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

Abstract

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.

Keywords: Quality of Service (QoS), Quality Model, Internet of Things (IoT), Monitoring, Systematic Mapping

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 [1, 2]. 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 [2].

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 [3]. 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 [4]. 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. [5], 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.

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.

*Corresponding author

Email addresses: whiteg5@scss.tcd.ie (Gary White), vivek.nallur@ucd.ie (Vivek Nallur), siobhan.clarke@scss.tcd.ie (Siobhán Clarke)

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

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 [6]. 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 [7] , Cabrera et. al. [8] and ISO/IEC 25010 [9], which could be used for the mapping. Based on the guidelines outlined by Wagner [10] and experience from other systematic mappings [11] 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 Figure 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. [11]. 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.

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 Figure 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 [12], 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. [13] focuses on QoS security threats in 6LoWPAN and countermeasures using an intrusion detection system approach. Malik et al. [14] 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 [15]. Other approaches have focused on cyber-physical systems and monitoring techniques which can take into account the network design and relevant protocols [16]. Rassam et al. [17] 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 [18, 19, 20]. 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 [21] when the seminal paper on evidence based engineering was published [22]. This has led to mapping studies of QoS in related domains such as web services [11] whose goal is to evaluate the state of the art in quality models for web services. They have also been used in cloud computing [23] to identify where more emphasis 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 [19].

After evaluating the papers which were returned by the search we did not find a related survey, systematic mapping or

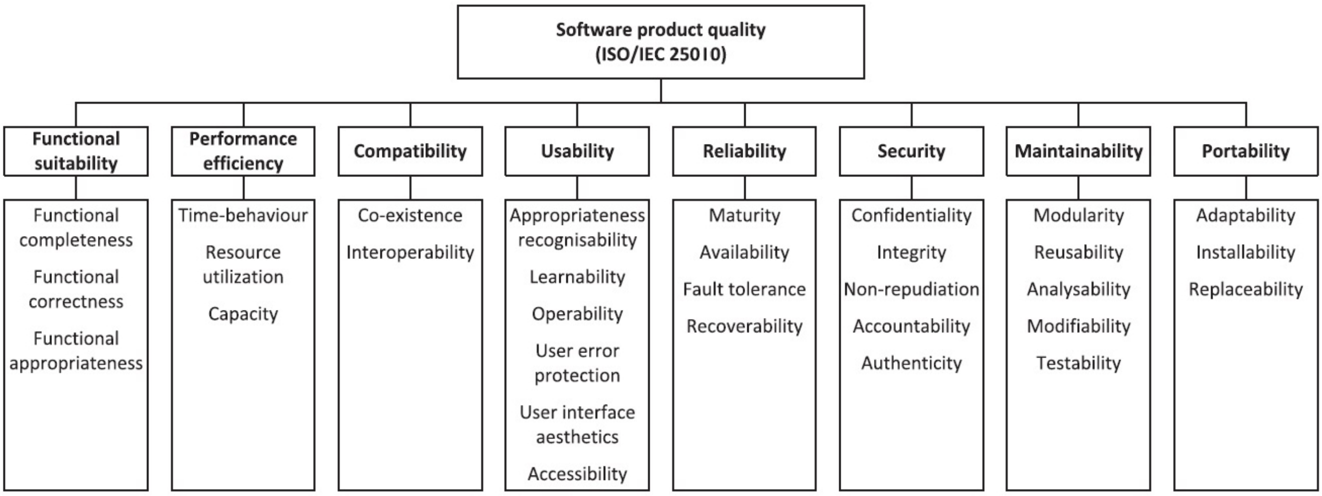

Figure 1: ISO/IEC 25010 proposal of quality model for software products

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 [23] 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 [24], multi-attribute auction model for resource allocation [25] 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 [12]. 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 [26, 27] 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.

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`	✓

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. [26] and keywords which have been extracted from known high quality papers. The PICO method is used to identify keywords and formulate search

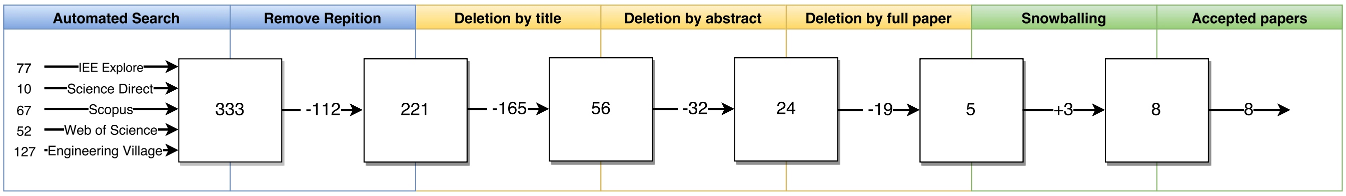

Figure 2: Selection of the related literature

strings from research questions. However as identified in other systematic literature reviews [28] and systematic mappings [29], 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 Figure 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.

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"))	1,067
IEEE	(QoS OR .QT.Quality of Service.QT. OR .QT.Monitoring.QT.) AND (.QT.Internet of Things.QT. OR IoT)	1,611
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))	2,395
Science Direct	((((qos or "quality of service" or "monitoring")) WN KY) AND (((IoT or "Internet of Things")) WN KY))	71

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 Figure 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

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		

Figure 3: Keywords that were used in the search

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 - 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 [30]. 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.

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 [31]. 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 Figure 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 Figures 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.

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			

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 [32, 33]. 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.
- 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.

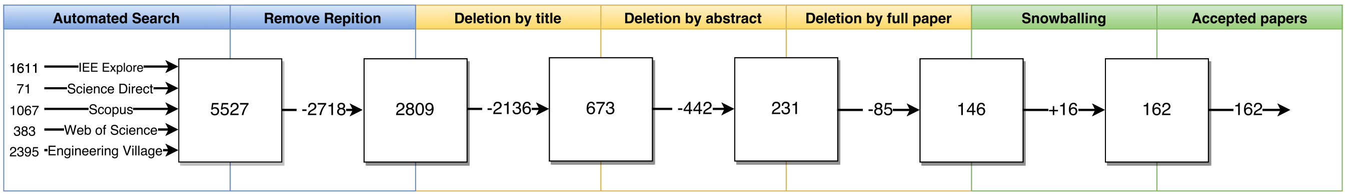

Figure 4: Selection of the mapping articles

- 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.

3.4.2. Research Type

In order to characterise the research approaches we use the classification scheme proposed by Wieringa et al. [30]. 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.

- 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.

- 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 [11, 23] 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 [9] 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 coexist 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 asses 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 [34]. For this mapping we take into account the description validity, theoretical validity, interpretive validity and repeatability.

3.5.1. Description Validity

To asses 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. [35], 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 [34]. As has been identified by Kitchenham et al. [27], 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 [36], 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?

Figure 6 shows that the physical device was addressed by 36% of the selected articles. Looking into more detail in Figure 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

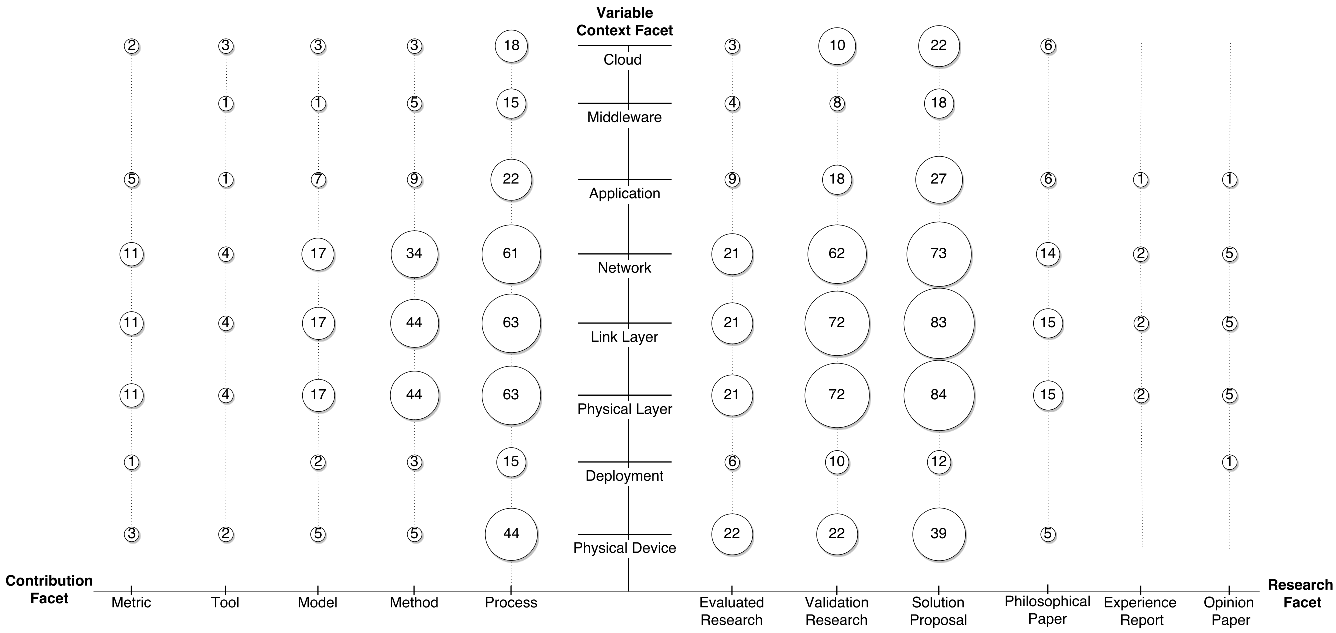

Figure 5: Overview of the mapping

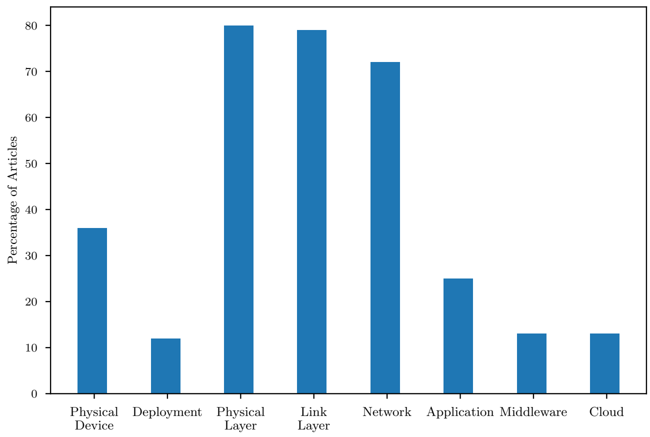

Figure 6: Percentage of articles addressing each layer

11% of the articles as can be seen in Figure 6. Looking at Figure 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 Figure 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 Figure 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. 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].

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

Table 4: Layer addressed by each paper

The middleware layer has had fewer papers published and is only taken into account in 13% of proposals, looking at Figure 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 Figure 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 QoS-MONaaS (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 Figure 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 cloud [A148].

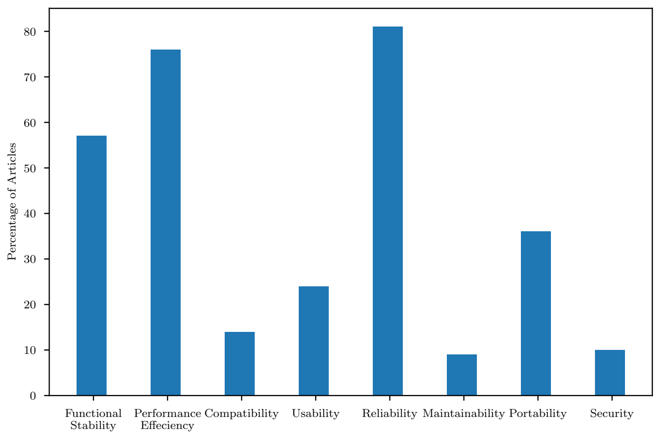

Figure 7: Percentage of articles addressing each quality factor

Performance efficiency is one of the most used quality categories and is addressed in 76% of the articles, which can be seen in Figure 7. It contains a number of important sub-characteristics such as the time-behaviour, resource utilisation

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 5: Quality Factors Addressed

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 Figure 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 Figure 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 Figure 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 Figure 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 Figure 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?*

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

Table 6: Research approach used

A validation of a solution proposal involves either a mathematical analysis, simulation or a mathematical proof

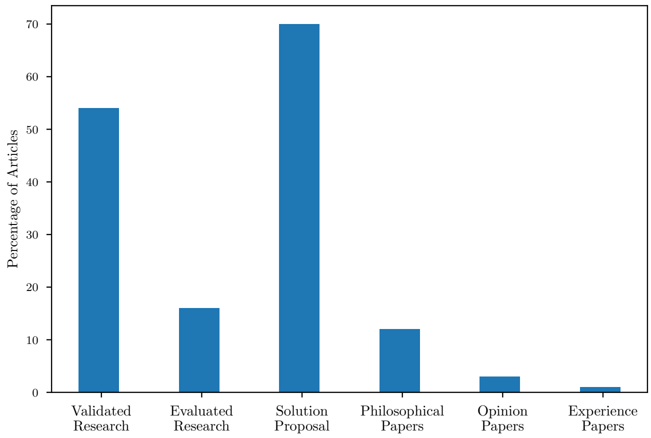

Figure 8: Percentage of articles using each research facet

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 Figure 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 Figure 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.

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

Table 7: Contribution Type

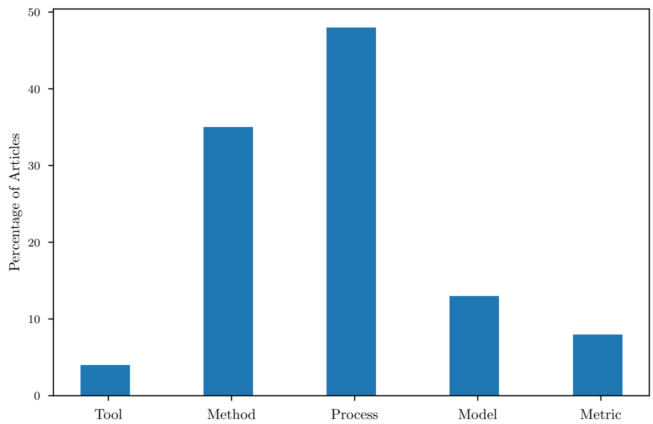

Figure 9: Percentage of articles contribution types

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 Figure 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 Figure 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 Figure 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 Figure 8. We can also see in Figure 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 Figure 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 Figure 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.

Acknowledgement

This work was funded by the Science Foundation Ireland (SFI) under grant 13/IA/1885.

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

[A1] [37], [A2] [38], [A3] [39], [A4] [40], [A5] [41], [A6] [42], [A7] [43], [A8] [16], [A9] [44], [A10] [45], [A11] [46], [A12] [47], [A13] [48], [A14] [49], [A15] [50], [A16] [51], [A17] [52], [A18] [53], [A19] [54], [A20] [55], [A21] [56], [A22] [57], [A23] [58], [A24] [59], [A25] [60], [A26] [61], [A27] [62], [A28] [63], [A29] [64], [A30] [65], [A31] [66], [A32] [67], [A33] [31], [A34] [68], [A35] [69], [A36] [70], [A37] [71], [A38] [72], [A39] [73], [A40] [74], [A41] [75], [A42] [76], [A43] [77], [A44] [78], [A45][79], [A46] [80], [A47] [81], [A48] [82], [A49] [83], [A50] [84], [A51] [85], [A52] [86], [A53] [87], [A54] [6], [A55] [88], [A56] [89], [A57] [90], [A58] [91], [A59] [92], [A60] [93], [A61] [94], [A62] [95], [A63] [96], [A64] [97], [A65] [98] , [A66] [99], [A67] [100], [A68] [101], [A69] [102], [A70] [103], [A71] [104], [A72] [105], [A73] [106], [A74] [107], [A75] [108], [A76] [109], [A77] [110], [A78] [111], [A79][112], [A80] [113], [A81] [114], [A82] [115], [A83] [116], [A84] [117], [A85] [118], [A86] [119], [A87] [120], [A88] [121], [A89] [122], [A90] [123], [A91] [124], [A92] [125], [A93] [126], [A94] [127], [A95] [128], [A96] [129], [A97] [130], [A98] [131], [A99] [132], [A100] [133], [A101] [134], [A102] [135], [A103] [136], [A104] [137], [A105] [138], [A106] [139], [A107] [140], [A108] [141], [A109] [142], [A110] [143], [A111] [144], [A112] [145], [A113] [146], [A114] [147], [A115] [148], [A116] [149], [A117] [150], [A118] [151], [A119] [152], [A120] [153], [A121] [154], [A122] [155], [A123] [156], [A124] [157], [A125] [158], [A126] [159], [A127] [160], [A128] [161], [A129] [162], [A130] [163], [A131] [164], [A132] [165], [A133] [166], [A134] [167], [A135] [168], [A136] [169], [A137] [170], [A138] [171], [A139] [172], [A140] [173], [A141] [174], [A142] [175], [A143] [176], [A144] [177], [A145] [178], [A146] [179], [A147] [180], [A148] [181], [A149] [182], [A150] [183], [A151] [184], [A152] [185], [A153] [186], [A154] [187], [A155] [188], [A156] [189], [A157] [190], [A158] [191], [A159] [192], [A160] [193], [A161] [194], [A162] [195]

References

[1] H. Bauer, M. Patel, J. Veira, The internet of things: Sizing up the opportunity, McKinsey.

[2] D. Evans, The internet of things: How the next evolution of the internet is changing everything, CISCO white paper 1 (2011) 14.

[3] P. Bellavista, G. Cardone, A. Corradi, L. Foschini, Convergence of manet and wsn in iot urban scenarios, Sensors Journal, IEEE 13 (10) (2013) 3558–3567.

[4] S. Kato, S. Tsugawa, K. Tokuda, T. Matsui, H. Fujii, Vehicle control algorithms for cooperative driving with automated vehicles and intervehicle communications, IEEE Transactions on Intelligent Transportation Systems 3 (3) (2002) 155–161. doi:10.1109/TITS.2002.802929.

[5] K. Petersen, S. Vakkalanka, L. Kuzniarz, Guidelines for conducting systematic mapping studies in software engineering: An update, Information and Software Technology 64 (2015) 1–18. doi:10.1016/j.infsof.2015.03.007.
URL http://www.sciencedirect.com/science/article/pii/S0950584915000646

[6] R. Duan, X. Chen, T. Xing, A qos architecture for iot, in: Internet of Things (iThings/CPSCom), 2011 International Conference on and 4th International Conference on Cyber, Physical and Social Computing, 2011, pp. 717–720. doi:10.1109/iThings/CPSCom.2011.125.

[7] Oasis, Web services quality factors version 1.0.
URL http://docs.oasis-open.org/wsqm/wsqf/v1.0/WS-Quality-Factors.pdf

[8] O. Cabrera, X. Franch, A quality model for analysing web service monitoring tools, in: 2012 Sixth International Conference on Research Challenges in Information Science (RCIS), 2012, pp. 1–12. doi:10.1109/RCIS.2012.6240444.

[9] ISO/IEC, ISO/IEC 25010 - Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - System and software quality models, Tech. rep. (2010).

[10] S. Wagner, Software product quality control, Springer, 2013.

[11] M. Oriol, J. Marco, X. Franch, Quality models for web services: A systematic mapping, Information and Software Technology 56 (10) (2014) 1167 – 1182. doi:10.1016/j.infsof.2014.03.012.
URL http://www.sciencedirect.com/science/article/pii/S0950584914000822

[12] C. Wohlin, Guidelines for snowballing in systematic literature studies and a replication in software engineering (2014). doi:10.1145/2601248.2601268.
URL http://dl.acm.org/citation.cfm?id=2601268

[13] A. Le, J. Loo, A. Lasebae, M. Aiash, Y. Luo, 6lowpan: a study on qos security threats and countermeasures using intrusion detection system approach, International Journal of Communication Systems 25 (9) (2012) 1189–1212. doi:10.1002/dac.2356.
URL http://dx.doi.org/10.1002/dac.2356

[14] A. Malik, J. Qadir, B. Ahmad, K.-L. A. Yau, U. Ullah, Qos in {IEEE} 802.11-based wireless networks: A contemporary review, Journal of Network and Computer Applications 55 (2015) 24 – 46. doi:10.1016/j.jnca.2015.04.016.
URL http://www.sciencedirect.com/science/article/pii/S1084804515000892

[15] N. Battat, H. Seba, H. Kheddouci, Monitoring in mobile ad hoc networks: A survey, Computer Networks 69 (2014) 82 – 100. doi:10.1016/j.comnet.2014.04.013.
URL http://www.sciencedirect.com/science/article/pii/S1389128614001662

[16] S. Ali, S. B. Qaisar, H. Saeed, M. F. Khan, M. Naeem, A. Anpalagan, Network challenges for cyber physical systems with tiny wireless devices: A case study on reliable pipeline condition monitoring, Sensors 15 (4) (2015) 7172. doi:10.3390/s150407172.
URL http://www.mdpi.com/1424-8220/15/4/7172

[17] M. A. Rassam, A. Zainal, M. A. Maarof, Advancements of data anomaly detection research in wireless sensor networks: A survey and open issues, Sensors 13 (8) (2013) 10087. doi:10.3390/s130810087.
URL http://www.mdpi.com/1424-8220/13/8/10087

[18] M. Daz, C. Martn, B. Rubio, State-of-the-art, challenges, and open issues in the integration of internet of things and cloud computing, Journal of Network and Computer Applications 67 (2016) 99 – 117. doi:10.1016/j.jnca.2016.01.010.
URL http://www.sciencedirect.com/science/article/pii/S108480451600028X

[19] E. Cavalcante, J. Pereira, M. P. Alves, P. Maia, R. Moura, T. Batista, F. C. Delicato, P. F. Pires, On the interplay of internet of things and cloud computing a systematic mapping study, Computer Communications 8990 (2016) 17 – 33, internet of Things Research challenges and Solutions. doi:10.1016/j.comcom.2016.03.012.
URL http://www.sciencedirect.com/science/article/pii/S0140366416300706

[20] A. Botta, W. de Donato, V. Persico, A. Pescap, Integration of cloud computing and internet of things: A survey, Future Generation Computer Systems 56 (2016) 684 – 700. doi:10.1016/j.future.2015.09.021.
URL http://www.sciencedirect.com/science/article/pii/S0167739X15003015

[21] Y. Zhou, H. Zhang, X. Huang, S. Yang, M. A. Babar, H. Tang, Quality assessment of systematic reviews in software engineering: A tertiary study, in: Proceedings of the 19th International Conference on Evaluation and Assessment in Software Engineering, EASE '15, ACM, New York, NY, USA, 2015, pp. 14:1–14:14. doi:10.1145/2745802.2745815.
URL http://doi.acm.org/10.1145/2745802.2745815

[22] B. A. Kitchenham, T. Dyba, M. Jorgensen, Evidence-based software engineering, in: Proceedings of the 26th International Conference on Software Engineering, ICSE '04, IEEE Computer Society, Washington, DC, USA, 2004, pp. 273–281.
URL http://dl.acm.org/citation.cfm?id=998675.999432

[23] A. Abdelmaboud, D. N. A. Jawawi, I. Ghani, A. Elsafi, B. Kitchenham, Quality of service approaches in cloud computing: A systematic mapping study, Journal of Systems and Software 101 (2015) 159–179. doi:10.1016/j.jss.2014.12.015.
URL http://www.sciencedirect.com/science/article/pii/S0164121214002830

[24] E. Y. Daraghmi, S.-M. Yuan, A small world based overlay network for improving dynamic load-balancing, Journal of Systems and Software 107 (2015) 187 – 203. doi:10.1016/j.jss.2015.06.001.
URL http://www.sciencedirect.com/science/article/pii/S0164121215001181

[25] G. Baranwal, D. P. Vidyarthi, A fair multi-attribute combinatorial double auction model for resource allocation in cloud computing, Journal of Systems and Software 108 (2015) 60 – 76. doi:10.1016/j.jss.2015.06.025.
URL http://www.sciencedirect.com/science/article/pii/S0164121215001272

[26] B. Kitchenham, R. Pretorius, D. Budgen, O. Pearl Brereton, M. Turner, M. Niazi, S. Linkman, Systematic literature reviews in software engineering a tertiary study, Information and Software Technology 52 (8) (2010) 792–805. doi:10.1016/j.infsof.2010.03.006.
URL http://www.sciencedirect.com/science/article/pii/S0950584910000467

[27] B. Kitchenham, O. Pearl Brereton, D. Budgen, M. Turner, J. Bailey, S. Linkman, Systematic literature reviews in software engineering a systematic literature review, Information and Software Technology 51 (1) (2009) 7–15. doi:10.1016/j.infsof.2008.09.009.
URL http://www.sciencedirect.com/science/article/pii/S0950584908001390

[28] M. Riaz, E. Mendes, E. Tempero, A systematic review of software maintainability prediction and metrics, in: Proceedings of the 2009 3rd International Symposium on Empirical Software Engineering and Measurement, ESEM '09, IEEE Computer Society, Washington, DC, USA, 2009, pp. 367–377. doi:10.1109/ESEM.2009.5314233.
URL http://dx.doi.org/10.1109/ESEM.2009.5314233

[29] K. Petersen, R. Feldt, S. Mujtaba, M. Mattsson, Systematic mapping studies in software engineering, in: 12th international conference on evaluation and assessment in software engineering, Vol. 17, sn, 2008, pp. 1–10.

[30] R. Wieringa, N. Maiden, N. Mead, C. Rolland, Requirements engineering paper classification and evaluation criteria: a proposal and a discussion, Requirements Engineering 11 (1) (2005) 102–107. doi:10.1007/s00766-005-0021-6.
URL http://dx.doi.org/10.1007/s00766-005-0021-6

[31] C. Han, J. M. Jornet, E. Fadel, I. F. Akyildiz, A cross-layer communication module for the internet of things, Computer Networks 57 (3) (2013) 622 – 633. doi:10.1016/j.comnet.2012.10.003.
URL http://www.sciencedirect.com/science/article/pii/S138912861200357X

[32] J. Gubbi, R. Buyya, S. Marusic, M. Palaniswami, Internet of things (iot): A vision, architectural elements, and future directions, Future Generation Computer Systems 29 (7) (2013) 1645 – 1660, including Special sections: Cyber-enabled Distributed Computing for Ubiquitous Cloud and Network Services; Cloud Computing and Scientific Applications Big Data, Scalable Analytics, and Beyond. doi:10.1016/j.future.2013.01.010.
URL http://www.sciencedirect.com/science/article/pii/S0167739X13000241

[33] A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, M. Ayyash, Internet of things: A survey on enabling technologies, protocols, and applications, IEEE Communications Surveys Tutorials 17 (4) (2015) 2347–2376. doi:10.1109/COMST.2015.2444095.

[34] K. Petersen, C. Gencel, Worldviews, research methods, and their relationship to validity in empirical software engineering research, in: Software Measurement and the 2013 Eighth International Conference on Software Process and Product Measurement (IWSM-MENSURA), 2013 Joint Conference of the 23rd International Workshop on, 2013, pp. 81–89. doi:10.1109/IWSM-Mensura.2013.22.

[35] C. Wohlin, P. Runeson, P. A. da Mota Silveira Neto, E. Engstrm, I. do Carmo Machado, E. S. de Almeida, On the reliability of mapping studies in software engineering, Journal of Systems and Software 86 (10) (2013) 2594 – 2610. doi:10.1016/j.jss.2013.04.076.
URL http://www.sciencedirect.com/science/article/pii/S0164121213001234

[36] M. Petticrew, H. Roberts, Systematic reviews in the social sciences: A practical guide, John Wiley & Sons, 2008.

[37] S. Abdullah, K. Yang, A qos aware message scheduling algorithm in internet of things environment, in: 2013 IEEE Online Conference on Green Communications (OnlineGreenComm), 2013, pp. 175–180. doi:10.1109/OnlineGreenCom.2013.6731048.

[38] M. Ahlsén, S. Asanin, P. Kool, P. Rosengren, J. Thestrup, Service-Oriented Middleware Architecture for Mobile Personal Health Monitoring, Springer Berlin Heidelberg, Berlin, Heidelberg, 2012, pp. 305–312. doi:10.1007/978-3-642-29734-2_42.
URL http://dx.doi.org/10.1007/978-3-642-29734-2_42

[39] M. Ahmad, Reliability models for the internet of things: A paradigm shift, in: 2014 IEEE International Symposium on Software Reliability Engineering Workshops, 2014, pp. 52–59. doi:10.1109/ISSREW.2014.107.

[40] M. Ahmad, Designing for the internet of things: A paradigm shift in reliability, in: 2015 IEEE 65th Electronic Components and Technology Conference (ECTC), 2015, pp. 1758–1766. doi:10.1109/ECTC.2015.7159836.

[41] A. Al-Fuqaha, A. Khreishah, M. Guizani, A. Rayes, M. Mohammadi, Toward better horizontal integration among iot services, IEEE Communications Magazine 53 (9) (2015) 72–79. doi:10.1109/MCOM.2015.7263375.

[42] N. Alhakbani, M. M. Hassan, M. A. Hossain, M. Alnuem, A Framework of Adaptive Interaction Support in Cloud-Based Internet of Things (IoT) Environment, Springer International Publishing, Cham, 2014, pp. 136–146. doi:10.1007/978-3-319-11692-1_12.
URL http://dx.doi.org/10.1007/978-3-319-11692-1_12

[43] Y. Al-Hazmi, T. Magedanz, Towards semantic monitoring data collection and representation in federated infrastructures, in: 2015 3rd International Conference on Future Internet of Things and Cloud, 2015, pp. 17–24. doi:10.1109/FiCloud.2015.40.

[44] A. Al-Saadi, R. Setchi, Y. Hicks, Cognitive network framework for heterogeneous wireless networks, Procedia Computer Science 60 (2015) 216 – 225, knowledge-Based and Intelligent Information & Engineering Systems 19th Annual Conference, KES-2015, Singapore, September 2015 Proceedings. doi:http://dx.doi.org/10.1016/j.procs.2015.08.121.
URL http://www.sciencedirect.com/science/article/pii/S1877050915022486

[45] A. Le, J. Loo, A. Lasebae, M. Aiash, Y. Luo, 6lowpan: a study on qos security threats and countermeasures using intrusion detection system approach, International Journal of Communication Systems 25 (9) (2012) 1189–1212. doi:10.1002/dac.2356.
URL http://dx.doi.org/10.1002/dac.2356

[46] K. Gama, L. Touseau, D. Donsez, Combining heterogeneous service technologies for building an internet of things middleware, Computer Communications 35 (4) (2012) 405 – 417. doi:https://doi.org/10.1016/j.comcom.2011.11.003.
URL http://www.sciencedirect.com/science/article/pii/S0140366411003586

[47] Anurag, S. R. Moosavi, A. M. Rahmani, T. Westerlund, G. Yang, P. Liljeberg, H. Tenhunen, Pervasive health monitoring based on internet of things: Two case studies, in: 2014 4th International Conference on Wireless Mobile Communication and Healthcare - Transforming Healthcare Through Innovations in Mobile and Wireless Technologies (MOBIHEALTH), 2014, pp. 275–278. doi:10.1109/MOBIHEALTH.2014.7015964.

[48] I. P. Žarko, A. Antonić, M. Marjanović, K. Pripužić, L. Skorin-Kapov, The OpenIoT Approach to Sensor Mobility with Quality-Driven Data Acquisition Management, Springer International Publishing, Cham, 2015, pp. 46–61. doi:10.1007/978-3-319-16546-2_5.
URL http://dx.doi.org/10.1007/978-3-319-16546-2_5

[49] Q. M. Ashraf, M. I. M. Yusoff, A. A. Azman, N. M. Nor, N. A. A. Fuzi, M. S. Saharedan, N. A. Omar, Energy monitoring prototype for internet of things: Preliminary results, in: 2015 IEEE 2nd World Forum on Internet of Things (WF-IoT), 2015, pp. 1–5. doi:10.1109/WF-IoT.2015.7389157.

[50] I. Awan, M. Younas, Towards QoS in Internet of Things for Delay Sensitive Information, Springer International Publishing, Cham, 2013, pp. 86–94. doi:10.1007/978-3-319-03737-0_10.
URL http://dx.doi.org/10.1007/978-3-319-03737-0_10

[51] F. Bajaber, Large scale environmental monitoring and maintaining sensing coverage in sensor networks, in: 2014 International Conference on Future Internet of Things and Cloud, 2014, pp. 253–257. doi:10.1109/FiCloud.2014.47.

[52] M. Banh, H. Mac, N. Nguyen, K. H. Phung, N. H. Thanh, K. Steenhaut, Performance evaluation of multiple rpl routing tree instances for internet of things applications, in: 2015 International Conference on Advanced

Technologies for Communications (ATC), 2015, pp. 206–211. doi:10.1109/ATC.2015.7388321.

[53] R. K. Behera, K. H. K. Reddy, D. S. Roy, Reliability modelling of service oriented internet of things, in: 2015 4th International Conference on Reliability, Infocom Technologies and Optimization (ICRITO) (Trends and Future Directions), 2015, pp. 1–6. doi:10.1109/ICRITO.2015.7359216.

[54] N. Benamar, A. Jara, L. Ladid, D. E. Ouadghiri, Challenges of the internet of things: Ipv6 and network management, in: 2014 Eighth International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing, 2014, pp. 328–333. doi:10.1109/IMIS.2014.43.

[55] N. Blum, J. Fiedler, L. Lange, T. Magedanz, Application-driven quality of service for m2m communications, in: 2011 15th International Conference on Intelligence in Next Generation Networks, 2011, pp. 41–45. doi:10.1109/ICIN.2011.6081100.

[56] A. Borodin, Y. Zavyalova, A. Zaharov, I. Yamushev, Architectural approach to the multisource health monitoring application design, in: 2015 17th Conference of Open Innovations Association (FRUCT), 2015, pp. 16–21. doi:10.1109/FRUCT.2015.7117965.

[57] D. Carvin, P. Owezarski, P. Berthou, A generalized distributed consensus algorithm for monitoring and decision making in the iot, in: 2014 International Conference on Smart Communications in Network Technologies (SaCoNeT), 2014, pp. 1–6. doi:10.1109/SaCoNeT.2014.6867769.

[58] L. Catarinucci, D. de Donno, L. Mainetti, L. Palano, L. Patrono, M. L. Stefanizzi, L. Tarricone, An iot-aware architecture for smart healthcare systems, IEEE Internet of Things Journal 2 (6) (2015) 515–526. doi:10.1109/JIOT.2015.2417684.

[59] A. A. Chandra, S. R. Lee, A method of wsn and sensor cloud system to monitor cold chain logistics as part of the iot technology, International Journal of Multimedia and Ubiquitous Engineering 9 (10) (2014) 145–152.

[60] C. Tao, X. Ling, S. Guofeng, Y. Hongyong, H. Quanyi, Architecture for monitoring urban infrastructure and analysis method for a smart-safe city, in: 2014 Sixth International Conference on Measuring Technology and Mechatronics Automation, 2014, pp. 151–154. doi:10.1109/ICMTMA.2014.40.

[61] C. Wang, H. T. Vo, P. Ni, An iot application for fault diagnosis and prediction, in: 2015 IEEE International Conference on Data Science and Data Intensive Systems, 2015, pp. 726–731. doi:10.1109/DSDIS.2015.97.

[62] W. s. Chen, Y. J. Chen, S. y. Wu, Dynamic aggregate: An elastic framework for qos-aware distributed processing of rfid data on enterprise hierarchy, IEEE Transactions on Parallel and Distributed Systems 25 (7) (2014) 1724–1734. doi:10.1109/TPDS.2013.177.

[63] C. Xiaojun, L. Xianpeng, X. Peng, Iot-based air pollution monitoring and forecasting system, in: 2015 International Conference on Computer and Computational Sciences (ICCCS), 2015, pp. 257–260. doi:10.1109/ICCACS.2015.7361361.

[64] C. Yongpan, Z. Jili, M. Xianmin, M. Jinxing, Study on the theoretical framework of the internet of building energy systems, in: 5th International Conference on Computer Sciences and Convergence Information Technology, 2010, pp. 973–976. doi:10.1109/ICCIT.2010.5711201.

[65] Z. Chen, F. Han, Y. Liu, A cognitive qos method based on parameter sensitivity, in: Green Computing and Communications (GreenCom), 2010 IEEE/ACM Int'l Conference on Int'l Conference on Cyber, Physical and Social Computing (CPSCom), 2010, pp. 496–499. doi:10.1109/GreenCom-CPSCom.2010.85.

[66] C. Zhou, X. Zhang, Toward the internet of things application and management: A practical approach, in: Proceeding of IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks 2014, 2014, pp. 1–6. doi:10.1109/WoWMoM.2014.6918928.

[67] X. Chi, W. Dong, D. Wu, L. Guan, Modeling multi-node network under heterogeneous m2m services arrival, JOURNAL OF INFORMATION &COMPUTATIONAL SCIENCE 11 (5) 1531–1543.

[68] G. Cicotti, L. Coppolino, R. Cristaldi, S. D'Antonio, L. Romano, QoS Monitoring in a Cloud Services Environment: The SRT-15 Approach, Springer Berlin Heidelberg, Berlin, Heidelberg, 2012, pp. 15–24. doi:10.1007/978-3-642-29737-3_3.
URL http://dx.doi.org/10.1007/978-3-642-29737-3_3

[69] I. Corredor, J. F. Martnez, M. S. Familiar, L. Lpez, Knowledge-aware and service-oriented middleware for deploying pervasive services, Journal of Network and Computer Applications 35 (2) (2012) 562 – 576, simulation and Testbeds. doi:https://doi.org/10.1016/j.jnca.2011.05.009.
URL http://www.sciencedirect.com/science/article/pii/S1084804511001111

[70] G. Dang, X. Cheng, Application of wireless sensor network in monitoring system based on zigbee, in: 2014 IEEE Workshop on Advanced Research and Technology in Industry Applications (WARTIA), 2014, pp. 181–183. doi:10.1109/WARTIA.2014.6976226.

[71] K. Das, P. Havinga, Evaluation of dect for low latency real-time industrial control networks, in: 2013 IEEE International Conference on Sensing, Communications and Networking (SECON), 2013, pp. 10–17. doi:10.1109/SAHCN.2013.6644954.

[72] P. D. Mil, T. Allemeersch, I. Moerman, P. Demeester, W. D. Kimpe, A scalable low-power wsan solution for large-scale building automation, in: 2008 IEEE International Conference on Communications, 2008, pp. 3130–3135. doi:10.1109/ICC.2008.589.

[73] R. Deepalakshmi, S. Rajaram, Effective heuristic algorithm for dynamic routing and bandwidth management under quality of service constraints in multistage interconnection networks, American Journal of Applied Sciences 11 (3) (2014) 414.

[74] D. Zhang, C. peng Zhao, Y. pin Liang, Z. jing Liu, A new medium access control protocol based on perceived data reliability and spatial correlation in wireless sensor network, Computers & Electrical Engineering 38 (3) (2012) 694 – 702, the Design and Analysis of Wireless Systems and Emerging Computing Architectures and Systems. doi:http://dx.doi.org/10.1016/j.compeleceng.2012.02.016.
URL http://www.sciencedirect.com/science/article/pii/S0045790612000389

[75] X. Deng, L. He, J. Gui, Q. Peng, T. He, Modeling and analysis mac layer performance for ieee 802.11s wireless mesh network in smart grid, in: 2015 International Conference on Identification, Information, and Knowledge in the Internet of Things (IIKI), 2015, pp. 280–283. doi:10.1109/IIKI.2015.67.

[76] F. Despaux, Y. Q. Song, A. Lahmadi, Modelling and performance analysis of wireless sensor networks using process mining techniques: Contikimac use case, in: 2014 IEEE International Conference on Distributed Computing in Sensor Systems, 2014, pp. 225–232. doi:10.1109/DCOSS.2014.20.

[77] D. Peng, Y. Ruan, Ahp-based qos evaluation model in the internet of things, in: 2012 13th International Conference on Parallel and Distributed Computing, Applications and Technologies, 2012, pp. 578–581. doi:10.1109/PDCAT.2012.36.

[78] S. K. Dhar, S. S. Bhunia, N. Mukherjee, Interference aware scheduling of sensors in iot enabled health-care monitoring system, in: 2014 Fourth International Conference of Emerging Applications of Information Technology, 2014, pp. 152–157. doi:10.1109/EAIT.2014.50.

[79] A. Dimitrios, G. Vasileios, G. Dimitrios, C. Ioannis, Employing internet of things technologies for building automation, in: Proceedings of 2012 IEEE 17th International Conference on Emerging Technologies Factory Automation (ETFA 2012), 2012, pp. 1–8. doi:10.1109/ETFA.2012.6489650.

[80] F. Ding, A. Song, E. Tong, J. Li, A smart gateway architecture for improving efficiency of home network applications, Journal of Sensors 2016.

[81] L. Ding, C. Zhou, Q. Deng, H. Luo, X. Ye, Y. Ni, P. Guo, Real-time safety early warning system for cross passage construction in yangtze riverbed metro tunnel based on the internet of things, Automation in Construction 36 (2013) 25 – 37. doi:https://doi.org/10.1016/j.autcon.2013.08.017.
URL http://www.sciencedirect.com/science/article/pii/S0926580513001313

[82] X. Ding, G. Xiong, B. Hu, L. Xie, S. Zhou, Environment monitoring and early warning system of facility agriculture based on heterogeneous wireless networks, in: Proceedings of 2013 IEEE International Conference on Service Operations and Logistics, and Informatics, 2013, pp. 307–310. doi:10.1109/SOLI.2013.6611431.

[83] Y. Ding, S. Gang, J. Hong, The design of home monitoring system by remote mobile medical, in: 2015 7th International Conference on In-

formation Technology in Medicine and Education (ITME), 2015, pp. 278–281. doi:10.1109/ITME.2015.168.

[84] S. Distefano, F. Longo, M. Scarpa, Qos assessment of mobile crowdsensing services, Journal of Grid Computing 13 (4) (2015) 629–650. doi:10.1007/s10723-015-9338-7.
URL http://dx.doi.org/10.1007/s10723-015-9338-7

[85] S. Distefano, G. Merlino, A. Puliafito, Application deployment for iot: An infrastructure approach, in: 2013 IEEE Global Communications Conference (GLOBECOM), 2013, pp. 2798–2803. doi:10.1109/GLOCOM.2013.6831498.

[86] M. Dong, K. Ota, A. Liu, Rmer: Reliable and energy-efficient data collection for large-scale wireless sensor networks, IEEE Internet of Things Journal 3 (4) (2016) 511–519. doi:10.1109/JIOT.2016.2517405.

[87] C. Doukas, I. Maglogiannis, Bringing iot and cloud computing towards pervasive healthcare, in: 2012 Sixth International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing, 2012, pp. 922–926. doi:10.1109/IMIS.2012.26.

[88] A. G. F. Elias, J. J. P. C. Rodrigues, L. M. L. Oliveira, B. B. Zarpel£o, A ubiquitous model for wireless sensor networks monitoring, in: 2012 Sixth International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing, 2012, pp. 835–839. doi:10.1109/IMIS.2012.33.

[89] A. El-Mougy, M. Ibnkahla, L. Hegazy, Software-defined wireless network architectures for the internet-of-things, in: 2015 IEEE 40th Local Computer Networks Conference Workshops (LCN Workshops), 2015, pp. 804–811. doi:10.1109/LCNW.2015.7365931.

[90] S. P. Eswaran, J. Bapat, Service centric markov based spectrum sharing for internet of things (iot), in: 2015 IEEE Region 10 Symposium, 2015, pp. 9–12. doi:10.1109/TENSYMP.2015.24.

[91] X. Fafoutis, E. Tsimbalo, E. Mellios, G. Hilton, R. Piechocki, I. Craddock, A residential maintenance-free long-term activity monitoring system for healthcare applications, EURASIP Journal on Wireless Communications and Networking 2016 (1) (2016) 31. doi:10.1186/s13638-016-0534-3.
URL http://dx.doi.org/10.1186/s13638-016-0534-3

[92] F. Shaoshuai, S. Wenxiao, W. Nan, L. Yan, Modm-based evaluation model of service quality in the internet of things, Procedia Environmental Sciences 11 (2011) 63 – 69, 2011 2nd International Conference on Challenges in Environmental Science and Computer Engineering (CESCE 2011). doi:http://dx.doi.org/10.1016/j.proenv.2011.12.011.
URL http://www.sciencedirect.com/science/article/pii/S1878029611008346

[93] S. Fang, L. D. Xu, Y. Zhu, J. Ahati, H. Pei, J. Yan, Z. Liu, An integrated system for regional environmental monitoring and management based on internet of things, IEEE Transactions on Industrial Informatics 10 (2) (2014) 1596–1605. doi:10.1109/TII.2014.2302638.

[94] M. Fazio, A. Celesti, F. G. Mrquez, A. Glikson, M. Villari, Exploiting the fiware cloud platform to develop a remote patient monitoring system, in: 2015 IEEE Symposium on Computers and Communication (ISCC), 2015, pp. 264–270. doi:10.1109/ISCC.2015.7405526.

[95] F. Wang, L. Hu, J. Zhou, K. Zhao, A data processing middleware based on soa for the internet of things, Journal of Sensors 2015.

[96] C. O. Fernandes, C. J. P. de Lucena, C. A. P. de Lucena, B. A. de Azevedo, Enabling a Smart and Distributed Communication Infrastructure in Healthcare, Springer International Publishing, Cham, 2016, pp. 435–446. doi:10.1007/978-3-319-23024-5_40.
URL http://dx.doi.org/10.1007/978-3-319-23024-5_40

[97] D. F. Lima, J. R. Amazonas, Tcnet: Trellis coded network - implementation of qos-aware routing protocols in wsns, IEEE Latin America Transactions 11 (3) (2013) 969–974. doi:10.1109/TLA.2013.6568841.

[98] C.-L. Fok, C. Julien, G.-C. Roman, C. Lu, Challenges of satisfying multiple stakeholders: Quality of service in the internet of things, in: Proceedings of the 2Nd Workshop on Software Engineering for Sensor Network Applications, SESENA '11, ACM, New York, NY, USA, 2011, pp. 55–60. doi:10.1145/1988051.1988062.
URL http://doi.acm.org/10.1145/1988051.1988062

[99] W. Fuertes, D. Carrera, C. Villacs, T. Toulkeridis, F. Galrraga, E. Torres, H. Aules, Distributed system as internet of things for a new low-cost, air pollution wireless monitoring on real time, in: 2015 IEEE/ACM 19th International Symposium on Distributed Simulation and Real Time Applications (DS-RT), 2015, pp. 58–67. doi:10.1109/DS-RT.2015.28.

[100] O. Gaddour, A. Koub¢a, M. Abid, Quality-of-service aware routing for static and mobile ipv6-based low-power and lossy sensor networks using {RPL}, Ad Hoc Networks 33 (2015) 233 – 256. doi:https://doi.org/10.1016/j.adhoc.2015.05.009.
URL http://www.sciencedirect.com/science/article/pii/S1570870515000992

[101] Z. Gl, H. Sndor, B. Genge, Information flow and complex event processing of the sensor network communication, in: 2015 6th IEEE International Conference on Cognitive Infocommunications (CogInfoCom), 2015, pp. 467–471. doi:10.1109/CogInfoCom.2015.7390638.

[102] L. M. L. da Gama, J. B. H. de Oliveira Gaia, A. de Padua Soares, A. Kimura, Wireless sensor network for monitoring environmental factors in industrial installations, in: 2015 CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies (CHILECON), 2015, pp. 707–710. doi:10.1109/Chilecon.2015.7404648.

[103] J. feng Gao, H. Huang, F. yi Wang, A lightweight data exchange protocol for campus environmental monitoring, in: International Conference on Software Intelligence Technologies and Applications International Conference on Frontiers of Internet of Things 2014, 2014, pp. 150–155. doi:10.1049/cp.2014.1551.

[104] T. N. Gia, M. Jiang, A. M. Rahmani, T. Westerlund, P. Liljeberg, H. Tenhunen, Fog computing in healthcare internet of things: A case study on ecg feature extraction, in: 2015 IEEE International Conference on Computer and Information Technology; Ubiquitous Computing and Communications; Dependable, Autonomic and Secure Computing; Pervasive Intelligence and Computing, 2015, pp. 356–363. doi:10.1109/CIT/IUCC/DASC/PICOM.2015.51.

[105] T. Gomes, J. Brito, H. Abreu, H. Gomes, J. Cabral, Greenmon: An efficient wireless sensor network monitoring solution for greenhouses, in: 2015 IEEE International Conference on Industrial Technology (ICIT), 2015, pp. 2192–2197. doi:10.1109/ICIT.2015.7125420.

[106] K. Govindan, A. P. Azad, End-to-end service assurance in iot mqtt-sn, in: 2015 12th Annual IEEE Consumer Communications and Networking Conference (CCNC), 2015, pp. 290–296. doi:10.1109/CCNC.2015.7157991.

[107] I. Grnbk, Architecture for the internet of things (iot): Api and interconnect, in: 2008 Second International Conference on Sensor Technologies and Applications (sensorcomm 2008), 2008, pp. 802–807. doi:10.1109/SENSORCOMM.2008.20.

[108] V. Gupta, R. Goldman, P. Udupi, A network architecture for the web of things, in: Proceedings of the Second International Workshop on Web of Things, WoT '11, ACM, New York, NY, USA, 2011, pp. 3:1–3:6. doi:10.1145/1993966.1993971.
URL http://doi.acm.org/10.1145/1993966.1993971

[109] H. Tai, A. Celesti, M. Fazio, M. Villari, A. Puliafito, An integrated system for advanced water risk management based on cloud computing and iot, in: 2015 2nd World Symposium on Web Applications and Networking (WSWAN), 2015, pp. 1–7. doi:10.1109/WSWAN.2015.7210305.

[110] M. A. Hail, S. Fischer, Iot for aal: An architecture via information-centric networking, in: 2015 IEEE Globecom Workshops (GC Wkshps), 2015, pp. 1–6. doi:10.1109/GLOCOMW.2015.7414020.

[111] H. J, Z. J., Study on monitor system of pollution discharge in chemical enterprise based on internet of things, in: Journal of Chemical and Pharmaceutical Research, 2014, pp. 1796–801.

[112] M. Hassanalieragh, A. Page, T. Soyata, G. Sharma, M. Aktas, G. Mateos, B. Kantarci, S. Andreescu, Health monitoring and management using internet-of-things (iot) sensing with cloud-based processing: Opportunities and challenges, in: 2015 IEEE International Conference on Services Computing, 2015, pp. 285–292. doi:10.1109/SCC.2015.47.

[113] S. Hiremath, G. Yang, K. Mankodiya, Wearable internet of things: Concept, architectural components and promises for person-centered healthcare, in: 2014 4th International Conference on Wireless Mobile Communication and Healthcare - Transforming Healthcare Through Innovations in Mobile and Wireless Technologies (MOBIHEALTH), 2014, pp. 304–307. doi:10.1109/MOBIHEALTH.2014.7015971.

[114] H. L. Truong, G. Copil, S. Dustdar, D. H. Le, D. Moldovan, S. Nastic, icomot – a toolset for managing iot cloud systems, in: 2015 16th IEEE International Conference on Mobile Data Management, Vol. 1, 2015, pp. 299–302. doi:10.1109/MDM.2015.65.

[115] M. S. Hossain, G. Muhammad, Cloud-assisted industrial internet of things (iiot) enabled framework for health monitoring, Computer Networks 101 (2016) 192 – 202, industrial Technologies and Applications for the Internet of Things. doi:https://doi.org/10.1016/j.comnet.2016.01.009.
URL http://www.sciencedirect.com/science/article/pii/S1389128616300019

[116] H. Lingling, L. Haifeng, X. Xu, L. Jian, An intelligent vehicle monitoring system based on internet of things, in: 2011 Seventh International Conference on Computational Intelligence and Security, 2011, pp. 231–233. doi:10.1109/CIS.2011.59.

[117] P. Hu, A system architecture for software-defined industrial internet of things, in: 2015 IEEE International Conference on Ubiquitous Wireless Broadband (ICUWB), 2015, pp. 1–5. doi:10.1109/ICUWB.2015.7324414.

[118] S. Hu, C. Tang, R. Yu, F. Liu, X. Wang, Intelligent coal mine monitoring system based on the internet of things, in: 2013 3rd International Conference on Consumer Electronics, Communications and Networks, 2013, pp. 380–384. doi:10.1109/CECNet.2013.6703350.

[119] H. Li, H. Wang, W. Yin, Y. Li, Y. Qian, F. Hu, Development of a remote monitoring system for henhouse environment based on iot technology, Future Internet 7 (3) (2015) 329–341. doi:10.3390/fi7030329.
URL http://www.mdpi.com/1999-5903/7/3/329

[120] G. Huang, D. Wang, M. Chen, X. Wang, Sensor performance analysis for crane structural health monitoring system, CRC Press, 2015, pp. 275–279. doi:doi:10.1201/b18510-5710.1201/b18510-57.
URL https://doi.org/10.1201/b18510-57

[121] J. Huang, J. Bi, A proportional fairness scheduling for wireless sensor networks, Personal and Ubiquitous Computing 20 (5) (2016) 695–703. doi:10.1007/s00779-016-0948-2.
URL http://dx.doi.org/10.1007/s00779-016-0948-2

[122] J. D. Huang, H. C. Hsieh, Design of gateway for monitoring system in iot networks, in: 2013 IEEE International Conference on Green Computing and Communications and IEEE Internet of Things and IEEE Cyber, Physical and Social Computing, 2013, pp. 1876–1880. doi:10.1109/GreenCom-iThings-CPSCom.2013.348.

[123] J. H. Huang, T. T. Wang, T. Y. Su, K. C. Lan, Design and deployment of a heart rate monitoring system in a senior center, in: 2013 IEEE International Conference on Sensing, Communications and Networking (SECON), 2013, pp. 71–75. doi:10.1109/SAHCN.2013.6644963.

[124] M. A. Ikram, M. D. Alshehri, F. K. Hussain, Architecture of an iot-based system for football supervision (iot football), in: 2015 IEEE 2nd World Forum on Internet of Things (WF-IoT), 2015, pp. 69–74. doi:10.1109/WF-IoT.2015.7389029.

[125] R. S. H. Istepanian, S. Hu, N. Y. Philip, A. Sungoor, The potential of internet of m-health things #x201c;m-iot #x201d; for non-invasive glucose level sensing, in: 2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2011, pp. 5264–5266. doi:10.1109/IEMBS.2011.6091302.

[126] M. S. Jamil, M. A. Jamil, A. Mazhar, A. Ikram, A. Ahmed, U. Munawar, Smart environment monitoring system by employing wireless sensor networks on vehicles for pollution free smart cities, Procedia Engineering 107 (2015) 480 – 484, humanitarian Technology: Science, Systems and Global Impact 2015, HumTech2015. doi:http://dx.doi.org/10.1016/j.proeng.2015.06.106.
URL http://www.sciencedirect.com/science/article/pii/S1877705815010590

[127] M. Jha, P. R. Marpu, C. K. Chau, P. Armstrong, Design of sensor network for urban micro-climate monitoring, in: 2015 IEEE First International Smart Cities Conference (ISC2), 2015, pp. 1–4. doi:10.1109/ISC2.2015.7366153.

[128] Y. Jiang, X. Liu, S. Lian, Design and Implementation of Smart-Home Monitoring System with the Internet of Things Technology, Springer India, New Delhi, 2016, pp. 473–484. doi:10.1007/978-81-322-2580-5_43.
URL http://dx.doi.org/10.1007/978-81-322-2580-5_43

[129] J. Jiao, H.-M. Ma, Y. Qiao, Y.-L. Du, W. Kong, Z.-C. Wu, Design of farm environmental monitoring system based on the internet of things, Advance journal of food science and technology 6 (3) (2014) 368–373.

[130] F. Jimenez, R. Torres, Building an iot-aware healthcare monitoring system, in: 2015 34th International Conference of the Chilean Computer Science Society (SCCC), 2015, pp. 1–4. doi:10.1109/SCCC.2015.7416592.

[131] J. Jin, J. Gubbi, S. Marusic, M. Palaniswami, An information framework for creating a smart city through internet of things, IEEE Internet of Things Journal 1 (2) (2014) 112–121. doi:10.1109/JIOT.2013.2296516.

[132] M. Jin, X. Zhou, E. Luo, X. Qing, Industrial-qos-oriented remote wireless communication protocol for the internet of construction vehicles, IEEE Transactions on Industrial Electronics 62 (11) (2015) 7103–7113. doi:10.1109/TIE.2015.2438774.

[133] J. Luo, Y. Chen, K. Tang, J. Luo, Remote monitoring information system and its applications based on the internet of things, in: 2009 International Conference on Future BioMedical Information Engineering (FBIE), 2009, pp. 482–485. doi:10.1109/FBIE.2009.5405813.

[134] J. Lv, V. C. S. Lee, M. Li, E. Chen, Supporting Multi-level Quality of Services in Data Broadcast Systems, Springer Berlin Heidelberg, Berlin, Heidelberg, 2012, pp. 142–153. doi:10.1007/978-3-642-31869-6_12.
URL http://dx.doi.org/10.1007/978-3-642-31869-6_12

[135] J. y. Wang, Y. Cao, G. p. Yu, M. z. Yuan, Research on application of iot in domestic waste treatment and disposal, in: Proceeding of the 11th World Congress on Intelligent Control and Automation, 2014, pp. 4742–4745. doi:10.1109/WCICA.2014.7053515.

[136] J.-W. Kim, J. R. R. Barrado, D.-K. Jeon, An energy-efficient transmission scheme for real-time data in wireless sensor networks, Sensors 15 (5) (2015) 11628–11652. doi:10.3390/s150511628.
URL http://www.mdpi.com/1424-8220/15/5/11628

[137] J. Ye, B. Chen, Q. Liu, Y. Fang, A precision agriculture management system based on internet of things and webgis, in: 2013 21st International Conference on Geoinformatics, 2013, pp. 1–5. doi:10.1109/Geoinformatics.2013.6626173.

[138] J. Zeng, L. Jiang, The cross-layer per-flow admission control with adaptive reservation of bandwidth and multiple qos guarantee in edca of ieee 802.11 e for internet of things., JCP 9 (10) (2014) 2405–2413.

[139] P. O. Kamgueu, E. Nataf, T. N. Djotio, On design and deployment of fuzzy-based metric for routing in low-power and lossy networks, in: 2015 IEEE 40th Local Computer Networks Conference Workshops (LCN Workshops), 2015, pp. 789–795. doi:10.1109/LCNW.2015.7365929.

[140] S. D. T. Kelly, N. K. Suryadevara, S. C. Mukhopadhyay, Towards the implementation of iot for environmental condition monitoring in homes, IEEE Sensors Journal 13 (10) (2013) 3846–3853. doi:10.1109/JSEN.2013.2263379.

[141] B. M. Khan, R. Bilal, High Quality of Service and Energy Efficient MAC Protocols for Wireless Sensor Networks, Springer Berlin Heidelberg, Berlin, Heidelberg, 2014, pp. 315–348. doi:10.1007/978-3-642-35016-0_12.
URL http://dx.doi.org/10.1007/978-3-642-35016-0_12

[142] R. A. Khan, A. H. Mir, Sensor fast proxy mobile ipv6 (sfpmipv6)-a framework for mobility supported ip-wsn for improving qos and building iot, in: 2014 International Conference on Communication and Signal Processing, 2014, pp. 1593–1598. doi:10.1109/ICCSP.2014.6950117.

[143] R. A. Khan, A. H. Mir, Ems: Enhanced mobility scheme for controlled and lossy networks, in: 2015 International Conference on Green Computing and Internet of Things (ICGCIoT), 2015, pp. 655–660. doi:10.1109/ICGCIoT.2015.7380545.

[144] F. A. Khasawneh, A. Benmimoune, M. Kadoch, M. A. Khasawneh, Predictive congestion avoidance in wireless mesh network, in: 2015 3rd International Conference on Future Internet of Things and Cloud, 2015, pp. 108–112. doi:10.1109/FiCloud.2015.69.

[145] N.-S. Kim, K. Lee, J.-H. Ryu, Study on iot based wild vegetation community ecological monitoring system, in: 2015 Seventh International Conference on Ubiquitous and Future Networks, 2015, pp. 311–316. doi:10.1109/ICUFN.2015.7182556.

[146] S. Kim, Learning-based qos control algorithms for next generation internet of things, Mobile Information Systems 2015.

[147] J. Kiruthika, S. Khaddaj, Software quality issues and challenges of internet of things, in: 2015 14th International Symposium on Distributed Computing and Applications for Business Engineering and Science (DCABES), 2015, pp. 176–179. doi:10.1109/DCABES.2015.51.

[148] D. Ko, Y. Kwak, S. Song, Real time traceability and monitoring system for agricultural products based on wireless sensor network, International Journal of Distributed Sensor Networks 10 (6) (2014) 832510.

[149] A. Kos, U. Sedlar, J. Sterle, M. Volk, J. BeÅter, M. Bajec, Network monitoring applications based on iot system, in: Proceedings of the 2013 18th European Conference on Network and Optical Communications 2013 8th Conference on Optical Cabling and Infrastructure (NOC-OC I), 2013, pp. 69–74. doi:10.1109/NOC-OCI.2013.6582870.

[150] A. J. J. Valera, M. A. Zamora, A. F. G. Skarmeta, An architecture based on internet of things to support mobility and security in medical environments, in: 2010 7th IEEE Consumer Communications and Networking Conference, 2010, pp. 1–5. doi:10.1109/CCNC.2010.5421661.

[151] D. Kovac, J. Hosek, P. Masek, M. Stusek, Keeping eyes on your home: Open-source network monitoring center for mobile devices, in: 2015 38th International Conference on Telecommunications and Signal Processing (TSP), 2015, pp. 612–616. doi:10.1109/TSP.2015.7296336.

[152] B. krishnan. N, S. S. S. S, S. B. Mohanthy, Real time internet application with distributed flow environment for medical iot, in: 2015 International Conference on Green Computing and Internet of Things (ICGCIoT), 2015, pp. 832–837. doi:10.1109/ICGCIoT.2015.7380578.

[153] M. T. Lazarescu, Design of a wsn platform for long-term environmental monitoring for iot applications, IEEE Journal on Emerging and Selected Topics in Circuits and Systems 3 (1) (2013) 45–54. doi:10.1109/JETCAS.2013.2243032.

[154] Q. Le, T. Ngo-Quynh, T. Magedanz, Rpl-based multipath routing protocols for internet of things on wireless sensor networks, in: 2014 International Conference on Advanced Technologies for Communications (ATC 2014), 2014, pp. 424–429. doi:10.1109/ATC.2014.7043425.

[155] L. Zhang, An iot system for environmental monitoring and protecting with heterogeneous communication networks, in: 2011 6th International ICST Conference on Communications and Networking in China (CHINACOM), 2011, pp. 1026–1031. doi:10.1109/ChinaCom.2011.6158307.

[156] L. W, W. F, R. X., Research of oil well working parameters monitoring system based on internet of things, in: Proceedings of the 2015 International Industrial Informatics and Computer Engineering Conference, 2015, pp. 241–5.

[157] L. Li, H. Xiaoguang, C. Ke, H. Ketai, The applications of wifi-based wireless sensor network in internet of things and smart grid, in: 2011 6th IEEE Conference on Industrial Electronics and Applications, 2011, pp. 789–793. doi:10.1109/ICIEA.2011.5975693.

[158] L. Li, S. Li, S. Zhao, Qos-aware scheduling of services-oriented internet of things, IEEE Transactions on Industrial Informatics 10 (2) (2014) 1497–1505. doi:10.1109/TII.2014.2306782.

[159] L. Li, M. Rong, G. Zhang, An internet of things qos estimate approach based on multi-dimension qos, in: 2014 9th International Conference on Computer Science Education, 2014, pp. 998–1002. doi:10.1109/ICCSE.2014.6926613.

[160] W. Li, F. C. Delicato, P. F. Pires, Y. C. Lee, A. Y. Zomaya, C. Miceli, L. Pirmez, Efficient allocation of resources in multiple heterogeneous wireless sensor networks, Journal of Parallel and Distributed Computing 74 (1) (2014) 1775 – 1788. doi:http://dx.doi.org/10.1016/j.jpdc.2013.09.012.
URL http://www.sciencedirect.com/science/article/pii/S0743731513002104

[161] Y. Li, K. K. Chai, Y. Chen, J. Loo, Qos-aware joint access control and duty cycle control for machine-to-machine communications, in: 2015 IEEE Global Communications Conference (GLOBECOM), 2015, pp. 1–6. doi:10.1109/GLOCOM.2015.7417682.

[162] S. C. Lin, K. C. Chen, Statistical qos control of network coded multipath routing in large cognitive machine-to-machine networks, IEEE Internet of Things Journal 3 (4) (2016) 619–627. doi:10.1109/JIOT.2015.2478435.

[163] C. Lv, B. Ma, X. Du, B. Li, T. Liang, Analysis and research of network measurement technologies, in: Proceedings of 2015 International Conference on Intelligent Computing and Internet of Things, 2015, pp. 117–121. doi:10.1109/ICAIOT.2015.7111551.

[164] Y. Ma, S. Yang, Z. Huang, Y. Hou, L. Cui, D. Yang, Hierarchical air quality monitoring system design, in: 2014 International Symposium on Integrated Circuits (ISIC), 2014, pp. 284–287. doi:10.1109/ISICIR.2014.7029544.

[165] K. Machado, D. Rosrio, E. Cerqueira, A. A. F. Loureiro, A. Neto, J. N. de Souza, A routing protocol based on energy and link quality for internet of things applications, Sensors 13 (2) (2013) 1942–1964. doi:10.3390/s130201942.
URL http://www.mdpi.com/1424-8220/13/2/1942

[166] A. Mayzaud, R. Badonnel, I. Chrisment, Monitoring and Security for the Internet of Things, Springer Berlin Heidelberg, Berlin, Heidelberg, 2013, pp. 37–40. doi:10.1007/978-3-642-38998-6_4.
URL http://dx.doi.org/10.1007/978-3-642-38998-6_4

[167] O. Mazhelis, M. Waldburger, G. S. Machado, B. Stiller, P. Tyrväinen, Retrieving Monitoring and Accounting Information from Constrained Devices in Internet-of-Things Applications, Springer Berlin Heidelberg, Berlin, Heidelberg, 2013, pp. 136–147. doi:10.1007/978-3-642-38998-6_17.
URL http://dx.doi.org/10.1007/978-3-642-38998-6_17

[168] Z. Ming, M. Yan, A modeling and computational method for qos in iot, in: 2012 IEEE International Conference on Computer Science and Automation Engineering, 2012, pp. 275–279. doi:10.1109/ICSESS.2012.6269459.

[169] A. Nieto, J. Lopez, Analysis and taxonomy of security/qos tradeoff solutions for the future internet, Security and Communication Networks 7 (12) (2014) 2778–2803. doi:10.1002/sec.809.
URL http://dx.doi.org/10.1002/sec.809

[170] D. Pavithra, R. Balakrishnan, Iot based monitoring and control system for home automation, in: 2015 Global Conference on Communication Technologies (GCCT), 2015, pp. 169–173. doi:10.1109/GCCT.2015.7342646.

[171] Q. Zu, X. Wu, X. Xu, W. Xie, Intelligent Data Acquisition and Processing of Remote Monitoring System Based on Internet of Things, Springer International Publishing, Cham, 2015, pp. 127–139. doi:10.1007/978-3-319-15554-8_11.
URL http://dx.doi.org/10.1007/978-3-319-15554-8_11

[172] T. Qiu, H. Xiao, P. Zhou, Framework and case studies of intelligence monitoring platform in facility agriculture ecosystem, in: 2013 Second International Conference on Agro-Geoinformatics (Agro-Geoinformatics), 2013, pp. 522–525. doi:10.1109/Argo-Geoinformatics.2013.6621976.

[173] Q. L, S. X, H. Y, T. C, L. L., Fpga implementation of qos multicast routing algorithm of mine internet of things perception layer based on ant colony algorithm, in: Advances in Information Sciences and Service Sciences, 2012, pp. 124–31.

[174] S. Zhou, K. J. Lin, C. S. Shih, Device clustering for fault monitoring in internet of things systems, in: 2015 IEEE 2nd World Forum on Internet of Things (WF-IoT), 2015, pp. 228–233. doi:10.1109/WF-IoT.2015.7389057.

[175] R. Sharma, N. Kumar, Qos-alert markov chain based scheduling scheme in internet of things, in: 2015 IEEE Globecom Workshops (GC Wkshps), 2015, pp. 1–6. doi:10.1109/GLOCOMW.2015.7414134.

[176] R. Sharma, N. Kumar, N. B. Gowda, T. Srinivas, Probabilistic prediction based scheduling for delay sensitive traffic in internet of things, Procedia Computer Science 52 (2015) 90 – 97, the 6th International Conference on Ambient Systems, Networks and Technologies (ANT-2015), the 5th International Conference on Sustainable Energy Information Technology (SEIT-2015). doi:http://dx.doi.org/10.1016/j.procs.2015.05.032.
URL http://www.sciencedirect.com/science/article/pii/S1877050915008327

[177] S. Y. Yu, C. S. Shih, J. Y. J. Hsu, Z. Huang, K. J. Lin, Qos oriented sensor selection in iot system, in: 2014 IEEE International Conference on Internet of Things (iThings), and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom), 2014, pp. 201–206. doi:10.1109/iThings.2014.37.

[178] E. Span, S. D. Pascoli, G. Iannaccone, Internet-of-things infrastructure as a platform for distributed measurement applications, in: 2015 IEEE International Instrumentation and Measurement Technology Conference (I2MTC) Proceedings, 2015, pp. 1927–1932. doi:10.1109/I2MTC.2015.7151576.

[179] S. Spinsante, S. Squartini, L. Gabrielli, M. Pizzichini, E. Gambi, F. Piazza, Wireless m-bus sensor networks for smart water grids: analysis and results, International Journal of Distributed Sensor Networks.

[180] K. G. Srinivasa, N. Siddiqui, A. Kumar, Parasense – a sensor integrated cloud based internet of things prototype for real time monitoring applications, in: 2015 IEEE Region 10 Symposium, 2015, pp. 53–57. doi:10.1109/TENSYMP.2015.6.

[181] Z. Sun, C. H. Liu, C. Bisdikian, J. W. Branch, B. Yang, Qoi-aware energy management in internet-of-things sensory environments, in: 2012 9th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks (SECON), 2012, pp. 19–27. doi:10.1109/SECON.2012.6275777.

[182] W.-T. Sung, K.-Y. Chang, Health parameter monitoring via a novel wireless system, Applied Soft Computing 22 (2014) 667 – 680. doi:https://doi.org/10.1016/j.asoc.2014.04.036.
URL http://www.sciencedirect.com/science/article/pii/S1568494614002129

[183] G. Tanganelli, C. Vallati, E. Mingozzi, Energy-efficient qos-aware service allocation for the cloud of things, in: 2014 IEEE 6th International Conference on Cloud Computing Technology and Science, 2014, pp. 787–792. doi:10.1109/CloudCom.2014.148.

[184] L. Torres, U. Killat, QoS Impact of Hierarchical Routing in Multichannel Sensor Networks, Springer Berlin Heidelberg, Berlin, Heidelberg, 2013, pp. 217–230. doi:10.1007/978-3-642-37935-2_17.
URL http://dx.doi.org/10.1007/978-3-642-37935-2_17

[185] E. Troubleyn, J. Hoebeke, I. Moerman, P. Demeester, Broadcast aggregation to improve quality of service in wireless sensor networks, International Journal of Distributed Sensor Networks 10 (3) (2014) 383678.

[186] G. Vithya, B. Vinayagasundaram, Qos by priority routing in internet of things, Research Journal of Applied Sciences, Engineering and Technology 8 (21) (2014) 2154–2160.

[187] F. Xue, Y. Jiang, Design of integrated fault management system based on intelligent mobile terminal, in: Proceedings of 2011 International Conference on Electronic Mechanical Engineering and Information Technology, Vol. 8, 2011, pp. 4297–4300. doi:10.1109/EMEIT.2011.6023991.

[188] T. Yang, W. Xiang, L. Ye, A distributed agents qos routing algorithm to transmit electrical power measuring information in last mile access wireless sensor networks, International Journal of Distributed Sensor Networks.

[189] Y. Zhang, L. Sun, H. Song, X. Cao, Ubiquitous wsn for healthcare: Recent advances and future prospects, IEEE Internet of Things Journal 1 (4) (2014) 311–318. doi:10.1109/JIOT.2014.2329462.

[190] M. A. Ameen, A. Nessa, K. S. Kwak, Qos issues with focus on wireless body area networks, in: 2008 Third International Conference on Convergence and Hybrid Information Technology, Vol. 1, 2008, pp. 801–807. doi:10.1109/ICCIT.2008.130.

[191] D. M. Han, J. H. Lim, Design and implementation of smart home energy management systems based on zigbee, IEEE Transactions on Consumer Electronics 56 (3) (2010) 1417–1425. doi:10.1109/TCE.2010.5606278.

[192] M. Hejmo, B. L. Mark, C. Zouridaki, R. K. Thomas, Design and analysis of a denial-of-service-resistant quality-of-service signaling protocol for manets, IEEE Transactions on Vehicular Technology 55 (3) (2006) 743–751. doi:10.1109/TVT.2006.873834.

[193] B. Kusy, H. Lee, M. Wicke, N. Milosavljevic, L. Guibas, Predictive qos routing to mobile sinks in wireless sensor networks, in: Proceedings of the 2009 International Conference on Information Processing in Sensor Networks, IPSN '09, IEEE Computer Society, Washington, DC, USA, 2009, pp. 109–120.
URL http://dl.acm.org/citation.cfm?id=1602165.1602177

[194] A. Ludovici, E. Garcia, X. Gimeno, A. C. Aug, Adding qos support for timeliness to the observe extension of coap, in: 2012 IEEE 8th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob), 2012, pp. 195–202. doi:10.1109/WiMOB.2012.6379074.

[195] S. M., P. Nayak, G. Ramamurthy, A novel approach to an energy aware routing protocol for mobile wsn: Qos provision, in: 2012 International Conference on Advances in Computing and Communications, 2012, pp. 38–41. doi:10.1109/ICACC.2012.66.