Protocol for a Systematic Literature Review on Security-related Research in Ubiquitous Computing
(second and updated version)

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Abstract

Context: This protocol is as a supplementary document to our review paper that investigates security-related challenges and solutions that have occurred during the past decade (from January 2003 to December 2014).

Objectives: The objective of this systematic review is to identify security-related challenges, security goals and defenses in ubiquitous computing by answering to three main research questions. First, demographic data and trends will be given by analyzing where, when and by whom the research has been carried out. Second, we will identify security goals that occur in ubiquitous computing, along with attacks, vulnerabilities and threats that have motivated the research. Finally, we will examine the differences in addressing security in ubiquitous computing with those in traditional distributed systems.

Method: In order to provide an overview of security-related challenges, goals and solutions proposed in the literature, we will use a systematic literature review (SLR). This protocol describes the steps which are to be taken in order to identify papers relevant to the objective of our review. The first phase of the method includes *planning*, in which we define the scope of our review by identifying the main research questions, search procedure, as well as inclusion and exclusion criteria. Data extracted from the relevant papers are to be used in the second phase of the method, *data synthesis*, to answer our research questions. The review will end by *reporting* on the results.

Results and conclusions: The expected results of the review should provide an overview of attacks, vulnerabilities and threats that occur in ubiquitous computing and that have motivated the research in the last decade. Moreover, the review will indicate which security goals are gaining on their significance in the era of ubiquitous computing and provide a categorization of the security-related countermeasures, mechanisms and techniques found in the literature.

Keywords: systematic review; ubiquitous computing; mobile computing; wearable computing; security

1 Note on the updates

This is a second and updated version of our research protocol. The following changes have been made:

1. We included the details on the automatic search conducted in January 2015 (pg. 30)
2. We included the mappings between papers and their corresponding categories (pg. 32-38)
3. We updated the list of selected papers (pg. 43-59)

Contents

2 Background

Ubiquitous computing, as envisioned by Mark Weiser [Wei99], assumes disappearance of technologies into the everyday environment, making them invisible to a user. With the proliferation of mobile and wearable devices enhanced with sensing capabilities, users are able to seamlessly collect and receive information from their surroundings [DMWS09] [PM03] [YHGY06] [ZMN06b]. Such an opposing image to virtual reality introduces a number of unprecedented characteristics to the era of ubiquitous computing. For one, devices participating in a ubiquitous environment are heterogeneous with respect to their hardware capabilities and operating systems. On the one hand, such a nature of devices introduces a number of advantages while designing ubiquitous infrastructures. For example, smartphones and tablets enriched with a number of embedded sensors, such as microphones, GPS, accelerometer and gyroscope [WCMA13], are able sense the changes of the environment and respond accordingly. Such a capability to react to the context has been recognized as an important factor in designing dynamic and complex infrastructures [LSP+14] which support the mobility of users. Furthermore, the notion of context-awareness has brought changes to the research and development in the human-computer interaction [HCS05] where the emphasis has been put on designing such interfaces, which do not interrupt or distract users from their surroundings.

Although such a vision offers many advantages to the way users interact with their environment and use available services, designing ubiquitous computing systems and environments that are privacy-sensitive and ensure security of user data still remains a challenge [Oh08][PAN05][RL07]. Over the last decade, a large and growing body of literature has tackled different security-related challenges, such as ensuring the availability of applications and services [ASA08], dealing with the lack of a fixed pre-deployed infrastructure [AHH+10] [AMD+08b], designing security mechanisms for the resource-constrained devices [HCC+12] [HHNL07] and managing trust among the large number of nodes participating in a mobile ad-hoc network (MANET) [WF07], to name a few.

To the best of our knowledge, there is no systematic review which provides a comprehensive overview of the research in the area of security in ubiquitous computing. It is, therefore, our aim to identify which attacks, vulnerabilities and threats have motivated the researchers in the last decade. Moreover, we are interested in security goals, as well as security countermeasures presented in the literature. Additionally, we will examine whether the necessary algorithms and technologies are publicly available and identify the validation mechanisms used to assess the appropriateness of the proposed solutions.

In order to provide an overview of the aforementioned security-related challenges and solutions, we will use a systematic literature review (SLR) method proposed by [KC07], which consists of 3 phases: planning, conducting and reporting. This document provides guidelines for our SLR developed in the first phase of the review (planning). To ensure rigor in the review process, the following procedures have been defined and presented in this document in detail:

1. Design of the research questions (see Section 3),
2. Search strategy (see Section 4),
3. Definition of the inclusion and exclusion criteria (see Section 5.1),
4. Quality assessment (see Section 5.4),
5. Data extraction (see Section 5.5),
6. Data synthesis (see Section 6).

Report on the pilot procedures will also be provided in this document, as well as any revisions to the first version of the protocol.

3 Research questions

The review is motivated by three research questions:

RQ1: Demographic data and trends.

RQ2: Which security-related goals have been addressed in ubiquitous computing in the last decade (from January 2003 - December 2014)?

RQ3: Is there a difference in addressing security in distributed systems in comparison with ubiquitous computing?

As suggested in [ATF09b] [KC07] [RHTi13], we used the *population*, *intervention*, *comparison*, *outcomes* and *context* (PICOC) criteria to clarify the general goal of the review (see Table 1). The details of each PICOC criterion will form the basis for the construction of our search terms (see section 4). In order to reach the goal of our review, we included additional terms that are related to ubiquitous computing. These are pervasive computing, mobile computing and wearable computing. The choice of the additional terms can be justified through the definition of ubiquitous computing found in the literature which identifies wireless networks, mobile and wearable devices as an essential part of a ubiquitous computing environment [DMWS09] [PM03] [YHGY06] [ZMN06b]. Moreover, we introduced *wireless body area network* (WBAN)[1] to the list of terms because we wanted to ensure that papers on the topic of security in wearable computing (that are considered relevant for the purpose of our research) are found and included in our review.

PICOC	Terms
Population	ubiquitous computing, pervasive computing, mobile computing, wearable devices, wearable computing, wireless body area network (WBAN).
Intervention	security mechanisms.
Comparison	distributed computing.
Outcomes	security of user data.
Context	empirical papers in industry and academic environment.

Table 1: PICOC criteria and research questions.

3.1 Details of the first research question

The main goal of the **first research question (RQ1)** is threefold:

RQ1.1: provide an overview of where the research on security in ubiquitous computing has been carried out (*expected outcome*: list of countries),

RQ1.2: examine when the research on security in ubiquitous computing has been carried out (*expected outcome*: number of articles per year),

RQ1.3: identify by whom the research on security in ubiquitous computing has been carried out (*expected outcome*: names of the researchers).

Moreover, we will also look for the information on the paper citations and venue where the paper was published.

RQ1.4: identify the most cited papers based on the Google Scholar citation count (*expected outcome*: number of citations).

[1] WBAN is the network of wearable computing devices and differs from traditional wired networks due to its specific characteristics, such as shared resources, node mobility and short transmission range [BR08].

We decided to use Google Scholar search engine to count the number of citations for each paper because it is able to search for scholarly literature across many disciplines and sources and, therefore, provide a more comprehensive citation count than individual databases.

RQ1.5: identify journals where the papers on security in ubiquitous computing have been published (*expected outcome*: list of journals),

RQ1.6: identify conferences where the papers on security in ubiquitous computing have been published (*expected outcome*: list of conference proceedings),

Data will be presented using the diagrams presented in Table 3.1. The list of countries (RQ1.1) will be presented using a bar diagram. Since we expect a lengthy list of countries, we will present only the first ten countries based on the number of times they have occurred in the papers. On the horizontal axis we will present the number of times (in percentages) a country occurred and on the horizontal axis the names of the countries. Since we expect to find at least one paper for each year in the interval [2003-2014], we will present the distribution of papers over years (RQ1.2) by a line diagram. The vertical axis will represent the number of papers published each year. On the horizontal axis we will plot the year interval. In case the distribution of numbers is not continuous, i.e. in case it happens that we could not identify any paper for one year within the interval, we will use a bar diagram. Author's names (RQ1.3) will be presented in a table format, which consists of two columns - author's name and number of papers identified. We will provide information for the first five authors based on the amount of papers identified in our SLR. Number of citations (RQ1.4) will be presented with a bar diagram, where the horizontal axis represents a paper and a vertical axis its corresponding number of citations. We will show the results for the first five papers based on the number of citations. The results of the questions RQ1.5 and RQ1.6 will be presented in a table, where the first column stands for a title of a journal/conference, and the second column for the number of papers identified, respectively. We will present the results for the first five journals/conference proceedings based on the number of papers found.

3.2 Details of the second research question

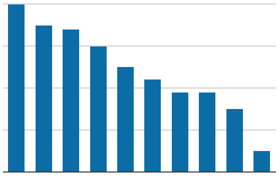
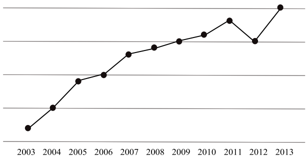
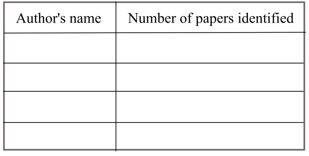
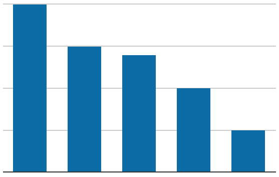
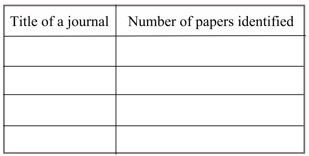
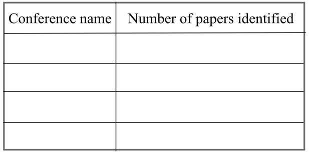
The **second research question (RQ2)** can be addressed in more depth. Therefore, six additional subquestions (see Table 2) are included to identify the security goals, motivation for the papers and proposed techniques, algorithms and methods used to solve security issues. We are also interested in the assessment of the proposed solutions, as well as limitations, recommendations and future work. Additionally, we will examine whether the algorithms and technologies used in the proposed solutions are publicly available, i.e. whether the results can be repeated and validated.

3.3 Details of the third research question

The aim of the **third research question (RQ3)** is to analyze the differences in addressing security in traditional distributed computing with those in ubiquitous computing based on the results obtained from the second research question. More specifically, we will compare security-related mechanisms and techniques that occur in both computing paradigms in order to find out whether the proposed solutions are inherited from distributed computing or newly introduced to ubiquitous computing.

4 Search strategy

In this section we will provide details of the following procedures: definition of the search terms, construction of the search strings, list of the resources to be searched and inclusion and exclusion criteria.

ID	**Expected outcome**	**Visualization**		**Restrict to**
		Type	Presentation	
RQ1.1	List of countries	bar diagram		10 countries
RQ1.2	Nr. of papers per year	line diagram		-
RQ1.3	Names of the researchers	table	Author's name Number of papers identified	5 researchers
RQ1.4	Number of citations	bar diagram		5 papers
RQ1.5	Number of journal papers	table	Title of a journal Number of papers identified	5 journals
RQ1.6	Number of conference papers	table	Conference name Number of papers identified	5 conferences

RQ	Motivation
RQ 2: Which security-related goals have been addressed in terms of ubiquitous computing?	Identify security goals addressed in the papers.
RQ 2.1: What is the motivation for the research?	Identify factors which motivated the papers, such as vulnerabilities, threats, and attacks.
RQ 2.2: Which solutions have been presented?	Identify suggested techniques, algorithms, and methods.
RQ 2.3: Are the algorithms and technologies publicly available?	Investigate whether the papers can be repeated in order to check the validity of results.
RQ 2.4: What kind of validation of the results has been performed?	Assess the appropriateness of the proposed solution.
RQ 2.5: Which future work has been proposed?	Investigate future trends in development and implementation of security mechanisms in ubiquitous computing.

Table 2: Refinement of the second research question.

4.1 Definition of the search terms

Based on the definition of the research scope and the PICOC details, we chose the first keyterms for a pilot search in order to determine whether the relevant papers will be identified. In addition to the PICOC terms (pervasive, ubiquitous, wearable, mobile computing and security), we included security goals to increase the probability of finding relevant papers. In order to identify the list of security goals that we will refer to in this review, we examined the proposed categorizations by [SRM13], [Wol08], [TS06] and [PS09]. Although the aforementioned categorizations include the same list of the basic security goals (data confidentiality, authentication, integrity and availability), the main difference lies in identifying the list of additional goals. For example, [PS09] identifies goals specific to the wireless sensor networks (WSN), such as data freshness, self-organization of a network, time synchronization and secure localization. Furthermore, categorization by [Wol08] includes only one goal (audit) additionally to the list of the basic goals. Therefore, we will use the list of security goals by [SRM13], which includes 4 basic goals (confidentiality, integrity, authentication and availability), 5 composite goals (access control, non-repudiation, authenticity of data, privacy and accountability) and audit. Throughout our SLR we will not exclude the possibility of identifying additional security goals, i.e. in addition to the predefined list of security goals we will use a general term "security" to increase our chances of finding as many relevant papers as possible.

We conducted a **pilot search** with a smaller subset of the search terms *pervasive*, *ubiquitous*, *wearable*, *mobile computing*, *security*, *authentication*, *confidentiality*, *privacy* and the alternative term *protection*. The results have shown that this combination of keyterms produces a large number of papers that are irrelevant for our review. For example, the keyword *protection* found papers on the topic of a homeland security, which was not in the scope of our review. Moreover, not many papers related to security in wearable computing were found. Thus, we included an additional search term "wireless body area network (WBAN)" to increase the chance of finding relevant papers on the topic. The list of keyterms was iteratively refined until we got a satisfactory list of initial papers. The final list of keyterms is presented below (Table 3), and includes the security goals proposed by [SRM13].

Keyterms		Alternative terms
T1	ubiquitous computing	pervasive computing, wearable computing, body area network, mobile computing
T2	security	confidentiality, authentication, access control, non-repudiation, audit, integrity, authenticity of data, availability, accountability, privacy

Table 3: Search terms.

4.2 Design of the search string

We constructed a search string using the identified keywords, their alternatives and related terms linked with Boolean *AND* and *OR* operators. Since our review will focus on identifying security goals in ubiquitous computing, the search string is built in the following way: $(T1_1 \lor T1_2 \lor \ldots \lor T1_\mathrm{n}) \land (T2_1 \lor T2_2 \lor \ldots \lor T2_\mathrm{n}) \quad where \quad T1_{1\,\ldots\,\mathrm{n}} \in T1 \land T2_{1\,\ldots\,\mathrm{n}} \in T2$.

Due to the large number of keywords and the specific limitations of search engines [FSGC13], the general search string is divided into three search strings, as presented in Table 4.

String	Form
S1	(ubiquitous *OR* "pervasive computing" *OR* "mobile computing" *OR* wearable *OR* "body area network") *AND* (security *OR* confidentiality *OR* "access control" *OR* authentication)
S2	(ubiquitous *OR* "pervasive computing" *OR* "mobile computing" *OR* wearable *OR* "body area network") *AND* (privacy *OR* integrity *OR* "authenticity of data" *OR* availability)
S3	(ubiquitous *OR* "pervasive computing" *OR* "mobile computing" *OR* wearable *OR* "body area network") *AND* ("non-repudiation" *OR* audit *OR* accountability)

Table 4: Search strings.

4.3 Resources to be searched

In order to find relevant papers for our review, we will perform the search procedure automatically by using scientific databases' search engines and manually by scanning through the selected conferences, as shown in Figure 1.

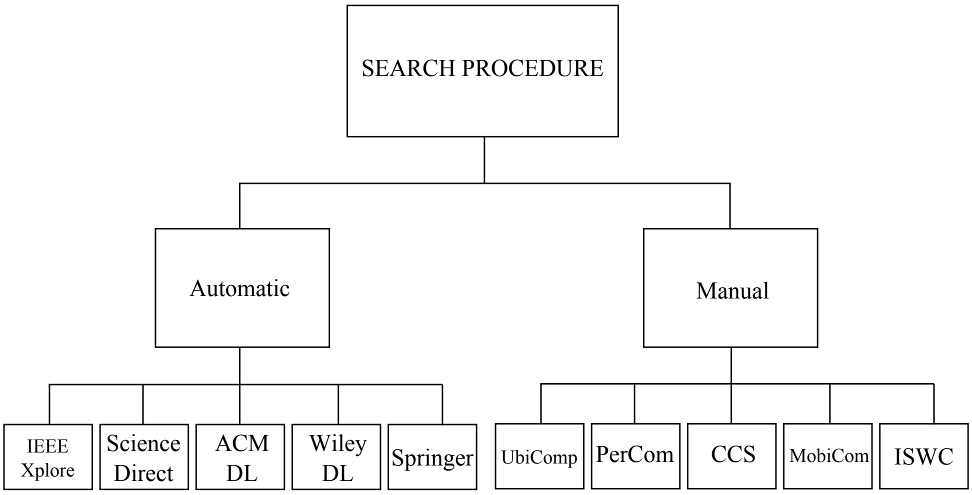


Figure 1: Manual and automatic search

The following 5 scientific databases have been chosen for our review because they publish a substantial amount of peer-reviewed papers on the subject of computer science, including security and privacy:

1. Science Direct,
2. IEEEXplore,
3. ACM DL,
4. Wiley DL,
5. Springer library.

In addition to the automatic database search, we identified 5 conferences that will be searched manually. The choice of the conferences has been made according to the topics the conferences focus on and encompass the search terms defined in 4.1, as shown in Figure 2.

1. ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp),
2. IEEE Pervasive Computing and Communication conference (PerCom),
3. ACM Conference on Computer and Communications Security (CCS),

4. Annual ACM International Conference on Mobile Computing and Networking (MobiCom),
5. International Symposium on Wearable Computers (ISWC).

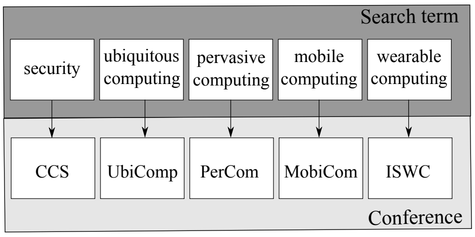


Figure 2: Conferences and search terms

4.4 Refinement of the general search string

Due to the specific requirements of each search engine, we adapted our search procedure to each scientific database, as seen in Table 5.

Scientific database	**Search type**	**Search in**	**Refinement**
Science Direct	Expert search	Title, abstract and keywords	Limit the search to journals and a time-frame [2003-2014]
Wiley DL	Advanced search	Abstract	Limit the search to a time-frame [2003-2014]
IEEEXplore	Command search	Abstract	Limit the search to a time-frame [2003-2014]
ACM DL	Advanced search	Abstract	Limit the search to a time-frame [2003-2014]
Springer	Advanced search	Title	Limit the search to a time-frame [2003-2014] and English

Table 5: Requirements of scientific databases.

Once the search procedure has been adapted for each database, we refined the general search string defined in 4.2 (see Table 6).

Scientific Database	**First set of search strings**
Science Direct	*TITLE-ABSTR-KEY(ubiquitous OR ”pervasive computing” OR ”mobile computing” OR wearable OR ”body area network”) and TITLE-ABSTR-KEY(security OR confidentiality OR ”access control” OR authentication)*
IEEEXplore	*(”Abstract”:ubiquitous OR ”Abstract”:”pervasive computing” OR ”Abstract”:”mobile computing” OR ”Abstract”:wearable OR ”Abstract”:”body area network”) AND (”Abstract”:security OR ”Abstract”:confidentiality OR ”Abstract”:”access control” OR ”Abstract”:authentication)*
ACM Digital Library	*(Abstract:ubiquitous OR Abstract:”pervasive computing” OR Abstract:”mobile computing” OR Abstract:wearable OR Abstract:”body area network”) AND (Abstract:security OR Abstract:confidentiality OR Abstract:”access control” OR Abstract:authentication)*
Wiley Digital Library	*(ubiquitous OR “pervasive computing” OR ”mobile computing” OR wearable OR ”body area network”) AND (security OR confidentiality OR ”access control” OR authentication)*
Springer	*(ubiquitous OR “pervasive computing” OR ”mobile computing” OR wearable OR ”body area network”) AND (security OR confidentiality OR ”access control” OR authentication)*
Scientific Database	**Second set of search strings**
Science Direct	*TITLE-ABSTR-KEY(ubiquitous OR ”pervasive computing” OR ”mobile computing” OR wearable OR ”body area network”) and TITLE-ABSTR-KEY(privacy OR integrity OR ”authenticity of data” OR availability)*

IEEEXplore	*(”Abstract”:ubiquitous OR ”Abstract”:”pervasive computing” OR ”Abstract”:”mobile computing” OR ”Abstract”:wearable OR ”Abstract”:”body area network”) AND (”Abstract”:privacy OR ”Abstract”:integrity OR ”Abstract”:”authenticity of data” OR ”Abstract”:availability)*
ACM Digital Library	*(Abstract:ubiquitous OR Abstract:”pervasive computing” OR Abstract:”mobile computing” OR Abstract:wearable OR Abstract:”body area network”) AND (Abstract:privacy OR Abstract:integrity OR Abstract:”authenticity of data” OR Abstract:availability)*
Wiley Digital Library	*(ubiquitous OR “pervasive computing” OR ”mobile computing” OR wearable OR ”body area network”) AND (privacy OR integrity OR ”authenticity of data” OR availability)*
Springer	*(ubiquitous OR “pervasive computing” OR ”mobile computing” OR wearable OR ”body area network”) AND (privacy OR integrity OR ”authenticity of data” OR availability)*
Scientific Database	**Third set of search strings**
Science Direct	*TITLE-ABSTR-KEY(ubiquitous OR ”pervasive computing” OR ”mobile computing” OR wearable OR ”body area network”) and TITLE-ABSTR-KEY(”non-repudiation” OR audit OR accountability)*
IEEEXplore	*(”Abstract”:ubiquitous OR ”Abstract”:”pervasive computing” OR ”Abstract”:”mobile computing” OR ”Abstract”:wearable OR ”Abstract”:”body area network”) AND (”Abstract”:”non-repudiation” OR ”Abstract”:audit OR ”Abstract”:accountability)*
ACM Digital Library	*(Abstract:ubiquitous OR Abstract:”pervasive computing” OR Abstract:”mobile computing” OR Abstract:wearable OR Abstract:”body area network”) AND (Abstract:”non-repudiation” OR Abstract:audit OR Abstract:accountability)*
Wiley Digital Library	*(ubiquitous OR “pervasive computing” OR ”mobile computing” OR wearable OR ”body area network”) AND (”non-repudiation” OR audit OR accountability)*
Springer	*(ubiquitous OR “pervasive computing” OR ”mobile computing” OR wearable OR ”body area network”) AND (”non-repudiation” OR audit OR accountability)*

Table 6: List of search strings.

The results for each database search and its corresponding search string are given in Appendix A.

4.5 Evaluation of the search process

Before undertaking the review, search strings will be evaluated by their ability to detect the papers presented in Table 7. The list of papers was identified by using the general keyterms “security” and “ubiquitous computing” over the scientific databases prior to the definition of the search strings.

DB	Author	Title	Venue	Year	Page Nr.	Reference
IEEE	Cahill et al.	Using trust for secure collaboration in uncertain environments	IEEE Pervasive Computing (2)3	2003	52-61	[CGS$^+$03]
	Ahmadian et al.	Recursive linear and differential cryptanalysis of ultralightweight authentication protocols	IEEE Transactions on Information Forensics and Security 8(7)	2013	1140-1151	[ASA13]
	Zhu et al.	Understanding and minimizing identity exposure in ubiquitous computing environments	International Conference on Mobile and Ubiquitous Systems: Networking Services, MobiQuitous'09	2009	1-10	[ZCK$^+$09]
	Hoque et al.	An Adaptive Initial Trust and Demand Aware Secure Resource Discovery (AID-SRD) model for pervasive environments	International Conference on Pervasive Computing and Communications, PerCom'09	2009	1-6	[HRA09]
Science Direct	Hengartner, Steenkiste	Exploiting information relationships for access control in pervasive computing	Pervasive and Mobile Computing 2(3)	2006	344-367	[HS06]
	Tan, Z.	A lightweight conditional privacy-preserving authentication and access control scheme for pervasive computing environments	Journal of Network and Computer Applications 35(6)	2012	1839-1846	[Tan12]
	Bahtiya, Caglayan	Extracting trust information from security system of a service	Journal of Network and Computer Applications 31(1)	480-490	2012	[BU12]
ACM	Shi et al.	BANA: body area network authentication exploiting channel characteristics	Proceedings of the Fifth ACM Conference on Security and Privacy in Wireless and Mobile Networks, WISEC'12	2012	27-38	[SLYY12]
	Shahzad et al.	Secure unlocking of mobile touch screen devices by simple gestures: You can see it but you cannot do it	Proceedings of the 19th Annual International Conference on Mobile Computing & Networking, MobiCom'13	2013	39-50	[SLS13]
Wiley	Jang et al.	Hybrid security protocol for wireless body area networks	Wireless Communications and Mobile Computing 11(2)	2011	277-288	[JLHP11]
	Yau et al.	Support for situation awareness in trustworthy ubiquitous computing application software	Software: Practice and Experience 36(9)	2006	893-921	[YHGY06]
Springer	English et al.	Towards self-protecting ubiquitous systems: monitoring trust-based interactions	Personal and Ubiquitous Computing	2006	50-54	[ETN06]
	Li et al.	An extended chaotic maps based user authentication and privacy preserving scheme against DoS attacks in pervasive and ubiquitous computing environments	Nonlinear Dynamics 74(4)	2013	1133-1143	[LLW13]

Table 7: The known subset of papers.

5 Paper selection

5.1 Inclusion and exclusion criteria

In order to identify the papers that are in line with the objective of our review, we conducted a consensus meeting where the inclusion and exclusion criteria were defined. The initial list of criteria is presented below (Table 8 and Table 9 present exclusion and inclusion criteria, respectively).

Criterion ID	Criterion
E01	Summaries of workshops and tutorials, title pages, editorials and extended abstracts as they do not provide sufficient information to the objective of our review.
E02	Workshop articles as they report on a study in its early stage.
E03	Posters, as they do not provide enough information for the purpose of our review.
E04	Books and PhD theses, as they are beyond the scope of this review.
E05	Double entries. If an extended journal article is found, it will be chosen over the conference article. If a more recent paper is found, it will be chosen over its preceding paper.
E06	Papers whose focus was not put on security goals in ubiquitous, mobile and wearable computing, i.e. papers that mentioned security in their abstracts as one of the issues.
E07	Opinion papers, discussion papers and survey papers that do not propose a solution.
E08	Any paper whose full text is not accessible.
E09	Papers not written in English.
E10	Papers with a low quality assessment score (to be done after the quality assessment procedure, see Section 5.4).

Table 8: Exclusion criteria

Criterion ID	Criterion
I01	Full version of journal and conference articles that report on, discuss or investigate security issues in ubiquitous, mobile and wearable computing.
I02	Papers that propose a solution to the identified security issue.
I03	Papers written in English.
I04	Papers published since 2003.

Table 9: Inclusion criteria

We conducted a pilot selection procedure with the criteria defined above, which resulted in a large number of potentially relevant papers (n=4369). Both reviewers participated in the search procedure, one searched for the papers according to the defined set of criteria, while the other checked titles and abstracts against the inclusion criteria.

Due to the large number of papers identified in the initial search process, two additional criteria are introduced to keep the selection process manageable:

1. Papers published in the journals with a Scimago Journal Ranking (SJR) where h-index [2] ≥ 35 or SJR ≥ 0.8.

2. Papers published in the conference proceedings with a rank A+ or A based on the CORE ranking (Computer Science Conference Rankings) [3]

The latter criterion was formerly used in literature review papers [WW02] where it was indicated that researchers should examine conference proceedings with a reputation for quality.

[2] journal's number of papers that have received at least h citations over the whole period. For additional information refer to [sci]

[3] For additional information refer to [Cor].

5.2 Filtering of the papers

We will use the inclusion and exclusion criteria on the initial pool of papers in the following way (see Figure 3). While obtaining the papers for the initial pool, we will check whether they are written in English. This criterion can be incorporated within the automatic database search for some databases, such as Springer. For the results of the remaining databases, we will manually check the list of papers and exclude those written in any other language than English (exclusion criterion E09).

Once the initial papers have been identified, we will begin with the first filtering phase in which the double entries will be removed (**P1**) with the help of the Zotero reference manager (exclusion criterion E5). In order to ensure that there are only unique entries left, we will check the papers and manually remove any doubles remaining in the pool. Our second phase will be to look for the workshop articles, summaries of workshops and tutorials, title pages, editorials, posters and extended abstracts (**P2**). If such papers are found, we will exclude them from the pool (exclusion criteria E01-E04). Next we will look for the papers whose focus is not put on security in ubiquitous computing based on the information provided in the titles and abstracts (**P3**, exclusion criterion E06). Moreover, opinion and discussion papers will also be removed from the pool (exclusion criterion E07). The filtering procedure will continue by checking the journal and conference rankings (**P4**), as described in section 5.1. Once the papers have been removed based on the rankings, our next step (**P5**) will be to combine the remaining ones with those found manually while scanning through the selected conference proceedings. Since we expect double entries to occur as a result of the phase P5, we will remove them before continuing with the filtering procedure (**P6**). The next phase (**P7**) is to obtain the full version of each paper. If it is not available in a corresponding database, we will check the authors' personal websites and, if necessary, contact the authors. If we still cannot obtain the full version of a paper, we will exclude it from our review (exclusion criterion E08). The following two phases will be conducted in parallel - quality assessment and screening of the content of the papers (**P8a** and **P8b**).

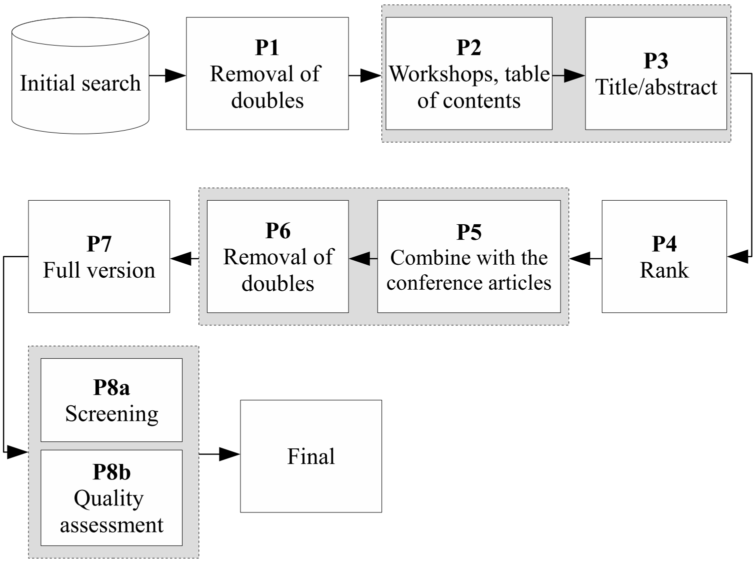


Figure 3: Filtering of papers.

If a paper is given a low quality assessment score, we will exclude it from our review, as described in Section 5.4 (exclusion criterion E10). We expect to identify the papers that are out of the scope of the review while screening through their full version and exclude them from our review, as well. After the filtering procedure has been completed, we expect to have a pool of relevant papers that will go through the data extraction procedure.

Report on the details of the selection procedure is given in Appendix B.

5.3 Tools to be used during the selection procedure

During the selection procedure, we will use a Zotero reference manager to automatically collect the general information about the papers, such as authors, publication venue, publication year and the corresponding source (titles of journals and conferences). In order to be able to track in which database each paper was found, we will organize the information into folders, as shown in Figure 4.

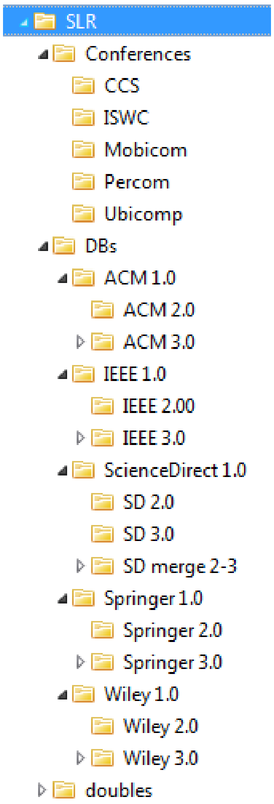
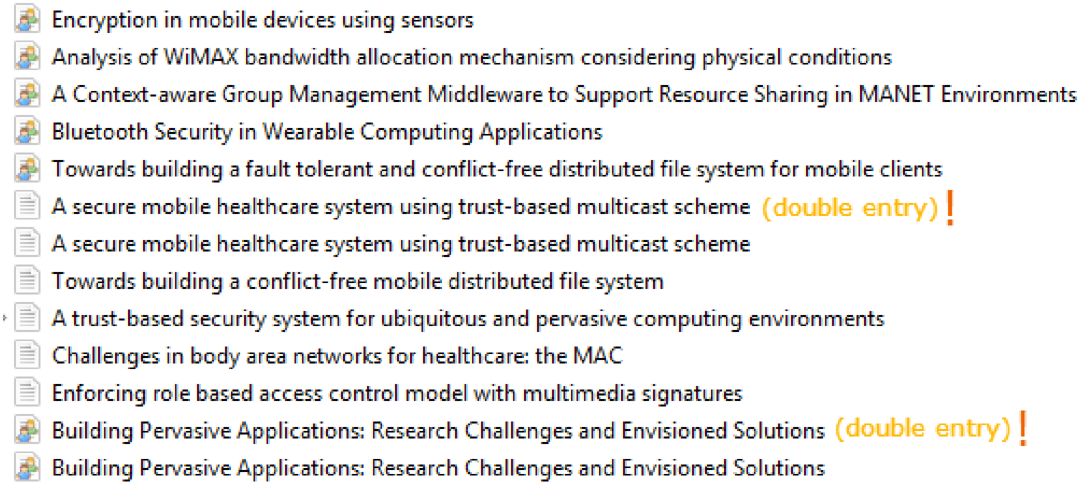


Figure 4: Zotero tree-like organization

Initially, the manager will consist of a root folder named "SLR" and two parent folders - one to store the information about the conference papers found manually (named "Conferences"), and the other to store the information about the papers found by an automatic search (named "DBs"). In each parent folder, the information will be further organized into subfolders that represent the specific source where the paper has been found. Therefore, the folder "Conferences" will include in total five subfolders (named "CCS", "ISWC", "Mobicom", "Percom" and "Ubicom"). Information collected in these subfolders will not be checked for the double entries, as they are mutually exclusive. However, the same is not valid for the information stored in the subfolders of the folder "DBs". This is the case for two reasons. First, some conference papers are indexed in both the ACM and the IEEEXplore database. Second, since our search procedure is based on three different search strings for each database, we expect to find a number of the same papers in each run. For this reason, after the automatic search has been completed, we will check for any double entries by using a separate folder called "doubles". This folder will initially hold all the entries found during the automatic search. We will go through the list of papers and gradually remove any double entries. The resulting list should hold only unique entries. This list will be used for the filtering procedure (as described in Section 5.2). A screenshot of the list of the papers prior to the removal of the double entries is presented in Figure 5.

It is important to note that both reviewers will participate in the selection process in order to minimize personal bias, as recommended in [GBBGG$^+$13] [KB13] [RHTi13].

In addition to Zotero, we will use a Google Spreadsheet (see Table 10) shared between the



Encryption in mobile devices using sensors
Analysis of WiMAX bandwidth allocation mechanism considering physical conditions
A Context-aware Group Management Middleware to Support Resource Sharing in MANET Environments
Bluetooth Security in Wearable Computing Applications
Towards building a fault tolerant and conflict-free distributed file system for mobile clients
A secure mobile healthcare system using trust-based multicast scheme (double entry) !
A secure mobile healthcare system using trust-based multicast scheme
Towards building a conflict-free mobile distributed file system
A trust-based security system for ubiquitous and pervasive computing environments
Challenges in body area networks for healthcare: the MAC
Enforcing role based access control model with multimedia signatures
Building Pervasive Applications: Research Challenges and Envisioned Solutions (double entry) !
Building Pervasive Applications: Research Challenges and Envisioned Solutions

Figure 5: Double entries

both reviewers to record search and selection details, such as a number of papers found for each search string, number of double entries identified for each database, number of workshops, number of papers left after the inclusion based the titles and abstracts, number of papers after checking the journal and conference rankings.

String Nr.	Database	Doubles	Workshops, table of contents, summaries	Title, abstract	Rank
	ACM				
S1					
S2					
S3					
	Springer				
S1					
S2					
S3					
	Science Direct				
S1					
S2					
S3					
	IEEE				
S1					
S2					
S3					
	Wiley				
S1					
S2					
S3					

Table 10: Search form

Once the initial pool of relevant papers has been made, we will obtain their full versions (in a PDF format) and put them in a shared Google Drive folder. These papers will be used in the collaborative quality assessment procedure.

5.4 Quality Assessment

After the relevant papers have been identified, we will prepare them for the quality assessment procedure by renaming each in the following way. Each paper will be given a prefix S[000]_ (*S* stands for *paper*) and a three-digit number starting from 000. For example, a paper with a title "A compensation scheme of fingerprint distortion using combined radial basis function model for ubiquitous services" is alphabetically first in our initial pool of relevant papers. After the renaming procedure, the PDF document will have the following title: "S001_A compensation scheme of fingerprint distortion using combined radial basis function model for ubiquitous services". The renaming will be done automatically by using a script written in Perl (see Listing 1).

Listing 1: Perl script

```
#!/usr/bin/perl -w
use File::Find;
use File::Basename;
use File::Spec;
use strict;

my $i='001';
find ({'wanted' => \&renamefile }, '(source)');

sub renamefile {
    my $file = $_;
     return unless (-f $file);
    my $dirname = dirname($file);
    my $file_name = basename($file);
    my $new_file_name = $file_name;
     $new_file_name = 'S'.$i.'_'.$file_name;
     rename($file, File::Spec->catfile($dirname, $new_file_name))
                or die $!;
          $i++;
}
```

Based on the suggestions by [ATF09b] [DD08] [GBBGG+13] [KB13] [SJV+12], we will use a quality assessment form that consists of 7 questions represented in a three-point scale with *Yes* (1), *No* (0) and *To some extent* (0.5) as the possible answers.

QA1: Is the paper based on research?

1.1 Yes, it is based on research (1).

1.2 To some extent (0.5).

1.3 No, it is a lessons learned based on expert opinion (0).

QA2: Is there a clear statement of the aim?

2.1 Yes, the aim is specific and mentioned explicitly (1).

2.2 To some extent (0.5).

2.3 No, there is no mention of the aim, or the aim is too general (0).

QA3: Is there an adequate description of the context in which the research was carried out?

3.1 Yes, the paper reports on the application domain for which the security mechanism is designed (1).

3.2 To some extent (0.5).

3.3 No, the application domain is unclear (0).

QA4: Did the paper make a review of previous research of the topic?

4.1 Yes, the paper provided a thorough review of the related work (1).

4.2 To some extent (0.5).

4.3 No, the paper did not provide a review of the related work (0).

QA5: Is the methodology described adequately?

5.1 Yes, the process of creating the research artifacts is clear and provides sufficient information on data collection and algorithms used (1).

5.2 The paper provides a description of the research process, but lacks in detail (0.5).

5.3 No, the paper does not report on the creation of research artifacts (0).

QA6: Is there a clear statement of the findings?

6.1 Yes, the paper provides an adequate description of the findings, as well as the corresponding evaluation (1).

6.2 The paper reports on the findings, but lacks in evaluation (0.5).

6.3 No, the paper does not clearly state its findings (0).

QA7: Did the paper discuss future work?

7.1 Yes, the paper discusses future work (1).

7.2 The paper briefly mentions future work (0.5).

7.3 No, the paper does not discuss future work (0).

The form is presented in Table 12.

ID	Question	Score
QA1	Is the paper based on research?	
QA2	Is there a clear statement of the aim?	
QA3	Is there an adequate description of the context in which the research was carried out?	
QA4	Did the paper make a review of previous research of the topic?	
QA5	Is the methodology described adequately?	
QA6	Is there a clear statement of the findings?	
QA7	Did the paper discuss future work?	

Table 11: Quality assessment scores.

The maximum value of the assessment for a paper is 7, indicating high quality, whereas 0 value means poor quality. The range is further divided into three categories:

1. High quality (*final score*≥6),
2. Medium quality (4≤*final score*≤5.5),
3. Poor quality (*final score*≤3.5).

For each paper we will calculate the final quality assessment scores. This information will be used to identify the number of papers placed in each quality assessment category (poor, medium and high quality). Additionally, we will find the final scores for each question to identify the overall weaknesses of the papers used in our review. For example, as reported in a systematic

Paper ID	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Final score per paper
S001								
S002								
S003								
...								
Final score per question								

Table 12: Quality assessment form

review paper [SLB14], future work scored low in the quality assessment procedure indicating that authors of the reviewed papers did not properly discuss future plans. The cumulative scores found for each quality assessment question will be presented in a form presented in Table 12.

Following the example of the other systematic reviews [MHGA13] [RHTi13], we will exclude the papers placed in the poor quality category and include those that have a substantial quality assessment score into the data extraction process.

In order to ensure that the selected papers will make a valuable contribution to the findings of the review, we considered the concepts of reporting, rigor, credibility and relevance (proposed in [DD08]) while designing our quality assessment questions.

- **Reporting:** questions QA1, QA2 and QA3 examine the quality of reporting on the rationale, aim and context of the research.
- **Rigor:** question QA5 is used to examine the rigor and validity of the research methodology.
- **Credibility:** question QA6 is designed to assess the validity and meaningfulness of a paper.
- **Relevance:** questions QA4 and QA7 are introduced to assess the relevance of a paper.

Both reviewers will be involved in the quality assessment procedure. The pool of the potentially relevant papers will be divided into two parts, each assessed by one author and checked by the other.

5.4.1 Report on the pilot quality assessment

Based on the suggestion by [KB13], we performed a pilot quality assessment with a random sample of 10 papers to ensure that all researchers understand how to apply the quality assessment checklist. Each author has individually assessed the papers. After comparing the quality scores, a Cohen's Kappa coefficient was calculated (23% fair). In order to reduce the differences in the individual understanding of the procedure, additional refinements to the quality assessment form were made. In particular, more explanation was given to the checklist of the *research methodology* and the *context of the research.*

5.5 Data extraction

In order to manage the data extraction procedure, we designed an online form using Google Forms, which will help us during the collaborative data extraction process and, later on, while aggregating and synthesizing the information for further analysis. The data extracted from the papers will be recorded in a Google Spreadsheet, which is automatically generated once an entry has been submitted to the form. As the data extraction procedure will be conducted in parallel with the quality assessment, reviewer A will check the data extracted by the reviewer B, and vice versa. We will discuss any potential disagreements and, if an agreement cannot be reached, we will ask for a third opinion.

5.5.1 Details of the extraction form

It is possible to choose one of the nine question types:

1. Text - includes a small one-line text box.

2. Paragraph text - includes a multi-line text box, which is well suited for writing a longer paragraph of text

3. Multiple choice - allows two types of answers: 1) predefined (as designed by the form owners), 2) custom answer (any additional answer a reviewer might come up with during the data extraction process). Though the name implies that this question is a multiple choice type of a question, we have found out that in practice a reviewer can choose only one option from the list. Therefore, this option stands for a single choice question type. While testing the questions types, we found out that it is not possible to allow a reviewer to enter an additional value to the ones already given in the list of options. The advanced settings additionally allow to shuffle option order. To avoid confusion, we decided not to use this option for any question in our data extraction form.

4. Checkbox - as in the multiple choice question type, it allows two types of answers: 1) predefined answer, 2) custom answer. In our case, we provided a list of security goals, which included confidentiality, integrity, authentication, availability, access control, non-repudiation, authenticity of data, privacy, accountability, and audit. The list of these security goals can be found in [SRM13]. In case an additional security goal is identified in the papers, a reviewer is given an option to enter it by using a custom answer textbox. In this way we wanted to ensure that the important information for our SLR get recorded without restricting the reviewers by the predefined options.

5. Choose from list - provides a drop-down list of options. For this type of a question it is impossible to have a custom answer textbox. We decided not to use this type of a question.

6. Scale - includes a scale of values on which a reviewer can place a response. We choose not to use this type of a question.

7. Grid - includes a grid of rows and columns where a reviewer has to click a single cell to place a response. This type is often used for Likert scale questions. We did not use this type of a question.

8. Date - includes a calendar on which a reviewer has to click to enter a date in the format *dd.mm.yyyy*, where *d* stands for day, *m* for month and *y* for year. In addition, it is also possible to enter time in the format *hh:mm*, where *h* stands for hours and *m* for minutes. Although this question type might have been useful to check the time and date an entry has been submitted to our data extraction form by each reviewer, we decided not to use it because the timestamps were automatically recorded for each form entry in the first column in a Google Spreadsheet.

9. Time

It is possible to define every question as a "required question", meaning that a reviewer will be forced to answer the corresponding question before being able to proceed to the next question. We used this option only for one textbox, namely *Paper ID.*

Once a reviewer is done with extracting the data from the papers, he/she is prompted to press the submit button. The data is then automatically transferred to the Google Spreadsheet in a sheet called "Form Responses", where the number of columns corresponds to the number of questions in a form and number of rows correspond to the number of entries a reviewer has submitted. In our case, the number of rows will respond to the number of papers that were identified as relevant for our SLR.

5.5.2 Description of the data extraction form

The form consists of four parts, as presented in Table 13.

Part	RQ	Data extracted	Question type
1[4]	**RQ1**	Name of the reviewer	Textbox
		Paper ID (***required**)	Textbox
		Title of the paper	Textbox
		Authors	Textbox
		Country/list of countries where the research has been carried out	Textbox
		Publication venue	Textbox
		Publication details for journal	Textbox
		Conference acronym	Textbox
		Page numbers	Textbox
		Date of publication	Textbox
		Cited by (number of citations based on the Google Scholar citation count)	Textbox
2	**RQ2**	Aim of the paper	Textbox
	RQ2	List of security goals addressed in the paper[5]	Checkbox with *confidentiality*, *integrity*, *authentication*, *availability*, *access control*, *non-repudiation*, *authenticity of data*, *privacy*, *accountability* and *audit* as possible choices.
	RQ2.1	Motivation for the research	Textbox
3	**RQ2.2**	Solutions	Textbox
	RQ2.3	Are the necessary algorithms publicly available?	Single choice with *yes* and *no* as possible answers.
	RQ2.4	Has the validation been performed?	Single choice with *yes* and *no* as possible answers.
	RQ2.4	If yes, which validation methods have been used?[6]	Checkbox with *experiment*, *case paper*, *data mining*, *opinion survey*, *lessons learned*, *example*, *formal verification* and *other* as possible answers.
4	**RQ2.5**	Did the authors identify limitations to their solution?	Single choice with *yes* and *no* as possible answers.
		List of limitations	Textbox
		Have any directions for future work been proposed?	Single choice with *yes* and *no* as possible answers.
		Which future work has been proposed?	Textbox

Table 13: Description of the data extraction form

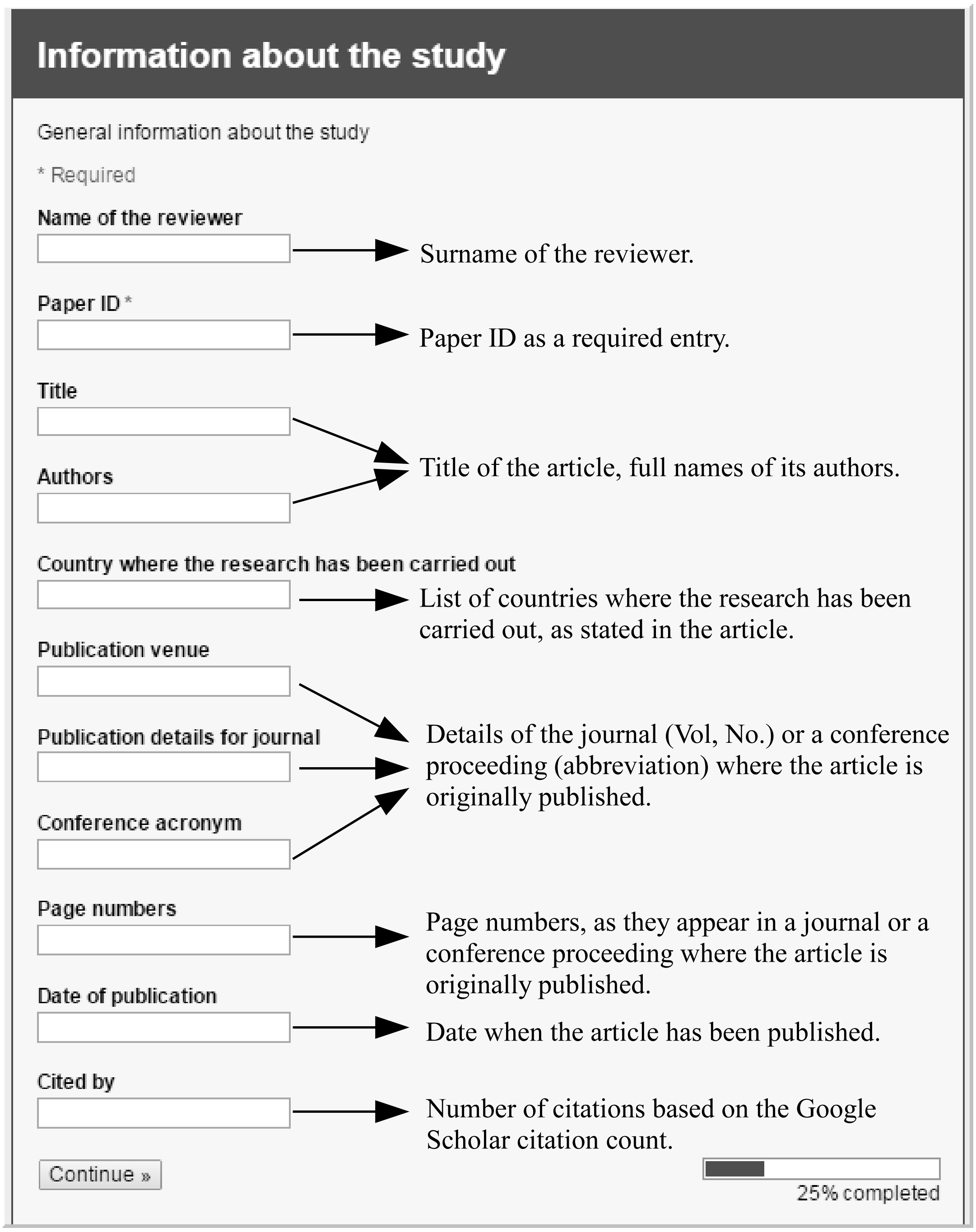
[4] We will not manually fill in the date when the information is extracted, as the timestamp is automatically assigned to each entry once the answers are submitted in the Google Forms.

[5] Due to the specific characteristics of the technologies, devices and networks that we will come across in our review, we expect to identify additional security goals and put them into the *Other* category.

[6] Validation methods are defined in Table 14

5.5.3 Description of the pages included in the form

The first page of the data extraction form (see Figure 6) consists of 11 data-entry fields, namely name of the reviewer, paper ID (required), title of the paper, author's name, country where the research has been carried out (country where the author worked at the moment when the paper written), publication venue, publication details for a journal (volume, number), conference acronym, page numbers (as they appear in the original publication venue), date of publication, number of cites (based on Google Scholar citation count).



Information about the study

General information about the study

* Required

Name of the reviewer

Surname of the reviewer.

Paper ID *

Paper ID as a required entry.

Title

Authors

Title of the article, full names of its authors.

Country where the research has been carried out

List of countries where the research has been carried out, as stated in the article.

Publication venue

Publication details for journal

Conference acronym

Details of the journal (Vol, No.) or a conference proceeding (abbreviation) where the article is originally published.

Page numbers

Page numbers, as they appear in a journal or a conference proceeding where the article is originally published.

Date of publication

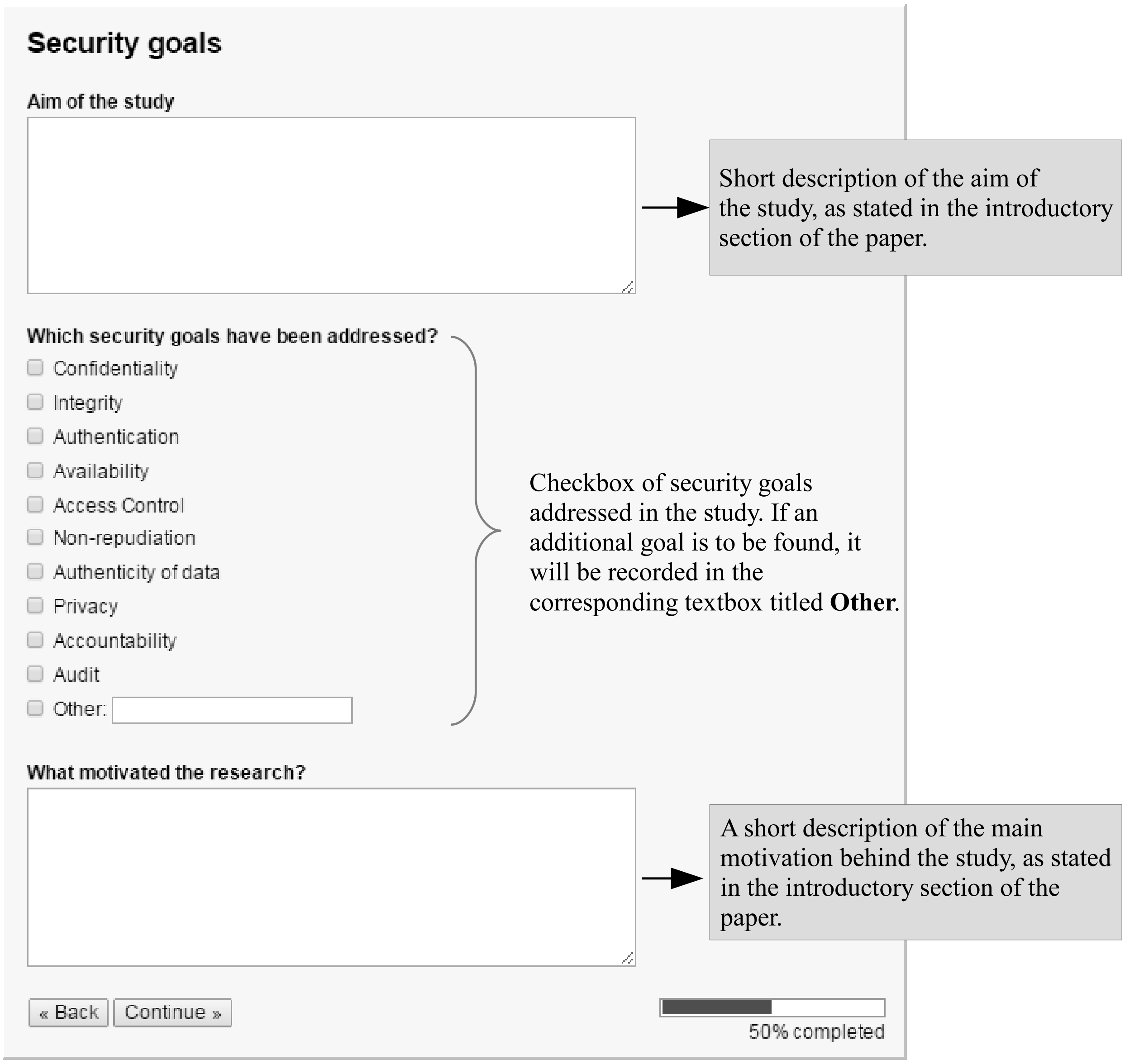
Date when the article has been published.

Cited by

Number of citations based on the Google Scholar citation count.

Figure 6: Extraction form, page 1.

The second page of the data extraction form (see Figure 7) consists of three questions, out of which two are multi-line textboxes (one for the aim of the study and the other one for the motivation behind the researcg) and one checkbox with the list of security goals, as proposed in [SRM13]. For the checkbox, the predefined possible answers are: confidentiality, integrity, authentication, availability, access control, non-repudiation, authenticity of data, privacy, accountability, and audit. The final check-box option is a blank single-line textbox in which a reviewer can write an additional security goal identified in the papers.



Security goals

Aim of the study

Which security goals have been addressed?

□ Confidentiality
□ Integrity
□ Authentication
□ Availability
□ Access Control
□ Non-repudiation
□ Authenticity of data
□ Privacy
□ Accountability
□ Audit
□ Other:

What motivated the research?

50% completed

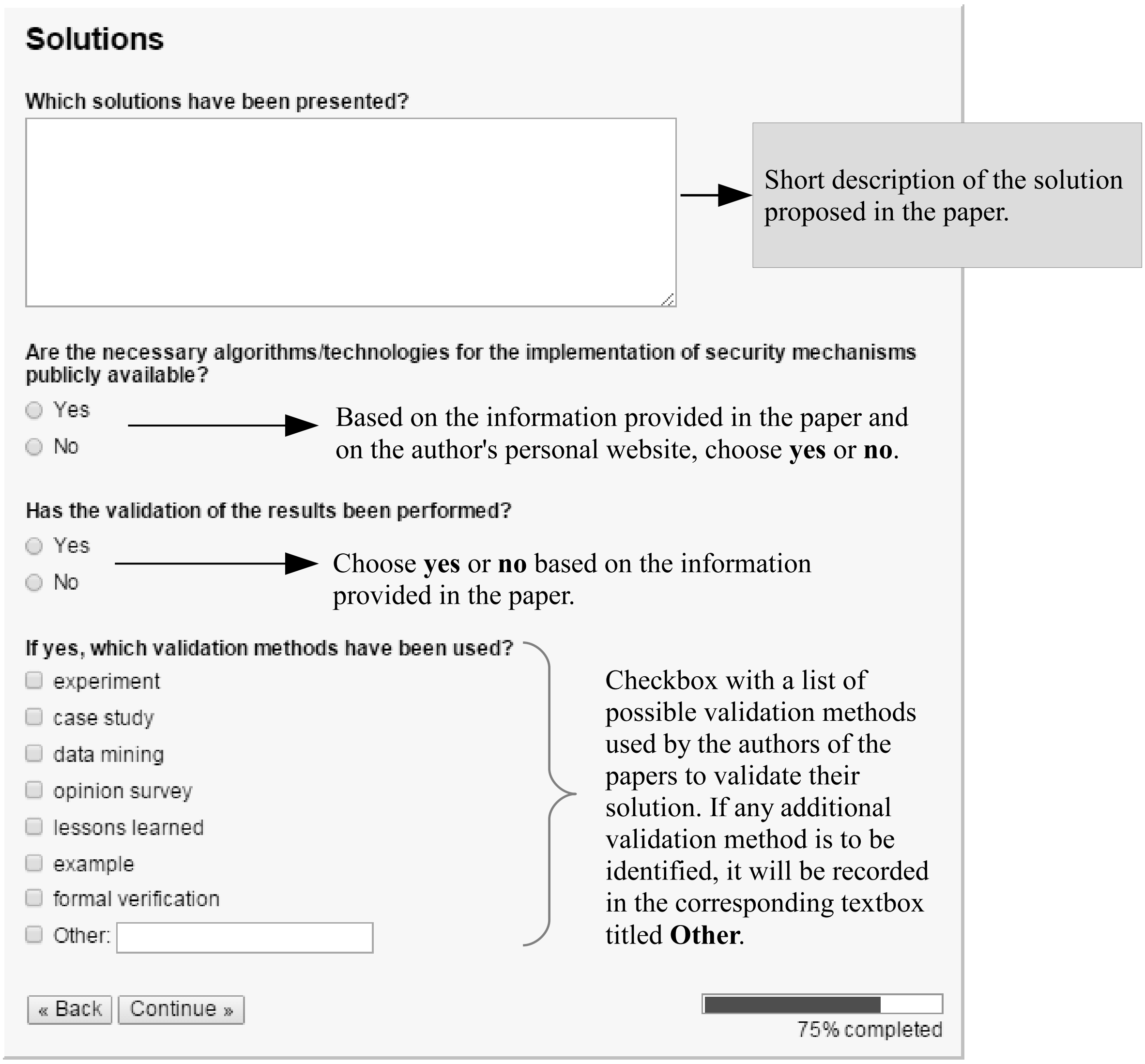
Short description of the aim of the study, as stated in the introductory section of the paper.

Checkbox of security goals addressed in the study. If an additional goal is to be found, it will be recorded in the corresponding textbox titled **Other**.

A short description of the main motivation behind the study, as stated in the introductory section of the paper.

Figure 7: Extraction form, page 2.

The third page of the data extraction form (see Figure 8) consists of four questions - one multi-line textbox, two single-choice questions, and one checkbox. The reviewer is expected to provide a short description of the solution proposed and described in the paper in the multi-line textbox. We will also check whether the algorithms and technologies needed for the implementation of security mechanisms are publicly available by checking the information provided in the paper, as well as authors' personal websites. If the algorithms and technologies are available, we will mark it as *Yes* in our form. The second single-choice question refers to the validation of results. We will examine the papers to identify whether the authors of the paper have validated their solution. If they reported on the validation, we will mark it as *Yes* in our form. The last question on the third page of the form should be answered only if the previous question was answered with *Yes*. Although Google Forms provides some navigation control (it is possible to define the page to be opened based on the respondent's answer), it did not react to a reviewer's response the way we wanted to. For example, by choosing an option *No* for the question "Has the validation of the results been performed?", we could not forbid a reviewer to choose validation methods presented in the checkbox on the bottom of the page. Therefore, we agreed to manually skip the checkbox question in case the previous question was answered with *No*.



Solutions

Which solutions have been presented?

Short description of the solution proposed in the paper.

Are the necessary algorithms/technologies for the implementation of security mechanisms publicly available?

○ Yes

○ No

Based on the information provided in the paper and on the author's personal website, choose **yes** or **no**.

Has the validation of the results been performed?

○ Yes

○ No

Choose **yes** or **no** based on the information provided in the paper.

If yes, which validation methods have been used?

□ experiment

□ case study

□ data mining

□ opinion survey

□ lessons learned

□ example

□ formal verification

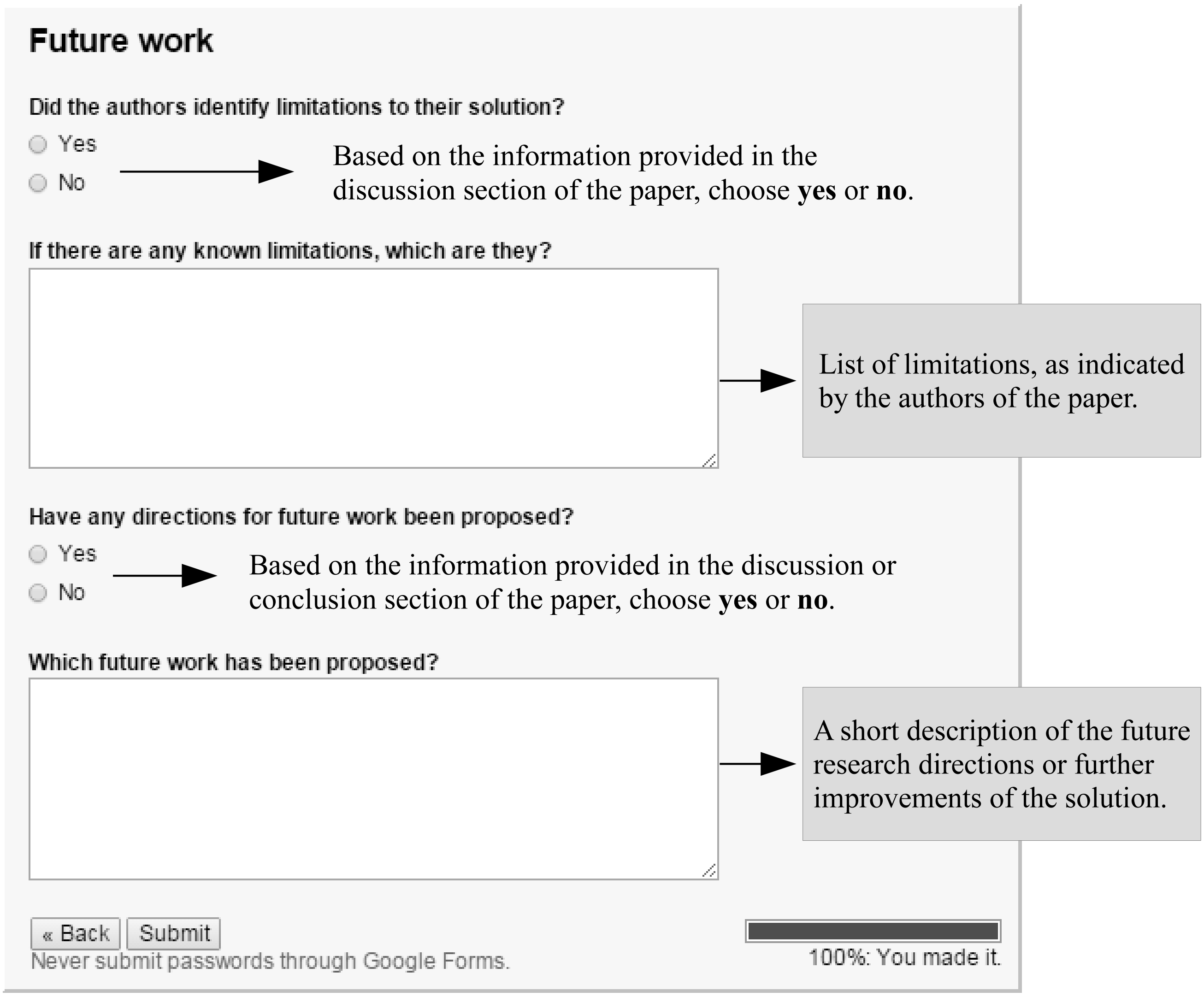
□ Other:

Checkbox with a list of possible validation methods used by the authors of the papers to validate their solution. If any additional validation method is to be identified, it will be recorded in the corresponding textbox titled **Other**.

Figure 8: Extraction form, page 3.

The final page of the data extraction form (see Figure 9) consists of four questions. The first one is a single-choice question, which refers to the limitations of the solution presented in the paper, with *Yes* and *No* as two possible answers. In order to provide an answer to this question, we will examine results, discussion, and conclusion sections of the papers. The second question is a multi-line textbox and refers to the description of the limitations, as stated by the authors of the paper. Again, we faced the same problem with restricting the reviewer to answer to the question once the previous question was answered with *No*. The third question is a single-choice question, which refers to the future work, with *Yes* and *No* as two possible answers. The final question in our data extraction form is a multi-line textbox, in which a short description of future work, as stated by the authors of the paper in the discussion and conclusion sections of the paper, is expected.

Once the data has been entered by a reviewer, the answers can be submitted by clicking on a button *Submit*, found at the very bottom of the form. As we linked the Google Forms with a Google Spreadsheet, the answers provided are automatically put into the corresponding cells in a Google Spreadsheet's sheet titled "Form Responses". An additional column, timestamp (date and time the answers have been submitted) is automatically created in the first column in the Spreadsheet.



Future work

Did the authors identify limitations to their solution?

○ Yes
○ No

Based on the information provided in the discussion section of the paper, choose **yes** or **no**.

If there are any known limitations, which are they?

List of limitations, as indicated by the authors of the paper.

Have any directions for future work been proposed?

○ Yes
○ No

Based on the information provided in the discussion or conclusion section of the paper, choose **yes** or **no**.

Which future work has been proposed?

A short description of the future research directions or further improvements of the solution.

Never submit passwords through Google Forms.

100%: You made it.

Figure 9: Extraction form, page 4.

The validation methods are defined as follows (see Table 14):

Method	**Description**	**Example**
Experiment	Manipulation of one or more independent variables. In our review, a simulation will be regarded as an experiment.	A simulation is conducted in [83] where the authors provide the objective of the simulation, a list of parameters, report on the simulation process and discuss the results.
Case paper	One case or a small number of cases are studied in detail with a holistic focus, i.e. it aims to understand the wholeness of the case.	In [36] the authors consider the case of a user moving through different localities and changes in the context condition while using a ubiquitous service.
Opinion survey	Inquiry designed to collect the opinion of a sample population.	A report on the opinion survey is given in [100]. The survey was conducted on a number of users to gain insight into whether a virtual password scheme is applicable in a certain scenario.
Lessons learned	After a solution had been implemented, authors report on the experience in working with the solution.	paper [82] reports on a home respiratory therapy system.
Example	Authors provide a description of a scenario, actors and procedures in order to illustrate a certain process or behavior.	Examples are provided in [164] in order to show how an algorithm assigns privileges to categories in an RBAC model.
Formal verification	Proving the validity of algorithms by using formal methods and mathematics. Formal proof and first-order logic were put into this category.	A protocol is formally verified using BAN logic in [221].
Other	Any other validation methods that could not be categorized into the above-mentioned categories, such as a theoretical comparison with existing solutions, usability test or data mining.	paper [107] provides a comparison of a a group device pairing protocol with existing schemes.

Table 14: Validation methods

6 Data synthesis

Before we start synthesizing and reporting on the findings, we will check if the data extraction procedure resulted in any missing information. If required, we will re-check the paper whose information might be missing. If the answer is not provided, we will mark the field in the data extraction form as “information unknown” or “general”, depending on whether the information is entirely missing or the authors of a particular paper provided general information. We expect to come across papers that provide, for example, a general list of attacks while reporting on the motivation. Therefore, we will write “general” in the respective textbox.

During the data synthesis procedure, we will use separate tables to group the information extracted in the Google Spreadsheet. This step will be taken to help summarize the information needed to answer to our research questions.

6.1 Synthesis of data for the RQ1

The first form used for the data synthesis will contain the information about the researchers who published papers on security in ubiquitous computing (see Table 15). We will provide a list of authors identified in our systematic literature review and count the number of papers published by each author. This information will identify the most active researchers in the area.

Paper ID	Author
S001	
S002	
...	

Table 15: Demographic data: active researchers

The second table (see Table 16) will present the demographic information. More precisely, we will look for the list of countries whose authors published the papers identified in our review. This information will give us an insight into where the research on security in ubiquitous computing is being carried out.

Paper ID	Country
S001	
S002	
...	

Table 16: Demographic data: country which contributed to the paper

In Table 17, we will present the number of papers published per year.

Year	Number
2003	
2004	
2005	
2006	
2007	
2008	
2009	
2010	
2011	
2012	
2013	

Table 17: Trends: Papers per year

The fourth table will present the most cited papers identified in our review (see Table 18).

Paper ID	Number of citations
S001	
S002	
...	

Table 18: Trends: citation count

Journals and conferences with the most published papers on security in ubiquitous computing will be identified by using the information given in Tables 19 and 20, respectively. Once identified, we will fill in the names of the journals in place of “JournalX” and conference abbreviations in place of “ConferenceX”.

Journal name	No. of papers
JournalX	
JournalX	
...	

Table 19: Number of papers found in each journal

Conference abbreviation	No. of papers
ConferenceX	
ConferenceX	
...	

Table 20: Number of papers found in each conference proceeding

6.2 Synthesis of data for the RQ2

The second research question "Which security goals have been addressed in terms of ubiquitous computing?" was examined in more depth by including six additional research questions, as reported in Section 3. We designed a data synthesis form for each additional research question.

6.2.1 Synthesis for the RQ 2.1: What is the motivation for the papers?

A list of threats, attacks and vulnerabilities that have motivated the papers will be recorded in Table 21. Instead of marking the cells with the uninformative "Yes" and "No", the table will contain a short description of each motivating factor found in a specific paper. For example, paper S004 (paper [151] in our list of references) reports on two vulnerabilities and one threat, as shown in Table 21. Since there were no attacks identified in the paper S004, the corresponding table cell is left blank.

	Motivation for the paper		
Paper ID	Vulnerability	Threat	Attack
S001			
S002			
S003			
S004	device's resource constraints (limited memory and processing power), insecure and untrustworthy nodes in a P2P network	presence of malicious and unreliable peers may deteriorate the accuracy and system performance	
...			

Table 21: Motivation for the paper

This information will be used to summarize and categorize the motivating factors found in the papers and to count the number of occurrences for each attack. The list of motivating factors with their corresponding source (paper) is given in the Appendix C.

6.2.2 Synthesis for the RQ 2.2: Which solutions have been presented?

Table 22 will hold the information on the solutions proposed in the papers. If additional information is needed during reporting, we will refer to the corresponding paper to find any further explanations or information missing from our data synthesis table. Additionally to the table, we are planning to provide a narrative description of the findings.

Paper ID	Short description of the solution
S001	
S002	
...	

Table 22: Solutions.

6.2.3 Synthesis for the RQ 2.3: Are the algorithms and technologies publicly available?

We are also interested in the availability of the algorithms and technologies used to present a solution (see Table 23). In particular, we will examine the way algorithms and technologies are presented (for the purpose of this review we will call it "presentation types"), such as diagrams and programming code excerpts, and categorize them during our reporting process.

Paper ID	**Availability of algorithms** (Y or N)	Presentation type
S001		
S002		
...		

Table 23: Algorithms.

6.2.4 Synthesis for the RQ 2.4: Which security goals have been addressed in the papers?

Using the information recorded in the spreadsheet, we will count the number of occurrences for each security goal (see Table 24) and present them in a bar chart. We will pay special attention to the list of goals placed in the *Other* category by examining whether there are any additional security goals with a high frequency of appearance. If such are found, we will add an additional row in the Table 24.

The information about the number of security goals identified in the papers will be used in the reporting phase of the review where we will explain and interpret the obtained results.

Security goals	Number
Confidentiality	
Integrity	
Authentication	
Availability	
Access control	
Non-repudiation	
Authenticity	
Privacy	
Accountability	
Audit	
Other	

Table 24: Security goals.

6.2.5 Synthesis for the RQ 2.5: What kind of validation of the results been performed?

To assess the appropriateness of the proposed solutions, we will synthesize the information about the validation mechanisms as reported in the papers. First we will identify the number of papers that did not report on any validation mechanisms used (see Table 25). For the remaining, we will count the number of occurrences of each validation mechanism and record it in the Table 26. This information will be used to identify the mechanisms that researchers tend and prefer to use.

Has the validation been performed?	**Number**
Yes	
No	

Table 25: Performance of the validation mechanisms.

Validation mechanism	**Number**
Experiment	
Case paper	
Opinion survey	
Lessons learned	
Example	
Formal verification	
Other	

Table 26: Validation mechanisms.

6.2.6 Synthesis for the RQ 2.6: Which future work has been proposed?

While summarizing the information about the future work, we will first use the data recorded in the Google spreadsheet to identify the number of papers that did not provide any plans for future work or research directions (see Table 27). The same data will be also available in our quality assessment form (0 points is given to the papers that do not report on the future work).

Future work reported?	**Number**
Yes	
No	

Table 27: Report on the future work.

Table 28 presents a data synthesis form in which we will summarize the short descriptions of future work extracted from the papers. Since we expect to encounter similarities in the reported future plans, we plan to categorize them and show frequencies for each category. For example, information about the performed validation of results given in the Table 25 may indicate that researchers who did not report on any validation mechanisms in they paper, might plan it as their future work. Therefore, "validate" can be regarded as a potential category of the planned future work.

Paper ID	**Short description of the future work**
S001	
S002	
...	

Table 28: Future work.

7 Potential conflict of interest

None known.

8 Review timetable

The SLR will be conducted within the following time-frame:

Task	**Date**	**Task description**
Completion of the protocol	30/12/2013	After the examples of the SLRs found in the literature[a] have been examined, identify and describe all the procedures and their details that are essential to conduct the SLR, such as definition of the research scope, search procedure, filtering of papers, quality assessment, data extraction and data synthesis.
Completion of the protocol review	20/01/2014	Conduct pilot procedures and report on their results. If necessary, refine the protocol.
Completion of search	10/02/2014	Use the defined search strings to automatically search for the papers in the scientific databases and manually in the conference proceedings, as defined in the protocol.
Completion of paper selection	23/03/2014	Perform the quality assessment procedure and filter the initial pool of papers according to the defined inclusion and exclusion criteria.
Completion of data extraction	20/05/2014	Extract the information by using a predefined form, as defined in the protocol.
Completion of data synthesis	30/06/2014	Synthesize the data extracted from the papers by using the predefined forms.
Completion of reporting	31/07/2014	Report on the results obtained from the review.

Table 29: Review timetable

[a] While defining review procedures we followed the examples from the following systematic reviews: [SLB14], [RHTi13], [DBCG14], [ATF09a], [BBH+08], [KB13], [KC07], [GBBGG+13] and [SJV+12].

We repeated our search in January 2015 to obtain results from papers published in 2014.

A Appendix: Results of the search and selection procedures

A.1 Results of the automatic search

We first obtained the papers for the time period 2003-2013.

Search string	**Database**	**Doubles**	**Workshops, table of contents, summaries**	**Title, abstract**	**Rank**
	ACM				
S1	384	638	537	302	24
S2	377				
S3	15				
	Springer				
S1	93	281	265	32	6
S2	246				
S3	31				
	Science Direct				
S1	247	506	498	95	66
S2	312				
S3	10				
	IEEE				
S1	1387	2018	1893	1144	97
S2	980				
S3	34				
	Wiley				
S1	116	213	209	52	6
S2	125				
S3	12				
Sum	4369	3656	3402	1625	199

Table 30: Details of the automatic search and selection.

We repeated the search with the same set of search strings in January 2015 to obtain the papers published in 2014.

Search string	Database	Doubles	Workshops, table of contents, summaries	Title, abstract	Rank
	ACM				
S1	49	74	49	22	13
S2	44				
S3	0				
	Springer				
S1	56	86	83	9	5
S2	34				
S3	1				
	Science Direct				
S1	47	95	95	23	15
S2	59				
S3	3				
	IEEE				
S1	140	200	169	59	16
S2	114				
S3	4				
	Wiley				
S1	30	59	59	14	3
S2	34				
S3	2				
Sum	617	514	455	127	52

Table 31: Details of the automatic search and selection, repeated search in 2015.

A.2 Results of the manual search

Conference name	Abbreviation	Results
ACM International Joint Conference on Pervasive and Ubiquitous Computing	Ubicomp	24
IEEE Pervasive Computing and Communication conference	PerCom	47
ACM Conference on Computer and Communications Security	CCS	34
Annual ACM International Conference on Mobile Computing and Networking	MobiCom	16
International Symposium on Wearable Computers	ISWC	2

Table 32: Details of the manual search.

B Report on the paper selection

Our initial pool (results for the time period 2003-2013) included n=4369 papers. We followed the filtering procedure and its corresponding phases in order to identify those papers that are of good quality and that would provide information relevant for the purposes of our review. In phase P4 we reached a more manageable number of papers (n=199) and combined them with those found during the manual search process (n=320). The double entries were removed, which further reduced the number of papers to n=291. After taking all the steps to obtain the full versions, we had to exclude in total 7 from our review. Therefore, the total number of papers that were considered for the quality assessment and data extraction phase was 284. The filtering procedure continued during the screening of the papers. We read the full versions of the articles while performing quality assessment and data extraction in parallel. Those papers that were not in scope of our research or had a poor quality assessment score were not considered for the data extraction process. As shown in Figure 10, out of 284 papers 70 (24%) were out of the research scope. For 8 (2%) papers a matching journal article or a more recent paper was found. Quality assessment was done for the remaining 206 (74%) papers.

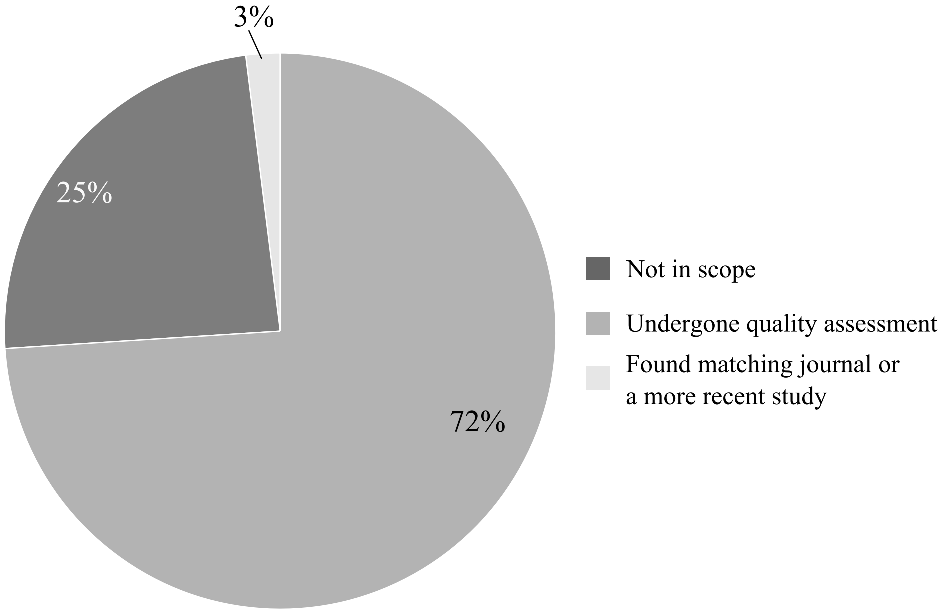


Figure 10: Filtering of papers.

C Motivation

List of vulnerabilities is presented in a Table 33.

Vulnerabilities	Papers	Nr.
1. Network dynamics	[1] [2] [4] [5] [6] [9] [11] [13] [14] [15] [20] [21] [22] [25] [32] [33] [35] [37] [38] [40] [43] [45] [49] [51] [52] [53] [60] [67] [70] [74] [75] [83] [88] [89] [96] [108] [112] [116] [122] [124] [127][132] [136] [139] [142] [143] [144] [148] [151] [156] [159] [161] [167] [165] [172] [176] [179] [182] [188] [191] [192] [193] [198] [195] [206] [210] [213] [214] [212] [215] [219]	**70**
2. Large scale networks	[5] [6] [8] [11] [13] [15] [20] [21] [27] [32] [33] [35] [54] [59] [60] [63] [74] [76] [81] [88] [89] [99] [103] [107] [112] [116] [117] [118] [122] [124] [123] [131] [139] [142] [143] [144] [147] [148] [151] [156] [159] [161] [167] [175] [177] [180] [184] [191] [192] [199] [213] [214] [216] [219] [222]	**55**
3. Resource constraints		**53**
3.1. RFID resource constraints	[24] [29] [64] [68] [82] [110] [111] [128] [158] [208]	10
3.2. WSN resource constraints	[23] [32] [34] [46] [72] [81] [89] [92] [118] [136] [107] [112] [113] [153] [154] [165] [192] [183] [191] [211] [212]	21
3.3. Mobile handheld devices' constraints	[2] [6] [5] [11] [39] [45] [67] [97] [108] [119] [121] [130] [147] [157] [151] [164] [177] [179] [181] [193] [198] [213]	22
4. Authentication-related challenges	[9] [17] [18] [19] [26] [31] [33] [35] [38] [39] [43] [44] [46] [48] [50] [94] [100] [102] [103] [109] [114] [119] [126] [137] [154] [155] [158] [160] [162] [163] [165] [170] [177] [184] [194] [196] [200] [209] [213] [221] [220]	**41**
5. Wireless link	[2] [24] [29] [30] [32] [55] [58] [59] [60] [71][79] [86] [90] [98] [116] [122] [124] [123] [135] [137] [139] [141] [156] [157] [161] [167] [171] [173] [177] [186] [212] [217] [218] [222]	**34**
6. Other		**19**
6.1. Malicious apps	[45] [69] [120] [134] [197] [201]	6
6.2. Service exploitation and misuse	[36] [115] [155] [189] [223]	5
6.3. Session vulnerabilities	[73] [113] [200]	3
6.4. Bluetooth vulnerabilities	[79] [140]	2
6.5. GPS receiver vulnerability	[138]	1
6.6. Mobile push notification vulnerability	[42]	1
6.7. RFID protocol vulnerability	[111]	1

Table 33: List of vulnerabilities.

List of threats is presented in a Table 34.

Table 34: Threats

Threat	**Papers**	**Nr.**
1. Privacy		**127**
1.1. Tracking a user	[3] [12] [16] [22] [24] [41] [29] [47] [51] [53] [54] [59] [62] [63] [64] [66] [68] [76] [84] [86] [89] [93] [117] [119] [120] [125] [128] [138] [143] [149] [155] [158] [168] [169] [171] [176] [178] [179] [181] [182] [190] [208] [200] [203] [204] [222] [221] [219]	52
1.2. Leaking private information	[6] [25] [33] [36] [50] [59] [63] [64] [70] [68] [77] [81] [89] [93] [102] [112] [113] [120] [133] [134] [143] [164] [171] [172] [176] [190] [192] [196] [200] [202] [213] [212] [217] [215] [221] [220] [223] [219]	38
1.3. Loss of a mobile device	[17] [31] [39] [88] [102] [119] [137] [154] [162] [160] [170] [145] [212]	13
1.4. Unlocked devices	[10] [17] [137] [154] [160] [162] [163] [177]	8
1.5. Identity exposure	[16] [17] [71] [93] [112] [117] [155] [222]	8
1.6. Recording	[58] [70] [182] [222]	4
1.7. Malicious apps	[69] [120] [134] [197]	4
2. Unauthorized access to data	[11] [14] [25] [38] [72] [71] [68] [81] [98] [107] [116] [140] [154][160] [176] [194] [197] [200] [201] [145] [211] [212] [213]	**23**
3. Communication interference	[13] [26] [29] [60] [75] [122] [135] [157] [165] [191]	**10**
4. Other[7]	[12] [16] [84] [142] [144] [154] [186] [191] [192] [197]	**10**
5. Installation of untrusted apps	[45] [69] [120] [134] [201]	**5**

Table 34: List of threats.

List of attacks is presented in a Table 35.

Table 35: Attacks

Attack	Refs.	Number
1. Denial of Service (DoS)		**99**
1.1. Network jamming		**25**
1.1.1. Network jamming	[24] [81] [84] [116] [135] [138] [142] [199] [153] [176] [190] [192] [211] [212]	14
1.1.2. Flashing cache with bogus references	[212] [213]	2
1.1.3. CPU processing time attack	[216]	1
1.1.4. Buffer overflow	[137] [150]	2
1.1.5. Rushing attack	[191]	1
1.1.7. On-off attack (dynamic behavior) attack	[40] [183] [192] [199]	4
1.2. Interrupting a communication channel		**42**
1.2.1. Packet interception	[64] [81] [88] [124] [180] [208]	6
1.2.2. Black hole (packet drop)	[142] [148]	2
1.2.3. Gray hole	[142] [148]	2
1.2.4. Jellyfish attack	[142]	1
1.2.5. Hello flood	[142] [144] [192]	3

[7] physically harm a patient, battery drain, stalking and harassment, disabling functionalities, destroying assets

Table 35: Attacks

Attack	Refs.	Number
1.2.7. Wormhole attack	[53] [116] [137] [144] [177] [191] [192]	7
1.2.12. SYN flooding attack	[191] [213]	2
1.2.13. Blocker attack	[190]	1
1.2.14. IMSI paging attack	[12]	1
1.2.15. Stolen verifier attack	[209] [196]	2
1.2.16. Fake base station attack	[12]	1
1.2.17. Injection and deletion of messages	[12] [79] [81] [88] [92] [107] [118] [122] [157] [177] [211] [212]	14
1.3. Disruption of the physical properties of a device		**12**
1.3.1. Power draining attack	[79] [121] [154] [191] [211] [212]	6
1.3.2. Physical corruption	[118] [142] [213]	3
1.3.3. Node compromise	[89] [175]	2
1.3.4. Deplete resources in general	[7]	1
1.4. False trust ratings	[5] [20] [37] [40] [60] [95] [116] [151] [199]	**9**
1.5. Other service degradation attacks		**9**
1.5.1. Storage space filling attack	[164]	1
1.5.2. Server timing attack	[119]	1
1.5.3. Denial of authentication (DoA)	[71]	1
1.5.4. Newcomer attack	[5] [199]	2
1.5.5. Denial of proof	[111]	1
1.5.6. Desynchronization attack	[88] [107] [205]	3
1.6. DDoS	[32] [46] [135] [213]	**4**
2. Impersonation or masquerading		**64**
2.1. Spoofing	[33] [38] [41] [84] [90] [102] [112] [122] [138] [142] [148] [165] [173] [176] [192] [205] [208] [209]	18
2.2. Consensual impersonation	[3]	1
2.3. Sybil attack	[8] [30] [37] [51] [60] [76] [97] [107] [133] [176] [192] [199]	12
2.4. Phishing	[31] [90] [100]	3
2.5. Man-in-the-middle	[3] [11] [24] [30] [37] [41] [46] [53] [62] [75] [76] [81] [90] [102] [110] [118] [119] [122] [128] [140] [142] [148] [165] [172] [174] [209] [212]	27
2.6. Relay attack (ghost and leech)	[3] [158]	2
2.7. Denning-Sacco attack	[209]	1
3. Eavesdropping		**53**
3.1. Passive		**14**
3.1.1. Shoulder surfing	[94] [100] [152] [160] [162] [163]	6
3.1.2. Snooping	[4] [12] [63] [119] [170] [171] [177] [211]	8
3.2. Active		**39**
3.2.1. Replay attack	[1] [2] [4] [12] [23] [24] [27] [46] [56] [68] [71] [76] [86] [88] [104] [111] [118] [119] [124] [123] [127] [128] [131] [138] [142] [144] [145] [147] [148] [155] [165] [177] [178] [192] [196] [200] [208] [209] [223]	39
4. Cryptanalytic attacks		**35**
4.1. Password cracking		20
4.1.1. Brute Force	[17] [25] [46] [66] [79] [175] [205]	7
4.1.2. Dictionary attack	[26] [31] [100] [209]	4

Table 35: Attacks

Attack	Refs.	Number
4.1.3. Password cracking	[71] [124] [126] [131] [138] [152] [162] [196] [213]	9
4.2. Side-channel attack		9
4.2.1. Electromagnetic attack	[120] [171]	2
4.2.2. Acoustic cryptanalysis	[120]	1
4.2.3. Side-channel attacks	[121] [154] [152] [177] [211] [212]	6
4.3. Key search attack	[150]	1
4.4. Birthday attack	[34] [128]	2
4.5. Preimage attack	[34]	1
4.6. RSA key generation attack	[16]	1
4.7. AKA protocol linkability attack	[12]	1
5. Other		**30**
5.1. Zero day	[79] [201]	2
5.2. Session hijacking	[142] [145]	2
5.3. Stealing a mobile device	[39] [88] [119] [163] [177]	5
5.4. Attack on a person by modifying sensor readings	[88] [192] [211]	3
5.5. RFID cloning attack	[16]	1
5.6. Smudge attack	[94] [160] [162] [163]	4
5.7. Reconnaissance attack	[186]	1
5.8. IMSI paging attack	[140]	1
5.9. Tampering attack	[37] [142] [144]	3
5.10. Pattern matching attack	[94]	1
5.11. Reverse attack	[74]	1
5.12. Conspiracy attack	[74]	1
5.13. Fabrication of false queries	[133]	1
5.14. Bluetooth-related attacks		3
5.14.1. BlueSnarfer	[140]	1
5.14.2. CarWhisperer	[140]	1
5.14.3. HIDattack	[140]	1
5.15. Physical node capture	[55]	1
6. Geo-location inference attacks		**19**
6.1. Tracking	[22] [41] [48] [64] [66] [86] [111] [120] [149] [158] [176] [178] [204] [205]	14
6.2. Location inference attack	[47] [168]	2
6.3. Distance intersection attack	[53] [57] [135]	3
7. Malware	[38] [48] [69] [79] [80] [81] [90] [102] [104] [121] [120] [126] [140] [145] [162] [181] [197] [212]	**18**
8. Cross-origin attack		**5**
8.1. Cross-site request forgery	[197]	1
8.2. Permission re-delegation	[201]	1
8.3. Permission misuse (confused deputy)	[134] [197] [201]	3

Table 35: List of attacks.

D Solutions

Table 36 summarizes solutions proposed in the papers analyzed.

Table 36: Solutions

Solution	**Papers**	**Nr.**
1. Authentication and access control mechanisms		**86/79**[8]
1A - Authentication mechanisms	[2] [3] [9] [17] [18] [24] [26] [28] [30] [31] [38] [39] [44] [46] [50] [71] [76] [78] [86] [89] [90] [94] [100] [100] [102] [105] [109] [116] [124] [123] [126] [128] [131] [137] [147] [145] [154] [155] [158] [160] [163] [165] [170] [177] [178] [179] [196] [208] [209] [214] [220]	51
1B - Access control mechanisms	[3] [9] [25] [33] [35] [36] [43] [52] [62] [61] [63] [74] [75] [85] [91] [98] [99] [103] [114] [121] [127] [129] [130] [139] [141] [145] [154] [155] [172] [179] [180] [184] [194] [202] [206]	36
Solutions based on identity		
1.1. Identity-based solutions	[2] [3] [9] [17] [18] [26] [28] [30] [31] [39] [38] [44] [46] [50] [71] [76] [78] [86] [89] [90] [94] [100] [105] [109] [121] [124] [123] [126] [128] [131] [137] [147] [145] [154] [155] [158] [160] [163] [170] [177] [179] [196] [209] [220]	43
1.2. Non-identity-based solutions	[24] [102] [124]	3
Properties		
1.1. Dynamics	[2] [9] [33] [35] [36] [62] [76] [89] [98] [116] [124] [126] [127] [130] [141] [154] [155] [165] [172] [179] [194] [145]	22
1.2. Unobtrusiveness	[3] [17] [28] [39] [50] [94] [124] [123] [137] [153] [170] [177] [221]	13
1.3. Speed	[2]	1
1.4. Lightweight	[179]	1
2. Privacy protection		**63/54**[9]
2.1. Masking	[13] [55] [59] [66] [69] [112] [113] [131] [142] [149] [155] [168] [169] [179] [196] [200] [204] [220]	19
2.2. Privacy protection layer	[22] [48] [80] [93] [143] [159] [182] [188] [197]	9
2.3. Proximity detection schemes	[3] [51] [53] [57] [106] [135] [182] [80] [119]	8
2.4. Game-based approach	[51] [95] [108] [168] [222] [218]	6
2.5. Consent and notification	[3] [58] [70] [77] [87] [185]	6
2.6. Negotiation approach	[47] [93] [145] [221] [223]	5
2.7. Blocker tag	[84] [190]	2
2.8. Other	[16] [125] [132] [203]	4
2.9. Obfuscation	[47] [188] [207]	3
3. Cryptographic protocols		**63**
3.1. Symmetric	[1] [7] [5] [41] [59] [68] [82] [86] [88] [92] [112] [115] [135] [166] [177] [176] [179] [192] [198]	19

[8] 79 stands for a number of unique papers.

[9] 54 stands for a number of unique papers.

3.2. Asymmetric	[19] [31] [34] [60] [63] [74] [71] [72] [76] [107] [111] [139] [153] [167] [173] [174] [189] [195]	18
3.3. Hybrid	[12] [20] [23] [46] [45] [54] [56] [81] [83] [89] [97] [103] [118] [130] [136] [145] [147] [155] [156] [157] [161] [171] [215]	23
3.4. Hashing	[122] [175] [205]	3
Lightweight protocols		
Lightweight	[1] [7] [12] [20] [41] [45] [46] [54] [56] [59] [63] [71] [76] [82] [83] [86][88] [92] [97] [112] [111] [113] [107] [115] [135] [139] [136] [155] [156] [157] [177] [176] [179] [189] [192] [205]	35
4. Trust	[1] [6] [4] [8] [11] [15] [21] [20] [27] [37] [40] [49] [65] [67] [76] [96] [107] [110] [119] [133] [134] [139] [144] [151] [164] [181] [182] [187] [188] [199] [210] [216]	**32**
5. Other		**16**
5.1. Security awareness model for BYOD	[10]	1
5.2. Framework for secure smart environment	[14]	1
5.3. Edge sampling algorithm for WSN	[32]	1
5.4. Model for secure mobile push services	[42]	1
5.5. Hash-chain for RFID systems	[64]	1
5.6. Key management for session mobility	[73]	1
5.7. Masking page references in databases	[117]	1
5.8. IdS	[140] [148] [213]	3
5.9. ILP security optimization	[150]	1
5.10. MAC for WBAN	[183]	1
5.11. Queue management	[186]	1
5.12. Framework for resource provisioning	[193]	1
5.13. Anomaly detection mechanism	[211]	1
5.14. Steganography	[217]	1
Papers that demonstrate novel attacks, but do not propose a solution		**9**
RFID attacks	[29]	1
Bluetooth viruses	[79]	1
Decoding keystrokes from nearby mobile phones	[120]	1
GPS software attacks	[138]	1
Input reconstruction from nearby mobile devices	[152]	1
Breaching mobile phones	[162]	1
DoS attacks on WSN	[191] [212]	2
Analysis of Android apps	[201]	1

Table 36: List of solutions.

D.1 Papers in common to two categories

- Authentication/access control mechanisms $\cap$ Cryptographic protocols = 16
- Authentication/access control mechanisms $\cap$ Privacy mechanisms = 6
- Authentication/access control mechanisms $\cap$ Trust-based solutions = 2
- Privacy $\cap$ Cryptographic protocols = 5
- Privacy $\cap$ Trust = 3
- Trust-based solutions $\cap$ Cryptographic protocols = 5

E List of journals

Journal name	Publisher	Coverage
ACM Transactions on Information and System Security	ACM	2003-2013
ACM Transactions on Sensor Networks	ACM	2006-2013
American Journal of Preventive Medicine	Elsevier	1985-2014
Computers & Security	Elsevier	1982-2014
Computer Communications	Elsevier	1978-2014
Computer Networks	Elsevier	1977-1984, 1989-1990, 1996-2014
Computer Standards and Interfaces	Elsevier	1985-2014
Data and Knowledge Engineering	Elsevier	1985, 1987-2014
Decision Support Systems	Elsevier	1985-2014
Future generation computer systems	Elsevier	1984-2014
IEEE/ACM Transactions on Networking	IEEE	1993-2013
IEEE Communications Magazine	IEEE	1979-2013
IEEE Journal on selected areas in communications	IEEE	1983-2014
IEEE Pervasive Computing	IEEE	2002-2013
IEEE Sensors Journal	IEEE	2001-2014
IEEE Transactions on Biomedical Circuits and Systems	IEEE	2007-2014
IEEE Transactions on Computers	IEEE Computer Society	1969-2014
IEEE Transactions on Consumer Electronics	IEEE	1975-2013
IEEE Transactions on Dependable and Secure Computing	IEEE	2004-2013
IEEE Transactions on Information Forensics and Security	IEEE	2006-2014
IEEE Transactions on Mobile Computing	IEEE	2002-2014
IEEE Transactions on Parallel and Distributed Systems	IEEE Computer Society	1990-2013
IEEE Transactions on Services Computing	IEEE	2008-2013
IEEE Vehicular Technology	IEEE	2006-2013
IEEE Wireless Communications	IEEE	2002-2013
Information Sciences	Elsevier	1968-2014
Journal of Network and Computer Applications	Academic Press Inc.	1996-2014
Lecture Notes in Computer Science	Springer Verlag	1981-1984, 1986, 1996-2013
Mathematical and Computer Modelling	Elsevier Limited	1988-2013
Mobile Networks and Applications	Springer Netherlands	1996-2014
Nonlinear Dynamics	Springer Netherlands	1990-2014
Journal of Computer Security	IOS Press	1994, 1996-2013
Journal of Computer and System Sciences	Academic Press Inc.	1967-2014
Journal of Intelligent Manufacturing	Springer Netherlands	1990-2014
Journal of Systems and Software	Elsevier	1979-2014
Personal and Ubiquitous Computing	Springer London	2005-2013
Pervasive and Mobile Computing	Elsevier	2005-2013
Science of Computer Programming	Elsevier	1981-2014
Sensors	MDPI	2001-2013
Software - Practice & Experience	John Wiley and Sons	1972-2014
Theoretical Computer Science	Elsevier	1975-2014
Wireless Communications and Mobile Computing	John Wiley and Sons	2001-2014
Wireless Networks	Springer Netherlands	1995-2014

Table 37: List of journals in alphabetical order.

F Journal ranking

Journal name	SJR Ranking	H-index	References	No. of articles
IEEE Wireless Communications	3.83	98	[187]	1
IEEE Journal on selected areas in communications	3.34	165	[20] [72] [75] [82] [165]	5
IEEE Communications Magazine	3.2	144	[59] [180]	2
IEEE Transactions on Wireless Communications	2.72	118	[178]	1
Information Sciences	2.61	91	[26] [98]	2
American Journal of Preventive Medicine	2.52	131	[87]	1
IEEE Transactions on Mobile Computing	2.26	80	[123] [137] [145] [191] [221]	5
IEEE/ACM Transactions on Networking	2.04	124	[116] [186]	2
IEEE Transactions on Biomedical Circuits and Systems	1.88	29	[211]	1
Decision Support Systems	1.81	76	[93]	1
Journal of Computer and System Sciences	1.61	56	[150]	1
ACM Transactions on Information and System Security	1.55	41	[24] [62]	2
IEEE Transactions on Information Forensics and Security	1.41	46	[7] [190]	2
Data and Knowledge Engineering	1.33	59	[117]	1
Nonlinear Dynamics	1.28	59	[105]	1
IEEE Transactions on Parallel and Distributed Systems	1.25	78	[111] [142] [204] [223]	4
Future generation computer systems	1.24	59	[194]	1
IEEE Transactions on Services Computing	1.18	27	[115]	1
Mathematical and Computer Modelling	1.16	59	[13]	1
Journal of Intelligent Manufacturing	1.09	44	[141]	1
Pervasive and Mobile Computing	1.03	28	[63] [127]	2
Journal of Computer Security	0.97	40	[184]	1
ACM Transactions on Sensor Networks	0.96	36	[107] [192]	2
Theoretical Computer Science	0.93	74	[35]	1
IEEE Pervasive Computing	0.92	69	[27] [58] [66] [106] [102]	5
IEEE Vehicular Technology	0.92	21	[155]	1
Journal of Network and Computer Applications	0.9	30	[15] [114] [133] [157] [166] [167] [179]	7
Personal and Ubiquitous Computing	0.9	31	[14] [28] [49] [76] [91] [172]	6
IEEE Transactions on Dependable and Secure Computing	0.87	36	[37] [79]	2
Computer Networks	0.88	78	[128]	1
Computers & Security	0.84	51	[3] [45]	2
Journal of Systems and Software	0.82	60	[4] [5] [73] [129] [188] [195]	6
IEEE Transactions on Computers	0.77	81	[147]	1
Mobile Networks and Applications	0.75	57	[31] [112] [189] [200] [210] [215]	6
Computer Standards and Interfaces	0.75	38	[74] [198]	2
IEEE Sensors Journal	0.73	56	[110]	1
IEEE Transactions on Consumer Electronics	0.73	69	[78] [89] [177]	3

Journal name	SJR Ranking	H-index	References	No. of articles
Science of Computer Programming	0.67	44	[161]	1
Sensors	0.66	63	[118]	1
Computer Communications	0.65	58	[21] [32] [40] [86] [97] [100] [104] [109] [131] [146] [151] [156] [169] [176] [196] [209] [216]	17
Software - Practice & Experience	0.63	49	[206]	1
Wireless Networks	0.53	65	[33] [99] [164] [213]	4
Wireless Communications and Mobile Computing	0.32	39	[81] [132]	2
Lecture Notes in Computer Science	0.31	118	[23] [101]	2
			Total	**113**

Table 38: List of journal rankings in descending order based on the SJR value.

G List of conferences

Conference abbr.	Conference Name	CORE ranking	References	No. of papers
ACSAC	Annual Computer Security Applications Conference	A	[140] [173]	2
CCS	ACM Conference on Computer and Communications Security	A*	[12] [16] [48] [51] [69] [84] [119] [120] [134] [138] [149] [152] [154] [162] [168] [197] [201]	17
CHI	International Conference on Human Factors in Computing Systems	A*	[77]	1
HICSS	Hawaii International Conference on System Sciences	A	[39]	1
ICDE	International Conference on Data Engineering	A*	[217]	1
ICWS	IEEE International Conference on Web Services	A	[202]	1
IEEE INFOCOM	IEEE International Conference on Computer Communications	A*	[199]	1
IJCNN	IEEE International Joint Conference on Neural Networks	A	[44]	1
IPDPS	IEEE International Parallel and Distributed Processing Symposium	A	[52]	1
LCN	IEEE Conference on Local Computer Networks	A	[2] [34] [43]	3
MobiCom	ACM International Conference on Mobile Computing and Networking	A*	[30] [122] [125] [163]	4
MobiQuitous	International Conference on Mobile and Ubiquitous Systems: Networks and Services	A	[6] [54] [83] [143] [218]	5
NCA	IEEE International Symposium on Network Computing and Applications	A	[36]	1
PerCom	International Conference on Mobile and Ubiquitous Systems: Networks and Services	A*	[9] [11] [19] [25] [22] [41] [55] [56] [60] [61] [64] [67] [68] [85] [88] [95] [96] [103] [108] [121] [130] [148] [158] [170] [175] [205] [222] [219] [220]	29
PERVASIVE	International Conference on Pervasive Computing	A*	[47]	1
S&P	IEEE Symposium on Security and Privacy	A*	[80]	1
SRDS	Symposium on Reliable Distributed Systems	A	[92]	1
TrustCom	IEEE/IFIP International Symposium on Trusted Computing and Communications	A	[17] [46] [50] [174] [181]	5
UbiComp	Ubiquitous Computing	A*	[57] [90] [124] [159] [171]	5
WOWMOM	IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks	A	[8] [29] [214]	3
			Total	**84**

Table 39: List of conferences in ascending alphabetical order based on abbreviations.

H Selected papers

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[14] F. Bagci, H. Schick, J. Petzold, W. Trumler, and T. Ungerer. The reflective mobile agent paradigm implemented in a smart office environment. *Personal and Ubiquitous Computing*, 11(1):11–19, February 2006.

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