Accessibility of the node-red iot framework: an integrative review

Acessibilidade do framework de IoT node-red: uma revisão integrativa

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Abstract

Industry 4.0 technologies are rising in the international market, especially the Internet of Things, better known as IoT (Internet of Things). The demand for software development for IoT technologies is also growing. Considering that human beings have several disabilities and specific needs, including among the professionals who can develop and deploy the technology, this work aimed to understand if there is accessibility in the IoT framework Node-Red®. To do so, an integrative literature review evaluated the use of the Node-Red framework®. We observed how the researchers applied the technologies and if there is accessibility and adequacy to the W3C (World Wide Web Consortium) rules since the W3C regulates ideal software development standards, including those of accessibility. With the analysis, it was possible to evidence that there are simple movements in favor of User Experience (UX) and accessibility in a generic way in several scenarios, from home use, business, industry, and health. The search results were demonstrated through data categorization, synthesis matrix, and descriptive analysis. The knowledge discussion and synthesis pointed out the contribution points of each paper and the literature gaps on accessibility for an IoT framework. Our findings showed that each paper contributed to this discussion and argued that even though there are no significant limitations pointed out by the authors reviewed for IoT implementation and accessibility, and they also discussed little or nothing about accessibility and W3C standards in their papers.

Keywords: Node-Red; Accessibility; W3C; Internet of Things; IoT.

Resumo

As tecnologias da Indústria 4.0 estão em ascensão no mercado internacional, em especial a Internet das Coisas, mais conhecida por IoT (Internet of Things). É crescente também a demanda por desenvolvimento de software para as tecnologias de IoT. Considerando que os seres humanos possuem deficiências e necessidades específicas diversas, inclusive entre os profissionais que podem desenvolver e implantar a tecnologia, este trabalho teve por objetivo a compreensão se há acessibilidade no framework de IoT Node-Red®. Para tanto, foi realizada uma revisão integrativa de literatura que avaliou a utilização do framework Node-Red®. Foi observado como as tecnologias foram aplicadas pelos pesquisadores e se existe acessibilidade e adequação às regras do W3C (World Wide Web Consortium), uma vez que o W3C regulamenta padrões ideais de desenvolvimento de software, inclusive os de acessibilidade. Com a análise, foi possível evidenciar que existem movimentos singelos em prol da Experiência do Usuário (UX) e acessibilidade de forma genérica em diversos cenários, desde o uso doméstico, empresarial, industrial e na saúde. Foram demonstrados os resultados da busca por meio de categorização dos dados, matriz de síntese e análise descritiva. A discussão e síntese do conhecimento apontou os pontos de contribuição de cada trabalho e as lacunas de literatura sobre a acessibilidade para um framework de IoT. Foi detalhado o que cada artigo contribuiu para esta discussão, e argumentado que mesmo não existindo grandes limitações apontadas pelos autores revistados para implementação de IoT e acessibilidade, estes também discutiram pouco ou nada sobre acessibilidade e padrões W3C em seus trabalhos.

Palavras-chave: Node-Red; Accessibility; W3C; Internet of Things; IoT.

1. INTRODUCTION

Accessibility is an intrinsic factor in the sine qua non-condition of usability and user experience (UX). For accessibility to be implemented, a given platform must contain a particular design whose components have a familiar and intuitive appearance, made available in different ways in terms of adaptability (GUIMARÃES and TAVARES, 2014). The World Wide Web Consortium provides accessibility criteria as good development practices (W3C, 2022). Accessible software must be programmed and developed to adapt according to the needs and experiences of each user with no additional costs for its use or any loss/delivery of information.

In times contemporary to the 4th Industrial Revolution and to the booming evolution of mobile phone networks and other wireless internet connections, the Internet of Things, better known as the Internet of Things (IoT), permeates homes, industries, and even urban spaces, as in the Smart Cities (Pinto Junior, 2021). Thus, as the presence of these devices in the market grows, so does the demand for software development for these technologies. Considering that the human population has several disabilities and specific needs, including among the professionals who can develop this type of technology, this work aimed to understand if there is accessibility in the development framework for IoT Node-Red®.

An integrative literature review was conducted to evaluate the use of the Node-Red® framework in the software industry. This type of review was chosen because, as explained by Whittemore (2005), Torraco (2011), and Botelho (2011), it makes it possible to visualize the evolution of a theme over some time and has the characteristic of systematizing,

organizing, integrating and synthesizing new knowledge from the review of this theme in the analyzed time frame.

For the study, the scientific databases Science Direct®, ACM Digital Library®, IEEE Xplore®, Scopus®, Web of Science® and CAPES® were chosen. The search key "Node-Red" AND "accessibility" AND "W3C" were used in all of them. The first three bases were chosen because they are the most directed to the publication of research carried out in the Computing area. It is part of the objective of this study to understand how the computing area has dealt with accessibility issues for the Node-Red framework®. The other databases were used to promote a more comprehensive search. In the retrieved studies related to the analysis of the Node-Red framework®, we verified if the accessibility issue was dealt with and/or if there was an investigation about the adequacy of the W3C standards since the W3C is the international organ that regulates ideal software development standards, including accessibility standards.

According to Pinto Junior (2017), "IoT is a network of physically identifiable objects globally, which integrate with the Internet and are representable in the virtual world." Thinking of technology of global scope that interconnects the most heterogeneous devices worldwide, the demand for software for these devices tends to grow over time. Following the trends of software development for other areas, the IoT area also increasingly uses the help of frameworks that allow programming with less code and more through graphical representations. In this sense that Node-Red® has emerged, which, like countless other Information and Communication Technology

(ICT) frameworks in the software industry, integrates UI and UX aspects. These implemented aspects ideally should include accessibility standards and conformance to W3C templates. Since design should be accessible and also universal to all users of software and hardware artifacts, this review sought to answer whether this is done in the ideal/appropriate way. It is recommended that these issues are constantly in research, particularly in the field of information design and software industry, because it is a duty and an act of social justice to enable the access of all people to information and media so widespread in today's society (ULBRICHT, 2013).

Node-Red® is an open-source web-based software framework for IoT, in Application Programming Interface (API) format originally developed by IBM's Emerging Technologies and Services segment® in 2003. It is a structure based on nodes that make up a flow of blocks, where each node has a specific code abstraction, and through drag-and-drop, one can drag and drop blocks to build applications. Each node, formed by a block, can be interconnected with others in order to generate applications for different purposes, with visually rich elements that generate a machine language conversion that will be executed (NODE-RED, 2022).

Besides this introduction that contextualizes and justifies the problem of accessibility for the Node-Red framework®, this study also counts on a review. Section 2 covers the concepts that support the discussions of the work, followed by the methodological description in section 3, with a presentation of the research questions, a presentation of the results from the extraction of data in section 4, the data analysis in section 5, and, lastly, the discussion and synthesis of knowledge in section 6. The concluding remarks conclude the paper.

2. THEORETICAL BACKGROUND

2.1 Industry 4.0

The 4th Industrial Revolution, or as it is popularly called - Industry 4.0, is the revolution of cyberconnected systems allowing devices to exchange information (PIANA, 2022). It is based on integrating information and communication technologies, allowing the generation of new strategies and business models.

The technologies that act as pillars for the modernization of the current scenario are Big Data, Cloud Computing, and IoT. Big Data refers to the enormous amount of data generated in industrial, commercial, and user behavior processes. For ease of access or security reasons, the data generated can be stored on servers in different locations through Cloud Computing (CC). Another relevant aspect is that the objects now have sensors and actuators and the ability to connect to the internet and interact with humans or other objects. Such technology is IoT or IoE (Internet of Everything) (KHODADADI et al., 2016).

2.2 IoT

IoT is an information and communications technology infrastructure for collecting and distributing data that can influence the efficiency and performance of systems. With the use of IoT, it is possible to connect heterogeneous devices, manage and exchange information, as well as accurately track location, optimize energy use, and preserve privacy and security by enabling the use of wireless communication technologies (KHODADADI et al., 2016; THULUVA et al., 2017).

Endres et al. (2022) have broken down the IoT interfaces in a way that bases them on encapsulation and distinct interfaces, thus making up the structures: physical, cloud, communication, and information service layer. These four layers cover hardware and software and all levels of integration required for any current IoT approach (Figure 1).

Figure 1 - IoT architecture is illustrated in its physical, cloud, service, and communication layers
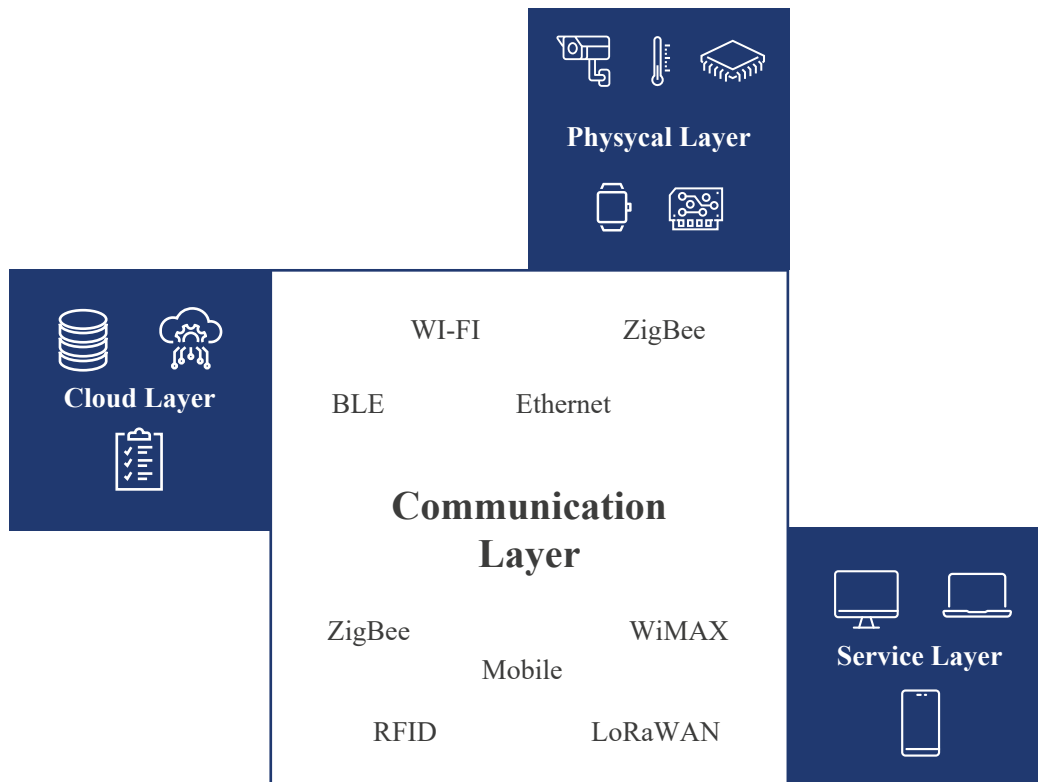
Source: Endres et al. (2022)

2.3 Node-Red

The Node-Red® data flow acts in a flow of blocks (which are called nodes or nodes), where each node has a code abstraction and specific function to drag and drop, which facilitates the technical implementation work and aims at a different approach from what is traditionally promoted within the proprietary and closed-source reality. Because it is open source, built on an HTML5 web interface, and with Javascript®, the software framework has high dynamism and a high degree of adaptability to different scenarios. Moreover, by working in a request format, the API Rest (Representational State Transfer) can handle countless requests as an efficient web service (NODE-RED, 2022).

In addition to the functions available for connecting IoT devices, it also composes its web service, a selected palette of sensors and actuators, which can be applied according to the programming logic for the appropriate events. Each node can be interconnected with others to generate applications of different purposes with visually rich elements that generate conversion to machine language that will be executed (XIAO et al., 2019; ANITHA, 2020; PADMA, 2019).

2.4 W3C

The W3C standards are referenced worldwide in programming languages and digital, enabling technologies to compose a range of language and code perspectives to create a well-crafted Internet standard for everyone. Through thousands of compendia, communities can draw upon to create the most diverse systems so that they can cross cultural barriers, eliminate impediments to use, and further enhance the experience and usability of those who use a given system. Several W3C assessment tools assess the different life cycles of software artifacts. It is up to software engineers, programmers, developers, and all those who work with data to choose the ideal assessment tool and application for each context. The benefits of applying their methods extend to technology users and systems that may significantly improve their operating performance (ATKINSON et al., 2017).

2.5 Accessibility

Accessibility is a marker for the final User Experience (UX) and should be evaluated continuously and inherently. The platform must have components with a familiar and intuitive appearance for users in its design. It must also be available in different forms of adaptability, judging the type of gadget or platform on which it will work. In other words, it must be programmed and developed to adapt according to the needs and experience of each user without burdening or hindering its use or any kind of loss of information and/or information delivery. Nevertheless, the W3C does not define specific accessibility characteristics or guidelines for devices based on the assumption that a computational artifact should be accessible to all, regardless of the access device. Its display can follow examples of best practices through modeling according to the W3C's international standards for content dis-

play, being responsive, and opting for best design and software practices. To do this, it is also necessary to follow the steps of Software Engineering, developing the technology with the support of the client/user, who will list the functional and non-functional requirements throughout the process. In an ideal development condition, the client will be present at all stages, co-creating with the development team, allowing the program to achieve the best user experience (UX) in a given interface (UI), according to their needs (KOREN 2018; KLAMMA, 2018; SOMMERVILLE, 2011).

3. METHODOLOGY

This article follows the integrative literature review method, which, according to Whittemore and Knafl (2005), aims to make a systemic, organized, and comprehensive synthesis of works relevant to answering a research question. In the integrative literature review, in addition to conducting the traditional literature review, it is necessary to analyze, critique, and synthesize new knowledge on the topic (TORRACO, 2011). The integrative review also brings the researcher closer to a particular theme because it allows him to know the evolutionary chronology of that theme in a given period (BOTELHO, 2011).

This study was conducted in 6 steps: 1) identifying the theme and elaboration of the research question, 2) elaborating the inclusion and exclusion criteria for the articles, 3) selecting the articles to be used through platform filters and reading of titles, keywords, and abstracts, 4) full reading of the articles to categorize the articles in affinity groups according to their characteristics, 5) analysis and interpretation of the results, and 6) finalization of the integrative review process with the synthesis of knowledge and answers to the research questions. Figure 2 shows a visual demonstration of the integrative review steps.

Figure 2 - Integrative literature review procedure
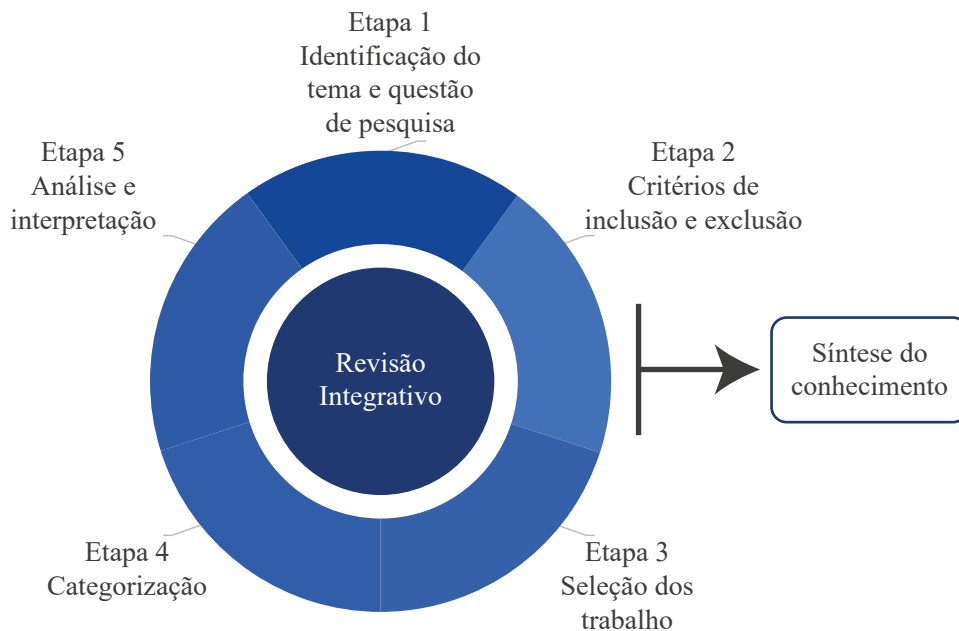
Source: Adapted from Botelho (2011)

3.1 Research Question

This study provides a comprehensive overview of the current literature. Also, it outlines trends, challenges, and research limitations that deserve to be investigated in the context of the application of Node-Red® in the software industry, in particular, regarding the presence of W3C standards and accessibility in it. Thus, the main research question of this paper is: "**Is there accessibility in the Node-Red IoT framework?**"

To answer the main question, supplementary research questions (CSQs) were developed to assist in answering the main research question. Table 1 presents an overview of the PCFs and the motivation for seeking to answer each of them.

Table 1 - Description of the complementary research questions and main motivations concerning the main research question

ID	QUESTION	MAIN MOTIVATION
QPC01	What are the main characteristics of the selected study?	Identify the characteristics and focus of each analyzed and selected study, since IoT can be applied to numerous distinct scenarios.
QPC02	Is there an accessibility specification within the technological process?	Identify the evaluative specificities of the accessibility process described in the studies.
QPC03	Do the technologies addressed in the work follow W3C standards?	Evaluate Web Content Accessibility Guidelines (WCAG) to international standard levels.

Source: From the authors (2022)

3.2 Databases

The articles were selected according to databases in the Engineering, Technology, and Humanities areas, evaluating the degree of importance that accessibility has compared to traditionally published works (Table 2). The first three databases were chosen for being the most directed to the publication of research carried out in the Computing area because it is part of the objective of study work to understand how the computing area has dealt with accessibility issues for the Node-Red framework®. The other databases were selected to promote a more comprehensive search, since Brazilian researchers frequently use them.

Table 2 - Databases used for the research

| DATABASES	WEBSITE
Science Direct®	https://www.sciencedirect.com/
ACM Digital Library®	https://dl.acm.org/
IEEE®	https://ieeexplore.ieee.org/
CAPES®	https://periodicos.capes.gov.br
Web of Science®	https://www.webofscience.com/
SCOPUS®	https://www.scopus.com/

Source: From the authors (2022)

3.3 Selection Process and Inclusion and Exclusion Criteria

First, an individual search was performed using the string < "Node-Red" AND "accessibility" AND "W3C">, adapting it to the syntax of each database. The initial search process identified 12 articles. After the filtering procedure for full articles resulted in 7 were selected, which, with the application of the last filter to restrict to the last 5 years, resulted in 5 selected papers (Figure 3). The procedures adopted in each search base considered only full articles, excluding works of other genres such as chapters, books, theses, or review articles.

Figure 3 - Paper selection process
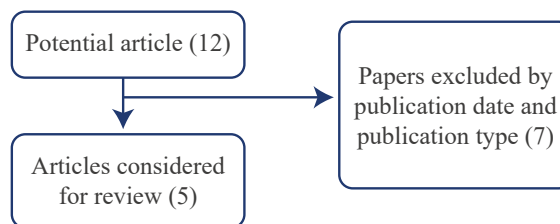
Source: From the authors (2022)

4. PRESENTATION OF RESULTS

4.1 Data Extraction Strategy and General Aspects

This section reports the aggregated results by research question based on the data extracted from the primary studies. Because the data included qualitative responses, a variety of approaches were used to synthesize the data. Descriptive synthesis was used to facilitate visualization of the findings and graphs and charts.

From the descriptive analysis that provides an overview of the articles selected in this study, Table 3 presents the number of articles found initially and the number of articles selected after applying the inclusion and exclusion criteria.

Table 3 - Quantitative number of papers found in the databases Science Direct®, ACM Digital Library®, CAPES®, IEEE®, Web of Science®, and SCOPUS.®

YEAR	STUDIES FOUND	SELECTED STUDIES
2017	0	0
2018	4	2
2019	2	2
2020	1	1
2021	1	0
2022	0	0

Source: From the authors (2022)

Table 3 also shows a decrease in publications in all years. In 2022, there were no publications, but this may have occurred because the sample was collected in July 2022. Figure 4 illustrates the percentage of studies published in the different databases over the 5 years of the literature review analyzed.

Figure 4 - percentage of articles found from 2017 to 2022

Extração de trabalho
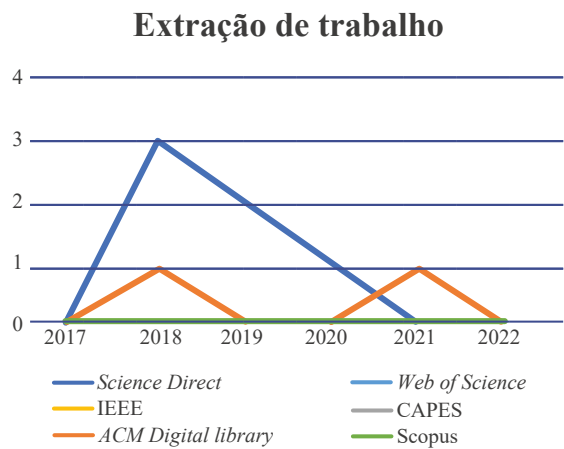
Source: From the authors (2022)

The largest number of studies was located in Science Direct®, followed by ACM®, and there were no results found in the others: CAPES®, IEEE®, Web of Science®, and Scopus®. The location of the study is an important factor because it makes it possible to map the countries dedicated to research on this topic. Figure 5 illustrates the countries where the retrieved research has been conducted.

Figure 5 - Location of the selected studies

Source: From the authors (2022)

As shown in Figure 5, the UK, Germany, Greece, Spain, Jordan, China, and Japan, all located in the northern hemisphere, had the most extensive range of published studies, totaling 87% of the selected total. In contrast, the only country in the southern hemisphere, Australia, had the remaining 13%.

5. DATA ANALYSIS AND INTEGRATION

This section presents the main characteristics of the selected studies, according to Complementary Research Question 01 (QPC01), the accessibility specifications within the technological process (QPC02),

and an evaluation of the observation to W3C standards (QPC03).

5.1 Categorization and Summary of the Papers

For data analysis, all articles were first read in their entirety. Then, each paper's descriptive synthesis was performed to obtain each paper's main contribution. The understanding gained from the synthesis allowed the categorization of data according to the proposed approaches and the preparation of a synthesis matrix based on the three keywords used in the search string (Node-Red, Accessibility, W3C), as listed in Tables 4 and 5.

Table 4 - Category and Correlation Matrix of the selected papers.

ID	DATABASE	AUTHORS	TITLE	CATEGORY
1	ACM	(Koren, 2018)	The Exploitation of OpenAPI Documentation for the Generation of Web Front Ends	Proposes/ implements an affordable solution
2	Science Direct	(Xhafa, 2020)	Evaluation of IoT stream processing at edge computing layer for semantic data enrichment	
3	Science Direct	(Kassab, 2020)	A-Z survey of Internet of Things: Architectures, protocols, applications, recent advances, future directions and recommendations	
4	Science Direct	(Xiao, 2019)	A Finite-State-Machine model-driven service composition architecture for the internet of things rapid prototyping	Based on W3C's ubiquitous accessibility standards
5	Science Direct	(Petrakis, 2018)	Internet of Things as a Service (iTaaS): Challenges and solutions for the management of sensor data on the cloud and the fog	

Source: From the authors (2022)

Table 5 - Synthesis Matrix of the selected papers

ID	NODE-RED	ACCESSIBILITY	W3C
1	It is cited as a software product that aggregates IoT devices.	It proposes a methodology for responsive web interfaces.	It follows W3C standards in the implementation of the proposal.
2	Cloud Application Server.	In the last stage of the study development, accessibility was implemented.	Cited W3C standards for RDF (Resource Description Framework).
3	One of the reviewed papers uses Node-Red® as an IoT middleware.	It is addressed in the W3C's concept of ubiquity: "technologies to enable Web access for anyone, anywhere, anytime, using any device."	Identified as a protocol standardizer.
4	One of three examples of flow-based composition tools analyzed.	Ubiquitous accessibility is referred to as a desirable requirement in cloud-based applications.	Cited as the originator of the OWL-S and SSN Ontology technologies.
5	Referred to as a service that supports "Mashup."	Ubiquitous accessibility is referred to as a desirable requirement in cloud-based applications.	Cited as the originator of the SSN Ontology technology.

Source: From the authors (2022)

In Table 4, the articles have been divided into two categories according to their purposes regarding accessibility. Koren (2018) and Xhafa (2020) are in the category where they propose/implement an accessible solution. Kassab (2020), Xiao (2019), and Petrakis (2018), nonetheless, differ in that they are not about developing accessible solutions but observing the W3C ubiquitous accessibility standards. Additionally, in this table, the five reviewed studies were arranged, and an ID was assigned to each one, making it possible to reference them in Table 5. Table 5 synthesizes how each of the studies addresses the Node-Red technology®, the accessibility issues, and the W3C entity.

5.2 Analysis of the Characteristics of the Papers

A critical analysis of the works was performed among themselves concerning the research questions and the ideal accessibility issues. The selected works presented great diversification of applications within the areas of knowledge and technology, varying the application of the IoT framework Node-Red®, such as in mobile applications, edge computing, and cloud computing that diversified in daily functions, in smart cities, and even connected with life maintenance systems (health). The authors used these technologies mainly as a service, identifying the abstraction layers as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), software as a Service (SaaS), and Internet of Things as a Service (iTaaS) architectures. With this, numerous practical examples of solutions and their application for commercial, domestic, and industrial uses were addressed.

Koren and Klamma (2018) performed an analysis under the gaze of Open APIs (Open Source), HTML5, and Javascript in their application for the different devices used and the effects they promote on the practices and use of the World Wide Web (WWW) users.

From requirements modeling to implementation and its transformation and adaptation to W3C standards. With this model, they sought to advocate the use of automatic and open source code generators, in a precursory way, as one of the areas for future work, reducing the limitations between software developers and users, aiming for an intentional way to evaluate the schemes produced in peer-to-peer validation.

Xhafa, Kilic, and Krause (2020) brought the concept of "Everything as a Service" (EaaS), which is intrinsic to cloud technologies and built knowledge from IoT data. In their study, they proposed to evaluate daily challenges applied to real life, for business and industry, with GUI accessibility and the use of Node-Red®.

Kassab and Darabkh (2020) created a compendium of several current real-world application examples, describing recommendations for architectures, protocols, applications, advancements, future directions, and recommendations for IoT usage. Their generalist implementation brought several possibilities for application environments with research challenges. They also identified that the architecture model of IoT as a service should be considered the most efficient design to obtain benefits such as availability, scalability, reusability, and platform independence, promoting the importance of ubiquity/accessibility of data for the agents involved in the process.

Xiao, Wu, and Wang (2019) exposed the vulnerabilities of traditional and proprietary IoT development models, highlighting the high cost of the architectures and the low reusability. Their work discussed practical cases in the technology implementation spectrum, seeking agile development models directed to events and open-source frameworks, obtaining unique implementation advantages in the Sensing-and-Actuation-as-a-Service

(SAaaS) application. The authors further defended the union of heterogeneous services and hardware as a worrisome factor of monolithic architectures that is dynamically solved by migrating to open-domain and modular implementation systems, such as Node-Red®. They highlighted that IoT accessibility among process agents is facilitated ubiquitously using web frameworks, compared to traditional market-based, closed-source solutions.

Lastly, Petrakis et al. (2018) proposed in their paper that the trend toward e-Health (healthcare) is inexorable. That is, it calls into question the traditional apparatus model for healthcare to cite several beneficial movements of virtualization of current and future devices, citing issues of intelligent intervention by healthcare agents for medical treatment that can assess and act under the patient. However, they also signaled the problems arising from data privacy and security, since synchronization would be taking place through web microservices, potentially exposing user data if precautionary interface measures are not implemented. In this sense, the work defended a modular and expandable construction of IoT for e-Health in the "Web of Things," oriented to Service-Oriented Architecture (SOA). They defended the application of Node-Red® with adaptability, low cost, and scalability for iTaaS, without clarifying specifically how they dealt with accessibility issues and only informing that the technology promotes several bonuses between patients and health professionals.

5.3 Accessibility Specifications and W3C Standards

One can observe the market and academic commotion to promote the development and implementation processes of technology applications accessible to users,

either by usability issues (UX) or financial-economic issues. Developing and using open hardware and software technologies reduce acquisition costs, and the collaboration made possible by this type of software also facilitates the implementation of accessibility. These technologies also make it easier for programmers to modify and adapt, implement bug fixes, and improve the availability, integrity, confidentiality, usability, and accessibility/uniqueness of information.

Among the reviewed works, accessibility references are brief or superficial in the works by Koren (2018), Xiao (2019), and Xhafa (2019). As for W3C standards, which also contribute to feature implementation, the emphasis is on the works by Koren (2018), Xhafa (2019), and Petrakis (2018). How these studies addressed these topics are presented below.

In the study of Koren and Klamma (2018), they noted examples of transformation for the web that was described as best practices seeking high user accessibility where they described ways to indent and organize inter-nal elements of the web page available to the user and background patterns for developing and programming the API for Node-Red®. They followed guide examples in templates and focused a lot on applying W3C standards for content display.

Koren and Klamma (2018) analyzed the application of HTML5 standards, Javascript, and responsive components for real-time edge computing applied to the Internet of Things. With the use of W3C standards in a method that meets Model Driven Architecture (MDA) for end-user responsiveness. In their approach, every device had its modeling flow-oriented navigation by components that were easy and familiar to navigate between its operation flows and actions, where each request from the device is handled by the API, as illustrated in Figure 6. Another important highlight of the authors is that when working in this format, the page identity can be recognized by its actors, activating triggers that will automatically transform its structure in favor of the best scenario.

Figure 6 - Workflows between the API, the proposed model, and the device access
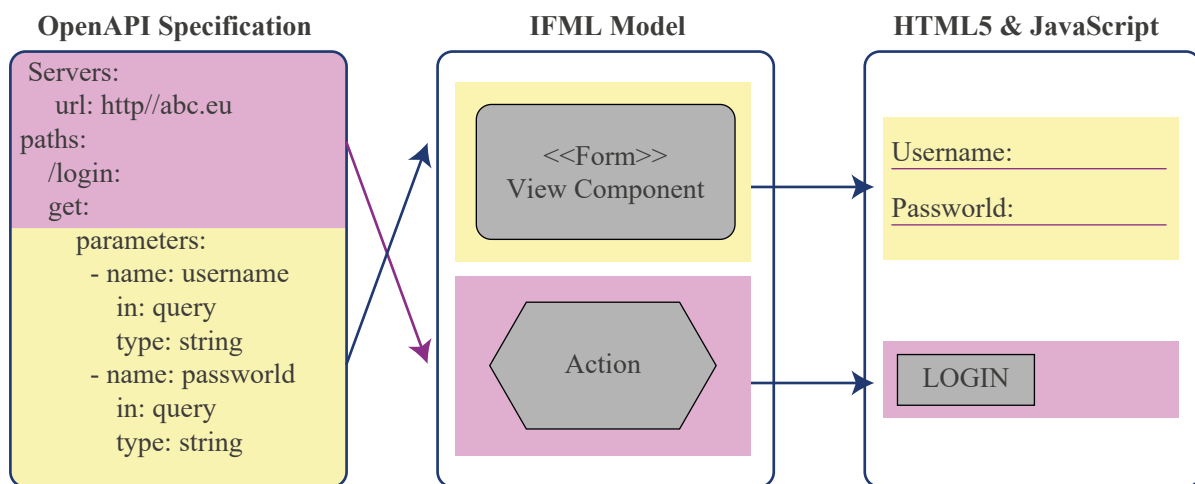

Source: Koren and Klamma (2018)

Koren and Klamma (2018) further defined that W3C standards have significantly contributed to a more open, standardized, and accessible web for different audiences making it practically universal. The researchers made the comparison that the web is like a galaxy of connections, where by implementing technological investments and the standardization and use of standards, one can share information through the W3C model. This model describes alternatives to support interoperable exchange in heterogeneous web and IoT environments and the Interaction Flow Modeling Language (IFML) and Scalable Vector Graphics (SVG) models.

Nevertheless, Petrakis et al. (2018) discussed several limitations of meeting the requirements of scalability, reusability, tenacity, security, and accessibility. Such requirements were pointed out in the analysis of health care scenarios, signaling an increasing connection of medical apparatus and life care sensors connecting to the growing flow of Big Data data. In this study, the researchers suggested the application of a Semantic Sensor Network (SSN) to meet a W3C standards ontology, enabling the application of a wide range of IoT devices using the SPARQL protocol for standardized querying of knowledge graphs. In this approach, they suggested that the iTaaS model be applied on two distinct sides: a) IoT Side and b) Cloud Side, as shown in Figure 7.

Figure 7 - Diagram of the logical application interfaces for the IoT and Cloud sides
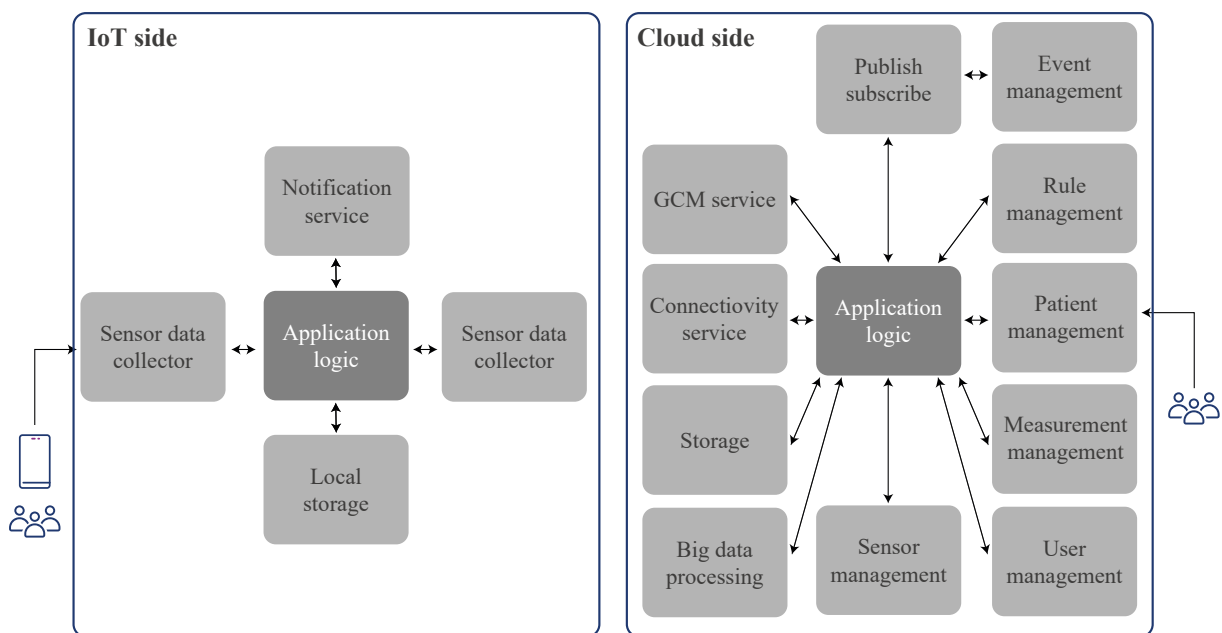
Source: Petrakis et al. (2018)

In addition, the work of Xiao, Wu, and Wang (2019), as well as Xhafa, Kilic, and Krause (2019) defined examples that focused on virtualization as a strategy for edge computing platforms, thinking about low cost but also automation of IoT services (where they call Servitization). They aimed for each solution to work on a generic, rather than specific, answer, reconciling that different platforms could talk to each other for end-consumer economic gains, as well as adaptability and accessibility according to each end-platform.

In the study by Xhafa, Kilic, and Krause (2020), from a generalist layered view, the standards for semantic application representation of the IoT web solution of the Node-Red framework® were cited, as can be seen in Figures 8 and 9. They presented standards formats for Resource Description Framework (RDF), Extensible Markup Language (XML), Turtle, N-Triples, Notation3 (N3), JavaScript Object Notation (JSON), JavaScript Object Notation for Linked Data (JSON-LD), Entity Notation (EN), Header-Dictionary-Triples (HDT), and Sensor Markup Language (SML).

Figure 8 - Interfaces and layers of the generalist IoT solution
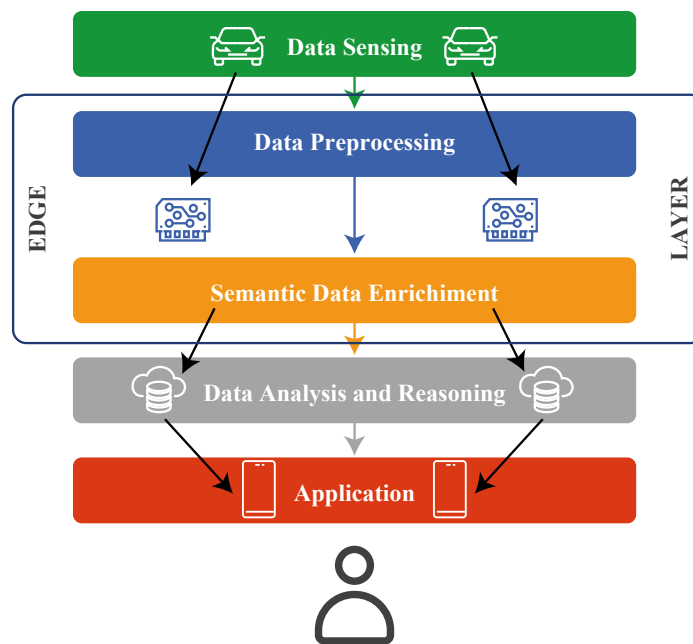
Source: Xhafa, Kilic, and Krause (2020)

Figure 9 - Breakdown of node flows in the drag-and-drop implementation of Node-Red in the implementation and the dashboards produced to the user

Source: Xhafa, Kilic, and Krause (2020)

6. DISCUSSION AND SYNTHESIS OF KNOWLEDGE

All the productions were published in the same way each year, with no significant difference from one year to another, demonstrating that this theme has not been explored at the same speed at which technologies expand worldwide. None of the selected studies were carried out in the Americas, which reinforces and justifies the relevance of the topic, in addition to serving as motivation for the realization and implementation of technologies that observe the accessibility standards and the W3C definitions in the implementation of systems for the Internet of Things and not only for the Node-Red framework®. This automation occurs through integrating cyber-physical systems, made possible by cloud computing and the Internet of Things, which are growing rapidly. It is projected that by 2026, computers will have accumulated processing power thousand times more powerful than a computer manufactured in 2010 (PIANA et al., 2019).

The authors proposed that one of the important applications of the technologies belonging to IoT is W3C standards. It is noticed that even applying heterogeneous systems with multiple layers of abstraction (XIAO WU; WANG, 2019) or systems focused on health solutions (PETRAKIS et al., 2019) all present a focus on open source development, mainly for economic-social reasons, facilitating access to more underserved communities and small and medium-sized enterprises, which generally have a higher initial barrier to acquiring consumer goods and investment compared to large corporations. It also facilitates the accompaniment of the different technical-scientific communities, which can collaborate to find a common solution through collaboration and co-participation in development, acting in co-production.

By applying IoT, the authors sought real-time data collection, storage, and creation of histories that monitor and evaluate the different processes presented in the selected articles. In addition, when associated with the IoT framework Node-Red®, as suggested by all, it enabled a better UX (Koren & Klamma, 2018), improving its access to people. For this, several technologies, from the different elements of abstraction through nodes, implementing hardware for IoT through sensors, actuators, and embedded equipment such as Raspberry Pi® and Arduino®, collect and display the data in dashboards for the end user.

In the searches, when applying "Node-Red," a high incidence of works was expected, since it presents low cost (since it is a scalable framework for the web), which facilitates its use and collaboration, as well as its usability and accessibility, which corroborates with the international UX standards. However, few results were found, which is why we also assigned to the search string the terms "accessibility" and "W3C."

Given this, it is necessary to observe the gaps in the studies that do not show specific applications of accessibility adaptations and also the low quantity of studies found in the specific databases of Computing and Engineering, becoming challenges that guide the future of the studies and application of new technologies concerned with accessibility to multiple publics. The applicability of studies in the field to obtain data is crucial, although it presents several challenges, such as large-scale implementation, validation, and acceptance by regulatory agencies with sampling and repeatability, operation by people with disabilities, and bringing technologies that are increasingly accessible. This shows that new studies should be conducted to evaluate new technologies and outline alternative cost strategies for implementation in favor of a UX for all users.

7. CLOSING REMARKS

The Node-Red® tool, like much other Information and Communication Technology (ICT) frameworks in the software industry, has UI and UX aspects, which enable the application of accessibility standards and the adaptation to W3C models. During the study, it was noticed that proprietary architectures have the biggest barrier to meeting accessibility standards and end-user usability compared to Node-Red®, an open-source web framework.

The authors believe that this occurs due to the manufacturer's retention of the solution in closed code, not allowing general support from the community, and because it is unprofitable and difficult to meet the needs of small portions of the population and their specificities (or disabilities). Furthermore, it was evaluated that there are usually no international requirements from the competent bodies which make the accessibility implementation process present in these products and services. Occasionally, the lack of sensitivity to the specificities and difficulties of the end user may result in the exclusion of these actors from the implementation process or even from the use of such technologies.

Nevertheless, IoT implementation demands specific manpower and skills, generating yet another barrier and a probable impediment to the proper understanding of UI, UX, and accessibility constraints since historically, in the engineering curricula and technical domain, the main focus is on device operation.

Another important point is that data security and privacy issues are recurrent in IoT implementations, regardless of the framework used, be it open source or closed source. This is because the market tends to prioritize the base and tool functionalities.

Nevertheless, we consider the open source movements from the viewpoint of evaluating how they allow the global community to contribute with feedback and improvements in the implementations. Together with this characteristic, the Node-Red® shows promise and is easy to implement features such as accessibility and ubiquity because it is in web format, using HTML5 and Javascript languages, besides working as a Rest API. It also handles high availability, integrity, and confidentiality requests per ISO 27000 and the software development and improvement cycle.

The analysis showed that most of the Node-Red® applications in the software industry focus on generalist contexts, addressing the most diverse needs of common users and companies. Regarding the selected articles, there are several possibilities raised for the use of the Node-Red IoT framework®: Home use — home automation, business use — real-time customer data collection, data collection for Business Intelligence and Big Data (data deluge / big data cloud), data collection for process management and automation, and e-Health applications, among others.

In addition, IoT technology has been widely applied in the reality of users, involved monitoring processes more efficiently and, consequently, can reduce the consumption of finite resources such as water and energy, making processes environmentally friendly and connected with the 2030 agenda of the Sustainable Development Goals (SDGs) of the UN and performing their control remotely and just-in-time.

The embedded hardware technologies Raspberry Pi® and Arduino® have stood out in applications, due to the practicality of implementation and cost, besides being dynamic to heterogeneous systems, which facilitates their implementation in different scenarios Node-Red IoT framework®.

There are no major limitations pointed out by the authors reviewed for implementing IoT and accessibility other than those already mentioned. Additionally, there was not much concern for exemplifying the application of technological accessibility for the different systems in terms of use by users with limitations or impediments. Therefore, the authors' main focus was to demystify and demonstrate the power of technology to be used with practicality by common people. In this sense, it is highlighted the need for the development of studies related to the use of the IoT framework Node-Red® and the other IoT frameworks to adapt to multiple needs and disabilities since this is little explored worldwide.

In closing, we reflect on the expansion of IoT technologies and the increasing demand for software in this area incrementally. However, the studies on accessibility for Node-Red® are disproportionate to this growth. Is this because it is irrelevant to include accessibility in development platforms? Is it that there is no demand for it? Or is it that the market is not paying enough attention to accessibility? Despite adding inclusion and humanity, is accessibility an intangible value with no direct commercial and financial value?

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