

Middleware for Healthcare Systems: A Systematic Mapping

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Abstract. The improvement of technological applications focused on the health context is growing. Different types of applications, such as Health Information Systems (HIS), Electronic Health Records (EHR), and e-Health and m-Health applications, are being developed. With the increasing use of technological solutions in this context, there is a need to integrate the data collected, stored, and processed in these systems. However, the heterogeneity of the data is a factor that makes this integration difficult. To mitigate this problem, middleware appears as an option. This paper aims to understand the current state and future trends of middleware for healthcare applications. To do so, we carried out systematic mapping of the literature on middleware for healthcare systems. This Systematic Mapping initially collected 1162 works, which after the execution of its stages, 34 works were selected for careful reading and, as a result, we present answers to the defined research questions, collected from a careful reading of the selected works. Finally, we concluded that, although there are several middleware solutions in the literature, there is no standard among these solutions, and they end up being limited to solving the problem in a specific context in the health area.

Keywords: Healthcare · Middleware · Interoperability · e-Health · m-Health

With the advancement of technological applications focused on the health context, there is a need to store, process, and extract information from the data used in the health area to support decisions and optimize processes, aiming to improve the service provided. In this sense, Health Information Systems (HIS) emerge, which, according to Fatima et al. [1], can be defined as "a set of interrelated components that collect, process, store and distribute information to support the decision-making process and assist in the control of health organizations."

HIS use medical information in digital format, also known as Electronic Health Records (EHR). Iakovids [2] defines EHR as "health information stored digitally about an individual's life to support the continuity of care, education, and research, ensuring confidentiality at all times." Thus, the use of EHR systems allows the clinical team to quickly access patients information without the

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need to ask them personally [3], bringing a series of advantages, such as reducing costs and increasing efficiency in the management and recovery of patient data, in addition to enabling centralization and remote access to the patient's health information [4,5].

Another concept related to the context of technologies for the health area is that of e-Health. E-Health is the field that emerges as an intersection between medical informatics, public health, and business, referring to health services that are improved through the use of technologies that operate through the internet [6]. Also, the advancement of mobile communications, which currently supports 3G, 4G, and even 5G mobile networks for data transport, means that mobile computing promotes numerous possibilities for creating solutions for m-Health [3,7]. M-Health consists of the use of mobile computing and communication technologies in health [8]. Systems based on m-Health can support clinical and administrative data management, systems for monitoring vital signs and sending alerts, predictive systems, and medication management [9].

The e-Health, m-Health, and SIS applications have resources that can provide solutions for different contexts in the health field. These solutions can support everything from EHRs to solutions for detecting and monitoring patient vital signs, including solutions for test management, hospital and clinic management data, and epidemiological data. These different solutions that can be used in the health context generate heterogeneous data, which, if integrated, better support clinical decision-making and patient care, providing meaningful and current information [10]. However, integration becomes a challenge since the data generated is increasingly heterogeneous [11]. In this sense, the degree to which two or more systems can exchange information through interfaces in a specific context is called interoperability. Therefore, in the context of healthcare applications, where data is highly heterogeneous, interoperability becomes a critical requirement to be met, and, for that, the proposal of developing a middleware can be a good option.

According to Atzori et al. [12], middleware is "the layer or set of sub-layers of a software interposed between the technological and application levels." Middleware allows the low-level development details to be abstracted, facilitating development and enabling the programmer to focus on the system's functional requirements [12,13]. Thus, the proposal of developing a middleware based on an open standard for health data interoperability, such as HL7 Health Level - 7 (HL7) that meets the interoperability requirements can facilitate the development and decrease the cost of promoting integration between different types of technological health solutions. HL7 is an international standard based on layer 7 of the Open System for Intercommunication (OSI) model, which contains a set of standards for transferring clinical and administrative data between software applications used by healthcare organizations [14].

Considering the advancements in the use of technologies in the health context, the heterogeneity of data in this context, and the challenge of integration between different healthcare systems, it is necessary to investigate the use of middleware on this challenge. Therefore, this article aims to describe a review to understand

the current state and future trends of middlewares for e-Health and m-Health applications and find areas for further investigation. For this, a study was carried out based on the Systematic Mapping Study methodology [15].

The paper is organized as follows: Sect. 1 deals with the methodology used in developing the research. The third section presents an analysis of the results found in the articles selected. Finally, we concluded the work dealing with general discussions and future works.

1 Methodology

According to Kitchenham et al. [16], Systematic Mapping is a type of secondary study that aims to identify existing research related to a specific topic, that is, to answer broader questions related to the evolution of the investigation, which can be classified as exploratory. This research was carried out based on the guidelines recommended by Kitchenham et al. [16]. In this section, the most important details of the protocol defined and validated for the Systematic Mapping are presented.

1.1 Objective and Research Questions

This Systematic Mapping aimed to understand the current state and future trends of middleware for e-Health and m-Health applications and find areas for future investigations. For this, the following Research Questions (**RQ**) were defined and used in the investigation of the articles:

- **RQ1:** What are the existing middlewares for healthcare systems?
  RQ1 aims to identify the main middleware solutions for healthcare systems described in the literature and understand how they promote interoperability.
- **RQ2:** What are the main characteristics of middleware for healthcare systems?
  RQ2 aims to map the main characteristics and requirements that middleware solutions for the healthcare area must meet.
- **RQ3:** How are middlewares evaluated in the works analyzed?
  Through RQ3, we intend to understand under which metrics middlewares are evaluated from the point of view of quality attributes such as performance and availability to identify possible obstacles in developing middleware for the health area.
- **RQ4:** What are the challenges and opportunities to develop middleware for healthcare systems?
  RQ4 aims to analyze the main challenges present in the development of middleware for healthcare solutions and, through this, to identify opportunities and gaps for future investigations and the development of healthcare middleware solutions.

1.2 Research Process

The search engine established for selecting the studies was the Elsevier's Scopus Platform [17]. This Platform indexes the main bases of scientific studies in the area of Computer Science, such as the ACM Digital Library [18], the IEEExplorer [19], the Science Direct [20], and the Springer Link [21]. For this reason, it was chosen to execute the search string defined in the protocol and perform the collection of the works.

The search string was built from the concatenation of terms present in the research questions, and, for search purposes, the titles, abstracts, and keywords of the works were considered. Therefore, in this Systematic Mapping, the following search string was used: "Middleware" AND ("Health" OR "Health-care").

1.3 Inclusion and Exclusion Criteria

In this Systematic Mapping, studies published in any year, provided they are written in the English language, were included. The Exclusion Criteria (EC) defined were:

- **EC1:** Duplicate papers;
- **EC2:** Articles derived from the same author and research;
- **EC3:** Works that do not present middleware solutions;
- **EC4:** Works that do not present middleware solutions for healthcare systems;
- **EC5:** Works not available for download;
- **EC6:** Papers that do not answer any research question.

1.4 Quality Assessment

Each study selected was evaluated according to the following Quality Assessment (QA) questions:

- **QA1:** Does the work have a clear statement of the research objectives?
- **QA2:** Does the work describe well the context in which the research was carried out?
- **QA3:** Are the results obtained clear?

The quality assessment questions were scored as follows: −1 in case of non-compliance with the criteria; 0 in case of partial fulfillment of the criteria; and 1 if it fully met the criteria. The evaluation is available in the spreadsheet that can be accessed through the following link: http://bit.ly/mapeamento-sistematico.

1.5 Extraction, Analysis, and Selection of the Articles

The data extracted from each study were: year of publication, link to access, number of citations, title, abstract, characteristics and requirements of the proposed solution, protocols used, challenges, and additional comments. Thus, the

process of extracting, analyzing, and selecting the articles included three phases, described below:

- Phase 1 - Execution of the search string in the search engine: in this phase, the search on the Scopus Platform returned 1,162 papers;
- Phase 2 - Analysis of the titles and abstracts of the papers obtained in Phase 1: the analysis was performed based on the inclusion and exclusion criteria defined. After completing this phase, 142 articles were selected;
- Phase 3 - Analysis of the introduction and conclusion of the articles selected in Phase 2: the articles selected in Phase 2 were read to identify and select those that answered at least two research questions defined in the protocol. In this phase, 34 articles were selected for detailed reading and final analysis.

Figure 1 shows the process of extracting, analyzing, and selecting the articles and the number of works that were picked after the execution of each phase.

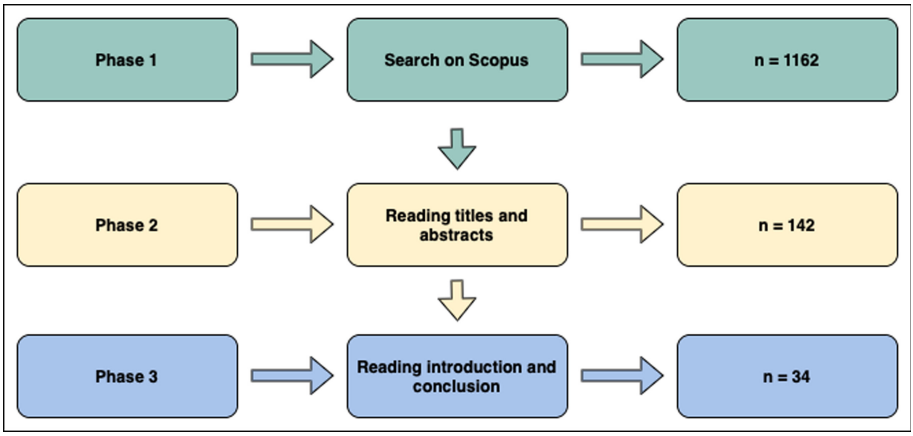

Fig. 1. Process of extracting, analyzing, and selecting the articles.

2 Results

Phase 3 of the data extraction and analysis process resulted in 34 articles, which were read in a detailed and attentive manner to understand how each work answers the research questions defined in the research protocol. This section reports the analysis of these articles from the point of view of each research question defined. An online spreadsheet was used to control better the analysis of the works, which is available at the following link: http://bit.ly/mapeamento-sistematico.

2.1 RQ1: What Are the Existing Middlewares for Healthcare Systems?

Many middleware-based solution proposals were found in the analyzed papers, as well as a series of analyses of the existing middleware. In general, as an alternative to promote interoperability between health systems, Pervez et al. [22] cite Device Interoperability Middleware (DIM), stating that these solutions have shown potential to solve such a problem. Also, Message Oriented Middleware (MOM) is used as well [23].

Solutions based on the $HL7$ standard [24] are mentioned as options for the development of middleware for healthcare systems [25]. In Zhang et al. [26], some solutions referred to as "standard" by the authors are cited, such as the "Medical Telemonitoring System," which consists of a method for sending physiological and medical information remotely over the internet to an analysis and diagnosis center, and the middleware described in the article itself, the "Mobile Context and Ontology-based Reasoning/Feedback ($MCOM$)," a system that monitors the health status of patients using the smartphone.

In Alonso et al.'s work [27], a study including several middlewares was carried out, among which was the Kura, a middleware proposed by the Eclipse consortium, which was designed to be installed on gateways; the AllJoyn, proposed by the Linux Foundation, which provides a version for restricted features, as well as different APIs for developers; and the Macchina.io, which, according to the author, is modular and extensible, implementing a messaging protocol based on the publication/subscription model. In the line of applications that use this model, Almadani et al. [28] propose a Middleware Real-Time Publish-Subscribe ($RTPS$), while Singh et al. [29] present a middleware model to control information sharing in a publication/subscription-based environment.

The $My{-}AHA$, described by Madureira et al. [30], is a multiplatform middleware designed to perfectly integrate different health and active aging solutions, aiming at well-being. According to the authors, the architecture proposed for the $My{-}AHA$ is a multi-module system architecture, fully scalable and easily implementable, focusing on helping caregivers and the elderly themselves improve their current condition, considering changes in cognitive, physical, social, and psychological parameters.

A framework for the interoperability between health systems is proposed by Ryan et al. [31]. The Health Service Bus (HSB) is a solution based on the Enterprise Service Bus (ESB) middleware software architecture, which provides a loosely coupled and highly distributed approach for enterprise systems integration. Along the same lines, Ayeni et al. [32] describes a framework for overcoming integration barriers between Nigerian health systems and improving health care delivery in Nigeria [10]. Another example of middleware is the SALSA, proposed by Rodriguez et al. [33], which allows developers to create autonomous agents that react to the medical environment's contextual elements and communicate with other agents, users, and services available in the environment.

The *POStCODE* (POstmarket SurveillanCe Of DEvices) is a middleware proposed by Chaudhry et al. [34] that provides the devices' operational details directly to the manufacturers, being careful to exclude private patient data, thus enabling the monitoring and maintenance of medical devices by the manufacturers. In the line of synchronization of medical data, we also have the solution proposed by Lomotey et al. [35], a middleware for the m-Health (mobile health) that facilitates the efficient process of synchronizing medical data with minimal latency.

The *SBUS* is a middleware presented by Singh et al. [36]. It is a solution that allows multiple forms of communication that are dynamically reconfigurable. It ensures that the terminals' message types match and that each transmission (message) conforms to the type scheme. Also, the *SBUS* supports several communication methods, including client-server (request-response and RPC) and streaming of push/pull messages.

Some initiatives used to promote interoperability between health systems continent or country-wise have also been identified in the literature. For example, Ferrara [37] proposes the DHE (Distributed Healthcare Environment), a middleware that follows the European Standard Health Information System Architecture proposal, implementing a distributed repository for all clinical, organizational, and management information of the healthcare structure, making them available when and where needed for all applications in the health information system. AlZghoul et al. [38] describe a middleware architecture to help healthcare providers in Jordan access electronic health data residing in a national health database.

Healthcare applications deal with a series of multimedia files, mainly tests in image format. In this sense, Kallepalli et al. [39] describe a security middleware for DICOM images that provide refined access control, policy management, demographic filtering, and record-keeping restricted to the Canadian-Manitoban PHIA and the DICOM standard. Another middleware solution proposed for use in healthcare data environments is the CORBA (Common Object Request Broker Architecture), which was used in Murshed et al. [40], Waluyo et al. [41], and Blobel and Holena [42]'s work.

Many technologies, systems, and standards are used by Hsieh et al. [43] to characterize a middleware solution, such as a Single Sign-On Server (SSOS) in a Healthcare Enterprise Information Portal (HEIP) and in a Health Information System (HIS). This set of solutions was implemented in the network infrastructure of the National Taiwan University Hospital (NTUH).

Finally, a series of middlewares were mentioned in the analyzed works, such as the *MiThrilNGN*, the *MyHearth* and the *X73uHealth* [44], the *ANGELAH* (AssistiNG ELders At Home) - proposed in Taleb et al. [45] - and the HYDRA, a solution that allows different devices to be incorporated into applications through a simple service interface.

Table 1 summarizes the main middleware for health systems proposed in the analyzed studies, indicating the authors and a brief description of each solution.

2.2 RQ2: What Are the Main Characteristics of Middleware for Healthcare Systems?

The analyzed papers cite the main characteristics of middleware for health systems. Rodriguez and Favela [33] state that the main characteristics of middleware for health are to provide data integration between different devices and artifacts, data mobility between doctors, patients, and users, and the mobility of documents and equipment.

In Alonso et al. [27]'s work, a set of middleware requirements based on an analysis of Structural Health Monitoring (SHM) deployments and desirable middleware resources is defined, bringing the following items: heterogeneity, high abstraction level, energy optimization, scalability, security, Quality of Service (QoS), reliability and fault tolerance.

According to Ferrara [37], middleware for healthcare systems must (i) provide optimized support to the specific needs of individual centers and units (which are intrinsically different from an organizational, clinical, and logistical point of view), allowing different suppliers to offer specialized applications and enabling users to select the most effective solutions for their needs; and (ii) allow the different centers and units to cooperate based on a substantial functional and informational consistency, capable of ensuring the general consistency of the health organization, which is necessary to increase the effectiveness and reliability of the clinical, administrative, epidemiological and management activities carried out at both local and territorial levels.

Data integration is one of the main characteristics cited for creating middleware for healthcare systems. In this sense, Taleb et al. [45] mention that middleware for healthcare systems must ensure that the integration of devices and middleware enables rapid response action to ensure user safety. Oliveira et al. [46] complement and state that middleware should be able to provide sharing and integration of information between third-party applications, provide support for data collection and be able to integrate with other mobile devices and applications. Furthermore, Martíez et al. [47] cites the need for transparency in data integration, that is, the integration needs to happen without being too costly for the integrated applications, conserving the business details of each application.

Concerning integration with other devices, the flexibility and dynamism characteristics emerge. That means that new components can be added or removed without modifying the existing application in different contexts and environments, reducing the burden of developing new resources [26,39]. The importance of this characteristic is also stated by Pereira et al. [48], who says that middleware must be able to provide flexibility, adaptability, and security for monitoring health devices.

Adaptability is an essential feature for healthcare middleware. According to Kliem et al. [49], such solutions must be able to handle standard and proprietary devices; quickly handle change in requirements; handle all existing medical devices, and preserve interoperability at the application level if they are replaced (extending the integration with a migration challenge).

According to Waluyo et al. [41], the characteristics that the middleware should provide are related to data acquisition, dynamic plug-and-play system,

Table 1. Middleware solutions for healthcare systems.

Author	Middleware	Description
Zhang et al. [26]	Mobile Context and Ontology-based Reasoning/Feedback (MCOM)	System for monitoring the patients' health status using the smartphone
Alonso et al. [27]	Kura	Proposed by the Eclipse consortium and designed to be installed on gateways
	AllJoyn	Proposed by the Linux Foundation, it provides a version for restricted features and different APIs for developers
	Macchina.io	Middleware that implements a publishing/subscription-based messaging protocol
Almadani et al. [28]	*RTPS*	It presents a middleware model to control information sharing in a publication/subscription-based environment
Singh et al. [29]	Publish/subscribe-based middleware for policy-based information sharing	Defines a template for defining and enforcing refined information sharing policies in an active notification environment. The model was described based on a publish/subscribe middleware
Madureira et al. [30]	$My - AHA$	Multiplatform solution based on multi-module system architecture for the integration of different health and active aging solutions
Ryan et al. [31]	Health Service Bus (*HSB*)	Solution based on the Enterprise Service Bus (ESB) middleware software architecture, which provides a loosely coupled and highly distributed approach for enterprise systems integration
Rodriguez and Favela [33]	*SALSA*	Solution based on the creation of autonomous agents that react to the contextual elements of the medical environment and communicate with other agents, users, and services available in the environment
Chaudhry et al. [34]	*POStCODE* (POstmarket SurveillanCe Of DEvices)	Middleware that provides operational details, being careful to delete private patient data from devices directly to manufacturers
Lomotey et al. [35]	Middleware for m-Health	Solution-focused on the data synchronization process and on reducing latency
Singh et al. [36]	*SBUS*	A solution that allows multiple forms of communication that are dynamically reconfigurable, supporting various communication methods, such as client-server and message streaming
Ferrara [37]	*DHE*® (Distributed Healthcare Environment)	Middleware following the European Standard Health Information System Architecture proposal, implementing a distributed repository for all clinical, organizational, and management information of the health structure
Kallepalli et al. [39]	Security middleware for DICOM images	Provides refined access control, policy management, demographic filtering, and record-keeping restricted to the Canadian-Manitoban PHIA and the DICOM standard

security, being light and easy to reconfigure, and having resource control management. Prados-Suarez et al. [50] cite, in addition to integration, access control. In this sense, the authors include an access control layer that guarantees privacy protection and adaptation and compliance with standards. Also, it has an access layer specially designed to facilitate the development of external access functions based on the principle of reuse. The need to control access to data is also mentioned by Singh et al. [29], making clear the need for these data to be available to those providing care, but the sensitivity of medical information means that it must also be protected. Also regarding safety, AlZghoul et al. [38] say that Electronic Health Data Record Systems contain private data that must be protected from any unwanted access and that separating the personal data database from the medical data database can preserve the patient's data and maintain the useful medical data without affecting privacy. Thus, providing solutions for access control in middleware is an important feature [37].

Finally, Table 2 summarizes the main requirements for health systems pointed out in the analyzed studies.

Table 2. Main requirements for middleware for healthcare systems.

Requirement	Description	References
Transparent data integration	Enable transparent data integration between different devices and mobile applications; data mobility between doctors, patients, users; and mobility of documents and equipment	[27,33,45–47,50]
Data heterogeneity	Provide ways to treat heterogeneous data with a high level of abstraction, flexibility, and dynamics in different contexts and environments	[26,27,37,39,48]
Flexibility and dynamism	Provide optimized and flexible support to the specific needs of each center and unit	[26,27,37,39,48]
Scalability	Provide means where applications can scale without compromising the Quality of Service (QoS)	[27,29,37,38,41,49,50]
Reliability	Allow data from different centers and units to be integrated, ensuring the reliability of the data involved	[27,37]
Security	Ensure the protection and privacy of the data used by doctors, patients, and users, mainly through access control	[29,37,38,41,49,50]

2.3 RQ3: How are Middlewares Evaluated in the Works Analyzed?

The middlewares are mainly evaluated from the point of view of performance, direct and indirect costs, and effectiveness. The *ANGELAH*, for example, was evaluated based on metrics from performance evaluation systems, which used probabilistic calculations and determined a satisfactory result for the prototype developed [45].

The middleware proposed in Lomotey et al. [51] is used by a mobile application and was evaluated from two perspectives: (i) the processing time of the clinical transactions, which are reported from the users' devices; and (ii) the indirect communication cost. In the second case, the evaluation is made by studying the data collected in three different categories: 1) less load, 2) average load, and 3) maximum load. The categorization is based on the use of the Health Information System (HIS).

The Device Nimbus had its performance evaluated through a series of tests that used different data sources and reached data collection, integration, and analysis expectations [46]. In Almadani et al. [28]'s work, to evaluate the middleware, a model of practice tests with devices consuming and sending data to the middleware was used to check the response time, the quality of the response, and the data in different scenarios.

In Waluyo et al. [41], the middleware was evaluated for its performance in wireless data transmission time, real-time performance (with and without security), and waiting in line. The *BioMIMS*, on the other hand, was validated by researchers from the Rizzoli Orthopedic Institute, in which researchers analyzed data provided by themselves regarding two types of diseases (Multiple Osteochondromas - MO and Osteogenesis Imperfecta - OI). Through empirical analysis, the researchers proved the effectiveness of using the solution [23].

In Pervez et al. [22], a probabilistic model tester called PRISM was used to analyze the reliability and performance of the systems. The Markov Decision Process (MDP) was used to find the probability of failures, while the Markov Continuous Time Chain (MCTC) was used to model the workflow and evaluate the probability of failures in real-time. The study concluded that this reliability analysis approach is more scalable than the analysis techniques based on traditional simulations.

Kim et al. [52] set up a test environment for the evaluation of the proposed middleware. The following items were evaluated through tests: the service start time on a public network, the average jitter (delay between packets with the increase in the number of receiving terminals), and the connectivity on a private network.

Finally, in general, from the performance point of view, it is evident that the main metrics investigated are transmission time and data processing in real-time (with and without security). Regarding costs, direct and indirect costs are considered; and concerning effectiveness, middleware is evaluated mainly through empirical analysis and probabilistic approaches to analyze the reliability and performance of the solutions, for example, evaluating the probability of failures in real-time.

2.4 RQ4: What are the Challenges and Opportunities to Develop Middleware for Healthcare Systems?

The general health scenario is currently characterized by many different, heterogeneous, and mutually incompatible applications, which are already installed and operational in individual centers, to support the particular needs of specific groups of users [37].

According to Schweiger et al. [53], the integration of standalone applications is a difficult task as they often represent similar information in different data schemas and any communication requires an agreement between the sender and recipient on a common data representation, this challenge is also cited by Soyemi et al. [54], which says that it is necessary to standardize the data that enables the communication between solutions implemented with different software languages, allowing the automation of processes and services in this sense.

On the other hand, Kliem et al. [49] say that semantic interoperability is an important challenge for integrating middleware and the e-Health domain in general since it allows the integration of all types of medical devices using different protocols and data formats. The diversity of sensor protocols is also one of the challenges for developing middleware for healthcare systems [44].

Therefore, Prados-Suarez et al. [50] state that several sources of information, not just from medical institutions, should be integrated, generating the need for a homogeneous access point for all of this data, with the capacity to adapt (to adequate itself to new systems, standards, and needs), but without the need to transfer data ownership. Also, according to Prados-Suarez et al. [50], promoting accessibility is also a challenge in developing these solutions since there are different access needs with different requirements - personal use, medical use, research purposes - especially regarding the protection of data privacy.

According to Lomotey et al. [51], the high latency in the m-Health system when sending data between the cell phone and the computing facilities in the hospital can make transferring medical data very slowly, bringing up the challenge of decreasing the data latency considering different network conditions.

Concerning safety and reliability, Arunachalan et al. [55] reinforce that the transmission of critical data, such as demographic data and vital signs, using wireless network infrastructure presents different requirements for the middleware solution. Besides, the authors pay attention to legal and privacy issues related to patient care data, which the middleware solution should consider.

Regarding handling images by digital means in the health area (such as tests, for example), Kallepalli et al. [39] mention that protecting and providing refined access control for Digital Imaging and Communication in Medicine (DICOM) based on the Personal Health Information Act (PHIA) is one of the biggest challenges in image uploading and sharing systems, which can also be applied for healthcare middleware solutions. Finally, Shand et al. [56] claim that as messaging middleware technology matures, users are increasingly demanding resources, leading to modular middleware architectures. However, the extra complexity increases the risk of a security breach.

We noticed that there are several challenges involved in the process of developing middleware for health systems. Among the main ones, it is possible to mention the heterogeneity of the data; the different means of communication between devices, sensors, and systems; reliability; and data security. Therefore, investigation and research opportunities arise regarding middleware solutions that use open standards, such as $HL7$ [24], that can meet the requirements of developing middleware for health systems while overcoming the challenges present in the development.

3 Conclusion

This work presented an analysis of the state the art of research on the use of middleware to solve the problem of interoperability between health systems to understand how the works available in the literature answer the defined Research Questions (RQ), as well as identify future trends in the development of middleware for e-Health and m-Health applications.

Therefore, a Systematic Mapping [15,16] was carried out, in which 1,162 articles were explored. After the extraction, analysis, and selection of the articles, 34 works were selected for analysis and data extraction. The analysis showed us that there is a large amount of middleware developed for the health area. However, they are not entirely flexible and applicable in different contexts in the area and, therefore, do not meet all of the essential requirements for middleware solutions for the health field. Given this, the opportunity to create middleware for health data that uses open standards, such as $HL7$, for integration and interoperability between different health solutions and that meet the requirements presented in this work is still open.

We understand that the corporate Electronic Health Records systems, as well as solutions based on mobile computing, are being increasingly used in the health context and, therefore, as future work, we intend to propose the architecture of a middleware that meets all of the requirements presented in this work, as well as carrying out the implementation and analysis of a case study of the developed solution.

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