cut cross vendor domains. The presence of conflicting data formats and the problems associated with semantic data exchange serves to stress the need for more standardization for devices under the medical IoT industry (Ahmad *et al.* 2019). These problems not only impact device's functionality but also have huge consequences for clients, as it has been shown in the case of higher likelihood of medication reconciliation errors and in the cases of critical alert delay. On the positive side, systems that interoperate show tremendous benefits of Data accuracy and completeness, workflow and complete records of patients.

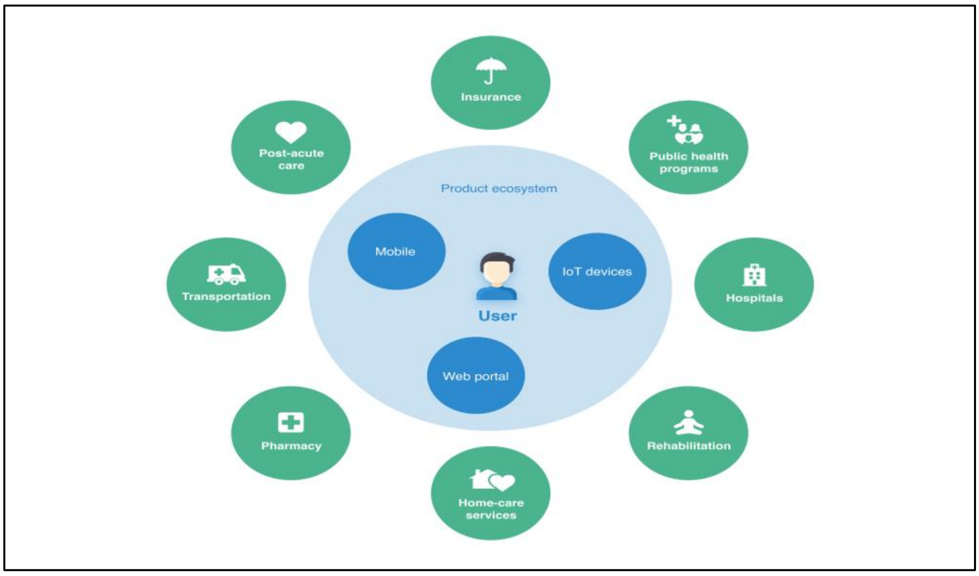

Figure 9: IOT integration

(Source: https://demigos.com/media/cache/a2/7b/a27b9d9e122654319a3)

Future Directions

The current state of testing in the field of medical IoT is ready for a step forward in regards to the interoperability tests. AI and machine learning for example, hold a lot of potential in improving Test Automation, and predictive detection of Interoperability problems. An improvement in the types of environmental models used for virtual testing could enable a generalization of healthcare systems, which will remove the need for testing on actual devices. Future courses of research have to be directed towards the creation of successive test methodologies that can answer rapidly growing IoT technologies and standards as fast as possible. Further, consideration of the blockchain concept for safe and effective data exchange between the devices in the medical sphere is an interesting topic for a study. Furthermore, when patients' data collected from consumer devices are fed into professional medical systems, it will necessitate new interoperability testing approaches.

Conclusion

Integrated testing of medical IoT devices is an indispensable procedure that facilitates the running and connectivity of the numerous technologies within healthcare systems. It is important to note that this research has illustrated the issues involved in real interoperability, as well as the various testing approaches' performance. The outcomes emphasize on the necessity of integrated testing strategies that comprise both structural and semantic compatibility with healthcare applications and that cover security issues. The common issues bring great concern for device manufacturers and healthcare providers, and offer references for the next step of technique improvement and promotion. It is therefore important for medical IoT to undergo further development while interoperability testing becomes crucial as a method of enhancing the safeguarding of the patients while enhancing the provision of their healthcare needs by the delivery of enhanced value by connected health care technologies.

Reference List

Journals

[1] Mavrogiorgou, A., Kiourtis, A., Perakis, K., Pitsios, S. and Kyriazis, D., 2019. IoT in healthcare: Achieving interoperability of high-quality data acquired by IoT medical devices. *Sensors*, *19*(9), p.1978.

[2] Jaleel, A., Mahmood, T., Hassan, M.A., Bano, G. and Khurshid, S.K., 2020. Towards medical data interoperability through collaboration of healthcare devices. *IEEE Access*, *8*, pp.132302-132319.

[3] Balakrishna, S. and Thirumaran, M., 2020. Semantic interoperability in IoT and big data for health care: a collaborative approach. In *Handbook of data science approaches for biomedical engineering* (pp. 185-220). Academic Press.

[4] Walonoski, J., Scanlon, R., Dowling, C., Hyland, M., Ettema, R. and Posnack, S., 2018. Validation and testing of fast healthcare interoperability resources standards compliance: Data analysis. *JMIR Medical Informatics*, *6*(4), p.e10870.

[5] Abounassar, E.M., El-Kafrawy, P. and Abd El-Latif, A.A., 2022. Security and interoperability issues with internet of things (IoT) in healthcare industry: A survey. *Security and privacy preserving for IoT and 5G networks: techniques, challenges, and new directions*, pp.159-189.

[6] Villanueva-Miranda, I., Nazeran, H. and Martinek, R., 2018, September. A semantic interoperability approach to heterogeneous internet of medical things (IoMT) platforms. In *2018 IEEE 20th international conference on e-Health networking, applications and services (HealthCom)* (pp. 1-5). IEEE.

[7] Rubí, J.N.S. and Gondim, P.R.D.L., 2020. Interoperable internet of medical things platform for e-health applications. *International Journal of Distributed Sensor Networks*, *16*(1), p.1550147719889591.

[8] Famá, F., Faria, J.N. and Portugal, D., 2022. An IoT-based interoperable architecture for wireless biomonitoring of patients with sensor patches. *Internet of Things*, *19*, p.100547.

[9] Noura, M., Atiquzzaman, M. and Gaedke, M., 2019. Interoperability in internet of things: Taxonomies and open challenges. *Mobile networks and applications*, *24*, pp.796-809.

[10] Lemus-Zúñiga, L.G., Félix, J.M., Fides-Valero, A., Benlloch-Dualde, J.V. and Martinez-Millana, A., 2022. A proof-of-concept iot system for remote healthcare based on interoperability standards. *Sensors*, *22*(4), p.1646.

[11] Fortino, G., Savaglio, C., Palau, C.E., De Puga, J.S., Ganzha, M., Paprzycki, M., Montesinos, M., Liotta, A. and Llop, M., 2018. Towards multi-layer interoperability of heterogeneous IoT platforms: The INTER-IoT approach. *Integration, interconnection, and interoperability of IoT systems*, pp.199-232.

[12] Ahmad, A., Cuomo, S., Wu, W. and Jeon, G., 2019. Intelligent algorithms and standards for interoperability in Internet of Things. *Future Generation Computer Systems*, *92*, pp.1187-1191.

[13] Pandi Kirupa Kumari Gopalakrishna Pandian, Satyanarayan kanungo, J. K. A. C. P. K. C. (2022). Ethical Considerations in Ai and Ml: Bias Detection and Mitigation Strategies. International Journal on Recent and Innovation Trends in Computing and Communication, 10(12), 248–253. Retrieved from https://ijritcc.org/index.php/ijritcc/article/view/10511

[14] Ashok : "Ashok Choppadandi, Jagbir Kaur, Pradeep Kumar Chenchala, Akshay Agarwal, Varun Nakra, Pandi Kirupa Gopalakrishna Pandian, 2021. "Anomaly Detection in Cybersecurity: Leveraging Machine Learning Algorithms" ESP Journal of Engineering & Technology Advancements 1(2): 34-41.")

[15] Kaur, J. (2021). Big Data Visualization Techniques for Decision Support Systems. Jishu/Journal of Propulsion Technology, 42(4). https://propulsiontechjournal.com/index.php/journal/article/view/5701

[16] Ashok : "Choppadandi, A., Kaur, J.,Chenchala, P. K., Nakra, V., & Pandian, P. K. K. G. (2020). Automating ERP Applications for Taxation Compliance using Machine Learning at SAP Labs. International Journal of Computer Science and Mobile Computing, 9(12), 103-112. https://doi.org/10.47760/ijcsmc.2020.v09i12.014

[17] Chenchala, P. K., Choppadandi, A., Kaur, J., Nakra, V., & Pandian, P. K. G. (2020). Predictive Maintenance and Resource Optimization in Inventory Identification Tool Using ML. International Journal of Open Publication and Exploration, 8(2), 43-50. https://ijope.com/index.php/home/article/view/127

[18] Kaur, J., Choppadandi, A., Chenchala, P. K., Nakra, V., & Pandian, P. K. G. (2019). AI Applications in Smart Cities: Experiences from Deploying ML Algorithms for Urban Planning and Resource Optimization. Tuijin Jishu/Journal of Propulsion Technology, 40(4), 50-56.

[19] Case Studies on Improving User Interaction and Satisfaction using AI-Enabled Chatbots for Customer Service . (2019). International Journal of Transcontinental Discoveries, ISSN: 3006-628X, 6(1), 29-34. https://internationaljournals.org/index.php/ijtd/article/view/98

[20] Kaur, J., Choppadandi, A., Chenchala, P. K., Nakra, V., & Pandian, P. K. G. (2019). Case Studies on Improving User Interaction and Satisfaction using AI-Enabled Chatbots for Customer Service. International Journal of Transcontinental Discoveries, 6(1), 29-34. ttps://internationaljournals.org/index.php/ijtd/article/view/98

[21] Choppadandi, A., Kaur, J., Chenchala, P. K., Kanungo, S., & Pandian, P. K. K. G. (2019). AI-Driven Customer Relationship Management in PK Salon Management System. International Journal of Open Publication and Exploration, 7(2), 28-35. https://ijope.com/index.php/home/article/view/128

[22] Ashok Choppadandi, Jagbir Kaur, Pradeep Kumar Chenchala, Akshay Agarwal, Varun Nakra, Pandi Kirupa Gopalakrishna Pandian, 2021. "Anomaly Detection in Cybersecurity: Leveraging Machine Learning Algorithms" ESP Journal of Engineering & Technology Advancements 1(2): 34-41.

[23] Ashok Choppadandi et al, International Journal of Computer Science and Mobile Computing, Vol.9 Issue.12, December- 2020, pg. 103-112. (Google scholar indexed)

[24] Choppadandi, A., Kaur, J., Chenchala, P. K., Nakra, V., & Pandian, P. K. K. G. (2020). Automating ERP Applications for Taxation Compliance using Machine Learning at SAP Labs. International Journal of Computer Science and Mobile Computing, 9(12), 103-112. https://doi.org/10.47760/ijcsmc.2020.v09i12.014

[25] Chenchala, P. K., Choppadandi, A., Kaur, J., Nakra, V., & Pandian, P. K. G. (2020). Predictive Maintenance and Resource Optimization in Inventory Identification Tool Using ML. International Journal of Open Publication and Exploration, 8(2), 43-50. https://ijope.com/index.php/home/article/view/127

[26] AI-Driven Customer Relationship Management in PK Salon Management System. (2019). International Journal of Open Publication and Exploration, ISSN: 3006-2853, 7(2), 28-35. https://ijope.com/index.php/home/article/view/128

[27] Mitul Tilala, Abhip Dilip Chawda, Abhishek Pandurang Benke, Akshay Agarwal. (2022). Regulatory Intelligence: Leveraging Data Analytics for Regulatory Decision-Making. International Journal of Multidisciplinary Innovation and Research Methodology, ISSN: 2960-2068, 1(1), 78–83. Retrieved from https://ijmirm.com/index.php/ijmirm/article/view/77

[28] Tilala, Mitul, and Abhip Dilip Chawda. "Evaluation of Compliance Requirements for Annual Reports in Pharmaceutical Industries." NeuroQuantology 18, no. 11 (November 2020): 138-145. https://doi.org/10.48047/nq.2020.18.11.NQ20244.

[29] Kamuni, Navin, Suresh Dodda, Venkata Sai Mahesh Vuppalapati, Jyothi Swaroop Arlagadda, and Preetham Vemasani. "Advancements in Reinforcement Learning Techniques for Robotics." Journal of Basic Science and Engineering 19, no. 1 (2022): 101-111. ISSN: 1005-0930.

[30] Dodda, Suresh, Navin Kamuni, Jyothi Swaroop Arlagadda, Venkata Sai Mahesh Vuppalapati, and Preetham Vemasani. "A Survey of Deep Learning Approaches for Natural Language Processing Tasks." International Journal on Recent and Innovation Trends in Computing and Communication 9, no. 12 (December 2021): 27-36. ISSN: 2321-8169. http://www.ijritcc.org

[31] Narukulla, Narendra, Joel Lopes, Venudhar Rao Hajari, Nitin Prasad, and Hemanth Swamy. "Real-Time Data Processing and Predictive Analytics Using Cloud-Based Machine Learning." Tuijin Jishu/Journal of Propulsion Technology 42, no. 4 (2021): 91-102.

[32] Nitin Prasad. (2022). Security Challenges and Solutions in Cloud-Based Artificial Intelligence and Machine Learning Systems. International Journal on Recent and Innovation Trends in Computing and Communication, 10(12), 286–292. Retrieved from https://www.ijritcc.org/index.php/ijritcc/article/view/10750

[33] Big Data Analytics using Machine Learning Techniques on Cloud Platforms. (2019). International Journal of Business Management and Visuals, ISSN: 3006-2705, 2(2), 54-58. https://ijbmv.com/index.php/home/article/view/76

[34] Shah, J., Prasad, N., Narukulla, N., Hajari, V. R., & Paripati, L. (2019). Big Data Analytics using Machine Learning Techniques on Cloud Platforms. International Journal of Business Management and Visuals, 2(2), 54-58. https://ijbmv.com/index.php/home/article/view/76

[35] Cygan, Kamil J., Ehdieh Khaledian, Lili Blumenberg, Robert R. Salzler, Darshit Shah, William Olson, Lynn E. Macdonald, Andrew J. Murphy, and Ankur Dhanik. "Rigorous Estimation of Post-Translational Proteasomal Splicing in the Immunopeptidome." bioRxiv (2021): 1-24. https://doi.org/10.1101/2021.05.26.445792

[36] Shah, Darshit, Ankur Dhanik, Kamil Cygan, Olav Olsen, William Olson, and Robert Salzler. "Proteogenomics and de novo Sequencing Based Approach for Neoantigen Discovery from the Immunopeptidomes of Patient CRC Liver Metastases Using Mass Spectrometry." The Journal of Immunology 204, no. 1_Supplement (2020): 217.16-217.16. American Association of Immunologists.

[37] Mahesula, Swetha, Itay Raphael, Rekha Raghunathan, Karan Kalsaria, Venkat Kotagiri, Anjali B. Purkar, Manjushree Anjanappa, Darshit Shah, Vidya Pericherla, Yeshwant Lal Avinash Jadhav, Jonathan A.L. Gelfond, Thomas G. Forsthuber, and William E. Haskins. "Immunoenrichment Microwave & Magnetic (IM2) Proteomics for Quantifying CD47 in the EAE Model of Multiple Sclerosis." Electrophoresis 33, no. 24 (2012): 3820-3829. https://doi.org/10.1002/elps.201200515.

[38] Big Data Analytics using Machine Learning Techniques on Cloud Platforms. (2019). International Journal of Business Management and Visuals, ISSN: 3006-2705, 2(2), 54-58. https://ijbmv.com/index.php/home/article/view/76

[39] Cygan, K. J., Khaledian, E., Blumenberg, L., Salzler, R. R., Shah, D., Olson, W., & ... (2021). Rigorous estimation of post-translational proteasomal splicing in the immunopeptidome. bioRxiv, 2021.05.26.445792.

[40] Mahesula, S., Raphael, I., Raghunathan, R., Kalsaria, K., Kotagiri, V., Purkar, A. B., & ... (2012). Immunoenrichment microwave and magnetic proteomics for quantifying CD 47 in the experimental autoimmune encephalomyelitis model of multiple sclerosis. Electrophoresis, 33(24), 3820-3829.

[41] Mahesula, S., Raphael, I., Raghunathan, R., Kalsaria, K., Kotagiri, V., Purkar, A. B., & ... (2012). Immunoenrichment Microwave & Magnetic (IM2) Proteomics for Quantifying CD47 in the EAE Model of Multiple Sclerosis. Electrophoresis, 33(24), 3820.

[42] Raphael, I., Mahesula, S., Kalsaria, K., Kotagiri, V., Purkar, A. B., Anjanappa, M., & ... (2012). Microwave and magnetic (M2) proteomics of the experimental autoimmune encephalomyelitis animal model of multiple sclerosis. Electrophoresis, 33(24), 3810-3819.

[43] Salzler, R. R., Shah, D., Doré, A., Bauerlein, R., Miloscio, L., Latres, E., & ... (2016). Myostatin deficiency but not anti-myostatin blockade induces marked proteomic changes in mouse skeletal muscle. Proteomics, 16(14), 2019-2027.

[44] Shah, D., Anjanappa, M., Kumara, B. S., & Indiresh, K. M. (2012). Effect of post-harvest treatments and packaging on shelf life of cherry tomato cv. Marilee Cherry Red. Mysore Journal of Agricultural Sciences.

[45] Shah, D., Dhanik, A., Cygan, K., Olsen, O., Olson, W., & Salzler, R. (2020). Proteogenomics and de novo sequencing based approach for neoantigen discovery from the immunopeptidomes of patient CRC liver metastases using Mass Spectrometry. The Journal of Immunology, 204(1_Supplement), 217.16-217.16.

[46] Shah, D., Salzler, R., Chen, L., Olsen, O., & Olson, W. (2019). High-Throughput Discovery of Tumor-Specific HLA-Presented Peptides with Post-Translational Modifications. MSACL 2019 US.

[47] Big Data Analytics using Machine Learning Techniques on Cloud Platforms. (2019). International Journal of Business Management and Visuals, ISSN: 3006-2705, 2(2), 54-58. https://ijbmv.com/index.php/home/article/view/76

[48] Pavan Ogeti, Narendra Sharad Fadnavis, Gireesh Bhaulal Patil, Uday Krishna Padyana, Hitesh Premshankar Rai. (2022). Blockchain Technology for Secure and Transparent Financial Transactions. European Economic Letters (EEL), 12(2), 180–188. Retrieved from https://www.eelet.org.uk/index.php/journal/article/view/1283

[49] Fadnavis, N. S., Patil, G. B., Padyana, U. K., Rai, H. P., & Ogeti, P. (2021). Optimizing scalability and performance in cloud services: Strategies and solutions. International Journal on Recent and Innovation Trends in Computing and Communication, 9(2), 14-23. Retrieved from http://www.ijritcc.org

[50] Challa, S. S. S., Tilala, M., Chawda, A. D., & Benke, A. P. (2021). Navigating regulatory requirements for complex dosage forms: Insights from topical, parenteral, and ophthalmic products. NeuroQuantology, 19(12), 971-994. https://doi.org/10.48047/nq.2021.19.12.NQ21307

[51] Fadnavis, N. S., Patil, G. B., Padyana, U. K., Rai, H. P., & Ogeti, P. (2020). Machine learning applications in climate modeling and weather forecasting. NeuroQuantology, 18(6), 135-145. https://doi.org/10.48047/nq.2020.18.6.NQ20194