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Quality of service approaches in IoT: A systematic mapping

Gary White*, Vivek Nallur[1], Siobhán Clarke

Distributed Systems Group, School of Computer Science and Statistics, Trinity College Dublin, College Green, Dublin 2, Ireland

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A B S T R A C T

In an Internet of Things (IoT) environment, the existence of a huge number of heterogeneous devices, which are potentially resource-constrained and/or mobile has led to quality of service (QoS) concerns. Quality approaches have been proposed at various layers of the IoT architecture and take into consideration a number of different QoS factors. This paper evaluates the current state of the art of proposed QoS approaches in the IoT, specifically: (1) What layers of the IoT architecture have had the most research on QoS? (2) What quality factors do the quality approaches take into account when measuring performance? (3) What types of research have been conducted in this area? We have conducted a systematic mapping using a number of automated searches from the most relevant academic databases to address these questions. This mapping has identified a number of state of the art approaches which provides a good reference for researchers. The paper also identifies a number of gaps in the research literature at specific layers of the IoT architecture. It identifies which quality factors, research and contribution facets have been underutilised in the state of the art.

1. Introduction

The development and realisation of a number of key technologies including RFID, sensor/actuators, embedded computing and cloud computing together with the emergence of a new generation of cheaper and smaller wireless devices with a number of communication protocols has led to the formation of the IoT. The number of physical devices which are being connected to the internet is growing at an increasing rate which is realising the vision of IoT. The latest forecasts have predicted that there will be between 26 and 50 billion connected devices by 2020 (Bauer et al., 2014; Evans, 2011). In 2010, the number of internet-connected devices surpassed the human population which shows that we are already in the early stages of the IoT (Evans, 2011).

The huge number of devices will enable services from a wide variety of sources such as home appliances, surveillance cameras, monitoring sensors, actuators, displays, vehicles, machines and so on. IoT will allow the development of applications in many different domains, such as home automation, industrial automation, medical aids, traffic management, and many others (Bellavista et al., 2013). These applications have a range of QoS requirements which can be typically categorised as best effort (no QoS), differentiated services (soft QoS) and guaranteed services (hard QoS). To provide hard QoS in the IoT it is necessary to ensure suitable mechanisms at each layer of the IoT architecture, since some factors such as delay are present from end-to-end (E2E). A delay in any layer can lead to unacceptable QoS for safety critical applications such as automated driving systems which need constant feedback to maintain control (Kato et al., 2002). In order to ensure that we can provide guaranteed services for safety critical applications, it is important to know if QoS has been addressed at all layers of the IoT architecture. In this paper, we report on a mapping, based on the guidelines by Petersen et al. (2015), that allows us to visualise in which architectural layers research on QoS in IoT has been conducted and in which layers where there is a lack of primary studies.

We also consider the quality factors that have been used to evaluate the QoS approaches and identify which factors need more consideration. This is important as QoS approaches need to be comprehensively evaluated due to the possible trade-offs with different quality factors. For example, an approach at the middleware layer may greatly reduce the E2E delay of the system but may also increase the amount of power required by the system. If a user deploys the middleware on a resource constrained device they need to know about the trade-offs of each approach. We use the mapping to identify which quality factors have been taken into account in current approaches. This will allow for a more comprehensive evaluation of future proposals.

* Corresponding author.
E-mail addresses: whiteg5@scss.tcd.ie (G. White), vivek.nallur@ucd.ie (V. Nallur), siobhan.clarke@scss.tcd.ie (S. Clarke).

[1] Present address: School of Computer Science, University College Dublin, Belfield, Dublin 4, Ireland.

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The remainder of the paper is structured as follows: Section 2 presents a background on E2E QoS, quality models and a discussion of related work. Section 3 describes the research method, which was used to conduct the mapping. Section 4 presents the results of the systematic mapping and Section 5 answers the research questions which were identified and outlines a research agenda based on the findings of the mapping.

2. Background and related work

2.1. E2E QoS In IoT

To ensure an acceptable level of QoS for safety critical applications in the IoT there must be QoS approaches at every layer of the IoT architecture. A delay in any layer from the physical sensor to the user can cause problems in a number of safety critical applications in different domains from automated driving vehicles to healthcare applications. To ensure that we can deal with delays at all levels of the architecture we need QoS approaches which can try to prevent and report such delays. This mapping identifies areas that current research concentrate on, and points out areas that need more attention.

When there are a suitable number of established approaches through the layers of the IoT it allows for negotiation and feedback between the different layers Duan et al. (2011). In a critical application where we have to ensure a maximum amount of delay, if we identify that there is some delay at the network level we can choose a middleware approach which will minimise the delay or raise an alert that we will not be able to comply with the service-level agreement.

There are a number of other QoS factors however, other than delay, such as security and reliability which users may want to take into account when requesting a service. For example a user may request a wind sensor in a particular location with high availability but will accept a long delay. To ensure that we can process these requests at each layer we need each of the approaches to evaluate themselves against a suitable quality model, so that we can identify any tradoffs between the QoS factors when choosing a suitable approach.

2.2. Quality models & QoS

There are a large number of QoS factors which can be taken into account in an IoT environment. Quality models are useful for this as they have a hierarchical set of quality factors which can be used to evaluate the approaches. There are a number of these models which have been developed in multiple domains and which differ on the structure and the detail of the quality factors they use.

We identified a number of different quality models such as OASIS WSQM Oasis (2012), Cabrera and Franch (2012), and ISO/IEC 25010 (ISO/IEC, 2010) which could be used for the mapping. Based on the guidelines outlined by Wagner (2013) and experience from other systematic mappings Oriol et al. (2014) we have chosen to use the ISO/IEC 25010 quality model. This model provides a broad coverage of quality attributes in terms of the quality characteristics identified such as security and reliability, as well as containing defined sub-characteristics as can be seen in Fig. 1 which allows for repeatability.

2.3. Literature review

To identify that a systematic mapping was necessary, we conducted a number of searches for related literature following the methodology outlined by Oriol et al. (2014). To maximise the amount of returned documents we searched for all types of reviews and state-of-the-art documents, not just systematic reviews and mappings. We used a number of automated searches selected from a range of academic databases listed in Table 1, using the same keywords as Table 2 with the addition of the following terms and their synonyms: “state of the art, systematic literature review, survey, systematic mapping”. As a result of the automatic search we found 333 papers which fulfilled the search criteria. 112 duplicates were eliminated to give 221 final papers.

Table 1
Database sources.

Source	URL	TAK
IEEE Explore	http://ieeexplore.ieee.org	✓
ACM	http://portal.acm.org	×
Springer	http://springerlink.com	×
Science Direct	http://sciencedirect.com	✓
Scopus	http://scopus.com	✓
Google Scholar	http://scholar.google.com	×
Web of Science	http://webofknowledge.com	✓
Engineering Village	http://engineeringvillage.com	✓

We use the selection criteria outlined in Section 3.3 to identify the most relevant studies, first selecting by title, then by abstract and finally reading the full paper, as can be seen in Fig. 2. Based on the title we selected 56 documents, this was reduced to 24 by reading the abstract and of those 24 papers we found 5 that were related to the research area that we were mapping by fully reading the paper. From these 5 papers we then included further works through the process of snowballing Wohlin (2014), where additional papers in the references of the final selection by full reading are evaluated against the selection criteria in Section 3.3. The selected papers are then added to the final list of papers to give a total of 8. Of these papers we found that none presented a detailed E2E coverage of QoS approaches through the IoT architecture.

Some of the reviews have focused on specific protocols. For example, Le et al. (2012a) focuses on QoS security threats in 6LoWPAN and countermeasures using an intrusion detection system approach. Malik et al. (2015) focus on techniques that have been developed to provide QoS in IEEE 802.11-based wireless networks, through the layers of the network. Other papers have focused on surveys in domains related to the IoT such as the use of network monitoring techniques in MANETS to detect anomalies such as failures, intrusions and disconnects Battat et al. (2014). Other approaches have focused on cyber-physical systems and monitoring techniques which can take into account the network design and relevant protocols Ali et al. (2015). Rassam et al. (2013) focus on the use of anomaly detection methods at the application level in WSN. As cloud technology is becoming more widely used in the IoT a number of papers have considered the integration between these approaches (Daz et al., 2016; Cavalcante et al., 2016; Botta et al., 2016). These papers have primarily focused on the integration between the middleware and cloud and have not considered other important layers such as the physical device and the deployment of the sensors.

Recently there has been a move to use more evidence based software engineering approaches such as systematic literature reviews and systematic mappings which can be seen by the large increase in these types of publications since 2004 (Zhou et al., 2015) when the seminal paper on evidence based engineering was published (Kitchenham et al., 2004). This has led to mapping studies of QoS in related domains such as web services (Oriol et al., 2014) whose goal is to evaluate the state of the art in quality models for web services. They have also been used in cloud computing (Abdelmaboud et al., 2015) to identify where more emphasis

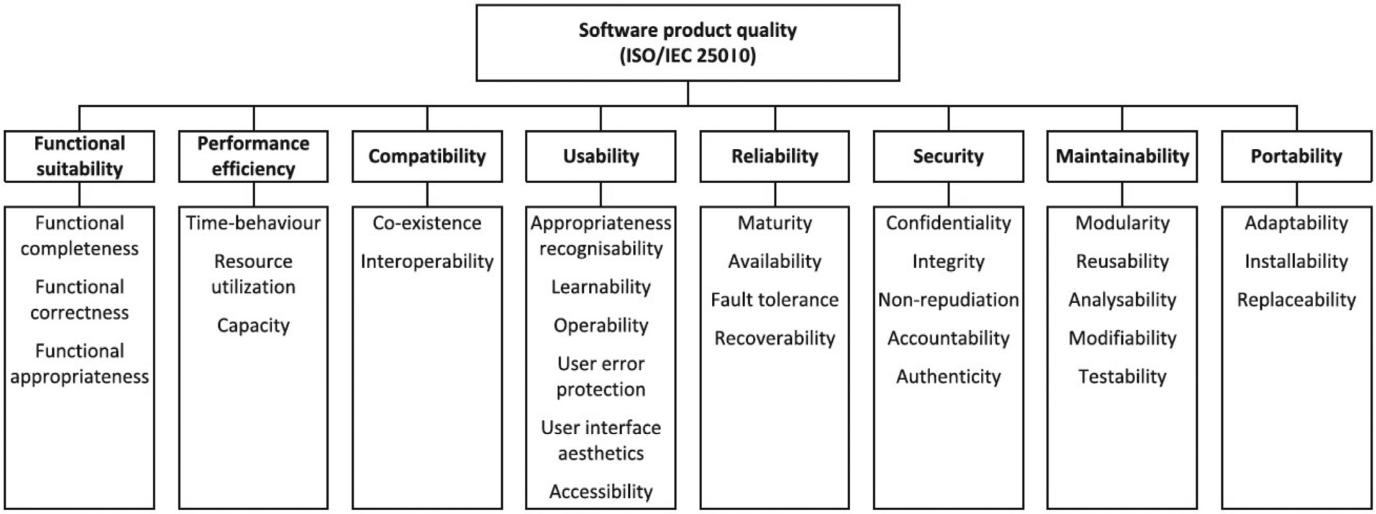

Fig. 1. ISO/IEC 25010 proposal of quality model for software products.

Table 2
Searches in databases.

Database	Search syntax	Results
SCOPUS	TITLE-ABS-KEY((qos or "quality of service" or "monitoring") and (IoT or "Internet of Things"))	1067
IEEE	(QoS OR .QT.Quality of Service.QT. OR .QT.Monitoring.QT.) AND (.QT.Internet of Things.QT. OR IoT)	1611
WOS	(TS=((qos OR "quality of service" OR "monitoring") AND (iot OR "Internet of Things")))	383
Engineering Village	((((qos or "quality of service" or "monitoring")) WN KY) AND (((IoT or "Internet of Things")) WN KY))	2395
Science Direct	((((qos or "quality of service" or "monitoring")) WN KY) AND (((IoT or "Internet of Things")) WN KY))	71

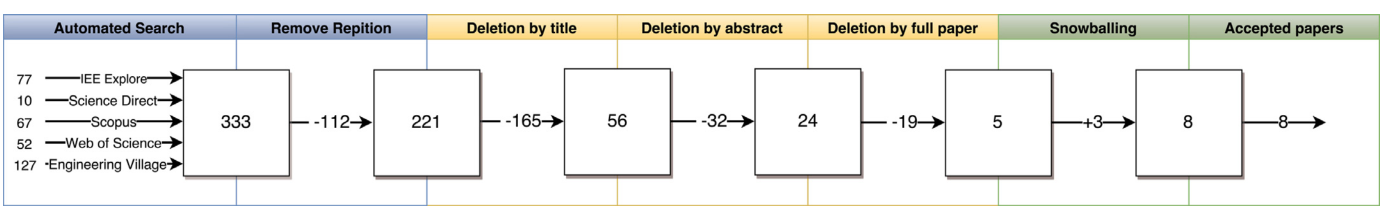

Fig. 2. Selection of the related literature.

should be placed in both current QoS approaches and future research directions based on the categories that were identified in the mapping. Such mapping studies have not been utilised in IoT until very recently, where they have been used to provide a comprehensive understanding on the integration of IoT and Cloud computing paradigms (Cavalcante et al., 2016).

After evaluating the papers which were returned by the search we did not find a related survey, systematic mapping or literature review which focused on the research questions that we have identified in IoT. These research questions are important as they map the state of the art in QoS approaches through the layers of the IoT and identify what quality factors they take into account when measuring performance, which in turn leads to the identification of gaps in the related literature. This is important as previous mapping studies such as those in cloud computing (Abdelmaboud et al., 2015) which have identified gaps in the literature have led to a number of publications to address those gaps such as overlay networks for dynamic load-balancing (Daraghmi and Yuan, 2015), multi-attribute auction model for resource allocation (Baranwal and Vidyarthi, 2015) as well as a number of other solutions. It is our hope that the gaps identified by our mapping also leads to further research in these particular areas.

3. Research method

3.1. Research question

The goal of this mapping is to identify what contributions have been proposed through the layers of the IoT, to identify areas where further research is necessary to deliver E2E QoS, which is needed for safety critical applications. We also identify which QoS factors have been taken into account when validating an approach and which have not been used. The research method is also taken into account for the approaches to identify which research methods have been underutilised.

- **RQ1:** What layers of the IoT architecture have had the most research on QoS?
- **RQ2:** What quality factors do the quality approaches take into account when measuring performance?
- **RQ3:** What types of research have been conducted in this area?

3.2. Search

3.2.1. Bibliographical sources

We use a combination of search strategies to ensure full coverage of the relevant literature, combining automated database searches with a snowballing process (Wohlin, 2014). This gives us good coverage of the area we wanted to map (IoT) while also ensuring that we capture relevant papers from related domains (MANET, WSN, Web Services, etc.). There are a number of bibliographical databases which are used in Computer Science (Kitchenham et al., 2010; 2009) as can be seen in Table 1. The features which were most useful for this mapping were the ability to use expert searches with a range of boolean operations and to focus the search on the Title, Abstract and Keywords fields (TAK) which return more relevant results compared to searching all fields. Based on these requirements we have chosen to use IEEE Explore, Science Direct, Scopus, Web of Science (WoS), and Engineering Village.

3.2.2. Keywords used

The keywords were extracted using a combination of PICO (Population, Intervention, Comparison and Outcome) which is suggested by Kitchenham et al. (2010) and keywords which have been extracted from known high quality papers. The PICO method is used to identify keywords and formulate search strings from research questions. However as identified in other systematic literature reviews (Riaz et al., 2009) and systematic mappings (Petersen et al., 2008), it is not always fully applicable. In our case, we retrieve the keywords from the Population and Intervention research questions.

- *Population:* The population of this search refers to the specific application area that we are interested in, which in this case is an IoT environment. The IoT has evolved from a number of related domains such as WSN, MANETS and Web Services, as these domains are highly related it is necessary to include them in the mapping.
- *Intervention:* The intervention of this search refers to a procedure, software methodology or tool, which in the context of this study is the QoS approaches which have been developed and the QoS factors which have been used to evaluate them.
- *Comparison:* This mapping is considered a more general analysis of the field as we do not rank the individual approaches.
- *Outcomes:* No outcomes are considered in the keywords used.

The identified keywords are: QoS, Quality Model, Quality Ontology, Monitoring, IoT, WSN, MANETS, Middleware and Web Services. These are then grouped into sets and their synonyms are including to formulate the final search string. The final search string contains a logical OR between all of the synonyms with a logical AND between the two sets.

- *Set 1:* Scoping the search to the specific area that we are interested in i.e "IoT, WSN, MANETS, Web Services, SOA, SDN, Middleware".
- *Set 2:* Search terms which are directly related to the intervention, e.g. "QoS, Quality Models, Monitoring, Quality Ontology, SLA".

When using a large string of keywords it can be difficult to ascertain which are contributing the most documents. To identify which keywords were contributing the most documents we conducted a number of individual searches using the SCOPUS database which can be seen in Fig. 3. Using this diagram we can see that over half (52.69%) or 19,411 of our returned results are from the "MANETS" OR "Mobile*" keyword searches. This gives us valuable information about the coverage of our final search string and allows us to refine our keywords to a more specific area as it would be too time consuming to conduct a systematic mapping with over 30,000 documents.

The final keywords and databases which were used in the mapping are shown in Table 2. We have decided to focus our mapping specifically on IoT, QoS and Monitoring which provides coverage of the specific areas that we wanted to map. To account for papers which may not have these specific keywords from other domains such as MANETS and WSN we add a snowballing phase to the review which allows for the addition of papers which have been identified in the references of the selected papers. This allows us to include the most influential papers from related domains which have been adapted to be used in the IoT.

3.3. Study selection

After retrieving the results using the procedure outlined in the previous subsection, we applied the following selection criteria to filter out the irrelevant candidates. The results removed from each stage can be seen in Fig. 4.

1. **Removal of duplicates:** Using our reference manager we were able to automatically find and remove duplicates based on the author names, year and title of the article.
2. **Selection by title:** This stage is used to quickly remove articles returned by the search results whose scope is clearly unrelated to QoS in IoT by the title.
3. **Selection by abstract:** This stage removes articles which do not present a quality approach as a contribution of the paper.
4. **Selection by full paper:** This stage is used to remove articles which did not present a quality approach as one of the contributions of the paper and does not define the quality factors taken into account.
5. **Related references (snowballing):** The final stage of the systematic mapping process is to include other works through the process of snowballing, which identifies additional papers in the reference of the final selection by the full reading which are evaluated against the criteria outlined above. The selected papers are then added to the final list of papers.

The following inclusion criteria were applied to the mapping:

- Studies published online from 01/01/2000 to 01/03/2016.
- Studies in the field of computer science.
- Studies presenting a quality approach as one of the contributions of the paper.
- Studies using defined quality factors to evaluate their quality approach.

The following exclusion criteria were applied to the mapping:

- Studies presenting non-peer reviewed material.
- Studies not presented in English.
- Studies not accessible in full-text.
- Studies that are duplicates of other studies.

3.4. Data extraction

To extract the data required from the returned articles, we developed the following template shown in Table 3. Table 3 shows the four facets used to map the current research proposals. The focus area is used to structure the topic in the layers of the IoT architecture and the research approaches are classified using an established classification approach (Wieringa et al., 2005). We also consider the type of contribution which has been proposed and the quality factors which have been considered. Each of these types and areas are described in detail in the following subsections.

SCOPUS 11-03-16	IoT, "Internet of Things"	Middleware	SOA	SDN	WSN	MANETS, "Mobile ad hoc network"	MANETS, "Mobile*"	"Web Services"	Pecentage	Count
QoS, "Quality of Service"	267	1329	1292	232	645	654	10948	4356	**53.53%**	19723
Monitoring	814	1165	779	105	2616	464	8168	1705	**42.93%**	15816
"Quality Model"	1	4	23	0	4	1	94	63	**0.52%**	190
"Quality Ontolog*"	0	1	1	0	0	0	0	11	**0.04%**	13
SLA, "Service Level Agreement"	21	118	232	26	3	4	201	495	**2.99%**	1100
Pecentage	**2.99%**	**7.10%**	**6.32%**	**0.99%**	**8.87%**	**3.05%**	**52.69%**	**18.00%**		
Count	1103	2617	2327	363	3268	1123	19411	6630		

Fig. 3. Keywords that were used in the search.

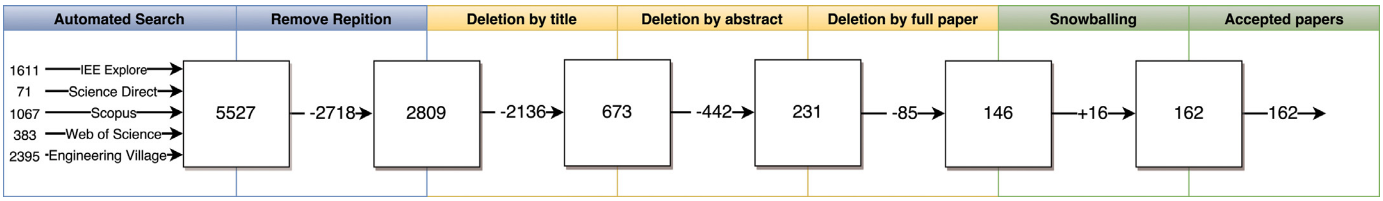

Fig. 4. Selection of the mapping articles.

Table 3
Mapping extraction.

Focus area	Research type	Contribution type	Quality factors
Physical Sensor	Validated Research	Tool	Functional Stability
Deployment	Evaluated Research	Method	Performance Efficiency
Physical Layer	Solution Proposal	Process	Compatibility
Link Layer	Philosophical Papers	Model	Usability
Network	Opinion Papers	Metric	Reliability
Application	Experience Papers		Maintainability
Middleware			Portability
Cloud			

The heterogeneity of device capabilities and the QoS requirements of different applications has led to some researchers questioning the performance of classical layered solutions for this environment and instead have suggested the use of cross layer techniques (Han et al., 2013). For these techniques, we map each of the layers that they address in the approach, which means that articles may appear in more than one layer. This allows us to map approaches which may only take into account one layer such as the link layer of the network [A40] as well as approaches which use a cross layer method taking into account the physical, link and network layers [A33]. This means that in some diagrams such as Fig. 5 there are more articles in each layer than in Table 4. This is due to an article belonging to multiple categories, for example an article at the cloud layer can contain a solution proposal as well as a validation, which we count as a one in each category. This applies to Figs. 5–9 where each of the articles can belong to more than one group, to give a sum of shown percentages greater than 100 and to the sum of articles in Tables 4–7, which sum to more than the total number of articles.

3.4.1. Focus area

Table 3 shows the range of layers which can be taken into account in an IoT architecture which is based on the most recent surveys of architectural approaches (Gubbi et al., 2013; Al-Fuqaha et al., 2015a). For highly critical applications especially in domains such as healthcare, we would expect to see an E2E focus on the QoS approaches, from the device to the user to ensure safety, as many of these applications are life critical and an anomaly in any layer could cause delays and errors.

- Physical Sensor: This layer is the actual physical device/sensor that conducts the measurement and also includes the gateway devices which are used in the system.
- Deployment: How the nodes are deployed in the area that we wish to measure.

Table 4
Layer addressed by each paper.

Architectural layers	Study	Articles
Cloud	A6, A7, A13, A18, A24, A26, A34, A44, A50, A51, A53, A60, A61, A63, A72, A76, A79-82, A84, A91, A98, A104, A114, A146, A149	27
Middleware	A2, A11, A13, A14, A20, A27, A35, A43, A51, A59, A60, A62, A65, A76, A81, A118, A122, A126, A134, A137, A143	21
Application	A1, A2, A5, A7-10, A19, A28, A30, A31, A33, A44, A45, A47, A49, A50, A53-55, A58, A60, A70, A74, A78, A83, A86, A89, A96, A97, A102, A104, A112, A117, A122, A125, A136, A139, A155, A156, A162	40
Network	A1, A2, A8-12, A15, A17, A19-20, A22-25, A30, A32, A33, A36-42, A44-49, A52-54, A57, A58, A60, A64-76, A78-83, A85, A86, A88-102, A104, A106-112, A114-125, A129, A130, A132, A133, A135-141, A144, A146, A148, A150-152, A155-157, A159-162	117
Link layer	A1, A2, A8-12, A15-17, A19-20, A23-25, A30, A32, A33, A36-42, A44-49, A52-54, A57, A58, A60, A64-83, A85, A86, A88-125, A127-133, A135-139, A141, A142, A144-148, A150-152, A154-162	128
Physical layer	A1, A2, A8-12, A15-17, A19-21, A23-25, A30, A32, A33, A36-42, A44-49, A52-54, A57, A58, A60, A64-83, A85, A86, A88-125, A127-133, A135-139, A141, A142, A144-148, A150-152, A154-162	129
Deployment	A4, A7, A16, A24, A47, A52, A58, A63, A78, A90, A92-94, A97, A112, A115, A119, A130, A153	19
Physical device	A2-4, A14, A21, A23, A24, A26, A44-47, A49, A53, A58, A63, A65, A66, A71, A72, A75, A76, A79, A80, A82-87, A89-92, A95-97, A99, A102, A107, A112, A114, A115, A117-119, A121, A122, A125, A130, A136-138, A140, A144, A146, A148, A155	58

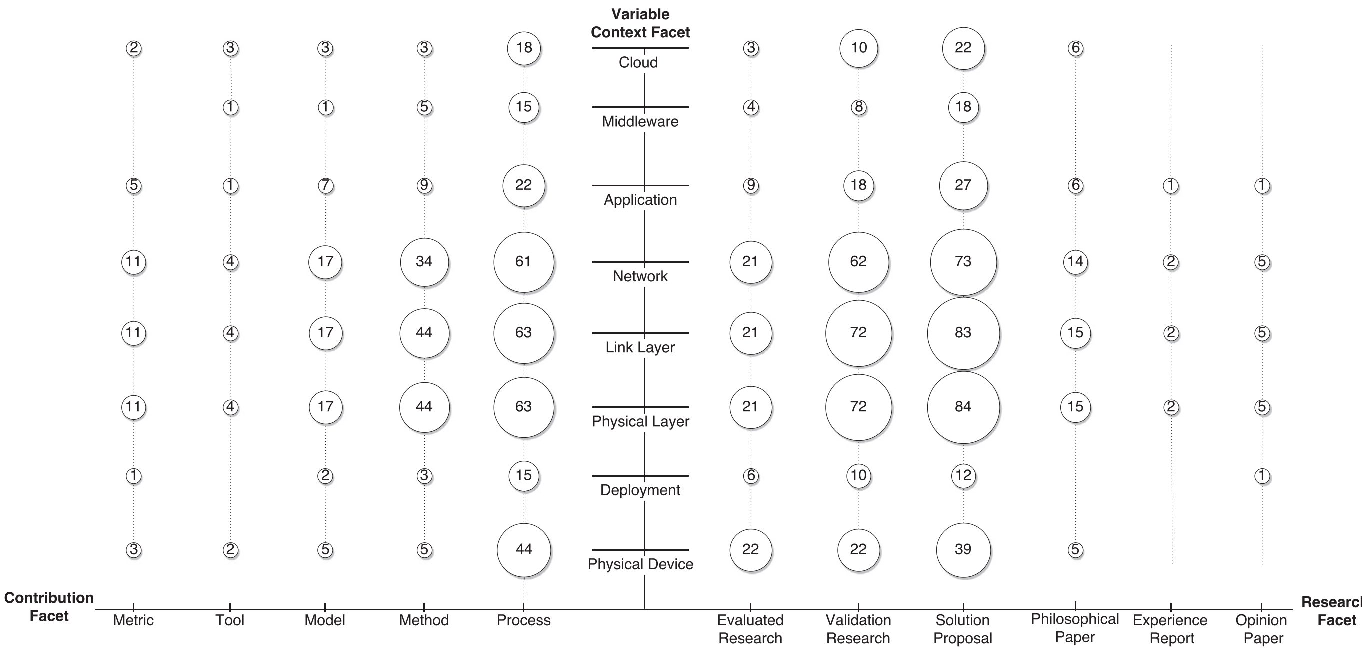

Fig. 5. Overview of the mapping.

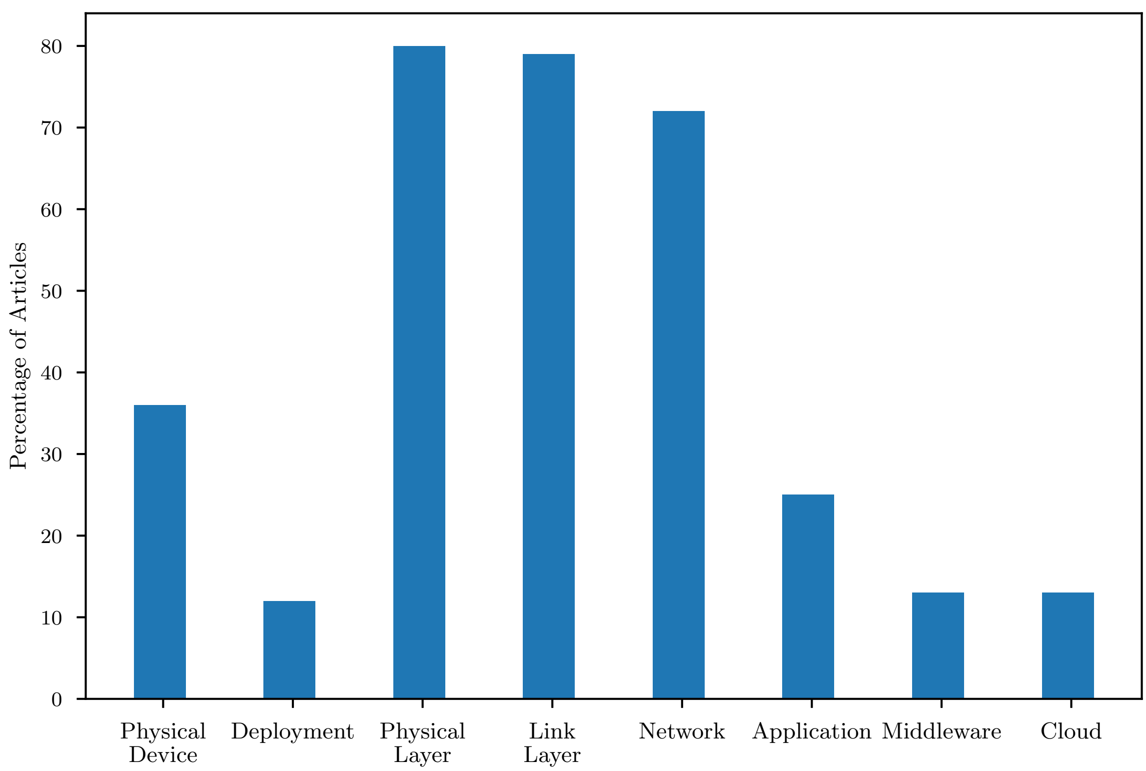

Fig. 6. Percentage of articles addressing each layer.

- Physical Layer: The physical layer of the network, it provides the physical sensor the means of sending and receiving data by defining the cables, and physical aspects.
- Link Layer: The link layer of the network which encodes and decodes data packets into bits and manages errors in the physical layer, flow control and frame synchronization.
- Network: The network layer is responsible for switching and routing as well as addressing other aspects such as congestion control and packet sequencing.
- Application: The application layer provides access to the network services as well as error handling and data flow over the network.
- Middleware: A mechanism to provide access to heterogeneous resources and support interoperability within diverse applications.
- Cloud: A network of remote servers which can be accessed on demand to store, manage and process data.

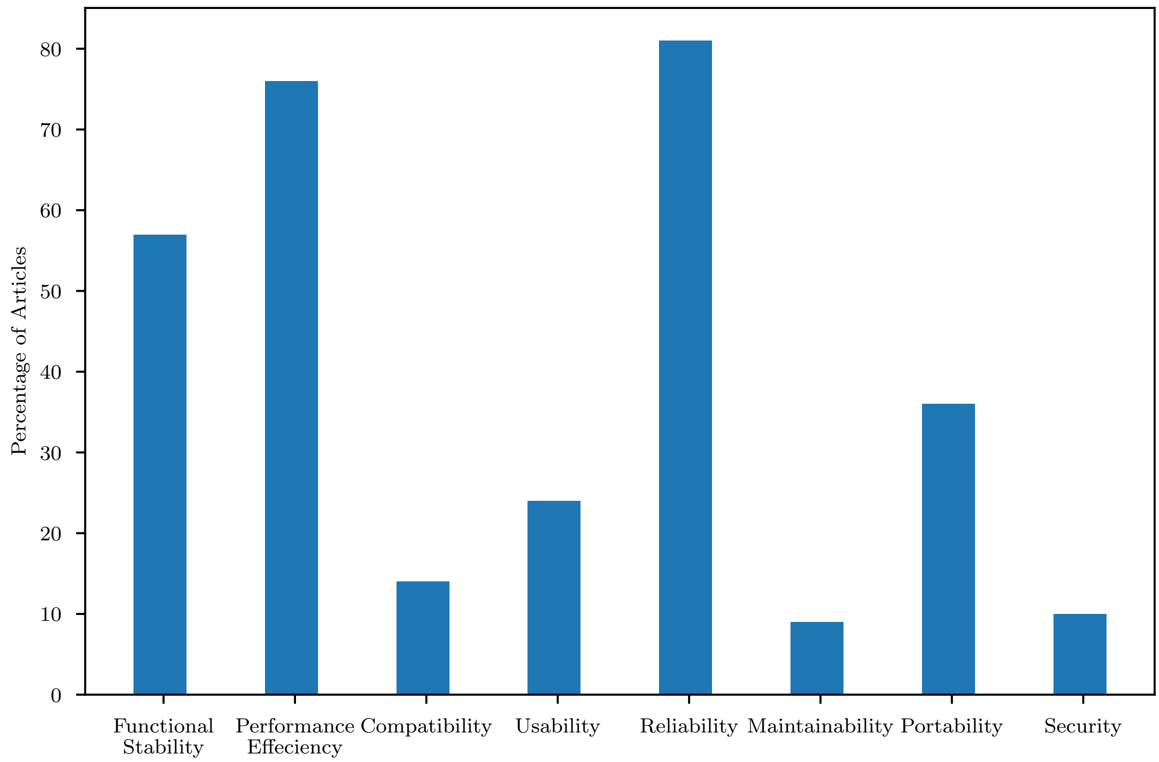

Fig. 7. Percentage of articles addressing each quality factor.

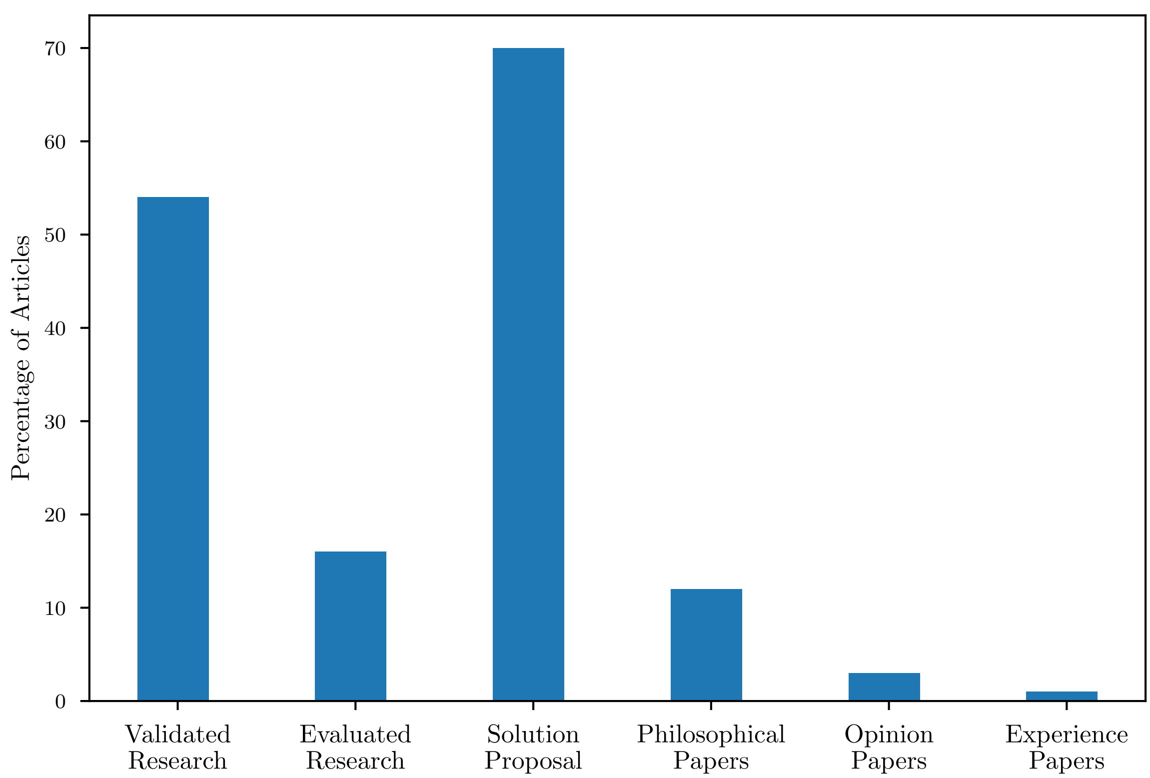

Fig. 8. Percentage of articles using each research facet.

3.4.2. Research type

In order to characterise the research approaches we use the classification scheme proposed by Wieringa et al. (2005). We follow this classification in our systematic mapping study and categorised the primary studies into six research types as follows:

- Validation Research: This investigates the properties of a solution proposal that has not yet been implemented in practice. The solution may be proposed elsewhere by another author. Possible research methods are mathematical analysis, simulation, experiments, mathematical proof of properties etc.

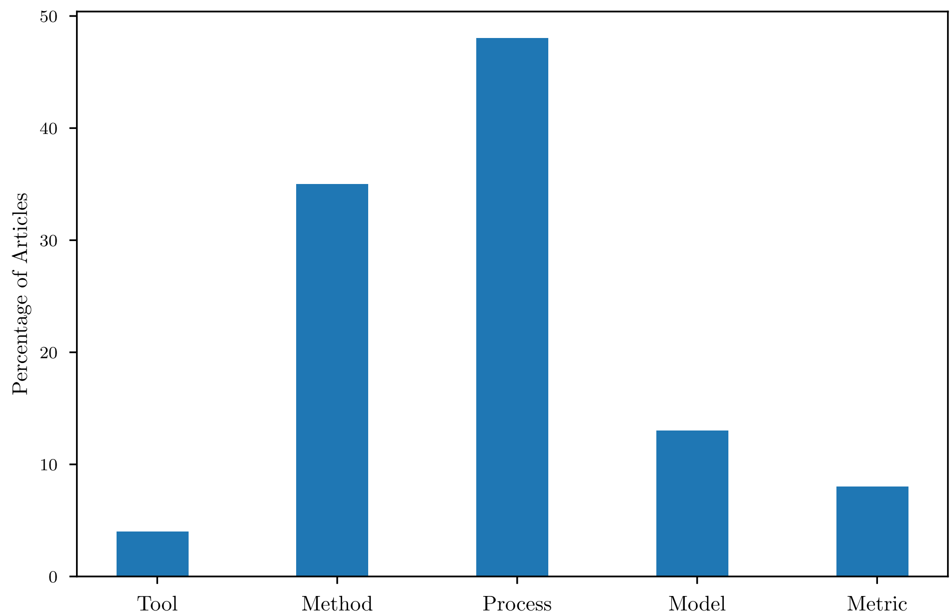

Fig. 9. Percentage of articles contribution types.

Table 5
Quality factors addressed.

Quality factor	Study	Articles
Functional stability	A1-4, A7, A9, A13, A18, A22, A26-28, A30, A33, A34, A39-44, A46, A47, A50, A52-56, A58, A59, A61, A63-68, A70-79, A81-86, A88-92, A94-103, A105-107, A109-112, A114, A115, A125, A131, A134, A136, A148, A153, A155-162	92
Performance efficiency	A1, A5, A7, A11, A13, A15, A17, A20, A22, A27, A30, A32-47, A50, A52-59, A63-68, A70-79, A81-84, A87-92, A95, A97-121, A123-135, A137, A139-147, A149-156, A158-160, A162	123
Compatibility	A3, A4, A6-9, A18, A20, A24, A27, A35, A46, A47, A58, A61, A62, A64-66, A74, A98, A143	22
Usability	A2-4, A6, A21, A23, A24, A26, A45-47, A49, A51, A53, A54, A58, A60, A62, A64, A66, A71, A74, A79-82, A88, A90-92, A95, A96, A112, A115, A119, A123, A124, A136, A148	39
Reliability	A1-4, A8, A9, A13-15, A18, A20, A23-30 A32-37, A40-47, A49-52, A54-58, A60, A61, A63-71, A73-92, A94-105, A107-111, A114, A116-120, A123-130, A132-134, A136, A137, A139-145, A147-151, A153-160, A162	131
Maintainability	A3, A4, A6, A7, A39, A54, A62, A65-67, A72, A79, A86, A91, A98	15
Portability	A2-4, A6, A7, A8, A10, A12, A15, A22, A27, A28, A31-34, A38, A43-45, A49, A51, A53, A54, A56, A60, A74-76, A79, A83, A84, A90, A94, A96-99, A101-104, A108, A109, A113-121, A123, A125, A142, A148, A148, A156, A158, A162	59
Security	A2, A10, A46, A57, A61, A62, A74, A77, A80, A82-84, A117, A132, A136, A158, A162	17

Table 6
Research approach used.

Research approach	Study	Articles
Validation research	A1, A3, A4, A9, A11, A12, A14, A16-18, A22, A24, A26-28, A30-33, A37-42, A44, A48-50, A33, A37, A38, A39, A40, A41, A42, A44, A48-50, A52, A55, A57, A60, A65, A67-70, A72, A73, A75, A78, A81, A84, A88, A89, A92, A95, A97, A99, A101, A103, A105, A106, A108-113, A115, A117, A120, A121, A124-128, A131, A133, A136, A139-147, A149-151, A153, A154, A158, A159	88
Evaluation research	A23, A35, A45-47, A53, A58, A62, A63, A66, A71, A83, A86, A87, A90, A96, A102, A107, A116, A118, A119, A130, A136 A138, A148, A160	26
Solution proposal	A1-7, A9, A11, A13-16, A18, A20-24, A26-28 A30-35, A37-40, A43, A44, A46, A49-52, A54, A55, A57-59, A61-65, A67, A68, A70-72, A74-79, A81, A82, A84-86, A88-92, A94-105, A111, A113, A116, A117, A120, A122, A125-128, A131, A134, A135, A137, A138, A140-142, A147, A149-152, A154-155, A157-162	113
Philosophical paper	A5, A6, A8, A10, A19, A25, A29, A45, A56, A64, A77, A79, A80, A82, A98, A114, A129, A135, A156	19
Opinion paper	A36, A93, A123, A132, A156	5
Experience paper	A19, A73	2

- Evaluation Research: This is the investigation of a solution proposal in practice. The solution again may be proposed elsewhere by another author. Casual properties are studied empirically such as by survey, field study, field experiment or case study. Logical properties are studied by conceptual means such as mathematics or logic.
- Solution Proposal: This is the proposal of solution for a problem, which should be novel or a significant extension to the state of the art. A proof of concept may be included by a logical argument or a small example.
- Philosophical Papers: This is a proposal of a new way of structuring the field, which is usually performed by either a taxonomy or a conceptual framework.
- Opinion Papers: This is the personal opinion of the author about whether a technique is good or bad, these papers usually do not include related work and research methodologies.

Table 7
Contribution type.

Contribution	Study	Articles
Tool	A14, A26, A34, A36, A37, A70, A81	7
method	A1, A5, A15, A16, A22, A27, A28, A30-32, A39, A40, A43, A44, A50, A52, A57-59, A64, A67, A68, A88, A99, A101, A103, A105, A106, A108, A110, A111, A113, A120, A121, A124, A126-128, A131, A139-143, A145, A147, A149-152, A154, A157-161	56
Process	A2, A6, A7, A9, A11, A13, A20, A21, A23, A24, A27, A29, A33, A35, A37, A38, A46-49, A51, A53-55, A58, A60-63, A65, A66, A69, A71, A72, A74-77, A79, A82-86, A89-98, A100, A102, A104, A107, A109, A112, A115-119, A129, A130, A134, A136-138, A144, A146, A148, A153, A155, A157	77
Model	A3, A4, A8, A10, A17-19, A25, A41, A42, A45, A56, A64, A73, A78, A80, A98, A122, A123, A132, A156	21
Metric	A7-10, A12, A41, A42, A73, A87, A88, A114, A125, A135	13

- Experience Papers: This is a paper which gives the authors personal experience of an actual project including what was performed and how it was done.

3.4.3. Contribution type

The contribution type was developed by looking at related systematic mappings (Oriol et al., 2014; Abdelmaboud et al., 2015) and by consulting relevant high quality approaches selected in the mapping. From these sources we have identified five contributions which are used in the majority of these papers.

- Tool: A tool refers to research which contributes a software tool or application to improve QoS in IoT.
- Method: A method refers to research which contributes either an algorithm or a specific approach to improve QoS in IoT.
- Process: A process refers to research which describes specific activities or an architecture which can be used to improve QoS in IoT.
- Models: A model refers to research which explores relationships and identifies challenges with different QoS approaches.
- Metrics: The contribution of metrics is the reporting of measurements which have been calculated for the QoS approaches.

3.4.4. Quality factors

There are a range of quality factors which can be used to quantify QoS and many different Quality Models have been proposed at different granularity to address these issues. For this mapping we use the ISO/IEC 25010 quality model ISO/IEC (2010) as a vehicle to demonstrate the quality factors which are being considered in these approaches.

- Functional Stability: This factor addresses the functional completeness, correctness and appropriateness of the factors which have been used to evaluate the approach.
- Performance Efficiency: This addresses the performance which takes into account the time-behaviour, resource utilization and the capacity.
- Compatibility: This addresses how the approach can co-exist with other approaches and the interoperability with other techniques.
- Usability: This factor takes into account a number of sub-characteristics such as the appropriate recognisability which includes the documentation and discoverability. It also focuses on a number of other sub-characteristics such as the learnability, operability and accessibility.
- Reliability: This takes into consideration the maturity, availability, fault tolerance and recoverability of the approach.
- Security: This addresses aspects such as the confidentiality, integrity and authenticity of the approach.
- Maintainability: This addresses aspects such as the modularity, reusability and testability of the approach.
- Portability: This addresses aspects such as how adaptable and replaceable the approach is for other environments.

3.5. Validity evaluation

To assess the validity of the mapping and to take into account areas where bias could have been introduced, we follow the guidelines in the review by Petersen and Gencel (2013). For this mapping we take into account the description validity, theoretical validity, interpretive validity and repeatability.

3.5.1. Description validity

To assess the description validity we take into account how each of the observations are described and whether they are described objectively. We have taken great care in the mapping to reducing this threat as can be seen in Section 3.4 which describes in detail the data extraction process which was used to conduct the mapping. We also describe each category which was used in the mapping process to ensure completeness.

3.5.2. Theoretical validity

The theoretical validity takes into account how the experiment was conducted and whether we have introduced any bias while selecting the studies and in the data extraction process.

Study sampling: As identified by Wohlin et al. (2013), it is possible for two mappings of the same topic to end up with a different selection of articles. To reduce this threat we have used a combination of the most popular academic databases to increase the coverage of the mapping. To ensure the most relevant studies from related domains were returned we conducted a backward snowballing sample of all of the studies after the full-text reading. This allowed us to obtain documents from related domains such as WSN, MANETS and Web Services.

When selecting and extracting data it is possible to introduce researcher bias (Petersen and Gencel, 2013). As has been identified by Kitchenham et al. (2009), it is useful to have one researcher select the studies and another review the selection which is common practice for conducting systematic reviews in the social sciences (Petticrew and Roberts, 2008), and is the methodology which has been followed in this mapping.

Data extraction and classification: Researcher bias may also appear during data extraction and classification. We use a similar process to the study sampling where another researcher reviewed the extraction, using the extraction tables which are described in Section 3.4.

3.5.3. Interpretive validity

Interpretive validity is the extent to which the conclusions from the mapping are reasonable given the data, which can be also be influenced by researcher bias. The authors are not involved with any of the approaches, which reduces the possibility of bias towards a particular approach. We have also listed the full results of the mapping which allows readers to verify the conclusions of the authors in Appendix A.

3.5.4. Repeatability

Repeatability allows for the complete repetition of the experiment to verify the results, and requires detailed reporting of the research method. We have made considerable effort to report the exact search strings that were used to build up the collection of documents for each of the databases. We also discuss in detail the extraction process and describe how each one of the categories is defined to allow for the repeatability of the experiment.

4. Results

4.1. RQ1: What layers of the IoT architecture have had the most research on QoS?

Fig. 6 shows that the physical device was addressed by 36% of the selected articles. Looking into more detail in Fig. 5 we can see the contributions of these approaches and the research facets used. The most contributed facet from the selected papers was a process, which provides an architecture to improve QoS. The research at this layer has been focused on the use of solution proposals with validated or evaluated research and no experience reports or opinion papers. Table 4 gives the complete list of papers which were mapped to this layer, the main proposed solutions come from a number of domains, with a large amount coming from healthcare where QoS is an important issue. Solutions include an architecture for an open source medical device connectivity kit, which is discussed as part of a service-oriented middleware [A2], an implementing and evaluating of a 6LowPAN host tag for a smart healthcare system [A23], an evaluation of a pervasive healthcare application using physical devices [A53] and the proposal and evaluation of an on-body sensing prototype which includes detailed discussion and evaluation of the antenna and firmware design. A number of other solution proposals deal with QoS in the home such as an integrated access gateway which provides standard interfaces for various applications in the home environment and is evaluated as a simple home network application system [A46], other proposals have reported effective implementation and evaluation of domestic condition monitoring systems by a ubiquitous sensing system [A107]. More generic solutions have also been proposed which can be used in multiple domains such as the design and evaluation of an embedded gateway architecture for monitoring systems in the IoT [A89].

The deployment of nodes is a crucial step to ensure that we are not only getting accurate measurements from the correct location but it can also improve the QoS of the network, however it is often overlooked and is only taken into account in 11% of the articles as can be seen in Fig. 6. Looking at Fig. 5 we see that the most contributed facet was a process and that there was a lack of alternative contributions especially tools and metrics. The research at this layer has focused on solution proposals and the validation or evaluation of those proposals, with a lack of focus on experience and philosophical papers. The main proposed solutions have focused on a number of areas including the design of a protocol to monitor a large scale network and reduce the number of working nodes in areas of overlapping coverage to save battery life [A16]. One article in particular presents an evaluation of a real-time safety early warning system to prevent accidents, which has been used in a real world setting [A47]. This article presents in detail the deployment of nodes at the project level and also at the device level, giving detailed diagrams of how the sensors were installed. Another interesting solution is presented in a WSN platform for long term environmental monitoring for IoT applications, which discusses in detail the deployment procedure, where the sensor node can be switched to deployment mode to receive link quality information from the gateway that receives the node. The node collects the received data and displays the suitability of that position [A119].

The communication layers are highly important for QoS in IoT and are taken into consideration in a number of proposals. From Fig. 6 we can see that the physical layer, link layer and network layer are the most considered layers in the IoT architecture, with less focus on the application layer. In Fig. 5 we can see that the contributions through these layers has been similar with a focus on processes and method contribution facets as well as solution proposals and validated research facets. Some approaches have focused on one specific communication layer such as developing a new markov chain model to analyse MAC layer performance in wireless mesh network [A41] as well as the development of a new MAC protocol based on perceived data reliability and spatial correlation in a wireless sensor network [A40]. A number of other proposals however have focused on cross layer approaches to deal with the heterogeneity of device capabilities. One such proposal presents a novel cross layer optimisation framework to capture the interaction among different layers as well as cross layer protocol to practically implement the proposed framework, with results showing that the proposed solution outperforms existing layered solutions [A33]. Another proposal presents a cross layer per-flow distributed admission control for 802.11e which outperforms the former layered solutions in the utilization of resources, based on the validated results. Some other solutions model the network as one component in a cross layer system for example an optimal service composition model using the knowledge of each component at the application, network and sensing layer [A125].

The middleware layer has had fewer papers published and is only taken into account in 13% of proposals, looking at Fig. 5 we can see that there has been a focus on processes and additional contributions are needed for metrics, tools and models. There is also a need for alternative research facets, with the majority of approaches focusing on solution proposals and their validation, there has been a lack of philosophical and opinion papers as well as experience reports. The middleware proposals cover a range of different domains and architectures, with many using a service oriented architecture (SOA). The middlewares are used to combine heterogeneous service technologies and deal with QoS at the service level, many of the approaches contain specific modules for dealing with QoS, this is especially important in healthcare where some approaches use specific health device profiles for devices to ensure QoS [A2]. Some middleware approaches focus on specific IoT technologies such as RFID and validate the extensibility and flexibility of the middleware in various usage scenarios [A11]. Other approaches have focused on the extension of SOA to a knowledge aware and service oriented middleware (KASOM) [A35]. In this proposal, they have implemented mechanisms and protocols which allow the management of knowledge generated in pervasive embedded networks in order to expose it in a readable way. Other architectural approaches have adopted a publish/subscribe middleware approach with additional QoS management to enable mobility and quality-driven acquisition from mobile sensors [A13].

The use of cloud technologies has become a popular approach to improve the QoS in an IoT environment with many new approaches including a cloud layer in their architecture, looking at Fig. 5 we can see that processes have been the most contributed facet and that there has been a focus on solution proposals and validation research, with a research gap for experience reports and opinion papers. The approaches at this layer are often used to address the reliability concerns of the IoT, especially in domains such as healthcare where approaches have been proposed to manage mobile and wearable healthcare sensors [A53,A61,A82]. For example [A53] presents an evaluation of a platform based on cloud computing for the management of mobile and wearable healthcare sensors, [A61] uses an existing cloud platform to develop a patient monitoring system and [A82] present a framework for enabling health monitoring using cloud-assisted IoT. Other approaches have also proposed frameworks for adaptive interaction support with algorithms to adapt QoS based on the quality of context information and the quality of services [A6]. Alternative approaches present QoSMONaaS (Quality of Service MONitoring as a Service), which build a QoS monitoring facility on top of existing cloud technology [A34].

4.2. RQ2: What quality factors do the quality approaches take into account when measuring performance?

Functional Suitability takes into account a number of parameters such as the functional completeness, correctness and appropriateness. As can be seen in Fig. 7 it is covered by 57% of the approaches mostly due to the functional correctness sub-characteristic which includes accuracy and precision. This sub-characteristic is addressed in a number of approaches throughout the layers of the architecture from the physical device [A86], network [A105], middleware [A13] and the [A148].

Performance efficiency is one of the most used quality categories and is addressed in 76% of the articles, which can be seen in Fig. 7. It contains a number of important sub-characteristics such as the time-behaviour, resource utilisation and capacity. The time-behaviour is important in IoT and is one of the factors which must be addressed at each layer of the architecture, as the time experienced by the end user is the sum of time through all the individual layers of the architecture. A number of approaches at each layer have been proposed, from an architecture to improve the efficiency of a physical gateway [A46], the deployment of sensors in an early warning system [A47], the QoS aware routing of packets through a network [A67], the use of a knowledge-aware and service oriented middleware [A35] and the use of cloud-assisted industrial internet of things [A82], the performance efficiency has been addressed by a number of articles at each layer of the architecture.

Compatibility is one of the least addressed quality categories and as can be seen in Fig. 7 it is only observed in 14% of the articles. The sub-characteristics which are most taken into account by the approaches are co-existence [A8,A20,A35,A98] and interoperability [A7,A18,A58,A98,A143], where they have used a modular design and allow a number of components in the system to be altered.

Usability contains a large number of sub-characteristics which deal with a number of issues such as the operability, accessibility and user error protection. However as can be seen in Fig. 7 it only taken into account in 24% of approaches, with the most used sub-characteristics being the appropriateness recognisability [A24,A49,A58,A64,A71,A90-92], the operability [A21,A23,A24,A51,A88,A90] and accessibility [A21,A45,A71,112,136] sub-characteristics.

Reliability is the most used QoS category as can be seen in Fig. 7 and is often the primary goal of many of the approaches. It contains a number of sub-characteristics such as availability, fault tolerance and recoverability which are addressed in a number of approaches. These approaches have been at different layers of the architecture from a cloud centric internet of things to improve recoverability [A18] to an alternative routing algorithm to address availability [A52]. A number of approaches in the health domain have focused on improving reliability, especially sub-characteristics such as fault tolerance [A2,A54,A92,A155,A162].

Maintainability is the least addressed quality characteristic and is only taken into account in 9% of approaches, which can be seen in Fig. 7. The main sub-characteristics taken into account are the modifiability [A6,A7,A39,A91] and modularity [A39,A72,A86,A91]. Portability is addressed more and taken into account in 36% of the approaches due to the adaptability [A8,A10,A12,A38,A54,A60] and installability [A10,A53,A54,A60,A123] sub-characteristics.

The lack of focus on security is one of the more interesting results from the mapping, which shows that it is only taken into account in around 10% of approaches as can be seen in Fig. 7. Some articles focus on specific security aspects of IoT, such as authentication, encryption and signing communications with medical devices [A117]. Other articles provide detailed comparison of security aspects such as authentication, integrity and confidentiality and the trade-offs for QoS in the future internet [A136] and for specific protocols such as 6LoWPAN [A10]. However, many of the other articles don't take into account the security aspect which needs special consideration when dealing with critical systems in domains such as healthcare.

4.3. RQ3: What types of research have been conducted in this area?

A validation of a solution proposal involves either a mathematical analysis, simulation or a mathematical proof of properties. The most popular method of validation is by simulation, either through the use of an established simulation environment such as NS2 [A38,A40,A73,A110] or by creating a simulation using a program such as Matlab with given parameters [A1,A37,A78,A105,A113, A124,A127,A136,A141,A147,A148]. These validation simulations are useful for initial solution proposals as they are repeatable and allow other researchers to verify the proposed improvements over alternative approaches.

An evaluation of a solution proposal is an investigation in practice by a number of methods such as field study, field experiment or case study. The most common approach for the proposed solutions was a field experiment or case study to verify that the approach worked for the proposed environment. For approaches in the health domain this is especially important due to their critical nature, which is why a number of approaches for this domain are evaluated using a case study [A12,A23,A35,A53,A58,A63,A71,A90,A118,A148]. This can identify the practical implications of an approach which may not be identified by a validation, such as the wearability of the sensor or how the approach reacts to different network conditions [A59].

There are a number of other research facets which can be used to contribute to the state of the art apart from a solution proposal which is validated or evaluated. This can be through a philosophical, opinion or experience paper, which give an indication of the research challenges through problems identified in previous projects. For example [A19] gives a list of the challenges of the IoT in IPv6 from both experience and related literature, which helps to structure the field and ensure that the most relevant research questions are being worked on. There are a number of papers which have been proposed at the network level which use these research facets such as [A8] which presents a list of network challenges for cyber physical systems after a case study and [A136] which present an analysis and taxonomy of security/QoS trade-off solutions at the network level.

The contributions of the articles have also been taken into account as can be seen in Table 7 and Fig. 9. From the results, it is clear that processes and methods make up the majority of contributions, this is related to the previous question where the solution proposal was the most used research facet. Looking at Fig. 5 we can see that a process is the most common contribution type through all the layers, but we can also identify that research at the network level has been much more diverse, with contributions of models, tools and metrics. The contribution of models and metrics are useful as they allow comparison between different approaches, such as different MAC approaches [A41,A42]. There have also been fewer tools built as many of the proposals are initial solution proposals, however there are some exceptions such as [A81] which presents a toolset for managing IoT cloud systems and [A34] which presents a QoS monitoring facility built on top of the SRT-15 complex event processing based platform.

5. Conclusion

The goal of conducting this systematic mapping study was to provide an overview of the state of the art QoS approaches in IoT. The interest in quality approaches through the layers of the IoT stems from the need to ensure strict EQE QoS in safety critical domains such as healthcare and to ensure that suitable quality factors are measured. We used the systematic mapping process to identify 162 articles which were used as primary studies. The answers to the research questions and the research agenda are considered the main outcome of this paper.

5.1. RQ1: What layers of the IoT architecture have had the most research on QoS?

From the results in Section 4.1 we can identify that the communication layers of the IoT architecture which take into account the physical, link and network layer are the most addressed as can be seen in Fig. 6. From this diagram, it is clear that there are areas, which have a lack of primary studies and need further research such as the deployment, middleware and cloud layers of the architecture. We can also identify from Fig. 5 the contribution and research types that are needed in each of the layers, which is discussed in the research agenda in Section 5.4.

5.2. RQ2: What quality factors do the quality approaches take into account when measuring performance?

From the results in Section 4.2 we can identify that the approaches most often take into account quantitative quality factors such as reliability, performance efficiency and functional stability which can be seen in Fig. 7. From this figure, we can also identify important qualitative factors such as security, compatibility and maintainability which are crucial to the success of the IoT but which are rarely taken into consideration.

We hope that this paper will highlight the need for the use of quality models such as ISO/IEC 25010, which provides a structured list of quality factors that should be taken into consideration when proposing an approach. This will allow researchers to identify trade-offs between the different approaches, for example an approach which decreases the delay time may also increase the power needed. These problems should be identified when the solution is being validated to allow other researchers to build on top of work where they know the shortcomings.

5.3. RQ3: What types of research have been conducted in this area?

From the results in Section 4.3 we can identify that the most used types of research in this area have focused on solution proposals and validated research which can be seen in Fig. 8. We can also see in Fig. 9 that most of the articles have contributed a method or process. From these figures, we can identify the research facets and contribution types which have been underutilised in the state of the art and using Fig. 5 we can identify research gaps through the layers of the IoT architecture which are discussed in the research agenda in Section 5.4.

5.4. Research agenda/future research

Based on the conclusions in the previous subsections we can now outline the future research directions which have been identified. We have identified that there is a need for further research at the deployment, application, middleware and cloud layers. These layers need a number of different contribution and research facets and by looking at Fig. 5 we can identify the areas where there has been a lack of research. At the physical device layer we can see that there have been no experience reports or opinion papers and very few philosophical papers. Solution proposals are the most used research facet which have led to a focus on processes with mush less focus on alternative contribution facets such as metrics, tools, methods and models.

At the deployment layer of the architecture there are a number of research gaps as there has been a lack of primary research at this layer. Specifically, there are research gaps for philosophical and opinion papers as well as experience reports. There is also a need for a number of different contribution facets such as metrics, tools, models and methods.

In the physical, link and network layers there has been a large amount of primary research but there are still areas which need additional research. We can see that there has been a lack of experience reports and opinion papers, as well as a small amount of evaluated research compared to the number of solution proposals. For these layers, there is a large amount of solution proposals and a need for further evaluated research and philosophical papers to compare the approaches which have already been proposed. At the application layer, there is a need for more primary research in a number of areas with contributions needed in metrics, tools, models and methods.

At the middleware layer, there are a number of research gaps where no papers have been published. We have identified the need for philosophical and opinion papers as well as experience reports. There is also a need for metrics but due to the lack of solution proposals this should be the primary focus of research at this layer. The cloud layer is similar as there are research gaps for experience and opinion papers but there is also a need for evaluated research to prove the solution proposals can work in a realistic setting.

We have identified research gaps for all the layers of the architecture, we can see that some research facets have been underutilised in almost all of the layers are the experience and opinion papers. Although these approaches may be less systematic, they provide the personal view of the author and can give insight into the practicalities of implementing an approach and future research directions about how the approach may be improved. They also serve to ground academic papers in problems that are actually affecting IoT implementations. We also suggest the use of quality models such as ISO/IEC 25010 which has been used to identify the quality factors in this mapping and will allow research to identify the trade-off between different approaches.

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Appendix A. Complete list of all articles included in the mapping study

[A1] Abdullah and Yang (2013), [A2] Ahlsén et al. (2012), [A3] Ahmad (2014), [A4] Ahmad (2015), [A5] Al-Fuqaha et al. (2015b), [A6] Alhakbani et al. (2014), [A7] Al-Hazmi and Magedanz (2015), [A8] Ali et al. (2015), [A9] Al-Saadi et al. (2015), [A10] Le et al. (2012b), [A11] Gama et al. (2012), [A12] Anurag et al. (2014), [A13] Žarko et al. (2015), [A14] Ashraf et al. (2015), [A15] Awan and Younas (2013), [A16] Bajaber (2014), [A17] Banh et al. (2015), [A18] Behera et al. (2015), [A19] Benamar et al. (2014), [A20] Blum et al. (2011), [A21] Borodin et al. (2015), [A22] Carvin et al. (2014), [A23] Catarinucci et al. (2015), [A24] Chandra and Lee (2014), [A25] Tao et al. (2014), [A26] Wang et al. (2015a), [A27] Chen et al. (2014), [A28] Xiaojun et al. (2015), [A29] Yongpan et al. (2010), [A30] Chen et al. (2010), [A31] Zhou and Zhang (2014), [A32] Chi et al. (2014), [A33] Han et al. (2013), [A34] Cicotti et al. (2012), [A35] Corredor et al. (2012), [A36] Dang and Cheng (2014), [A37] Das and Havinga

(2013), [A38] Mil et al. (2008), [A39] Deepalakshmi and Rajaram (2014), [A40] Zhang et al. (2012), [A41] Deng et al. (2015), [A42] Despaux et al. (2014), [A43] Peng and Ruan (2012), [A44] Dhar et al. (2014), [A45] Dimitrios et al. (2012), [A46] Ding et al. (2016), [A47] Ding et al. (2013a), [A48] Ding et al. (2013b), [A49] Ding et al. (2015), [A50] Distefano et al. (2015), [A51] Distefano et al. (2013), [A52] Dong et al. (2016), [A53] Doukas and Maglogiannis (2012), [A54] Duan et al. (2011), [A55] Elias et al. (2012), [A56] El-Mougy et al. (2015), [A57] Eswaran and Bapat (2015), [A58] Fafoutis et al. (2016), [A59] Shaoshuai et al. (2011), [A60] Fang et al. (2014), [A61] Fazio et al. (2015), [A62] Wang et al. (2015b), [A63] Fernandes et al. (2016), [A64] Lima and Amazonas (2013), [A65] Fok et al. (2011) , [A66] Fuertes et al. (2015), [A67] Gaddour et al. (2015), [A68] Gl et al. (2015), [A69] da Gama et al. (2015), [A70] Gao et al. (2014), [A71] Gia et al. (2015), [A72] Gomes et al. (2015), [A73] Govindan and Azad (2015), [A74] Grnbk (2008), [A75] Gupta et al. (2011), [A76] Tai et al. (2015), [A77] Hail and Fischer (2015), [A78] Han and Zhang (2014), [A79] Hassanalieragh et al. (2015), [A80] Hiremath et al. (2014), [A81] Truong et al. (2015), [A82] Hossain and Muhammad (2016), [A83] Lingling et al. (2011), [A84] Hu (2015), [A85] Hu et al. (2013), [A86] Li et al. (2015a), [A87] Huang et al. (2015), [A88] Huang and Bi (2016), [A89] Huang and Hsieh (2013), [A90] Huang et al. (2013), [A91] Ikram et al. (2015), [A92] Istepanian et al. (2011), [A93] Jamil et al. (2015), [A94] Jha et al. (2015), [A95] Jiang et al. (2016), [A96] Jiao et al. (2014), [A97] Jimenez and Torres (2015), [A98] Jin et al. (2014), [A99] Jin et al. (2015), [A100] Luo et al. (2009), [A101] Lv et al. (2012), [A102] Wang et al. (2014), [A103] Kim et al. (2015a), [A104] Ye et al. (2013), [A105] Zeng and Jiang (2014), [A106] Kamgueu et al. (2015), [A107] Kelly et al. (2013), [A108] Khan and Bilal (2014), [A109] Khan and Mir (2014), [A110] Khan and Mir (2015), [A111] Khasawneh et al. (2015), [A112] Kim et al. (2015b), [A113] Kim (2015), [A114] Kiruthika and Khaddaj (2015), [A115] Ko et al. (2014), [A116] Kos et al. (2013), [A117] Valera et al. (2010), [A118] Kovac et al. (2015), [A119] krishnan et al. (2015), [A120] Lazarescu (2013), [A121] Le et al. (2014), [A122] Zhang (2011), [A123] Lei et al. (2015), [A124] Li et al. (2011), [A125] Li et al. (2014a), [A126] Li et al. (2014b), [A127] Li et al. (2014c), [A128] Li et al. (2015b), [A129] Lin and Chen (2016), [A130] Lv et al. (2015), [A131] Ma et al. (2014), [A132] Machado et al. (2013), [A133] Mayzaud et al. (2013), [A134] Mazhelis et al. (2013), [A135] Ming and Yan (2012), [A136] Nieto and Lopez (2014), [A137] Pavithra and Balakrishnan (2015), [A138] Zu et al. (2015), [A139] Qiu et al. (2013), [A140] Qu et al. (2012), [A141] Zhou et al. (2015a), [A142] Sharma and Kumar (2015), [A143] Sharma et al. (2015), [A144] Yu et al. (2014), [A145] Span et al. (2015), [A146] Spinsante et al. (2014), [A147] Srinivasa et al. (2015), [A148] Sun et al. (2012), [A149] Sung and Chang (2014), [A150] Tanganelli et al. (2014), [A151] Torres and Killat (2013), [A152] Troubleyn et al. (2014), [A153] Vithya and Vinayagasundaram (2014), [A154] Xue and Jiang (2011), [A155] Yang et al. (2013), [A156] Zhang et al. (2014), [A157] Ameen et al. (2008), [A158] Han and Lim (2010), [A159] Hejmo et al. (2006), [A160] Kusy et al. (2009), [A161] Ludovici et al. (2012), [A162] Nayak et al. (2012)

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Gary White received the B.A.I and M.A.I degrees in computer engineering from Trinity College Dublin, Ireland and is currently working towards a Ph.D. degree in computer science at the same university. His research interests include anomaly detection, QoS prediction and middleware for IoT. His research is funded by Science Foundation Ireland (SFI).

Vivek Nallur is an assistant professor at UCD, with eight years of industry experience. He has worked for large companies such as VMWare Inc. as well as small startups and public-sector research-labs. His research interests span autonomous multi-agent systems to economics-inspired techniques for self-adaptation. He is particularly interested in scaling effects of multi-agent systems, communications, and the emergent effects that they have, on various properties such as resilience, resistance, and evolvability.

Siobhán Clarke is a Professor and Fellow of Trinity College Dublin, where she leads the Distributed Systems Group and is Director of Future Cities, the Trinity Centre for Smart and Sustainable Cities. Her research interests are in software engineering models for the dynamic provision of smart and dynamic software services to urban stakeholders in large-scale, mobile environments.